The 21st International Sedimentological Congress

A New Journey of Sedimentology: from the Pacific to the Himalaya

Abstract book

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Plenary talk

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Sedimentology Futures: Geoheritage, Planetary Exploration, and Technology

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Keywords: sedimentology, geoheritage, Mars, planetary, technology, future

Looking forward, the field of sedimentology and its future must include advances in geoheritage, planetary exploration, and technology.

Of foremost importance, the many diverse landscapes where we conduct sedimentology research comprise our geoheritage – the geologic sites or areas with significant scientific, educational, cultural, and/or aesthetic value. Geoheritage sites are vital to advancing knowledge and for understanding geodiversity as well as the biodiversity the land supports. The sedimentary record at many geosites has implications for understanding climate change. Over the last few decades, a rising international geoconservation movement is bringing attention to special geological features with intrinsic value. Sedimentologists need to contribute to good stewardship of important geoheritage sites.

Sedimentology plays a key role in planetary explorations, with the discovery of more sedimentary rocks on Mars and the continuing search for extraterrestrial life. The potential for extraterrestrial life will be enhanced by more studies of microbial life in terrestrial authigenic minerals and their detection as biosignatures. Earth has a life bias throughout over three eons of geologic history, yet analyzing the variability of analogous Earth systems with the sedimentologic context for habitable environments will lead to a better understanding of sedimentary deposits on other planetary bodies.

Finally, technology will continue to change the way we conduct our research from data collection to archiving, processing, visualizing, and sharing. All sedimentology studies can benefit from the use of digital technology, accompanied by open data and more avenues for communicating what our science is about.

The more we can learn from geoheritage landscapes that have strong scientific value, the better we can apply knowledge to planetary explorations. The more we use new digital technologies, the more we can share and make new discoveries. It's an exciting frontier of sedimentology futures!

Scientific Themes: Plenary talk
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Secular evolution of tectonics and volcano-sedimentology

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Keywords: basin, tectonics, secular change, volcanism

Sedimentary basins are a critical archive of Earth history. They lie at the interface between, and provide an evolutionary record of, the solid (crust, mantle) and surficial (atmosphere, oceans, biosphere) reservoirs of the Earth.

Types of sedimentary basin and the nature of their fill derive from the interplay of subsidence (and resultant accommodation space) and the nature of the source. Subsidence results from extension, compression or thermal cooling of the lithosphere, and is tied to tectonic environment. The scale and magnitude of subsidence is guided by lithospheric rigidity, which has evolved through Earth history.

Volcano-sedimentary basins are characterized by syn-sedimentation magmatism. They have formed throughout Earth history (irrespective of tectonic mode) either at the sites of lithospheric compression or extension, and may record post-magmatic thermal subsidence.

Rapid geochemical and isotopic analyses of sedimentary basin-fills have transformed provenance analysis, paleogeographic reconstructions, and our understanding of continental crust evolution, as well as of geological cycles within the Earth system. For example, age-dating of detrital zircons has allowed us to constrain the maximum depositional age that approaches the timing of sedimentation in volcano-sedimentary basins, which has proven especially useful in dating the non-fossiliferous Precambrian basins. Analyses of Hf-and-O isotopes in detrital zircons allow us to evaluate the relative contribution of surficial, crustal, and mantle reservoirs to the magmatic sources of volcano-sedimentary basins. Trace element systematics of zircon underpin new proxies for the crystallisation temperature, crustal thickness, aluminium saturation index, and magmatic source of zircon-bearing melts. The integrated information coming from these proxies offer a more refined evaluation of the tectonic setting of zircon crystallization, which is particularly useful for studying ancient volcano-sedimentary basins decoupled from their original geodynamic context. Although zircon remains the most widely used detrital mineral petrochronometer, inherent bias in source rock fertility and a susceptibility to recycling remain fundamental limitations of detrital-zircon provenance analysis. In this regard, ongoing developments in in situ age dating, isotopic and elemental analysis of other detrital minerals, such as apatite, rutile, monazite, and titanite, offer a more holistic view of the evolution of volcano-sedimentary basins from the detrital record as they form in a broader range of source rock compositions, are sensitive to lower temperature tectonothermal events, and are more labile than zircon within the sedimentary cycle.

Evolution of the volcano-sedimentary basin settings and fills provide salient clues about continental freeboard conditions, composition of the emerged crust and the atmosphere-ocean chemistry. For example, early episodes of transition from dominantly sub-marine to sub-aerial volcano-sedimentation at craton-scale during the Mesoarchean provided direct clues about the first episodes of continental emergence, basin formation due to thermal subsidence and terrestrial sedimentation, and the concomitant instances of transient atmospheric-ocean oxygenation (O2-whiffs) and glaciation. Subsequently, the widespread emergence of the continental crust and resultant weathering and sediment transport in the Neoarchean-early Paleoproterozoic likely exemplified larger-degree of tectonic (compressional) control on basin formation and had a profound impact on the atmosphere and oceans that has been linked to glaciations, the Great Oxygenation Event, and enhanced supply of bio-essential nutrients to the oceans.

Scientific Themes: Plenary talk
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Spatiotemporal changes of hydroclimate in East China since late Miocene

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Keywords: geobiology, bacteria, archaea, hopanoids, tetraethers, drought

The East Asian Monsoon systems in late Cenozoic are paid great attention to for decades of years. The loess-paleosol sequences in North China and the marine sediments in South China Sea provide critical records to decipher the evolution history of the monsoon systems in China. However, it remains largely unknown about the spatiotemporal evolution of the hydroclimate driven by the East Asian Summer Monsoon in East China where is heavily populated. In the past years, we proposed a series of hydroclimate proxies on the basis of the microbial lipid biomarkers extracted from soils, peat deposits, lacustrine sediments as well as the cave sediments (Xie et al., 2012, 2013; Yang et al., 2014; Dang et al., 2016). These proxies enable us to explore the spatiotemporal changes of the hydroclimate in East China since the late Miocene (Tang et al., 2017; Zhu et al., 2017; Lu et al., 2021). We found the anti-phased trends on the hydroclimate changes in the Middle Yangtze regions in comparison with those in the North and South China on both the millennial and tectonic time scales, known as the tripole patterns as observed in modern days rainfall (Zhang et al., 2018; Lu et al., 2021).

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Scientific Themes: Plenary talk
Session
Presentation Preference: Plenary Talk

Carbonate diagenesis: why we need to look small, think big and remember to process!

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Keywords: Diagenesis, Carbonate, Fluid flow

Carbonate diagenesis embraces all physical, chemical and biogenic processes that modify a sediment after deposition. It begins at the seafloor, continues during burial and uplift, and can dramatically transform mineralogy and rock physical properties. Over the last 20 years, there have been major advances in our understanding of carbonate diagenetic process, through high resolution imaging, micro-sampling and geochemistry. There has also been significant progress in the integration of hydrogeological and geochemical modelling, particularly via reactive transport models. These have dramatically improved our ability to interpret the genesis and distribution of diagenetic products. This raises the opportunity - and challenge - to use our knowledge of basin-scale fluid flow and reaction to interpret high resolution, micro-sampled data in the context of an understanding of diagenetic process. Conversely, construction of reactive transport models using robust information on stratigraphic architecture, palaeoclimate and burial history, alongside calibration of model outputs with geological data, improves confidence in the modelling process. In totality, sampling, analysis, modelling and interpretation of data should be conducted within the framework of our knowledge of the tectonostratigraphic and palaeo-environmental evolution of a basin allowing us to move away from generic, conceptual models.

In this talk, a number of case studies will be used to show how multi-scale characterisation and analysis of mineral phases can be integrated with conceptual and numeric models to map and predict the distribution of diagenetic products in time and space. In all cases, analysis began at the basin scale, through evaluation of the tectonic and burial history, palaeoclimate and stratal architecture of the basin. Through integration of hydrogeological concepts, reaction pathways and kinetics it is possible to the map the diagenetic pathway of strata, taking into account sedimentary, tectonic and diagenetic inheritance and feedback mechanisms. In all cases, detailed petrographical analysis and representative microsampling were vital to ensuring that micron-scale analysis of diagenetic products provided critical information as to the timing and mechanism of fluid flow. Concept testing using forward models was then integral to the final interpretation. Ultimately, this presentation will emphasise the criticality of systematically building knowledge from multi-proxy, multiscale sources to predict the distribution of diagenetic products, rather than fitting results to prior conceptual models. In this way, we are able to move towards predicting the occurrence and distribution of diagenetic products.

Scientific Themes: Plenary talk
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Volcanic Source to Sink: From Subaerial Eruptions to Deep-water Turbidity Currents

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Keywords: Volcanic source-to-sink, Volcaniclastic Sedimentology, Sedimentary Volcanology

Volcanic or volcaniclastic sedimentology includes studies of volcaniclastic sediments focusing on facies, depositional processes, environmental impacts by explosive eruptions, and decadal to millennial-scale sedimentary and geomorphic responses to volcanism. It also encompasses studies of *lahar*, Indonesian term for sediment laden flow of volcanic materials and water, which travels down from a volcanic slope through a river valley, occasionally reaching a far-located lake or ocean. Hydrological reconstruction of lahars and volcanogenic floods approached from flood geomorphology can reveal flow volume and spatiotemporal changes during the event. These results are critical for hydrological volcanic hazard assessments of populated downstream areas and to predict the laharic events during and after an eruption.

Recent awareness of other facets of volcaniclastic sedimentology has emphasized the importance of sediment delivery to the deeper part of the subaqueous sedimentary system, such as lacustrine and marine environments by volcanic hyperpycnal flows. The nature of high sediment laden flows in volcanic settings enhances generation of density flow traveling a deep-water environment and leaves distinct event deposits among the sedimentary successions with high time-resolution owing to high sedimentation rates of background sediments. The active Adatara and Bandai volcanoes adjacent to Lake Inawshiro-ko, Fukushima, Japan offer a compact natural laboratory to understand a cascading process from subaerial eruptions and lahars to deep-water density currents during the past 50,000 years. Subaqueous density flow deposits in sediment cores from Lake Inawashiro-ko clarify their origin (source volcano) and trigger (eruption style). Classical facies analysis, grainsize, and petrography together with geochemistry using micro-XRF and clay mineralogy by XRD suggest that each density current layer can be linked to individual eruptions at Mts. Adatara and Bandai. Shorter recurrence intervals of the small-scale explosive eruptions indicating higher activity at both volcanoes was revealed, which could not be evaluated solely by proximal tephra records due to the low preservation potential of the near source area.

Thus, volcaniclastic sediments transported via water can be interface between source volcano and sink with traceable petrographic and geochemical fingerprints, even in the absence of correlative eruption records in proximal areas and/or volcanic edifice itself. A broad view from the volcanic source to the sink as a collective system of volcanic slope, fluvial, and deep-water environments dealing with eruptions, lahars, fluvial transport, and deep-water turbidity currents will attract both sedimentologists and volcanologists. The future research of water transported volcaniclastic sediments and their sedimentary sequences, especially using well-preserved core-sections, will be focus on understanding “source volcanism” from the sink of distally located alluvial, lacustrine and submarine sedimentary successions. Also, the sedimentological view and approaches will be key to reveal process and mechanism of volcanic sediment-laden flows (pyroclastic density currents, volcanic debris avalanches, lahars, and subaqueous volcaniclastic turbidity currents) as they share several common features of non-volcanic density currents except for higher temperatures of flow and density variation of volcaniclastic particles. Further, studies of volcaniclastic sediments from sedimentologists’ view may cultivate an innovative realm of “Sedimentary Volcanology”, and fusion of sedimentology and volcanology is necessary to predict and prevent volcanic cascading hazards.

Scientific Themes: Plenary talk
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Presentation Preference: Plenary Talk

Observing source-to-sink processes of terrigenous siliciclastics and particulate organic carbon in the deep sea

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Keywords: terrigenous siliciclastics, particulate organic carbon, source-to-sink process, deep-sea mooring observation system, South China Sea

Source-to-sink transport processes of deep-sea sediments are of great scientific significance for understanding land-to-sea material fluxes, marine carbon cycling, and global environmental change. The lateral transport of solid material from land to sea, dominated by terrigenous siliciclastics, and the vertical sinking of suspended particles from the photic zone, composed mainly of particulate organic carbon, intersect in the deep sea and jointly affect global sediment fluxes, biogeochemical cycles, and climate change. However, observations of these two deep-sea processes and their interactions are scarce, hindering the general understanding of the deep-sea environment and its influence on the formation of deep-sea sediments. Here, we select the South China Sea, the largest marginal sea in the western Pacific, where we have performed in-situ time series observations of deep-sea currents and their transport of sediments for more than 10 years through deployment of deep-sea mooring systems equipped with sediment traps, acoustic Doppler current profilers, and other observation facilities.

These observations have shed light on significant deep-sea sedimentary dynamics and biogeochemical processes that have not been previously confirmed or observed in the deep sea. (1) Contour currents are observed for the first time to have tunnel-like velocity structures that dominate the long-distance along-slope transport of deep-sea sediments in passive continental margins, like the South China margin in the northern South China Sea. (2) Typhoon rainfall can be the direct trigger of the frequent development of turbidity currents in deep-sea canyons, such as the occurrence of turbidity current events four times a year in the Gaoping Submarine Canyon in the northeastern South China Sea. (3) Terrigenous phyllosilicates undergo differential transport, such as the deep basin of the South China Sea, where illite and chlorite are transported mainly by deep currents, while smectite is transported mainly by surface currents. These transport mechanisms control the distribution pattern of clay minerals on the deep seafloor. (4) The fate of terrigenous organic carbon in deep-sea sediments is controlled by phyllosilicate minerals, such us pedogenic organic carbon being stripped form smectite mineral surfaces while petrogenic organic carbon being tightly associated with illite and chlorite upon their dispersal and sedimentation in the deep South China Sea. (5) Zooplankton fecal pellets are an important form of marine organic carbon export, for example, the monsoon climate driven fecal pellet production and sinking in the southern South China Sea, where the repackaging and producing of deep-dwelling communities in mesopelagic and bathypelagic zones may contribute to higher export of particulate organic carbon to the deep sea.

Theme1

Deep-time Climate& Environment

Session T1-1: Cenozoic stratigraphic ages, sedimentary records, weathering-erosion and climate-environmental changes in Asia

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-1: Cenozoic stratigraphic ages, sedimentary records, weathering-erosion and climate-environmental changes in Asia
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

The genetic mechanism of the Oligocene sedimentary hiatus in the western Pacific seamounts: Evidence from the cobalt-rich crust of the Weijia Guyot

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Keywords: Sedimentary processes,Cobalt-rich crust growthing hiatus,Eocene-Oligocene transition,Paleoclimate change,Western Pacific seamounts

Sedimentary process of seamounts is a new direction to explore the occurrence of global climate events since Cenozoic and to predict future global climate change due to its close relationship with global climate change. Eocene-Oligocene transition (E/O) global cooling event is one of the most important climate events experienced by the earth. Some studies indicate that Oligocene sedimentary hiatus exists at western Pacific seamounts, and the cobalt-rich crusts developed at the summit of seamounts occur more than one growthing hiatus since Eocene. However,there are not adequate researches on the genetic mechanism and internal relation between these two sedimentary events. This research will consider the accomplishment form recently ocean scientific research, deep-sea drilling data and other related studies. The study will focus on the oceanic sedimentation rate and the growth process of cobalt-rich crusts in Weijia Guyot since Cenozoic at the Magellan Seamounts, which is located in the Western Pacific Ocean. The study content will be compared with the important global geological events and geological records during the E/O in order to clearly explore the influence of global climate cooling event during E/O on seamount deposition and cobalt-rich crusts growth. Additionally, study the genetic mechanism of Oligocene sedimentary hiatus at western Pacific seamounts, which also provides a possible new basis for E/O global climate change events.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-1: Cenozoic stratigraphic ages, sedimentary records, weathering-erosion and climate-environmental changes in Asia
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Late Miocene reorganization of lake hydrological systems in the northern Tibetan Plateau linked to topographic growth

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Keywords: Paleohydrological systems, Reorganization, Topographic growth, Late Cenozoic, Tibetan plateau

The hydrological cycles of lakes in the Tibetan Plateau have had profound impacts on the climatic and environmental evolution of the Asian interior and hence they are crucial for the well-being of the large human population of the region. The Late Miocene is regarded as the most recent interval when the Tibetan Plateau was extensively occupied large paleolakes. However, it is unclear when and how these mega paleolakes shrank and the environment evolved into its present status of dominant desert and semi-desert. To address these issue we conducted detailed analyses of diffuse reflectance spectroscopy, sedimentology, paleomagnetic-based tectonic rotation, and geochemistry of a Middle to Late Miocene sedimentary sequence in the Xining Basin in the North-eastern (NE) Tibetan Plateau, supplemented by a spatiotemporal comparison of the results with equivalent records from adjacent regions. The results reveal a clear transition of the lacustrine system in the Xining Basin at ~11 Ma, characterized by decreased water level and an increase in the oxidation state of the depositional environment. A synthesis of these observations with available evidence of lake evolution from the NE Tibetan Plateau leads us to conclude that a fundamental reorganization of lake hydrological systems in the NE Tibetan Plateau occurred at ~11 Ma, and that tectonic activity and topographic growth-rather than changes in climate or solar insolation, as previously proposed-was the principal factor responsible. This hydrological reorganization was of profound significance for the regional hydrological cycle and the climatic and ecological environment of Asia, because due to the elevated topography, the NE Tibetan Plateau was unable to reattain its Middle Miocene paleohydrological configuration.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-1: Cenozoic stratigraphic ages, sedimentary records, weathering-erosion and climate-environmental changes in Asia
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Tectonic and orbital forcing on South Asian monsoon in the late Oligocene

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Keywords: Asian monsoon, Tibetan Plateau, Nima Basin, orbital cycles, uplift

The modern pattern of the Asian monsoon was thought to be formed around the Oligocene/Miocene boundary, which has been generally attributed to Himalaya-Tibetan Plateau (H-TP) uplift. However, the timing of the ancient Asian monsoon over the TP and its response to orbital forcing and tectonic uplift remains poorly known because of the paucity of well-dated orbital-scale records from the TP interior. Here we present a ~2-thousand-year resolution cyclostratigraphic results from the Nima Basin to show that the South Asian monsoon (SAM) precipitation has already advanced to the central TP (32ºN) at least at ~27.4 million years ago (Ma) which is indicated by periodical arid-humid fluctuations with orbital cycles based on environmental magnetism parameters. The lithology shift and amplified amplitude of proxy around ~25.5 Ma as well as a hydroclimate transition from obliquity and precession dominated cycles to oscillations paced by a combination of eccentricity, obliquity, and precession confirm that the SAM has intensified at ~25.5 Ma, suggesting the TP might have reached a paleo-elevation threshold for enhancing the coupling between the uplifted plateau and the SAM by then. Eccentricity-paced precipitation variability was argued to be mainly driven by eccentricity-modulated low-latitude summer insolation rather than glacial-interglacial Antarctic ice sheet fluctuations. Our new monsoon data provide key evidence to link the Asian monsoon intensification with regional tectonism and conclude a combination of tectonic and orbital forcing on the SAM evolution on variable timescales in the late Oligocene.

Scientific Themes: Theme 1: Deep-time Climate & Environment
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Presentation Preference: Oral Preferred

From mega-fresh lake to salt playa: when and why does the paleolake evolution in the Qaidam Basin cross a possible tipping point?

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Keywords: Linear and non-linear time series analysis, Orbital forcing, Ice sheet expansion, System regime change

The Qaidam Basin in the NE Tibetan Plateau is now dominated by a desert condition with sporadic salt lakes, however, a large paleolake existed in this 120,000 km^2 vast basin during most of the Cenozoic. Determining when and how the paleolake system collapsed and evolved to its modern condition is crucial for understanding the drying processes of the inland Asia and the associated formation of salt resources in this region. A deep Sino-German drilling core retrieved from the depo-center of the western Qaidam Basin (spanning 2.7 to 0.08 Ma) provides a unique window to address these issues. Here we performed comprehensive linear and nonlinear analyses (i.e., statistical, cluster, wavelet and recurrence quantification analyses) on a large amount of published and newly obtained data of the core. The results show that the lake evolution and salt deposits in the Qaidam Basin experienced four critical periods at ~2.2, 1.2, 0.8-0.6 and 0.3 Ma, and crossed a possible tipping point at 0.6 Ma, characterized by striking changes in proxy variations and regime change at 0.6 Ma. We suggest that the co-occurrence of low obliquity amplitudes and low eccentricity is responsible for the identified transitions in the paleolake evolution of the Qaidam Basin, by facilitating the ice sheet expansion in the Northern Hemisphere and its subsequent effects on the Westerlies. These results are further corroborated by our ECHAM5 general circulation modeling. Our study provides new evidence on the evolution process and related mechanisms of past climatic evolution in inland Asia. The presented comprehensive linear and nonlinear data analysis on a large quantity of paleoclimatic-environmental data demonstrated that the data integration analysis can reveal more important information hidden in the primitive paleoclimate data, and thus has great prospects in related research in the future.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-1: Cenozoic stratigraphic ages, sedimentary records, weathering-erosion and climate-environmental changes in Asia
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Chemical weathering of the Mekong River basin with implication for East Asian monsoon evolution during late Quaternary: Marine sediment records in the southern South China

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Keywords: clay minerals, major elements, chemical weathering, East Asian monsoon, Mekong River, southern South China Sea

Clay mineralogy, major-element geochemistry, and Sr-Nd isotopic compositions from Core MD05-2896 collected in the southern South China Sea have been utilized to investigate discrimination of sediment provenance and to reconstruct a history of chemical weathering in the Mekong River basin over the last 45 ka. Our results display that the clay mineral assemblage of the core is characterized by abundant smectite and illite, with moderate kaolinite and chlorite and 87Sr/86Sr ratios and εNd values narrowly vary in the range of 0.7232 to 0.7272 and from –10.9 to –9.6, respectively. Clay mineralogy and Sr-Nd isotopic composition analyses indicate that the Mekong River is the main terrigenous sedimentary source to the southern South China Sea, with no detectable change over the time span of the study, despite strong sea-level fluctuations. Based on clay mineralogy and elemental geochemistry, higher smectite/(illite + chlorite), smectite/kaolinite, TiO2/K2O, and SiO2/K2O ratios during the Marine Isotope Stage (MIS) 3 and 1 suggest enhanced chemical weathering, while lower values of these ratios during MIS 2 indicate weakened chemical weathering. These proxies reveal a close relationship with the available climate records of the East Asian monsoon evolution, implying that the East Asian monsoon evolution significantly controls the chemical weathering of the Mekong River basin that mainly causes terrigenous sediment variations in the southern South China Sea.

Scientific Themes: Theme 1: Deep-time Climate & Environment
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Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Eocene Paratethys Sea transgression-regression revealed by eolian dust records from the Altun Mountains, northern China

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Keywords: Environmental magnetism, Altun Mountains, Paratethys Sea, Red clay, Eocene

General circulation model simulations show that the Paratethys Sea retreat plays as important a role as uplift of the Tibetan Plateau in affecting Eurasian climates over the Neogene. The Paratethys Sea was larger and experienced dramatic transgression and regression over the Eocene, which could have had major impact on Eocene central Asian climate and environments. However, no consensus has been reached regarding its first order transgression/regression feature. Here we report a set of environmental magnetic records of the Eocene eolian dust in the Xorkol Basin within the Altun Mountains, near easternmost maximum boundary of the Eocene Paratethys Sea. We found that the hematite content and dust accumulation rate variations of this record are consistent with proposed Paratethys sea level variations over the Eocene, with higher sea level corresponding to lower hematite content. Because hematite forms in dry environments and our hematite and dust accumulation rate records have independent age model as the Paratheys sea level record, the consistent variations between them are best interpreted as their capturing the transgression/regression variations of the Paratethys Sea over the Eocene. Furthermore, the hematite record shows high frequency variations that is absent from the previously reconstructed Paratethys sea level record, which we attribute to detailed variations of the Paratethys Sea transgression/regression. This study not only demonstrates that dramatic dry-wet variations occurred in central Asia over the Eocene, it also clarifies the detailed Paratethys Sea transgression/regression history over this time interval and demonstrates its dominant control over central Asian climate.

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Session T1-1: Cenozoic stratigraphic ages, sedimentary records, weathering-erosion and climate-environmental changes in Asia
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Eccentricity and obliquity metronomes recorded in the lacustrine sediments of Jiuxi Basin, northeastern Tibet are used to calibrate the Middle Miocene astronomical time scale

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Keywords: Middle Miocene, Astronomical time scale, Orbital cycles, Jiuxi Basin, Northeastern Tibet

High-precision chronostratigraphy is key to the study of the uplift and concomitant environment and climate change that have affected the Tibetan Plateau during the Cenozoic Era. Magnetostratigraphic studies have established the geomagnetic polarity time scale for fluvial-lacustrine sedimentary deposits around the northeastern Tibet Plateau. Complementary cyclostratigraphic studies have reconstructed an astronomical time scale to improve chronostratigraphic precision from 100-kyr to 10-kyr scale. To date, these cyclostratigraphic studies (Nie et al., 2017; Wang et al., 2018, 2019, 2021) cover most of the Miocene Epoch but a significant age gap remains from 17Ma to 14Ma, corresponding to the Miocene Climate Optimum period. To bridge this gap, we investigate the orbital cycles recorded in lacustrine mudstones from the Middle Miocene Epoch in Jiuxi Basin. We construct lithological color rank series of green-red mudstone rhythms, and establish a 3.6 Myr-long astronomical time scale from 16.0 Ma to 12.4 Ma. Time series analysis reveals multiple signals with precession index, obliquity and orbital eccentricity cycles, including dominant 405-kyr cycles associated with the precession index modulation, and 173-kyr and 1.2-Myr cycles associated with obliquity amplitude modulations. The eccentricity (405-kyr cycle) and obliquity (173-kyr cycle) metronomes are proposed to have originated from insolation forcing, and recorded as orbital metronome cycles via climate-sedimentary threshold responses. Importantly, the 1.2-Myr cycles observed in the lacustrine records are in phase with the obliquity amplitude modulations of the La2004 astronomical solution, supporting the accuracy of our chronostratigraphic framework. The reconstructed astronomical time scale reveals that the recorded astronomical cycles correlate well with those from marine and aeolian archives, suggesting that lacustrine sediments (16 Ma to12Ma) in the Jiuxi Basin provide high-precision chronostratigraphic templates for deciphering Middle Miocene global climate change and the evolution of the Asia monsoon.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
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Cenozoic multi-stage deformation of the Qilian Shan orogenic belt, northern Tibetan Plateau: Insights from a detrital zircon provenance study of an Oligocene-Miocene intermontane basin sedimentary succession

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Keywords: Detrital zircon, Provenance, Tectonic deformation, Qilian Shan orogenic belt, Subei Basin

Timing and patterns of the Cenozoic deformation of the Qilian Shan orogenic belt (QSOB) in the northern Tibetan Plateau are key to elucidating the mechanism(s) of plateau growth but remain matters of debate. The Oligocene-Miocene sediments in the Subei Basin, an intermontane basin situated at the junction of the central and southern QSOB, provide direct insight into the Cenozoic deformation of the QSOB. Here, a comprehensive provenance study based on detrital zircon geochronology, paleocurrents, conglomerate components and sedimentary facies in the Subei Basin demonstrates that this region experienced three stages of tectonic events during the Cenozoic. (1) Oligocene strata contain zircons of 200-300, 400-500, 700-1000, 1600-2000 and 2400-2700 Ma, indicating primary derivation from recycled Mesozoic sedimentary rocks in the QSOB and suggesting early Cenozoic deformation in this region. (2) One sample (21.5 Ma) yields similar age populations to those of Oligocene samples, except for the complete disappearance of 200-300 Ma zircons as a result of the widespread deformation of the QSOB. (3) Two samples (18.5-13.6 Ma) show a unimodal age cluster at 400-500 Ma, while one sample (9 Ma) contains zircon ages similar to those of Oligocene samples, indicating tectonic uplift of the southern QSOB in the middle-late Miocene, which is also recorded by the sedimentary transition from fluvial to alluvial fan. Based on these findings and those of previous studies, we suggest that the entire QSOB has undergone multistage tectonic events since the early Cenozoic due to far-field effects associated with the India-Eurasia plate collision and the continued convergence.

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Presentation Preference: Oral Preferred

The provenance change of sediments in Weihe Basin (central China) and their implications for the regional river drainage evolution during early Cenozoic

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Keywords: Yellow River, Cenozoic, fluvial drainage organization, provenance

The evolution of continental-scale drainage systems is profoundly affected by the paleo drainage system in the early stage of tectonic deformation. Whether there is a proto Yellow River-Weihe River system connecting the northeastern Qinghai-Tibet Plateau and the Weihe Basin in the Early Cenozoic is still controversial. The Weihe Basin is located in the middle and lower reaches of the Weihe River. It has been subsiding continuously during Cenozoic. It is a possible catchment basin of the proto Yellow River-Weihe River. This study presents the detrital zircon U-Pb ages and heavy mineral assemblages of middle Eocene to middle Miocene sediments in the Weihe Basin. Quantitative estimate of potential sources shows that sediments at middle Eocene to early Oligocene show local sources of the Weihe drainage, while sediments at the middle Miocene may receive provenance from the upper reaches of the Yellow River west of the present Weihe River. Detrital zircon U-Pb age from basin sediments at the upstream of the modern Weihe River and upper reach of the Yellow River on the NE Tibetan Plateau also showed similar river drainage connection. This indicates there may be a connection between the early drainage systems of the paleo Weihe River and the paleo Yellow River at middle Miocene. We argue that this connection is probably controlled by both regional tectonic deformation and climate changes.

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New insights into the ages of the potash bearing strata in the Simao and Khorat basins and its geological implications

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Keywords: Potash bearing strata, chronology, Simao Basin, Khorat Basin

It has long been suggested that the potash bearing strata in the Simao and Khorat basins are possibly closely related. However, their correlations, such as formation ages, origins and metallogenic regularities are still poorly constrained. Here we present detailed detrital zircon U-Pb geochronologic-magnetostratigraphic studies of the potash-bearing strata from the Simao and Khorat basins, try to establish well age constraints on the potash bearing strata and provide a better understanding on the correlation of two potash mines. Through an integrated chronological study of radiometric dating, pollen assemblage and magnetostratigraphy on a ~932-m thick outcrop in Jiangcheng, Simao Basin, the potash bearing Mengyejing Formation is well confined to be ~112 - 63 Ma; Through a detailed bio-magnetostratigraphic study of a 596 m-deep potash bearing borehole in the southeast Sakhon Nakhon Basin in central Laos, the potash-bearing Nong Boua Formation is confined to be ~92 Ma-~ 63.5 Ma, with magnetostratigraphic age of the potash bed at ~85 Ma. Thus, the deposition of the potash bearing strata in the Simao commenced ~20 Ma earlier than those in the adjacent Khorat basins, opposite to the traditional viewpoint that the former would rather correspond to the middle and lower parts of the latter. Given the paleogeographic reconstruction of likely a pan-Simao-Khorat basin during the Cretaceous, we would believe that, beside the new suggested the Middle-Late Jurassic, ~85 Ma would be another important potential period for future potash exploration in the Simao Basin.

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Session T1-1: Cenozoic stratigraphic ages, sedimentary records, weathering-erosion and climate-environmental changes in Asia
Presentation Preference: Oral Preferred

Asian environmental change and its global impact: clues from the NE Tibetan Plateau

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Keywords: Tibetan Plateau, eolian dust, silicate weathering, carbon cycle

The Cenozoic uplift of the Tibetan Plateau has exerted profound effects on Asian environment change. Here, we used accurately dated Cenozoic fluvial-lacustrine sedimentary sequences in the northeastern Tibetan Plateau to study the Cenozoic long-term evolution of the Asian environment and its potential global impact. Carbonate elemental and Sr isotopic compositions and silicate Nd isotopes in river and lake sediments were used to trace the evolution of the Asian eolian dust system, and clay mineral assemblage was applied to establish silicate weathering history in the Asian inland. The results showed that the development of Asian eolian dust and continental weathering could impact the global geological carbon cycle with two important periods at the late Oligocene-Early Miocene and ~8 Ma. Our studies suggested that the uplift of the Tibetan Plateau has promoted CO_2 consumption not only through erosion-driven high silicate weathering and organic carbon burial in the tectonically active plateau but also through intensifying the enhanced weathering Asian dust systems over central-east Asia.

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Cenozoic uplift of Tanggula Range and Tuouohe Basin, northern Tibet: insights of the anisotropy of magnetic susceptibility

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Keywords: Tuotuohe Basin, anisotropy of magnetic susceptibility, Tanggula Range, tectonic uplift, Tibet

The timing and intensity of deformation of the Tanggula Range and Tuotuohe Basin are in debatable but strengthening the research on them is necessary for better understanding the geodynamic models of the Tibet and the tectonic-climate connections during the Cenozoic. Here we present the anisotropy of magnetic susceptibility (AMS) records from the foreland Tuotuohe Basin to understand the tectonic uplift history of the Tanggula Range for the interval of ~37–19.7 Ma. Rock magnetic analyses indicate that the main magnetic carrier is paramagnetic and the minor is hematite. Thus, the AMS in the Tuotuohe Section (TS) can be used to track the tectonic strain related to tectonic processes. The distribution direction of the maximum principle susceptibility (Kmax) is approximately NW–SE, which intersects at about 10°with the strike of the strata and is nearly parallel to the Tanggula thrust fault system, whereas the minimum principle susceptibility (Kmin) is oriented in the NE–SW direction with a girdle distribution. This is consistent with the sedimentary fabric imprinted by the NE–SW shortening direction, representing the earliest deformation stage. AMS data in the TS can be divided into two phases at 30 Ma. From ~37 to 30 Ma, the AMS parameters indicate an active tectonic strain and the Tanggula Range uplift induced by the India–Asia convergence, whereas between 30 and 19.7 Ma, the strain is weak compared with the earlier phase. Finally, the weak strain environment between 30 and 19.7 Ma indicated by the AMS indexes of the TS and the paleoelevation evidence from the Tuotuohe Basin all together suggest that an additional 1000–2000 m of surface uplift of the basin may have begun after 19.7 Ma.

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Relative paleointensity correction of radiocarbon reservoir effect for lacustrine sediments on the northeast Tibetan Plateau

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Keywords: Relative paleointensity, Radiocarbon reservoir effect, Lacustrine sediment, Hurleg lake, Tibetan plateau

An accurate chronological framework is vital if we are to use lacustrine sediments on the Tibetan Plateau (TP) for paleoclimate reconstruction. Radiocarbon (14C) dating is the most frequently used method for dating late Quaternary lacustrine sediments. However, it is often affected by potential reservoir effects. Owing to the complex hydrogeology and sedimentology processes of the lake we study in this paper, it is difficult to correct this effect. Geomagnetic relative paleointensity (RPI) method has demonstrated the potential to construct an accurate high-resolution chronological framework for sediments in the Brunhes chron. In this study, we present an RPI record as well as environmental magnetism results from a core (HL) on the Hurleg Lake in the northeast TP. We aim to determine the reservoir effect and establish an accurate timescale for the core. The RPI record was constructed by normalizing the natural remanent magnetization after 30 mT alternating field demagnetization with saturation isothermal remanent magnetization (NRM30mT/SIRM). This exhibits a general agreement with other geomagnetic intensity stacks from the world, suggesting that global-scale patterns of geomagnetic paleointensity behavior were also documented in Hurleg Lake sediments. Our RPI record can be adequately matched to RPI references to provide three additional age tie points for the HL core. We then evaluated the reservoir effect and constructed a timescale for the core using chronological controls from both RPI and 14C dating. The estimated RE age was weak below 272 cm, was 2–3 ka at the upper 50 cm, and was inferred to have increased between depths of 272 and 50 cm. Environmental magnetism sequences from core HL display a similar paleoclimatic pattern with records from core HL05-2 and core K-2 both in the Hurleg Lake area, suggesting that correction for the radiocarbon reservoir effect is accurate and timescale of core HL is reliable. Our study further demonstrates that the method of obtaining age control points from RPI is applicable to lake sediments on the TP.

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Geomorphic development characteristics and control factors of mountainous watershed of the Yarkant river based on Hypsometric Integral

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Keywords: Hypsometric Integral,mountainous watershed of the Yarkant River,geomorphology,tectonic activity,lithology,climate

Pamir syntaxis is an active structural belt, bearing abundant information about geomorphic evolution, and its linking to tectonic activities, climate shifts, and other factors. Yarkant River Basin (74°28'~80°54' E, 34°50'~40°31' N) is located in the east edge of Pamir syntaxis, which is divided into southern mountain basin and northern plain basin. As a whole, the development of fault zones in the Yarkant River Basin is controlled by Karakoram fault, Karakax fault and Kashgar-Yecheng transfer system from west to East. And magmatic rocks, metamorphic rocks and sedimentary rocks are widely crop out in the mountain basin. Therefore, mountainous watershed of the Yarkant River (MYR) is an ideal place to study the geomorphic characteristics of the Pamir syntaxis. The DEM data of MYR (with a spatial resolution of 30 m×30 m, the spatial reference is WGS_1984_UTM_ZONE_43N, download from http://www.gscloud.cn) were processed by using the Hydrological Analysis Tools of ArcGIS 10.2. We extracted HI values in order to quantitatively study the geomorphic development characteristics of MYR, and discuss the relationship between structure, lithology, climate and geomorphic development. We obtained 1357 watersheds, and the correlation with the mean HI value is poor (R2=0.0981). That infers that the watershed has little impact on the mean HI value in MYR. We found the HI values of watersheds in MYR range from 0.0717 to 0.6485, with an average value of 0.4056, suggests that geomorphological development trend in mature stage. And order of mean HI value of MYR is (0.4148) in strong tectonic activity areas > that average in the whole basin (0.4056) > that in weak tectonic activity areas (0.4004), which suggests tectonic activity is a factor affecting the geomorphic development of the basin, and its effect on the geomorphic development is mainly monitor by its intensity and size. The sequence of mean HI value in areas covered by different lithology in weak tectonic activity areas in MYR is metamorphic rocks (0.491353) > ice, snow and modern glaciers (0.491351) > granite (0.4426) > marine sedimentary rocks (0.4098) > continental sedimentary rocks (0.3890) > marine interbed continental sedimentary rocks (0.3813) > Quaternary sediments (0.3598). It indicates that the difference of rock erosion resistance is an important factor affecting topography. In addition, the climate conditions in MYR mainly control the regional annual volume of surface runoff through precipitation and temperature. This influences the erosion in catchment and transportation of rivers, and affects the geomorphic development. However, the average annual precipitation has less influence on the geomorphic development of the basin than the mean annual temperature in MYR. Our study provides evidence for that the mean annual temperature is the main factor of climate affecting the geomorphic development in MYR.

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The demise of the Neotethys seaway and its potential links with the global cooling following the Early Eocene Climatic Optimum

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Keywords: Tethys seaway, EECO,larger benthic foraminifera,carbon isotope, southern Tibet

Tracking the demise of the Tethys seaways is essential to understand the successive tectonic evolution after initial India-Asia continental collision as well as effects on global climate and environment. Based on the extensive study of the early Paleogene sedimentary record in Southern Tibet, we constrained the age of youngest shallow-marine carbonate strata, reconstructed the demise of the Tethys seaways and discussed its potential links with the termination of peak global warmth following the Early Eocene Climatic Optimum. The youngest shallow marine carbonate strata illustrated here is located in Tethys Himalaya and represented by the Zongpu Formation exposed in Tingri, Gamba and Yadong areas (Hu et al., 2016). The youngest shallow marine carbonate in topmost of the Zongpu Formation was deposited in inner to middle ramp environment, and was constrained to SBZ12-SBZ13 (48-49 Ma) by larger benthic foraminifera, suggesting that the demise of the shallow marine carbonate sedimentation ceased by 48-49 Ma. The bulk-rock carbon isotopic values show a gradual positive shift from -0.2‰ ~1.5‰, followed by a positive carbon isotopic plateau with values ranging from 1.5‰ ~1.7‰, and then carbon isotopic values gradually decrease and approximate the pre-excursion level at the topmost of the Zongpu Formation, which was represented the Early Eocene Climatic Optimum. The demise of the shallow marine carbonate sedimentation coincides with the termination of peak global warmth following the Early Eocene Climatic Optimum, highlighting the complexity and importance of Tethys seaway circulation in the greenhouse climate of the Eocene.

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Quantifying the provenance of dune sediments in the Taklimakan desert using machine learning, multidimensional scaling and sediment source fingerprinting

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Keywords: Tarim, Taklimakan, multidimensional scaling, geochemistry, provenance analysis, source fingerprinting

Study of windborne sediments in the Taklimakan Desert is of great significance in the context of global change. Much effort has gone into characterizing the Taklimakan dune sediments, but quantitative understanding of the source contributions from the surrounding mountains is lacking. Accordingly, using elemental data, we applied random forest (RF), multidimensional scaling (MDS) and sediment source fingerprinting (SSF) to examine homogenization of the dune sediments in the desert, and to quantify the contributions of key sources. The results underscored the heterogeneity of geochemistry in dune sediments in the Taklimakan Desert. On the basis of dominant wind directions and the drainage network in the Tarim Basin, as well as lithologic features in the surrounding mountains, potential sources of sand dune sediments comprised three groups: “Tianshan”, “Pamirs-Kunlun”, and “Kunlun-Altun”. Using the FingerPro and MixSIAR fingerprinting models our results suggested that the contributions of the three sources to the target dune sediments were: “Kunlun-Altun” > “Pamirs-Kunlun” > “Tianshan”. However, substantial variations in the respective contributions were observed for different target dune samples. Although both the frequentist and Bayesian models performed well in the calculations of the relative source proportions based on goodness of fit (GOF) (0.97 on average for the two models respectively), virtual mixtures (VM) tests indicated that the frequentist model returned more accurate predictions. Consequently, using the frequentist results, we propose that the “Kunlun-Altun”-derived sediment (an average of 56%) is mainly delivered to the Taklimakan Desert via fluvial transport; sediment supply from the “Pamirs-Kunlun” source (33%) depends on fluvial and wind transport and that aeolian processes are mainly responsible for distribution of the “Tianshan”-derived sediment (11%) in the desert by transporting the fine fraction. Our findings thereby highlight the interaction between fluvial and aeolian transport within the Tarim Basin.

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Eocene sedimentary-tectonic evolution of the Jianchuan Basin in southeastern Tibetan Plateau

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Keywords: Southeastern Tibetan Plateau, Eocene, Jianchuan Basin, Sedimentary-tectonic evolution

The southeastern margin of the Tibetan Plateau plays an important role in understanding the region's basin-orogen coupling. As a representative Cenozoic basin in the southeast margin of the Tibetan Plateau, the Jianchuan Basin is of great significance for studying the tectonic evolution of the Tibetan Plateau. In this study, we carried out a comprehensive study of the Eocene strata and sedimentary systems in the Jianchuan Basin, and obtained the results as follows: (1) The Eocene stratigraphy of the Jianchuan basin can be subdivided into the early to middle Eocene Baoxiangsi Formation, the middle to late Eocene Jinsichang Formation, Jiuziyan Formation, Shuanghe Formation and the Jianchuan Formation in ascending order. (2) The Baoxiangsi Formation, as the most widely distributed and thickest strata in the basin, developed alluvial fan, desert, fluvial, delta and lacustrine sedimentary systems from the basin margin to the center. These deposits are vertically arranged into several fining upward cycles, indicating an extensional tectonic setting. (3) The Jinsichang, Jiuziyan, Shuanghe and Jianchuan formations limited present in the southeast of the basin are composed of fluvial, lacustrine, marsh and volcaniclastic deposits, which suggest a rapid decrease of depositional accommodation and shrinking of the basin. (4) The Jianchuan basin died out in the latest Eocene due to the regional uplift of the Tibetan Plateau. The Eocene sedimentary-tectonic evolution of the Jianchuan basin was consistent with the coeval tectonic uplift of the southeast margin of the Tibetan Plateau.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-1: Cenozoic stratigraphic ages, sedimentary records, weathering-erosion and climate-environmental changes in Asia
Presentation Preference: Oral Preferred

The role of the westerlies and orography in Asian hydroclimate since the late Oligocene

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Keywords: Paleoclimate, Cenozoic, Paratethys, Pamir-Tian Shan orogen, Westerlies, Central Asia

The Cenozoic Asian aridification has been related to the retreat of the Paratethys, the uplift of the Tibet, and/or global cooling. However, the details of the mechanisms responsible for this paleoclimate shift remain poorly constrained. Modern observations indicate that interactions between mid-latitude westerlies and the Pamir-Tian Shan Mountains significantly impact hydroclimate patterns in central Asia today, and may have played an important role in driving Asian aridification during the Cenozoic. However, the timing when this topographic-atmospheric framework was established remains poorly constraints. Here, we present magnetostratigraphy, U-Pb geochronology, thermochronology, paleoclimatology, stable carbon and oxygen isotope geochemistry, and climate modelling techniques to the Cenozoic sedimentary sequences in the Tajik Basin. Our results show that: 1) the penultimate and ultimate retreat of the Paratethys from central Asia occurred at ~41 and ~37.4 Ma, respectively; 2) the Pamirs have experienced active deformation and accelerated exhumation during the late Oligocene to early Miocene; 3) the windward (western) side of the Pamir and Tian Shan has been characterized by a wetter climate changes, whereas, the leeward (eastern) side of the orogen has been characterized by more arid conditions since the Late Oligocene; 4) This distinct east-west hydroclimate differences, when integrated with climate modeling results, suggests that at least part of the Pamir-Tian Shan mountains had reached elevations ≥ 3 km and acted as a moisture barrier for the westerlies since ~25 Ma. We suggest that the interactions between the westerlies and the Pamir-Tian Shan orogen played an important role in driving Asian aridification since the Late Oligocene.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-1: Cenozoic stratigraphic ages, sedimentary records, weathering-erosion and climate-environmental changes in Asia
Presentation Preference: Oral Preferred

Sedimentary record, Provenances and Paleoclimatic Response of Holocene Sediments in the Inner Shelf of the East China Sea

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Keywords: The inner shelf of ECS, Grain size, Clay minerals, Source areas, the East Asia Monsoon

Holocene sediments from the inner shelf of the East China Sea (ECS)with its high deposition and continuously sedimentary record which is sensitive to enviromental changeis an important recorder of regional responses to global paleoclimatic and paleoenvironmental changes. Based on the precise AMS14C dating data, We analyze grain size, clay minerals and trace elements of S05-3 sediment cores, investigating the sediment provenances of the the southern inner shelf of ECS, deducing the evolution of East Asia Monsoon in the past 4.7ka. Comparing the clay minerals in the southern inner shelf of ECS with one from different potential source areas, the results indicate that sediments in the study area came from the Yangtze River, the Yellow River and rivers from Taiwan, while every potential source area making contribution in the different periods. In the period of 4.7-4.2ka, sediments from the Yantze River and Taiwan's river is the main source of sediments. From 4.2ka to 3.2ka, sediments of study area mainly consist of the sediments of the Yanze River and the Yellow River. Since 3.2ka, sendiments from all of potential source areas had some response on the study area.

The evolution of East Asia Monsoon in the past 4.7ka can be deduced based on the grain size sensitive components, the ration of Rb/Sr and montm orillonite/kaolinite. Refering to the δ18O of GSP2 and stalagmite of Dongge Cave and the evidence of cooling of different materials in other regions, 9 high values could be recognized corresponding to the cooling events caused by the East Asia Monsoon. The core S05-3 records 4 strengthen periods of the East Asia Monsoon: weak and stable during 4.7-4.2ka BP; increased and began to fluctuate during 4.2-3.2ka; a little weak with highly fluctuation during 3.2-2.0ka BP; the East Asia Monsoon incresed slighly with fluctuations weakened.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-1: Cenozoic stratigraphic ages, sedimentary records, weathering-erosion and climate-environmental changes in Asia
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Palynological Assemblages from the Neogene in Western Songliang Basin and their Paleoclimatic Characteristics

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Keywords: western Songliao Basin, Miocene, Pliocene, Palynological, paleoclimate

The Neogene deposit in the Songliao Basin was developed in the atrophic stage. Since the Upper Cretaceous Mingshui Formation was deposited, the Songliao Basin had been uplifted and eroded. Until Oligocene, it began to be filled gradually in the Yi'an area, north part of the basin. The depositional areas extended southward and westward in the Neogene, therefore the western slope area of the Songliao basin is the most developed area of the Neogene deposit. Due to the poor preservation, most of the Neogene palynomorphs were identified only in the family level, and the assemblage characteristics were obscure.

Based on the new material of Neogene palynomorphs in recent years, two assemblages are identified separately from the Da'an Formation and the Taikang Formation. Such as: 1) Momipites coryloides—Caryapollenites simplex—Celtispollenites sp. Assemblage. This assemblage is composed of angiosperm pollen (34.4-82.76%), gymnosperm pollen (15.17-64.8%), algae (0-5.51%) and fern spores (0-3.15%). The above assemblage in the Dan'an Formation shows diverse terrestrial vegetation including aquatic algae. The angiosperms are mainly composed of temperate and north tropical tree of Juglandaceae (Caryapollenites, Juglanspollenites) and temperate tree of Ulmaceae (Ulmipollenites, Celtispollenites), Betulaceae (Alnipollenites, Carpinipites) and Fagaceae (Quercoidites, Faguspollenites). Some xerocole shrub represented by Zygophyllaceae (Nitrariadites) and some aquatic plants such as Potamogetonacidites indicated a warm and humid climate with seasonal draught. Since there are not any tropical elements such as Dicolpopollis, Florshuetzia, Lagerstroemia and Verrucatosporites found in this assemblage, the climate might be warm temperate or north subtropical. The vegetation might be mesophytic deciduous broad-leave forest mixed with some evergreen broad-leave trees and conifers. 2) Betulaceoipollenites sp.—Artemisiaepollenites minor—Carpinipites sp. Assemblage. This assemblage bearing in the Taikang Formation consist of angiosperms pollen (33.33-90.45%), gymnosperms pollen (7.87-65.96%), ferns spores (0.44-9.86%) and algae (0-9.33%). This assemblage in the Taikang Formation is similar to that in the Da'an Formation in general. However the content of Rosaceae widely distributed in the temperate and subtropical forest in north hemisphere increased obviously, and the content of Caryapollenites which distributed in the north subtropical area reduced slightly. In addition, the content of Artemisiaepollenites, a kind of xerocole herb in composite family increases obviously; and other xerocole plants such as Nitrariadites, Ephedripites and Chenopodipollis are common. This indicates that the climate of the Taikang Formation is slightly cooler and drier than that of the Da'an Formation. This climatic change is consistent with the background of Neogene climatic evolution in eastern China.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-1: Cenozoic stratigraphic ages, sedimentary records, weathering-erosion and climate-environmental changes in Asia
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Paleoclimate of late Eocene lacustrine sediments in Huangyanghe section of Wuwei Basin, northwestern China: Implications from grain size and SEM analysis

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Keywords: Eocene paleoclimate, grain size, SEM, Huangyanghe section, aridification

Eocene paleoclimate changes are of great significance for understanding the evolution of paleoclimate in Asia. Paleogenic-Neogenic fluvial and lacustrine sediments of Huangyanghe section in the Wuwei Basin in the east of the Hexi Corridor of northwestern China were investigated by grain size measurement and scanning electron microscope (SEM). Additionally, the grain size distributions (GSDs) of detrital fractions were subjected to parametric end-member modeling analysis (EMMA) using the Analysize software. Results show that typical aeolian shapes such as irregular dish-shaped depressions and pockmarks were observed on the surface of quartz sand. Fine-grained components of the lacustrine sediments in the middle Huangyanghe section are aeolian and aqueous origins, and can be divided into three stages based on the vertical variations in sedimentary facies and particle components. The grain size increases along the profile, possibly indicating the shift of climate from humid to dry. Moreover, EMMA shows that the grain size was composed of three end-members (EM) . EM1 (mode particle size is 6.32 μm) may be the clay suspension components by high-altitude wind and the silt component by regional wind; EM2 (mode particle size of 112.47 μm) may be those sediments transporting into lakes by surface runoff; EM3 (mode particle size of 224.4 μm) may represent coarse-grained saltation components deposited by flood or redeposited by secondary perturbation in lake. The EM1 components were compared with loess sediments from the Chinese Loess Plateau, producing that the separated aeolian components are approximately consistent with the era of aridification of Altyn red clay (Li et al, 2018) and Xining Basin (Dupont-Nivet et al, 2007). This study provides an improtant guide for studying the process of aridification in the Hexi Corridor and the reconstruction of the paleoclimate in this area.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-1: Cenozoic stratigraphic ages, sedimentary records, weathering-erosion and climate-environmental changes in Asia
Presentation Preference: Oral Preferred

Shifting of Marine Phosphorus Storage Through the Cenozoic

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Keywords: Phosphorus, phosphorite, phosphatization, phosphogenesis, weathering, ferromanganese crust

Previous records of phosphorus burial derived from continental margin sediments, seamount phosphorites and pelagic sediments are asynchronous. To better understand the spatiotemporal evolution of marine phosphorus burial, we investigated the timing and mode of phosphatization in two hydrogenous ferromanganese (Fe-Mn) crusts dredged from Pacific seamounts. With all archives considered together, three episodes of peak phosphogenesis can be identified: E1 during the first half of Eocene, E2 during the late Eocene and late Oligocene, and E3 during the middle Miocene and late Miocene. These episodes are asynchronous but complementary to each other: E1 was recorded in all three archives; E2 was recorded on Pacific seamounts but in neither continental margin nor pelagic sediments, and E3 was recorded in continental margin sediments and Atlantic seamounts but not on Pacific seamounts or in pelagic sediments. E1 occurred during a greenhouse climate with a large oxygen minimum zone (OMZ) and shallow carbonate compensation depth (CCD), likely linked to large-scale orogenesis. E2 occurred during rapid seafloor spreading that resulted in intense glaciation, leading to the formation of the Antarctic ice sheet and fast ocean overturning, which, together with the lowered sea level, compressed the OMZ to smaller sizes. The lowered sea level led to decreased continental margin sedimentation and pushed P into deeper OMZ water, leading to a hiatus of P burial in marginal areas but a peak phosphogenesis on seamounts. During E3, P storage location shifted from the deep Pacific to the continental margin and Atlantic seamounts due to even stronger ocean circulation in response to the cooling climate and the opening of the Drake Passage leading to the establishment of the Antarctic Circumpolar Current and enhanced upwelling in the Atlantic. The temporal shift of P storage location among oceanographic settings means that previous approaches of using P burial rate derived from a single setting to reconstruct global riverine P input flux may lead to large uncertainties. Instead, a composite P burial curve built from multiple archives is needed.

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Session T1-1: Cenozoic stratigraphic ages, sedimentary records, weathering-erosion and climate-environmental changes in Asia
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Sedimentary Records of aridity in Asia inland in the Cenozoic-A case study of the Aertashi section in Xinjiang

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Keywords: Aridity in Asia inland, Sedimentary Records,Aertashi section.

In the Cenozoic, the inland areas of Asia experienced a remarkable climate change from humid to dry. However, the starting time, evolution process, and controlling factors of aridity in Asia inland are hotly debated. In this study, a detailed sedimentological study was carried out in the Aertashi section in the southwest of Tarim. The Aertashi section, 9.5 km long and 5.2 km thick, can be subdivided into Eocene Wulagen Formation, Bashibulak Formation, Oligocene Wuqia Group and Neogene Xiyu Formation in ascending order. 22 lithofacies types and 16 lithofacies associations have been identified and grouped into 6 depositional systems, including coastal depositional system, alluvial fan depositional system, fluvial depositional system (braided river, and high-energy shallow water river), delta depositional system, lacustrine depositional system (shore shallow lake, salt lake, and hyperpycnal flows) and eolian depositional system. These depositional systems show a transition from coastal depositional systems to deltaic, lacustrine, desert, lacustrine, deltaic, fluvial ,alluvial fan, lacustrine ,fluvial and alluvial fan depositional systems, indicating frequent shift of dry-wet climatic cycles flowing the regression of the Para-tethys. The occurrence of high-energy shallow fluvial deposits in the top part of the Wuqia Group represents the onset of the aridity in Asian inland. The above climatic changes suggest that the regression of the Para-tethys only resulted in a short-term effect on the aridity, instead of playing a decisive role in aridity in Asian inland. The uplift of the Tibetan Plateau and global cooling may be the main controlling factors.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-1: Cenozoic stratigraphic ages, sedimentary records, weathering-erosion and climate-environmental changes in Asia
Presentation Preference: Oral Preferred

Paleogeographic characteristics of key time nodes of Neogene in Qilian Shan area, northeastern margin of Tibet Plateau

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Keywords: Qilian Shan and its adjacent areas, Neogene, key time nodes, aridification, paleogeographic characteristics

The Neogene is a key period for the formation of the current tectonic landform on the northeast edge of the Tibet Plateau and the arid pattern in the interior of Asia. During this period, Qilian Shan and its adjacent areas have experienced different stages of tectonic uplift and climate changes. These processes have a good coupling relationship with major global tectonic climate events. The study of paleogeographic characteristics of Neogene key time nodes in the northeast margin of the Tibet Plateau is of great significance to understand the formation and development of modern environmental model and the growth of the Tibet Plateau. In this study, 22 Ma (initial aridity in inland Asia) and 8 Ma (large-scale aridity in inland Asia) are selected as the key time nodes. Based on the systematic collection of regional geological survey reports and previous research results in the study area, the Neogene stratigraphic characteristics, sedimentary evolution in the study area are analyzed by means of stratigraphy and sedimentology, combined with previous studies on tectonic background and paleoclimate, the paleogeographic pattern of the key time nodes of Neogene in the study area is restored, and the coupling history of sedimentation, structure and climate in the study areas since Neogene is comprehensively discussed. The main achievements are as follows:

The Neogene strata in the study area are divided into Qaidam, Hexi Corridor and Guide-Lanzhou-Xining stratigraphic division, and the Neogene stratigraphic sedimentary sequence of the study areas is established. According to the facies markers, the sedimentary environment in the study area can be divided into Alluvial fan, Fluvial, Delta and Lacustrine.

22 Ma is the development stage of Qilian Shan and its adjacent lacustrine basins. A large area of lacustrine deposits are developed in the study area, and aridification has occurred in some areas. At 8 Ma, the tectonic movement became strong, and the Qilian Shan and its adjacent lacustrine basin began to shrink. The sedimentary facies are mainly alluvial fan facies and fluvial facies, and the phenomenon of aridification intensified.

The Neogene sedimentary-tectonic-climate evolution history of Qilian Shan and its adjacent areas can be roughly divided into three stages: 22-20 Ma tectonic uplift period: the tectonic uplift event occurred in Qilian Shan and its adjacent areas, and the initial uplift of Qilian Shan, Altun Shan and Laji Shan in the area. And at this stage, the phenomenon of aridification has appeared in Qilian Shan and some adjacent areas. 20-13 Ma lacustrine basin expansion period: the tectonic movement of Qilian Shan and its adjacent areas was relatively calm, the basins in the area develop stably, gradually expand to their peak, and mainly develop lacustrine facies mixed with delta facies. Strong uplift period since 13-8 Ma: the tectonic movement in the study area was strong, the large lakes in the area begin to shrink, and enter the lake regression period. The sedimentary environment was dominated by alluvial fan facies and fluvial facies, and the aridification in the interior of Asia was intensified.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-1: Cenozoic stratigraphic ages, sedimentary records, weathering-erosion and climate-environmental changes in Asia
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Biomarker evidence for late Miocene-Pliocene temperature and aridity evolution from the Maxian Mountains, NE Tibetan Plateau

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Keywords: Biomarker, Temperature, Hydroclimate, NE Tibetan Plateau

Late Miocene-Pliocene environmental change is critical to understand the interactions among the global cooling, regional tectonic activity and Asian climate evolution. However, their relationship remains uncertain due to scarcity of quantitative temperature and hydroclimate conditions, thereby, limiting our further understanding of the Asian climate evolution. Here we quantitatively reconstruct the late Miocene-Pliocene (~6.2-3.6 Ma) temperature and hydroclimate history via based on the Xiaoshuizi red clay GDGTs evidence from the Maxian Mountains, NE Tibetan Plateau. Our results indicate that the mean annual temperature (MAAT) can be divided into two stages: the MAAT decreases from 20.6 ℃ to 13.5 ℃ during the interval of 6.2-4.0 Ma, subsequently replaced by the increased trend since 4.0 Ma. Meanwhile, the relative low Ri/b values reveal that the hydroclimate condition is generally humid and stable during 6.2-4.0 Ma. Then the obvious enhancement of Ri/b proxy demonstrates the onset of climate aridification since 4.0 Ma. So our integrated results reveal that the Xiaoshuizi climate turn into warm-arid condition during 4-3.6 Ma, which is contradictory with the global cooling and regional humid hydroclimate in the eastern Chinese Loess Plateau and Qaidam basin. We ascribe this abnormal warm-arid event during 4-3.6 Ma to the rain shadow effect of growing topography in the Maxian Mountains caused by the tectonic uplift of NE Tibetan Plateau. Our results not only emphasize the importance of quantitative terrestrial climate record during the interval of late Miocene-Pliocene, but also highlight the necessity of combining tectonic and geomorphological background for illustrating the paleoclimate evolution in NE Tibetan Plateau.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-1: Cenozoic stratigraphic ages, sedimentary records, weathering-erosion and climate-environmental changes in Asia
Presentation Preference: Oral Preferred

A case study using monomineral chemical composition to reconstruct Paleogene weathering history in a thick sedimentary sequence with frequently changing facies and lithologies in the northern Qaidam Basin

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Keywords: Chemical weathering, Illite chemistry index, Chlorite, Global cooling, Qaidam Basin

An integrated multiproxy dataset involving both mineralogical and geochemical investigations of the northern Tibetan Plateau helps in assessing regional weathering processes linked to topographic evolution and environmental change. However, changes in landscape and drainage reorganizations caused by active tectonics and remarkable climate change during the Cenozoic characterize the basins in and around the Tibetan Plateau by frequent facies changes and coarse lithologies, which largely limit the reliability of bulk geochemical indicators for revealing the regional weathering history. To minimize the influence of these factors (e.g., grain size and sortings) in long sedimentary sequences, a better approach is to use the variation in the chemical composition of a certain mineral in response to weathering (e.g., Rieu et al., 2007).

In this study, we present some monomineral indices to reconstruct Paleogene (54-26 Ma) weathering history in a sedimentary sequence with frequent interbedded conglomerates and facies changes in the Qaidam Basin, northern Tibetan Plateau. The studied sequence contains the Lulehe, Xiaganchaigou, and Shangganchaigou Formations. The Lulehe Formation is coarse-grained and generally consists of conglomerates, sandy conglomerates, sandstones, and purple mudstones, indicating alluvial fan–fan delta facies. The Xiaganchaigou and Shangganchaigou Formations contain lacustrine sediments, the former contains brownish–red and purple mudstones and interbedded sandstone while the latter contains brown-yellow and brown mudstone with gray sandstone. The monomineral indices, illite chemistry index (e.g., Wan et al., 2010), chlorite chemistry index (e.g., Ye et al., 2018), and chlorite Mg/Al ratios of hydrochloric acid (HCl) leachates (e.g., Li et al., 2008) collectively present a continuously decreasing trend. The intense weathering process occurred in the early Eocene (54-49.5 Ma), followed by a long-term decrease from the middle to late Eocene (~49.5-34 Ma), and finally a weakened stage at ~34-26 Ma. The weakening weathering process during the Paleogene is mainly attributed to the decreasing global temperature and decline in precipitation caused by global cooling (Fang et al., 2019). Our study further suggests that monomineral chemical variation serves as an efficient proxy in regional chemical weathering reconstruction, even in thick sedimentary sequences with frequently changing facies and lithologies.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-1: Cenozoic stratigraphic ages, sedimentary records, weathering-erosion and climate-environmental changes in Asia
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Palynomorph assemblages evidence for river reorganization 8.5 million years ago in Southeast Asia

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Keywords: River reorganization, palynology, tectonics, late Miocene, Southeast Asia

Palynology is a sensitive proxy for the reconstruction of paleovegetation and paleoclimate changes. The comprehensive palynological comparison at multiple points in a large space is very important for further clarifying the vegetation-climate macro pattern and basic evolutionary trend, and can provide an important reference for understanding the regional and even global climate change background of plateau uplift and its climate effects.

River reorganization occurs frequently in Southeast Asia, due to the rugged topography and heavy precipitation. However, accurately constraining the age of past reorganization events is difficult. Here we apply a novel palynological approach to evaluate how rivers evolved during the late Cenozoic (~12–0 Ma), based on three deep-sea drilling cores from the South China Sea (SCS): International Ocean Discovery Program (IODP) Sites U1499 in the north and U1433 in the central SCS (Miao et al., 2017), and Ocean Drilling Program (ODP) Site 1143 in the south (Luo and Sun, 2007). A rapid, dramatic runoff reorganization event at 8.5 Ma is identified in the cores by a sharp decrease in terrestrial pollen and freshwater algae input in the northern SCS, coeval with a contrasting increase in the South SCS, which is supported by contemporaneous changes in neodymium isotopes composition (ε_{Nd}) (Clift et al., 2002; Liu et al., 2017; Liu et al., 2007), and sediment rates and budgets across the SCS (Clift, 2006). At the same time, no similar changes are observed in palynological records in the inland or Sea of Japan. We postulate that the reorganization of rivers was the main dynamic driver of rapid changes in palynomorph assemblages, which took place against a background of tectonic and climatic changes.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-1: Cenozoic stratigraphic ages, sedimentary records, weathering-erosion and climate-environmental changes in Asia
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

A new Oligocene chronostratigraphic framework in the Jiuxi Basin, northeastern Tibetan Plateau: evidence from high-resolution magnetostratigraphy

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Keywords: Northeastern Tibetan Plateau, Jiuxi Basin, Oligocene, magnetostratigraphy, Baiyanghe Formation

Cenozoic sediments of internal and external basins in the Tibetan Plateau sensitively archive the spatial-temporal patterns of the deformation and surface uplift processes during the India-Asia collision. The Jiuxi Basin, located at the northeastern margin of the plateau, is the northernmost area responding to plate collision effect and preserves crucial information on the extension processes of the NE Tibetan Plateau. The Oligocene Baiyanghe Formation are widely distributed in Hexi Corridor and Qilian Shan areas. These strata generally rests unconformably on the underlying Huoshaogou Formation in the northern Jiuxi Basin and southern Jiudong Basin, and directly unconformities over the Mesozoic and older strata in the other areas, and is overlain by the Shulehe Formation in a conformity. Existing work on the tectono-sedimentology and tectonic evolution of the Jiuxi Basin and Qilian Shan regions has severe limitations because of the lack of systematic and precise chronology control. The controversial ages of Baiyanghe Formation have been reported by magnetostratigraphy at Ciyaokou section (30.9-23.8 Ma) and Sunan section (27.8-24.6 Ma) in southern Jiudong Basin, and Caogou section (>24.2-17 Ma) in northern Jiuxi Basin. In this study, we focus on the Baiyanghe section in the southern margin of the Jiuxi Basin and the section is the type section for the Baiyanghe Formation without dating works, which is dominated by a set of approximately 430 m thick fluvial and lacustrine deposits with thick gypsum. We carried out the high-resolution magnetostratigraphy analysis on the Baiyanghe Formation with an aim to establish the precise chronology framework. We identified 13 normal magnetic chrons (marked as N1-N13) and 12 reverse magnetic chrons (marked as R1-R12) from 257 out of 328 paleomagnetic samples in the Baiyanghe section, with each magnetozone defined by two or more specimens. According to the sedimentary facies, sedimentary rate, gypsum marker bed and age limitation of underlying Huoshaogou Formation and overlying Shulehe Formation, we constrained the new age of Baiyanghe Formation between approximately 22.6-29.5 Ma. This age determination is in good agreement with those obtained from the Ciyaokou section and Sunan section, but older than that in the Caogou section. The results are of great significance for understanding the Oligocene tectonic evolution of the northeastern Tibetan Plateau.

Scientific Themes: Theme 1: Deep-time Climate & Environment
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Presentation Preference: Oral Preferred

Early-middle Miocene oceanic red beds: Evidence of CCD evolution and deep basin subsidence in the South China Sea

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Keywords: Oceanic red beds, Grain size, Carbonate compensation depth (CCD), South China Sea, International Ocean Discovery Program (IODP)

International Ocean Discovery Program (IODP) Expedition 367 recovered early-middle Miocene oceanic red beds at Site U1500 in the South China Sea. The red beds stand out compared to other parts of the sedimentary sequence at this site and similar age interval deposits previously discovered in the South China Sea. The 77.15 m thick red beds (22.8-11.8 Ma) at Site U1500 were subjected to grain size and carbonate content analyses to understand deepwater sedimentary environment throughout the early-middle Miocene.

The mean grain size varies from 1.2 to 3.6 μm over the red beds interval, while the carbonate content ranges from 0 to 63.7 %. There are four lithological units identified: (1) 22.8-18.5 Ma, reddish chalk (~20.0-63.7% carbonate, average 31.3%) with relatively fine mean grain size (2.0 μm); (2) 18.5-16.0 Ma, reddish-brown calcareous-rich claystone (0.8-29.9% carbonate, average 16.2%) with very fine mean grain size (1.6 μm); (3) 16.0-13.0 Ma, dark-reddish-brown claystone (almost 0% carbonate) with fine mean grain size (1.8 μm); (4) 13.0-11.8 Ma, dark-reddish-brown silty-claystone (almost 0% carbonate) with relatively coarse mean grain size (2.2 μm). The sedimentation rate varies from 0.7 cm/ka for chalk, 0.5 cm/ka for calcareous-rich claystone, 0.4 cm/ka for claystone, and 1.9 cm/ka for silty-claystone. Because of the very fine mean grain size together with the low sedimentation rate, the early-middle Miocene oceanic red beds are thought to have formed in a pelagic environment in the South China Sea.

Carbonate mass accumulation rate is utilized to reconstruct the CCD (carbonate compensation depth) level change. The carbonate mass accumulation rates in reddish chalk (22.8-18.5 Ma) are larger than 0.5 $g/cm^2/ka$, indicating the red beds evolved above the CCD level. The decreased mass accumulation rates (0.1-0.5 $g/cm^2/ka$) in reddish-brown calcareous-rich claystone might be attributed to CCD shoaling between 18.5 and 16 Ma. After 16 Ma, the carbonate mass accumulation rates significantly dropped close to zero, implying that the red beds developed below the CCD level. Considering the regional tectonic history, we suggest the drop of carbonate accumulation rate in this interval occurred from the rapid subsidence of the deep basin following the cessation of the South China Sea spreading. This study provides insights into the deepwater sedimentary properties of pelagic red beds developed in the South China Sea, significantly related to the CCD level change and tectonic evolution.

Scientific Themes: Theme 1: Deep-time Climate & Environment
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Presentation Preference: Oral Preferred

High resolution magnetostratigraphy of the Cenozoic Lunpola Basin constraining a late Oligocene-Miocene rapid uplift of the central Tibetan Plateau

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Keywords: Lunpola Basin, tuff and magnetostratigraphy, central Tibetan Plateau, late Oligocene-Miocene rapid uplift

Understanding the Tibetan Plateau (TP) topographic history is essential to determining its building mechanisms and its role in driving regional climate, environments and biodiversity. The Lunpola Basin (central-southern Tibet) is the key place to constrain the Tibet building because it deposits the most complete Cenozoic stratigraphy sequence in the central TP and bears many layers of tuffs, abundant fossil plants and mammals and paleosols. It is also the first place that stable isotope based paleoaltimetry was applied to, which suggested that similar to present elevation was attained in the central TP at least 35 Ma ago, implying a much earlier uplift of the TP than before. This view was soon widely accepted by international society but was challenged by recent discoveries of low elevations tropical fossil apparently deposited at 25.5 Ma. However, we use magnetostratigraphic and radiochronologic dating to robustly revise the chronology of regional elevation estimates both from the stable isotope and fossils in the Lunpola Basin. The results indicate that both ages estimated for the stable and fossil based elevations are wrong with the former from ~40 Ma revising to ~26-21 Ma and the later from ~26 Ma to ~40 Ma. Thus this revised chronology demonstrates that central Tibet was generally low (<2.3 km) since at least ~40 Ma and became high (3.5-4.5 km) since at least ~26 Ma. This supports the Eocene existence of a lowland between the Gangdese Shan and Tanggula Shan until their early Miocene uplift. This later uplift of central-southern Tibet has important implications for Tibetan Plateau (TP) growth mechanisms and agrees well with recently updated studies of the TP-imposed impacts on Asian atmospheric circulations, surface processes and biotic evolution and diversification differentiation.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-1: Cenozoic stratigraphic ages, sedimentary records, weathering-erosion and climate-environmental changes in Asia
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Multistage tectonic activity of the eastern Qilian Shan during the late Eocene to middle Miocene: insight from Wuwei Basin stratigraphy and provenance

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Keywords: Wuwei Basin, Qilian Shan, Cenozoic stratigraphy, provenance, tectonic activity

The northeastern Tibetan Plateau is a key area to understand the Cenozoic uplift and environmental effects of the plateau, in which developed a series of sedimentary basins. The study of tectonic evolution of these basins is an important way to recover the uplift process of the plateau in the past. In recent years, the Cenozoic stratigraphy of Hexi Corridor basin has been focused on Jiuquan Basin in the west, but less attention has been paid to Wuwei Basin in the east. The Cenozoic strata of Wuwei Basin are mainly distributed in the southern margin of the basin, including the Paleogene Xiliugou Formation and Huangyanghe Formation, and Neogene Xianshuihe Formation. In this study, four outcropping profiles in the southern margin of Wuwei Basin were investigated in detail, and the relationship between basin evolution and the faults in the northern margin of Qilian Shan and the uplift of the northern Tibetan Plateau was discussed by analyzing the heavy minerals, palaeoflow and composition of gravels. The results show that the Xiliugou Formation mainly consists of orange sandstone and fine sandstone interbedded with maroon mudstone. The lithology of Huangyanghe Formation is mainly composed of giant thick bedded orange-red conglomerate and sandstone, interbedded with orange-yellow sandstone and maroon-red mudstone. The Xianshuihe Formation is mainly brownish red to brownish yellow sandstone, brown red mudstone, intercalated with gray white sandstone. Alluvial fan, fluvial and lacustrine facies are developed in this area. The analysis of heavy minerals, palaeoflow and composition of gravels shows that the sediments of Xiliugou and Huangyanghe Formations in the southwestern Wuwei Basin are mainly derived from the Proterozoic and Early Paleozoic strata in the south of Basin. The Xianshuihe Formation strata are characterized by multiple provenances. According to the information of stratigraphy and provenance changes in the southern Wuwei Basin, multi-stage tectonic activities occurred in the eastern Qilian Shan during the late Eocene to middle Miocene. In the late Eocene, the Wuwei Basin, Lanzhou basin to the east and Xining Basin to the south became active, indicating the initial uplift of the eastern segment of Qilian Shan. The deposition of Huangyanghe Formation indicates that the eastern Qilian Shan was active again, and this event is synchronous with the western Qilian. The absence of strata in the early Oligocene may be a response to the large-scale uplift of the plateau. Subsequently, the deposition of the southern part of the basin ended after the Xianshuihe Formation, again suggesting the uplift of the Qilian Shan in the south.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
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Presentation Preference: Oral Preferred

Orbital- and millennial-scale Asian winter monsoon variability across the Pliocene–Pleistocene transition

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Keywords: Pliocene–Pleistocene transition,Asian winter monsoon,orbital-and millennial-scale periodicities

Onset of major Northern Hemisphere glaciation (NHG) across the Pliocene–Pleistocene transition (PPT) is the most profound late Cenozoic climate shift. It led to the rise of modern climates and ecosystems on Earth and hominin lineage in Africa. Here, we report on a centennial-resolution grain size record from the Chinese Loess Plateau that enables to assess orbital- and millennial-scale Asian winter monsoon (AWM) evolution between 3.6 and 1.9 million years ago in detail. We find a persistent coexistence of distinct ~40- and ~100-thousand-year cycles in the long-term AWM record in response to ice sheet forcing. Major NHG did not shift orbital-scale AWM periodicities but instead drove long-term AWM strengthening across the PPT. Our results suggest that the orbital-scale AWM variability was superimposed by sustained millennial-scale oscillations, during both the warm (higher CO_2) late Pliocene and cold (lower CO_2) early Pleistocene—a broad range of climate-cyrospohere boundary conditions.

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Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Early Cenozoic Onset of Tectonic Deformation and Topographic Growth of the Qilian Shan in the Northeastern Tibetan Plateau Derived from Low-temperature Thermochronology

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Keywords: Tibetan Plateau, Qilian Shan, Thermochronology, Exhumation, Cenozoic

The evolution of topography throughout the Tibetan Plateau remains debated for the causality with plate collision, plateau growth, intracontinental deformation, and climate effects. The Qilian Shan serves as a topographic boundary on the northeastern Tibetan Plateau, and the processes of its upper crustal deformation and related formation of its high topography are crucial for understanding the progress of plateau growth and its geodynamic mechanisms. However, when deformation and relief growth began and how it has developed in this pivotal region remain controversial. To assess the histories of tectonic deformation and topographic development in the Qilian Shan, we applying apatite fission-track (AFT) and (U-Th)/He (AHe) thermochronology to rocks in the Qilian Shan and adjoining basins.

Detrital AFT analysis was performed on Cenozoic sediments in the northern Qaidam Basin and Subei Basin, where detritus is sourced from the Qilian Shan. Age components of buried but unannealed detrital AFT samples in the northern Qaidam Basin reveal two static peaks (i.e., peak ages that are consistent upsection) at ca. 60–50 Ma and ca. 40–36 Ma and a moving peak (i.e., peak ages that are younger upsection) with increased lag time during ca. 30–8 Ma. Samples with unannealed detrital AFT ages in the Subei Basin reveal a dominant ~60–50 Ma age population. These detrital AFT ages integrated with the analysis of sedimentary provenance indicate that Cenozoic exhumation began in the Qilian Shan in the late Paleocene-early Eocene.

In-situ bedrock AFT and AHe analysis was performed on two primary thrust belts (Qaidam Shan and Danghenan Shan) in the southern Qilian Shan. The age-elevation relationships of the two transects both show enhanced exhumation in the late Paleocene-early Eocene, followed by rapid exhumation in the middle-late Miocene. Thermal modeling of the Danghenan Shan transect shows an episode of rapid cooling in the late Paleocene-early Eocene. Thermal modeling of the Qaidam Shan transect shows slightly accelerated cooling in the early Eocene and rapid cooling since the middle Miocene. The results indicate two pulses of enhanced thrust of major thrust belts in the southern Qilian Shan in the late Paleocene-early Eocene and middle-late Miocene.

An integration of new detrital and in-situ thermochronologic data and published data indicates that terranes in the Qilian Shan experienced prominent tectonism-driven exhumation in the late Paleocene-early Eocene, which imply an early Cenozoic onset of tectonic deformation and topographic growth in the Qilian Shan. These results suggest that the northeastern Tibetan Plateau responded to the India-Asia collision almost instantaneously and the northeastern boundary of the Tibetan Plateau was roughly established since the early Cenozoic.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
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Presentation Preference: Oral Preferred

Late Paleogene Climate Change and Its Driving Mechanism in the Ningnan Basin, Northeastern Tibetan Plateau

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Keywords: Climatic change, Sali,ne lacustrine basin, Tibetan plateau uplift, Late Paleogene, Ningnan Basin

The sedimentary record of the saline lacustrine Qingshuiying Formation is the perfect object for the study of the late Paleogene climate change and its driving mechanism in the Ningnan Basin, northeastern Tibetan Plateau, which is taken as the research target in this study. Through field geological investigation, sample collection, and the tests of the major elements and strontium isotopes in gypsum, the chemical weathering and paleoclimate changes recorded in sedimentary strata are analyzed. Based on the comparison with the global climate change and the uplifting process of the Tibetan Plateau, the driving mechanism of the late Paleogene climate change in the Ningnan Basin, northeastern Tibetan Plateau is studied. The results show that the indices of Al_2O_3/SiO_2, Al_2O_3/Ti_2O, K_2O/Na_2O, and $^{87}Sr/^{86}Sr$ well reflect the late Paleogene climate change. During the 5 periods of 38-36 Ma, 34.5-33 Ma, 32-31 Ma, 30-27 Ma, and 26-23 Ma, the chemical weathering decreased, and the climate was arid, while during the 4 periods of 36-34.5 Ma, 33-32 Ma, 31-30 Ma, and 27-26 Ma, the chemical weathering increased, and the climate was humid. During the late Paleogene 38-26 Ma, the climate change in the study area was mainly driven by the global climate change. While during 26-23 Ma, the climate change in the Basin was affected by the Tibetan Plateau uplift.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
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Presentation Preference: Oral Preferred

Late Miocene sedimentary chronology and paleoclimate significance of the Jianzha Basin in the northeastern margin of the Tibetan Plateau

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Keywords: Northeast of Tibet Plateau, Jianzha basin, Late Miocene, Chronology, Plaeoclimate change

Jianzha Basin is located in the northeastern part of the Tibetan Plateau and contains a thick sequence of Cenozoic sediments which are crucial for investigating the growth of the Tibetan Plateau and the record of the evolution of the Asian inland arid environment. Magnetostratigraphic results show that Late Cenozoic sedimentary sequence from the Jianzha Basin has recorded a continuous geomagnetic polarity sequence from C5r.3r to C3r, the section spans the interval from 11.8-5.8 Ma in the Late Miocene. Based on the high precision paleomagnetic dating framework and frequency susceptibility index (cfd), the cycle stratigraphy of Jianzha Basin was studied, whose results show the cfd of the deposit sediment displays a significant periodic change at around 7.2 Ma, which the record reveals that the East Asian summer monsoon (EASM) is dominated by 41 ka obliquity period before ~7.2 Maand controlled by 100 ka short eccentricity period after 7.2 Ma. Spectral analysis of oxygen isotope records of benthic foraminifera from the South China Sea shows strong short eccentricity period and weak obliquity period between ~5.8 and ~7.2 Ma, and strong obliquity period and weak short eccentricity period between ~7.2 and ~11.8 Ma, which is consistent with the spectral analysis of frequency susceptibility (cfd) from the Jianzha Basin. In addition, it is found that the EASM climatic transition from 100,000-year orbital period to 40,000-year obliquity period occurred around 7.2 Ma, which is similar to the climatic transition around 0.9 Ma in the Middle Pleistocene. Therefore, the climate change result will provide a new similar model for predicting future monsoon climate changes. This study was supported by projects funded by the Second Tibetan Plateau Scientific Expedition (STEP) program (2019QZKK0704); and supported by the National Natural Science Foundation of China (Grants 41772167); and supported by the Central University Research Foundation, Chang’an University (Grants 300102272901).

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Scientific Themes: Theme 1: Deep-time Climate & Environment
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Presentation Preference: Oral Preferred

Carbon, oxygen and strontium isotopic and elemental characteristics of the Cambrian Longwangmiao Formation in South China: Paleoenvironmental significance and implications for carbon isotope excursions

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Keywords: Isotope geochemistry, Paleoenvironment, Redlichiid–Olenellid Extinction Carbon Isotope Excursion, Cambrian Toyonian, South China

The biosphere experienced episodic perturbations during the Neoproterozoic–early Cambrian, accompanied by major fluctuations of the carbon cycle. However, compared to the Ediacaran–early Cambrian, geochemical records of the Cambrian Toyonian Stage (Longwangmiao), which contains the significant Redlichiid–Olenellid Extinction Carbon Isotope Excursion (ROECE), are scarce. To address this data gap, we conducted measurements of carbon, oxygen and strontium isotopes and element contents of a continuous series of carbonate samples from the Longwangmiao Formation of Well HS2, located in the central Sichuan Basin of South China. Our specific aims were to reconstruct the paleoenvironment and to determine the origin of the ROECE. Strict sample screening was used to ensure that the isotopes and elements were not affected by diagenesis. The $^{87}Sr/^{86}Sr$ values of Well HS2, and for sites elsewhere, show that sea level gradually decreased during the Cambrian Toyonian Stage. Additionally, the pronounced negative $\delta^{13}C$ excursion in the late Toyonian is globally associated with the ROECE, which is widely thought to have resulted from extinctions caused by a transgression. However, a transgression is not shown in the $^{87}Sr/^{86}Sr$ profile of Well HS2, which we attribute to local karst formation and erosion caused by frequent regional regressions. The interrelationships among several paleoenvironmental proxies show that continental weathering was climatically controlled, which affected the supply of terrigenous detritus, and that the carbonate platform was semi–restricted. Furthermore, profiles of paleoenvironmental proxies indicate that the environment was warm and humid, favoring high biological productivity and diversity during Interval I (early Toyonian), and that it gradually became colder and drier during Interval II (middle Toyonian). We suggest that by the time of Interval III (late Toyonian), the adverse effects of a cold and arid environment were superimposed on the transgression, triggering the ROECE. Our results provide a reference and possible interpretation for other carbon isotope excursion events.

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Presentation Preference: Oral Preferred

Another look at Cenozoic source-to-sink history of the Qaidam Basin, NE Tibet: Insights from solute Sr isotope

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Keywords: Qaidam Basin, Tibetan Plateau, Cenozoic, Sr isotope

The Qaidam Basin on the northeastern Tibetan Plateau comprises vital information about the Cenozoic history of the northern Tibet uplift and Asian climate change due to its exceptionally long and continuous terrestrial sediment records. However, the paleolake evolution in the basin and the associated source-to-sink history remain highly debated. We provide a novel perspective of solute Sr isotopes to reconstruct source-to-sink history in the Qaidam Basin, which is notably different from a particulate perspective constrained from traditional methods, e.g., zircon U-Pb ages, paleocurrent, Nd isotopes. The Sr isotopes of basin water are a mixture of the input from various sources. Based on the remarkable contrasts of the solute Sr isotope regime with a high 87Sr/86Sr source from the Qilian Shan to the north and a low 87Sr/86Sr source dominantly from the southern sources, we reconstructed basin paleo-water solute Sr using bulk carbonate from two parallel outcrops in the northern basin. Our results show that solute Sr isotopes of basin paleowaters fluctuate between 0.711 and 0.715 since ~54 Ma, during which most of the interval remains constant at ~0.713, which is similar to the 87Sr/86Sr ratios of modern lakes supplied solely by the Qilian Shan. However, two low 87Sr/86Sr ratio periods at ~44.5-~32 Ma and after ~16 Ma suggest the existence of two paleomegalakes with hydrological connections between the northern and southern sources. The two low 87Sr/86Sr paleomegalakes followed a south-eastward migration of the basin depocenter due to tectonic uplift, which implies a more complex solute versus particulate provenance history in a large basin than expected.

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Late Cenozoic deposition of the Nihewan basin in the North China

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Keywords: Nihewan basin, Late Cenozoic stratra , sedimentary environments, paleogeography, North China Craton

The Nihewan basin is an important part of the Neogene NE-SW-trending Weihe-Shanxi graben system between the Taihangshan and Lüliangshan uplifts around the Ordos block in the west and the Paleogene North China plain in the east. It hosts late Cenozoic nonmarine sediments in a highly subsiding basin formed due to the Oligocene-Pleistocene rifting. The main basin-fills are the Pliocene Yuxian Formation, early Pleistocene Nihewan Formation, middle Pleistocene Xiaodukou Formation, and late Pleistocene Haojiatai Formation. The Yuxian Formation unconformably overlies Pre-Cretaceous strata and is dominated by erythrinus silty clay with a variable thickness of ca. 9-100 m from the margin to the interior of basin, containing hipparion fauna fossils. The Nihewan Formation with a thickness of ca. 70-90 m is subdivided into three units. The lower unit comprises gravel-bearing medium- to coarse-grained sand with planar cross-beddings at the lower part, grading upward into brown clay with interlayers of gray-yellow silt. The middle unit consists of thick interlayers of green clay silt and yellow silty clay with abundant calcareous and fine-grained sand layers, characterized by parallel laminations. The upper unit consists of interlayers of gray-yellow, yellow-brown and yellow-green silty clay and clay silt with fine-grained sand and gravel-bearing coarse-grained sand lenses. The Xiaodukou Formation has a thickness of <40 m and consists of grey-yellow coarse-grained sands with abundant fine gravels and fossils of mammals and mollusks at the lower part, which grade upwards into yellow-brown silty sands and interbedded clay silty sand with parallel laminations. The <40-m-thick Haojiatai Formation is characterized by dark-gray, gray-green and gray interlayers of silt and clay with gravels at the bottom, grading upward into gray-yellow, yellow-green, gray-green, and gray clay silt with brown clay silt. Lenticular gypsum occurs in the upper and lower portion of the Haojiatai Formation. In addition, the middle and upper units of the Niehewan Formation is thickening towards of the interior of basin, whereas the Xiaodukou and Haojiatai formations are thinning. Paleocurrent data demonstrate a southward origin for the Nihewan, Xiaodukou, and Haojiatai formations perpendicular to the trend of the basin, but they show a northward and southward origin along the trend of basin respectively. Detrital zircon U-Pb age data demonstrate that they are dominated by detritus derived from a mixed source of early Cretaceous, early Permian and Paleoproterozoic in age. These results indicate that Pleistocene sediments deposited in a fluvial environment initially that subsequently evolved into a lacustrine environment upwards with a southwestward-facing paleogeography, and the Nihewan basin and associated graben system developed during the Pleistocene and were dominated by sediments from uplifted Pre-Cretaceous rocks in North China Craton.

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Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Clay mineralogy of the Middle Miocene to Early Pliocene sediments in Xunhua Basin, Northeastern Tibetan Plateau and its paleoclimatic implications

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Keywords: the Middle Miocene-Early Pliocene, clay minerals, Xunhua Basin, aridification, global cooling, uplift of Tibetan Plateau

To reveal palaeoclimatic evolution and aridification events of the Middle Miocene to Early Pliocene in the northeast margin of Tibetan plateau, micro-morphology, relative content and VCh+I/VKao+S value of clay minerals in Xunhua Basin were investigated using scanning electron microscopy SEM and X-ray diffraction XRD. Clay mineralogy shows that the Middle Miocene and Early Miocene sediments are composed of illite, smectite, chlorite and kaolinite. All the clay minerals were detrital formation and less influenced by diagenesis. And the source area is close to the study area, which belongs to near-source transport. The relative content and Ch+I/Kao+S value of clay minerals in the Xunhua Basin can effectively reflect paleoclimate change in the study area. Combined with pollen record, sedimentary rates, geochemistry ratio of sediments in Xunhua Basin and δ18O isotope record from the global deep-sea, the palaeoclimate evolution in Xunhua Basin can be divided into 3 stages as follows: I, relative cold and dry period 14.6~12.5Ma; II, relative warm and humid period 12.5~8Ma; III, cold and dry period 16.0~13.2 Ma. Comparing with the regional geological records, we consider that the drying environment in the Xunhua Basin was controlled by global cooling and uplift of Tibetan Plateau, respectively. The relative wetting and humid stage may be influenced by the orographic interception around the Xunhua Basin.

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Luminescence dating of loess deposits from the eastern margin of the Tibetan Plateau

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Keywords: OSL dating, loess, mass accumulation rate, Tibetan Plateau

Extensive loess deposits exist in the eastern margin of the Tibetan Plateau (ETP), which are one of the most important terrestrial archives regarding past dust activity and environmental changes in East Asia. However, they remain insufficiently known and poorly understood. Herein, we conducted detailed optically stimulated luminescence (OSL) analysis on two typical loess sequences. Our results show that: 1) The quartz OSL signals of the loess at the eastern Tibetan Plateau are dominated by the fast component with good performance for De measurements by single aliquot regenerative dose protocol. 2) The bottom ages of the studied loess sequences are ~60 ka, indicating an important dust event in the ETP. 3)The mass accumulation rate (MAR) significantly varied during the last glacial period. The highest MAR occurred in Marine Isotope Stage (MIS) 2, and the MIS 3 MARs were relatively low and stable. The discrepancy in the MARs of the ETP loess since the last glacial period compared with that of the Chinese Loess Plateau may imply different dust deposition processes in the Tibetan Plateau.

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Provenances and Paleoclimatic Response of Holocene Sediments in the Inner Shelf of the East China Sea: Evidence from clay minerals and foraminifera species.

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Keywords: Provenances, Grain size, Clay minerals, benthic foraminifer, the East Asia Monsoon, Inner shelf of ECS

Holocene sediments from the inner shelf of the East China Sea (ECS)with its high deposition and continuously sedimentary record which is sensitive to enviromental changeis an important recorder of regional responses to global paleoclimatic and paleoenvironmental changes. Based on the precise AMS^{14}C dating data, We analyze grain size, clay minerals and trace elements of sediment cores, investigating the sediment provenances of the the southern inner shelf of ECS, deducing the evolution of East Asia Monsoon in the past 4.7ka.

Comparing the clay minerals in the southern inner shelf of ECS with one from different potential source areas, the results indicate that sediments in the study area came from the Yangtze River, the Yellow River and rivers from Taiwan, while every potential source area making contribution in the different periods. In the period of 4.7-4.2ka, sediments from the Yantze River and Taiwan's river is the main source of sediments. From 4.2ka to 3.2ka, sediments of study area mainly consist of the sediments of the Yanze River and the Yellow River. Since 3.2ka, sendiments from all of potential source areas had some response on the study area.

Using benthic foraminifer cold and warm water indicator species and Taiwan warm current representative species analysis, we obtain Cold water combination*Protelphidium tuberculatumCribrononion vitreum Bulimina marginataFlorilus spp.Eggerella advena* sensitive to climate change, has a good indicator.The evolution of East Asia Monsoon in the past 4.7ka can be deduced based on the grain size sensitive components, the ration of Rb/Sr and montm orillonite/kaolinite. Refering to the δ^{18}O of GSP2 and stalagmite of Dongge Cave and the evidence of cooling of different materials in other regions, 9 high values could be recognized corresponding to the cooling events caused by the East Asia Monsoon. The core records 4 strengthen periods of the East Asia Monsoon: weak and stable during 4.7-4.2ka BP; increased and began to fluctuate during 4.2-3.2ka; a little weak with highly fluctuation during 3.2-2.0ka BP; the East Asia Monsoon incresed slighly with fluctuations weakened.

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Presentation Preference: Oral Preferred

Paleoenvironmental and paleoclimatic evolution during late Oligocene to early Miocene: indicated by trace element ratio of Ostracod shells in the western Qaidam Basin

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Keywords: Paleohydrology, Paleoenvironment, The Ostracods, Trace elements, The Qaidam Basin

The restoration of paleohydrological condition in sedimentary basins has a very crucial significance for reconstructing the regional paleoenvironment and paleoclimate evolution. For closed-inland lake in arid and semi-arid area, the effective precipitation rate (Precipitation/Evaporation) and runoff flowing into lake are the primary factors affecting water level change, and the variation of water level directly affect water chemistry, salinity and redox status (Jeremy M C et al., 2019). On the contrary, the paleo-salinity and paleo-redox implied by sediments can be used to indicate paleohydrological change in sedimentary basins and further to infer regional paleoclimate. In this study, we use Sr/Ca, Ba/Ca and U/Ca, Mn/Ca of Ostracod fossil shells as paleo-salinity proxy and paleo-redox proxy respectively to reconstruct paleohydrology and paleoclimate of middle and upper section of Shangganchaigou Formation in the western Qaidam Basin. Based on paleomagnetic age studied by Ji et al.(2017) and combined with average deposition rate of drilling, we determined the sedimentary age for Ostracod shells ranging from 29.32 Ma to 20.01 Ma.

The Sr/Ca, Ba/Ca, U/Ca and Mn/Ca of Ostracod shells have obvious three phases, and the average value of those ratios are I phase (0.00228, 0.00054, 0.000012, 0.00105, n=4), II phase (0.00322, 0.00072, n=8; 0.000024, 0.00323, n=10) and III phase (0.00335, 0.00206, 0.000005, 0.00981, n=3). In the phase I(29.32-26Ma), the ancient lake of the western Qaidam Basin was deep lake environment with low salinity, strong reducibility and high water level, and the climate was relatively warm and moist; In the phase II(23-21.75Ma), the ancient lake was shallow lake environment as a whole with high salinity, strong oxidability and low water level, and the overall climate was hot and arid, and at the end of this phase, the salinity and oxidation of lake water decreased with the water level rising, and the arid degree reduced; In the phase III(21.75-20.01Ma), the salinity and oxidation of lake water increased with the water level dropping, and the climate changed to cold and arid. At the same time, the aridity starting from about 26Ma in II phase corresponds to the aridification of inland Asia that was studied by previous researchers(Qiang et al., 2011; Zhang et al., 2014).

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Tracing the source of Asian dust using the chemical composition of single-particle muscovite

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Keywords: Asian dust, Single-particle muscovite, Aridification, Loess

Debates persist surrounding the source and long-term stability of Asian dust (e.g. loess). However, the chemical compositions of muscovite, a widely-distributed characteristic mineral, in loess have the potential to trace its provenance. In this study, the chemical composition of single-particle muscovite in loess on the Chinese Loess Plateau (CLP) and potential sources areas was analyzed using the electron microprobe method to better understand the provenance of the CLP – the largest aeolian deposit in the world. Results show that the chemical compositions of muscovite in potential sources have significant regional characteristics. The content of phengite (muscovite with a Si atom number greater than 3.3) in potential source deserts (ie. Taklimakan Desert, Qaidam Basin, Tengger Desert and Mu Us Desert) near the northern margin of the Tibetan Plateau and the upper Yellow River is relatively high (from 3.41-9.68%), whereas there is almost no phengite in the Horqin Sandy Land or Gurbantunggut Desert. The RSI (the ratio of Si atom number between 3.1-3.2 to the Si atom number less than 3.1) of the Tengger Desert, Mu Us Desert and Horqin Sandy Land is about 1, while the RSI of other samples deviates significantly from 1. Loess on the CLP contains about 10% phengite, and the RSI is about 1. Examination of the phengite, RSI and Nd isotope values (alone and in combination) reveals that the provenance of the loess on the CLP is mainly from the Alxa Plateau desert region. In addition, analysis of the muscovite in loess also shows that the provenance of CLP has not experienced significant changes since at least 8 Ma, and the existing spatial distribution of deserts in Western China has remained relatively stable over this period.

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Session T1-2: Using the magnetic record of sediments to understand fundamental geological processes in tectonics, environment, and climate

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-2: Using the magnetic record of sediments to understand fundamental geological processes in tectonics, environment, and climate
Presentation Preference: Oral Preferred

Turbidite cycles in Pliocene–Pleistocene sediments of the South China Sea: constraints from magnetostratigraphy of IODP Expedition 349 drill sites

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Keywords: Turbidite, South China Sea, Magnetostratigraphy, International Ocean Discovery Program

Turbidites provide a mechanism for assigning a tectonic and depositional setting to ancient sedimentary sequences as they usually represent deep water rocks. Turbidites can represent a high resolution record of seismicity as they generally require some form of tectonism to trigger density-based avalanches. International Ocean Discovery Program (IODP) Expedition 349 investigated the tectonic and oceanographic evolution of the South China Sea (SCS). Paleomagnetic results show that sediments from the sites drilled by Expedition 349 contain both reversely and normally magnetized samples. Thus, paleomagnetic directions can be used to construct magnetostratigraphy for dating sediments. The similarity of results between Holes U1431A and U1431D for the upper 30 m, which is characterized by graded, fining-upward turbidite cycles, strongly attests to the fidelity of the paleomagnetic records. In order to examine the frequency distribution of graded turbidite cycles, an integrated magnetostratigraphy, biostratigraphy, and sedimentology of the Site U1431 was conducted. At Site U1431. the average frequency of turbidite distribution during Pleistocene ranges from about 9-24 cycles/ka. These records reflect the magnitude, intensity, duration and extent of the frequency distribution of graded turbidite cycles in Site U1431. Our magnetostratigraphic work should help to refine the ages of sedimentation events and tectonic activities within and beyond the South China Sea basin.

Scientific Themes: Theme 1: Deep-time Climate & Environment
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Presentation Preference: Oral Preferred

Paleomagnetic constraints on the Late Devonian and Early Carboniferous paleo-position of South Qinling Belt and its implications for the evolution of the Central China Orogenic Belt

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Keywords: South Qinling Belt, Late Devonian-Early Carboniferous, Paleomagnetism, Mianlue Suture, South China Block, North China Block

To define the paleo-position of the South Qinling Belt (SQB) and thereby constrain the spatial configuration of the middle segment of the Central China Orogenic Belt, we carried out a paleomagnetic investigation on Upper Devonian and Lower Carboniferous limestones from the South Qinling Belt, central China. Characteristic remanent magnetizations (ChRM) resolved from limestones of Upper Devonian Lengshuihe Formation and Lower Carboniferous Jiehejie Formation both passed the fold test and suggested a primary origin. These results show that the SQB was located at a paleolatitude of 12.9°N±3.3° and -1.1°N±2.5° during the Late Devonian and Early Carboniferous separately. The paleolatitude of the SQB is close to that of the North China Block but is relatively different to that of the South China Block during the Late Devonian to Early Carboniferous, demonstrating that SQB is in proximity to the NCB but is away from the SCB. Combined with geological and geochronological evidences, paleomagnetic constrains indicate that the SQB lies on the southern margin of the NCB and is separated from the SCB by the Mianlue Suture during the Late Devonian and Early Carboniferous.

Scientific Themes: Theme 1: Deep-time Climate & Environment
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Presentation Preference: Oral Preferred

Cenozoic episodic uplift and kinematic evolution between the Pamir and Southwestern Tien Shan

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Keywords: Magnetostratigraphy, Anisotropy of magnetic susceptibility, Paleomagnetic rotation, Pamir-Southwestern Tien Shan, Uplift and kinematic evolution

The Pamir Salient and Southwestern Tien Shan belong to different systems, which collided due to the continuous northward drift of the Indian Plate during the Cenozoic, resulting in a shortening of ~300 km. The uplift history and kinematic evolution of the Pamir-Southwestern Tien Shan remain unclear. In this study, we chose the 2025 m-thick Pakabulake formation in the East Wuqia section, in the southern-most margin of the Southwestern Tien Shan system, to obtain a high-resolution magnetostratigraphic record, spanning ~16.61 Ma to ~9.78 Ma. Based on high sedimentation rate, stable ca. E-W paleocurrents and stable magnetic susceptibility values, the nearby Southwestern Tien Shan was inferred to have undergone stable uplift during this period of sedimentation. Combining our results with the previous low-temperature thermochronology, magnetostratigraphy and re-calculated block rotations, we conclude that four episodic uplift events occurred in the Pamir-Southwestern Tien Shan during the Cenozoic, at times of ~50–40 Ma, ~35–16 Ma, ~11–7 Ma and <5 Ma, and that the first episodic uplift only occurred in the Pamir Salient. In addition, the Pamir Salient underwent a tectonic transformation from an entire- to a half-oroclinal bending rotation process during the Miocene, caused by the activity along the Karakorum Fault and Kashi-Yecheng Transfer System.

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Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Similar magnetic enhancement mechanisms between Chinese loess and alluvial sediments from the Teruel Basin, NE Spain, and paleoclimate implications

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Keywords: Pliocene, Spain, Teruel Basin, alluvial sediments, magnetic enhancement, climate change

The Pliocene is considered an analog for future climate. Insolation is found the dominant forcing for Asian precipitation over the late Pliocene, evidenced by magnetic enhancement of Chinese loess caused by formation of nanometer-scale ferrimagnetic grains during pedogenesis corresponding to high precipitation. However, lack of European loess limits understanding of Pliocene European climate. We identified likely similar magnetic enhancement mechanism between Pliocene alluvial sediments from Spain and Chinese loess despite different depositional settings. This provides an opportunity to improve understanding of Pliocene climate in Europe. Spectral analysis shows that European wet-dry variations during the early Pliocene were forced by insolation and during the late Pliocene by both insolation and ice sheet development. During the Quaternary, in contrast, the forcing was dominantly from high latitude. These results demonstrate the importance of insolation during warm climates and the growing importance of ice sheets with global cooling in controlling NH precipitation changes.

Scientific Themes: Theme 1: Deep-time Climate & Environment
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Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

A Sedimentary Funneling Effect and the Biogeochemical Remanent Magnetization in Mariana Hadal Trench

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Keywords: Subducting carbon, Biogeochemical remanent magnetization, Sedimentary funnel effect, Hadal trench.

Abyssal subduction zone, known as the subduction factory, is a very important channel for the transportation of fluid and material from upper mantle to the lower, which consequently affect the element input and fluid property of the lower mantle. One of the most important scientific issue in this process is the subducting carbon, in which the move carbon from the sedimentary and oceanic crust is transformed into fluids, magmas, volcanic gases and diamonds and then disappear into subduction zones. However, the sedimentary rate in surface sediment of hadal trench is still poorly known which hampers the understanding of the carbon flux in there. Precise age model of the abyssal sediments is a prerequisite for robust determination of the materials deposition rate and recycle of subducting carbon in the hadal trench. Previous study has suggested that the sedimentary rate in Mariana trench is relatively high. But other studies showed that the sedimentary rate is very slow in there. Due to the lack of research materials and comparison with the surrounding sedimentation rate, the sedimentary process in hadal trench is still an enigma. Here, we have selected two sediment columns near the Mariana trench and obtained the sediments age by magnetostratigraphic study. The results show that deposition rates in hadal trenches is higher than elsewhere, suggesting a sedimentary funnel effect. It provides a significant insight on the carbon subduction in hadal trench. Furthermore, we also find a well-crystallized biogenic magnetite in a kind of hollow Fe–Mn micronodules. It may represent a unique process about biogeochemistry and a new important biogeochemical remanent magnetization in the special hadal trench environment.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-2: Using the magnetic record of sediments to understand fundamental geological processes in tectonics, environment, and climate
Presentation Preference: Oral Preferred

Quantifying the extent of the Paleo-Asian Ocean during the Late Carboniferous to Early Permian

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Keywords: Paleomagnetism, Paleogeographic reconstruction, Paleo-Asian Ocean, Central Asian Orogenic Belt

The Paleo-Asian Ocean (PAO) separated North China and Tarim from Mongolia and Siberia. Dating the closure of the PAO is critical to our understanding of East Asian tectonics during the formation of Pangea, yet existing estimates differ by up to 130 Myr (380 Ma to 250 Ma). In this study, we report two robust paleomagnetic results from 320-280 Ma volcanic-sedimentary strata in the South Mongolia-Xing'an Belt. Stable characteristic remanences of both results are likely primary and characterized by positive fold tests, consistent polarity with the Kiaman Superchron (~318-262 Ma) and average paleosecular variation. The new results indicate that the northward motion of North China and Mongolia paralleled Laurussia from the Late Carboniferous to Early Permian. The N-S width of the PAO in the east-central segment (reference site: 43°N/114°E) was ca. 2700 km during the Late Carboniferous to Early Permian. The existence of this wide oceanic basin impeded floral and faunal interchange between North China and Mongolia. The PAO finally closed and formed a unified North China-Amuria block at ca. 250 Ma.

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Presentation Preference: Oral Preferred

Growth of the Tian Shan drives migration of the conglomerate-sandstone transition in the southern Junggar foreland basin

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Keywords: Conglomerate-sandstone transition, foreland basin, Tian Shan, seismic profile

The conglomerate-sandstone transition (CST) preserved in foreland basins records the stratigraphic equivalent of the gravel to sand transition (GST) which migrates in response to shortening in steady state orogen-foreland basin systems. Two seismic profiles in the southern Junggar foreland basin provide the first seismic record of migrating CSTs and an opportunity to quantify its migration history in response to the growth of the northern Tian Shan. We identify the horizontal positions of the CSTs based on the distinct seismic signature of conglomerate versus sandstone and estimate their ages according to magnetostratigraphic sections. The linear regression analysis reveals that the CSTs migrated northward at 0.4 ± 0.1 mm/yr along 84°E from ~23 Ma to ~6 Ma and at 4.0 ± 1.2 mm/yr along 87°E from ~3.1 Ma to ~0.7 Ma. The discrepancy relates to variations in crustal shortening along strike of the range. Temporal deviations in the CST positions suggest the second-order impacts of climatic change.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
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Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

An unusual case of wide liquefaction caused by the M5.1 earthquake: mobilization effects of salt dissolution on liquefaction

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Keywords: Liquefaction, M5.1 earthquake, mobilization, salt dissolution, Hami

Earthquake liquefaction threshold is a very important scientific problem, it is generally believed that the M5 earthquake will not form a large area of liquefaction. On December 14, 2009, a M5.1 moderate-sized earthquake just 4 km in depth occurred in the city of Hami, Xinjiang, Western China. It struck an area roughly 12,000 km2 in size, and formed large quantities of spectacular, noticeable, randomly-oriented, and polygonal sand dikes that were wedge-like and oblique (on average 75.10°) in vertical section, as well as relatively well-sorted and from tens of centimeters to more than two meters in plane. Typically, they occur almost exclusively in a fine-grained rich salted sand gravel layer (SSGL) by liquefaction and fluidization differentiation, which are extremely susceptible to liquefaction in brine, albeit with no fine-grained caps and parent depositional sand bodies. The maximum epicentral distance of liquefiable sites may well extend to at least 80 km, and probably as far as 120 km, which is equivalent to that of M7.0~8.0 earthquake. Undeniably, the formation of Hami sand dikes and especially unusual significant liquefaction and fluidization is mainly attributed to the five unusual advantages: (1) salt mobilizations of SSGL prone to liquefaction and fluidization. The brine can largely decrease the shearing ability of sands, on average 58.30~70.0% and reduce the liquefaction threshold value of the earthquake to 0.060~0.083g. Thus, this is favoured for liquefaction and meanwhile, the brine may also reduce the minimum fluidization velocity (Umf) of 12.51~21.58% in the fresh water and thus is favoured for fluidization; (2) widely-distributed salt and detrital mixture cap (SDMC); (3) very shallow earthquake source (only 4 km deep); (4) very shallow basement (c. 0-3 m deep); (5) widely-distributed salted sandy gravel layer (SSGL), and (6) special sandwich texture of SDMC+SSGL+ basement. Otherwise, we obtained a map of fluidized distribution and fluidized boundary of different granular sand grains within a LSSGL and find that the sands mainly come from LSSGL below the bottom of the sand dikes, not the LSSGL on either side.

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Presentation Preference: Oral Preferred

Magnetite magnetofossils record biogeochemical remanent magnetization in hydrogenetic ferromanganese crusts

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Keywords: Bogeochemical remanent magnetization (BRM), Hydrogenetic ferromanganese crusts, Rock magnetic, Synchrotron analysis

Records of natural remanent magnetization (NRM) and geomagnetic polarity reversals preserved within ferromanganese (Fe-Mn) crusts, together with the application of fine-resolution magnetostratigraphic analysis, have been successfully demonstrated. However, as Fe-bearing precipitates or minerals are thought to be either oxides/hydroxides precipitated from ambient oxic seawater, or detrital minerals, the magnetic properties of the ferromagnetic minerals and the genetic mechanisms remain controversial; moreover, the origin of the NRM is unclear. Here, we show that nanometer-scale magnetite crystals found in Fe-Mn crusts from the Pacific Ocean and South China Sea are magnetosome fossils based on their narrow size range, chain arrangement, chemical purity, and crystallographic perfection, as indicated by transmission electron microscopy (TEM). Furthermore, our new data of rock magnetic and electron paramagnetic resonance analyses, combined with a previously reported micro-magnetostratigraphic sequence, indicate that the magnetotactic bacteria (MTB) and their post-mortem remains contribute to a biogeochemical remanent magnetization (BRM) of Fe-Mn crusts. In addition, the results provide evidence for a previously unappreciated pathway for the biogeochemical cycling of iron in the deep ocean.

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Presentation Preference: Oral Preferred

Sedimentation rates in the Central Arctic Ocean according to the paleomagnetic study

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Keywords: paleomagnetic studies, Actic Ocean, Mendeleev Ridge, Lomonosov Ridge, mean sedimentations rates

Until today, understanding of the geological and environmental processes taking place in the Arctic Ocean throughout its evolution is a high-priority geological objective. Nevertheless, accurate age determination of marine sediments from the Central Arctic Ocean is still challenging and remains a subject of great debates. Due to the lack of adequate materials for biostratigraphy and stable isotope analyses, paleomagnetic reconstructions came into play here but though yielded ambiguous interpretations.

Numerous paleomagnetic studies were carried out on marine sediments from various parts of the Arctic Ocean where reverse magnetized sediments were assigned to different time scales and geochemical processes. That, as a result, led to the existence of contrasting age models, varying by an order of magnitude, for the Quaternary and, to some extreme, to discredit the application of paleomagnetic stratigraphy in the Arctic Ocean in general.

Our comprehensive paleomagnetic study carried out on a number of long sediment cores (up to 8 m) from the area of the Central Arctic Rises (Stein, 2015; Stein et al., 2010), firstly, has established sedimentation rates of 1-2 mm/kyr for the Mendeleev Ridge up to the Pliocene age, complemented with 230Th excess results (Geibert et al., 2021; Elkina et al., 2020; Elkina et al., 2019; Piskarev and Elkina, 2017; Piskarev et al., 2013).

Secondly, in contrast to the Mendeleev Ridge, in the direction of the Eurasian Basin, the calculated mean sedimentation rates increase, at the same time showing a more complex paleomagnetic record with a relevant shift to negative geomagnetic inclinations significantly deeper downcore. This could imply a relevant difference in the sedimentation regimes, at least between the Mendeleev and Lomonosov ridges, during the Quaternary.

Finally, if considering a stable sedimentation environment, such slow sedimentation rates raise a question not only about times of glaciation onsets but whether it could “age”, to some extent, seismically identified horizons in the deeper sediment cover.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
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Presentation Preference: Oral Preferred

Paleomagnetic constraints on the origin of Late Paleoproterozoic Xuanlong-type ironstone in the northern margin of the North China Craton

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Keywords: Chuanlinggou Formation, oolitic hematite, paleomagnetism, rock magnetism, paleogeographic reconstruction, paleoenvironment

The disappearance of banded iron formation (BIF) at ~1.8 Ga and the emergence of granular iron formation (GIF) in Mesoproterozoic have attracted a lot of attentions. The redox state of late Paleoproterozoic GIF, the Xuanlong-type ironstone (~1.645 Ga) of the Chuanlinggou Formation has been investigated mainly by geochemical methods (Li and Zhu, 2012; Lin et al., 2019; Tang et al., 2022; Wang et al., 2022). No paleomagnetic studies have been operated on the Xuanlong-type ironstone in the in the northern margin of the North China Craton, and therefore the paleogeographic location of the Xuanlong-type ironstone was unsolved. Moreover, there are still controversies on the mechanism for the formation of hematite in the Xuanlong-type ironstone, adding difficulties to extract paleoenvironmental information.

In this contribution, we used paleomagnetism, rock magnetism and in-situ analysis technology to explore the paleogeography and environmental information of the Xuanlong-type ironstone. Two new understandings have been obtained as follow:

(1) Normal and reversed directions of characteristic remanent magnetization could be isolated for samples from the Xuanlong-type ironstone. The mean direction of this primary remanent magnetization after bedding correction was Ds=50.1°, Is=54.4° (κ=22.2, α_{95}=5.5°, n=32) and the corresponding paleomagnetic pole was at 49.5°N, 192.8°E (dm/dp=7.7/5.5, n=32). These directions have passed a C-classification reversal test (McFadden and McElhinny, 1990) and a fold test at 95% confidence radius (McFadden, 1990). This paleomagnetic pole at ~1.645 Ga fulfilled a Van der Voo (1990) value Q=6. Thus, this characteristic remanent magnetization was interpreted to be a primary remanent magnetization carried by Al-substituted hematite during the precipitation of the Xuanlong-type ironstone. A paleo-latitude of 34.93°N was obtained for the NCC at ~1.645 Ga.

(2) Rock magnetic, scanning electron microscope-X-ray energy dispersive spectrometer (SEM-EDS) and electron probe microanalysis (EPMA) analytical results revealed that the primary remanent magnetization preserved in the Xuanlong-type ironstone was a chemical remanent magnetization carried by Al-substituted hematite acquired in early diagenesis. After analyzing the possible transformation of ferrihydrite to Al-substituted hematite, we revealed that the formation of porous and dense laminae indeed reflected two source of water (hydrothermal fluids input and runoff input) that dominated differently in the pore water of sediments during the precipitation of Al-substituted hematite. This process was actually controlled by the relative sea-level changes because the Xuanlong-type ironstone precipitated in the land-ocean transitional zone.

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The Mid-Pleistocene Birth of the Yellow River

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Keywords: Magnetostratigraphy, Yellow River, Landscape evolution, Mid-Pleistocene transition, Tectonic-climate interaction

The integration between the middle and lower reaches of the Yellow River marks the final formation of the Yellow River, but the timing varies from the late Miocene-early Pliocene to the late Pleistocene (~0.15 Ma) and the underlying forcing mechanisms vary from the uplift of the Tibetan Plateau to global climate change. Here, we report magnetostratigraphy, sedimentology, and provenance data from a drill core near the Sanmen Gorge, the last gorge along the main course of the Yellow River. Our results indicate that typical river channel deposits, with detritus from the Ordos Block, started to accumulate in the Sanmen Gorge at ~1.25 Ma, which is consistent with a shift in the regional depositional environment from a closed saline lake to a fluvial-dominated system. When integrated with river terrace evidence from upstream and downstream regions, the results provide robust evidence that the final integration of the Yellow River occurred around ~1.25 Ma, consistent with the beginning of the Mid-Pleistocene transition (MPT). We propose that the accelerated lowering of eustatic sea-level during the MPT may plays as important a role as tectonism in driving the birth and development of the Yellow River.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-2: Using the magnetic record of sediments to understand fundamental geological processes in tectonics, environment, and climate
Presentation Preference: Oral Preferred

Paleomagnetic and geochronologic evidence for the Mesozoic tectonic evolution of the Indochina block

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Keywords: Paleomagnetism, Indochina Block, Mesozoic, Detrital zircon U-Pb chronology, Tectonic evolution

The collage of the Indochina Block to the Eurasia continent during the Late Triassic led to the transition from marine sedimentary environment to continental environment in the Simao and Khorat basins. Our previous work has carried out paleomagnetic constraints on the collision process and tectonic evolution. A significant southward migration of ~1200-1400 km of the Indochina Block occurred during the Mesozoic times, which was also accompanied by a clockwise rotation of 18.8° ± 7.8°. To better complement our paleomagnetic work and constrain the paleoposition of Indochina block during the Mesozoic times, we performed U-Pb geochronologic analyses on detrital zircons from Late Triassic to Late Jurassic sedimentary rocks in the Simao and Nakhon Thai basins of the Indochina Block. Late Triassic sedimentary rocks reveal a significant age cluster of Cambrian to Triassic (~ 500–220 Ma), with few Precambrian zircon grains. In contrast to Late Triassic sedimentary rocks, the detrital zircon spectra of Late Jurassic sedimentary rocks shows a number of age populations at 135-500 Ma, 950 Ma, 1800 Ma and 2500 Ma. The age distribution pattern of detrital zircons from Late Jurassic sedimentary rocks is different from that of Late Triassic sedimentary rocks, indicating that a sediment provenance transition occurred in the Indochina Block during the Middle Jurassic times. The paleomagnetic and geochronologic constraints indicates that the Indochina Block gradually collided with other Eastern Asia main blocks and received their clastic sediments during the Jurassic southward migration.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-2: Using the magnetic record of sediments to understand fundamental geological processes in tectonics, environment, and climate
Presentation Preference: Oral Preferred

Environmental magnetism and astronomically driven magnetic records of the Lower K1sh formation in the Early Cretaceous Songliao basin, northeastern China

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Keywords: SK-2 borehole, lower Shahezi Formation, lower Cretaceous, environmental magnetism, cyclostratigraphy

Continuous cores of the lower Cretaceous in Songliao Basin, northeastern China, have been drilled out by the International Continental Drilling Project of SK-2 borehole, providing unprecedented geological materials for investigations of the early Cretaceous continental paleoenvironment and paleoclimate. In this study, we systematically studied the lacustrine successions of the lower Shahezi Formation (K1sh) in depth 4542-5694 m using the techniques of environmental magnetism, microscopic imaging, geochemical stratigraphy and cyclostratigraphy. Magnetic analysis reveals that there is an inverse correlation between magnetic susceptibility (MS) and lithology, where mudstones hold the largest values, and sandstones hold the smallest. The main magnetism carriers in the lower K1sh are pseudo-single-domain (PSD) and/or multi-domain (MD) ferromagnetic minerals, whilst the mainly dominant minerals of MS are paramagnetic and ferromagnetic minerals. To further explore the genesis of the environmental and climatic variations, MS was utilized as an alternative proxy to proceed with cyclostratigraphic analysis. Sedimentary cycles of 113.04 m, 34.11 m, 13.34 m and 6.00m are significant in power spectrum, which are in ratio highly accordant with long eccentricity (405 kyr), short eccentricity (124 kyr), obliquity (47 kyr), and precession (21 kyr) cycles in Early Cretaceous, proving the considerable impact of astronomical cyclicity on sedimentary rhythmicity. Long eccentricity controlled sedimentary facies, short eccentricity and precession are regarded to have mutually shaped the lake level oscillations. It should be noted that semi-precession periods identified from MS and the U sequence is most likely to directly drive the sand-mudstone alternations with the seasonal discrepancies of summer insolation. Finally, by tuning the inferred long and short eccentricity cycles to 405 kyr and 124 kyr orbital eccentricity theoretical curves, we established floating astronomical time scales (FATS) of 3356.99 kyr and 3248.80 kyr respectively, both of which fall into the range of the published U-Pb ages. Sedimentation rate was estimated ranging from 27.50 cm/kyr to 28.91cm/kyr, confirming the rapid deposition characterized within the fault lacustrine basin. In summary, our study acquired experimentally detailed magnetic characteristics of the early Cretaceous terrestrial sediments, shed new light on the astronomically forced configurations of paleoclimate on these magnetic properties, and provided a preliminary geochronological constraint for further marine-terrestrial comparison towards coeval strata.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-2: Using the magnetic record of sediments to understand fundamental geological processes in tectonics, environment, and climate
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Late Ediacaran inertial-interchange true polar wander (IITPW) event: new road to reconcile the enigmatic paleogeography prior to the final assembly of Gondwanaland

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Keywords: Inertial-interchange true polar wander (IITPW), Paleomagnetism, Paleogeography, Late Ediacaran

The Ediacaran to Early Cambrian plate tectonics was dominated by a full dispersal of the supercontinent Rodinia and subsequent amalgamation of Gondwanaland. There is a consensus that the final assembly of the Gondwanaland did not complete until the Early Cambrian. Prior to the final assembly, however, one major uncertainty remains on the quantitative paleogeography: the mainland of Gondwana was plausibly positioned at either a high or low latitude at a single time instant to meet the dual-latitude ('high-latitude' and 'low-latitude') options of Laurentia and requirement of <600 Ma Iapetus Ocean opening between Amazonia and Laurentia. This uncertainty arises from the equivocal selections on the ca. 590-560 Ma paleopoles from Laurentia and very few paleomagnetic data from Gondwana continents. In this paper, we expanded the dataset of high-quality paleomagnetic poles on the basis of Robert et al. (2017, 2018) and Wen et al. (2020) and confirmed an inertial interchange true polar wander (IITPW) event from ca. 590-580 to 560 Ma. We then provide a continuously kinematic reconstruction in the TPW-based ('absolute') framework and thus reconciling the two enigmatic paleogeographic models in this interval. The occurrence of IITPW in late Ediacaran has important implications for understanding the co-evolution of Earth system and multi-disciplinary investigations of the IITPW associated processes are needed in future work.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-2: Using the magnetic record of sediments to understand fundamental geological processes in tectonics, environment, and climate
Presentation Preference: Oral Preferred

Magnetic fabric and sedimentary structure constraints on the Paleozoic paleocurrent changes in the northwestern margin of the Tarim basin and their provenance implications

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Keywords: Magnetic fabric, Paleocurrent, Keziertage Formation, Tarim Basin, South Tianshan Ocean

The magnetic fabric technique is widely used to measure the direction of paleocurrent and paleo-stress as its speediness, precision, and cheapness. However, there is still a lack of direct comparison between the sedimentary structure-based and magnetic fabric-based paleocurrent direction. The Early Devonian Keziertage Formation in Tarim Basin preserves a wealth of sedimentary structure information on paleocurrent directions, which provides a natural laboratory for the comparison with magnetic fabric recovery. Furthermore, it bears the provenance evolution and tectonic implications on the South Tianshan Ocean opening. Here, we report 120 sedimentary structure-based paleocurrent and 382 anisotropy of magnetic susceptibility (AMS) data from the Keziertage Formation in the Kalpin area, Xinjiang. The distribution of AMS directions suggests that the sedimentary magnetic fabrics have been subjected to incipient deformation. While in the layer of tabular cross-bedding, the imbricate direction of the minimal axis of the AMS is consistent with the sedimentary structure-based paleocurrent direction. Both the magnetic fabric and the sedimentary structure show the paleocurrent changed from WSW to NE at the mid-upper part of Keziertage Formation. It implies the significant provenance transition that occurred in the Keziertage Formation of the Kalpin basin, which may further support the opening of the South Tianshan Ocean during the Early Devonian.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-2: Using the magnetic record of sediments to understand fundamental geological processes in tectonics, environment, and climate
Presentation Preference: Oral Preferred

Magnetostratigraphic constraints for late Carboniferous rocks of the western Junggar Basin, China

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Keywords: late Carboniferous,Magnetostratigraphy,Kiaman ,Fengcheng formation,Jiamuhe formation,Junggar basin

The reverse polarity Kiaman Superchron has strong evidence for sparse normal magnetochrons from the middle Permian to late Carboniferous.There,we present results of geochronologic,microscopy,rock magnetic and paleomagnetic analyses of a ~454 m-thick continuous vertical drill core(MY I Well) that intersect the Jiamuhe Formation and Fengcheng Formation (late Carboniferous) of the western Junggar Basin, China. U-Pb zircon dating of tuff yielded a concordant age of 308±2 Ma; andesite yielded a concordant age of 309±2 Ma.Rock magnetic and optic microscopy experiments indicate magnetite and hematite in the mudstones, sandstone, andesite and basalt as carriers of characteristic remanent magnetization(ChRM),which is primary remanent magnetization.Stepwise demagnetization and thermally less stable magnetizations reveal the preservation of a dual polarity ChRM in 180 samples. These are used to construct a magnetostratigraphic profile for the core that is dominantly reversed polarity with two short normal polarity subchrons.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-2: Using the magnetic record of sediments to understand fundamental geological processes in tectonics, environment, and climate
Presentation Preference: Oral Preferred

Remagnetization age and mechanism of Cretaceous sediments in relation to dyke intrusion, Hainan Island: Tectonic implications for South China and the Red River Fault

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Keywords: Remagnetization, Redbed, Paleogeography, South China, Cretaceous

Hainan Island lies near the Red River Fault, a prominent tectonic feature produced by the India-Asia collision. There, we carried out a geochronologic and paleomagnetic study on Cretaceous rocks in order to better understand the kinematic history of the region. U-Pb zircon dating of tuff intercalated in red bed sedimentary rocks yielded a concordant age of 106.6±0.3 Ma; a mafic dyke intruding the red beds yielded a concordant age of 104.6±0.7 Ma. Stepwise demagnetization experiments on 448 sedimentary rock samples and 191 dyke samples isolate solely normal polarities. Paleomagnetic directions of the dykes cluster in two distinct populations in geographic coordinates, indicating that dyke intrusion occurred in two pulses of limited duration (secular variation was not averaged) after tilting of the sediments. Baking of the sediments from the dykes only occurred near the contacts. Together with published data, the mean directions of 104 sites most tightly group at 58.3±3.2% unfolding, indicative of a synfolding remagnetization, which can be constrained to have occurred within a 2 Myr period between sedimentation and dyke intrusion. We suggest that warm (50-100°C) fluid interaction during basin development led to new mineral growth spawning chemical remagnetization. The corresponding paleomagnetic pole at 81.5°N, 145.2°E (A95 = 2.4°) is indistinguishable from the coeval Eurasian reference pole, suggesting the South China Block has remained fixed to Eurasia since 105 Ma. A contour map of paleomagnetic rotations from 115 studies in the region shows that the Red River Fault roughly demarcates rotation magnitudes/signs, suggestive of a major tectonic boundary.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-2: Using the magnetic record of sediments to understand fundamental geological processes in tectonics, environment, and climate
Presentation Preference: Oral Preferred

Magnetostratigraphy and preliminary environmental magnetism of of IODP Hole U1524A from the Ross Sea, Antarctica

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Keywords: Magnetostratigraphy, Ross Sea, Plio-Pleistocene

Earth's climate during the Plio-Pleistocene was characterized by a significant change from warmer-than-present conditions before 3 Ma to a global cooling trend with rhythmic glacial-interglacial cycles. Feedbacks associated with variability of the West Antarctic Ice Sheet have been implicated in amplifying this cooling, but its exact role within this framework remains uncertain due to lack of continuous proximal records. Hole U1524A recently drilled by International Ocean Discovery Program (IODP) Expedition 374 consists of an almost continuous Plio-Pleistocene sedimentary sequence. In this study, we refine the originally noisy shipboard magnetostratigraphy of Hole U1524A by comprehensive analyses of paleo- and rock magnetic data. We demonstrate that drilling overprints can be used to infer the quality of natural remanent magnetization (NRM) at Hole U1524A. It allows a new strategy to identify problematic data when characteristic remanent magnetization directions are unavailable, yielding an improved continuous magnetostratigraphy. Based on the refined age-depth model, we show that the low coercivity NRM component of Hole U1524A captures major climate transitions over the past 3.3 Myr and that its variations in intensity are indicative of changes in terrigenous material transported to the drill site, which is potentially linked to the glacial history of the West Antarctic Ice Sheet advancing and retreating across the Ross Sea continental shelf.

Session T1-3: Climatic cooling events, glaciations, and glacial sedimentology

ID: T1-30105

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-3: Climatic cooling events, glaciations, and glacial sedimentology
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Glacial fluctuations during the LGM and Lateglacial in the Zhuxi and Songlong valleys, eastern Nyainqêntanglha Range, southeastern Tibet

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Keywords: OSL dating,10Be exposure dating,glacier-climate modeling,LGM,Lateglacial,southeastern Tibet

This study presents the glacial history and climatic conditions during the Last Glacial Maximum (LGM) and Lateglacial (LG) of the Songlong and Zhuxi valleys in the eastern Nyainqêntanglha Range, southeastern Tibet. Two sets of moraines were identified at the valley mouths, and were dated using cosmogenic 10Be exposure and optically stimulated luminescence (OSL) dating. The ages suggest that two glaciations occurred at ~20-21 and ~14-16 ka, respectively, coinciding with the LGM and LG glacial event. Based on glacier-climate modeling results, temperature drops ranged from 6.3 to 7.8 ℃ during the LGM-LG, with precipitation being 40%-60% of present value. The model results in the model domain are generally consistent with other climate records on the Tibetan Plateau. Glacial advances in monsoon-dominated southeastern Tibet during the LGM-LG were likely driven by low temperatures rather than by high precipitation, which was usually produced by the enhanced Indian summer monsoon during warming periods.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-3: Climatic cooling events, glaciations, and glacial sedimentology
Presentation Preference: Oral Preferred

Weakening of continental weathering and cold event in the Late Mesoproterozoic, North China Craton

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Keywords: cold event, continental weathering, Late Mesoproterozoic, Xiamaling Formation, Longshan Formation, North China Craton

A giant unconformity has long been considered to exist in the Late Mesoproterozoic (Xiamaling Formation and Longshan Formation transition), North China Craton (NCC), but whether this unconformity existed and whether there were other important unrevealed geological events during the transition have not been comprehensively explored. In particular, if there are several hundred million years of depositional discontinuities during the transition, they must have experienced a long exposure process, and physical or chemical weathering information must be recorded in the sediments. So, sedimentary detrital zircon dating is employed to explain whether an unconformable interface exists and geochemical methods such as Li isotope and sensitive geochemical elements in sediments are analysized to study the weathering intensity changes at the interface. Furtherly, the possible driving mechanism and geological significance can be better understood in the evolution of the late Mesoproterozoic North China Craton.

The detrital zircon age spectrum characteristics of the main Neoproterozoic strata from the NCC show that besides the detrital zircons with ages similar to those of Mesoproterozoic sandstones (dominated by > 1600 Ma), the zircons with the age of 1500-1000Ma are found which are not developed in Mesoproterozoic sandstones. However, the detrital zircon age spectrum of the Longshan Formation, which is considered as Neoproterozoic, shows two peaks at 2500 Ma and 1800 Ma, and no zircons less than 1500 Ma are obtained. This means that the Longshan and Xiamaling Formations were integrated deposits, and both belong to the Late Mesoproterozoic.

The abundance of Li shows a decreasing trend from the top of the Xiamaling Formation (mean of 53.2 ppm in Huailai, Hebei; mean of 30.97 ppm in Jixian, Tianjin) to the bottom of the Longshan Formation (mean of 30.8 ppm in Huailai; mean of 24.36 ppm in Jixian), while the δ^7Li value shows a correspondingly increasing trend from the top of the Xiamaling Formation (mean of 1.4‰ in Huailai; mean of 1.75‰ in Jixian) to the bottom of the Longshan Formation (mean of 11.8‰ in Huailai; mean of 7.13‰ in Jixian). The chemical index of alteration (CIA), chemical index of chemical weathering (CIW), and plagioclase index of alteration (PIA) show a decreasing trend from the top of the Xiamaling Formation to the bottom of the Longshan Formation, while the compositional change index (ICV) shows a corresponding increasing trend. In addition, the substitute index of chemical weathering intensity, such as K_2O/Al_2O_3, Na_2O/Al_2O_3, and FeO/Fe_2O_3, presents an increase in value, while the Rb/Sr value is decreased. All above indicate that continental chemical weathering weakened during the sedimentary transition period of the Xiamaling and Longshan Formations, which may be related to global climate cooling and even glacier event in the Late Mesoproterozoic (~1.30-1.00 Ga).

In general, the Longshan Formation is probably a series of shore-shallow sedimentary strata that developed in the global, relatively cold climate of the Late Mesoproterozoic.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-3: Climatic cooling events, glaciations, and glacial sedimentology
Presentation Preference: Oral Preferred

Scale, characteristics and age constraints of the Ediacaran Luoquan glaciation

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Keywords: Luoquan glaciation, characteristics, age constraints, Ediacaran, snowball Earth

The Luoquan Formation unconformably overlaid different systems of the Mesoproterozoic (>1.6 Ga) with large discontinuities of about 1.0 Ga, on which the huge erosional landforms, such as striated pavements of different sizes, various striations, grooves and ridges and P-forms are well preserved, indicating a north to south movement direction of glacier (Le Heron et al., 2018, 2019; Chen et al., 2020). The Luoquan Formation is mainly composed of subglacial massive diamictites and weakly stratified diamictites, periglacial fluvial conglomerate, pebbly sandstone with rhythm layer, and marine laminated siltstone and mudstone with and without dropstone, which constitute a vertical sedimentary succession of subglacial, periglacial and glacial marine facies from continent to sea. In particular, the periglacial sand wedge (cast) structure occurred at the interface between the Luoquan Formation (including Dongpo Formation) and the Xinji Formation at the bottom of Cambrian, which is rare in the Neoproterozoic glacial records in China, indicating the palaeogeographic background of periglacial frozen soil during the Ediacaran-Cambrian transition period and the periglacial landform of the deglaciation during the Luoquan glaciation in the southern margin of North China. Paleontological and zircon dating indicate that the Luoquan glaciation was developed between the Ediacaran-Cambrian transition period or earlier than 574-539 Ma and later than the period of Gaskier glaciation. Represented by the Luoquan diamictite, the Ediacaran glacial sedimentary records span more than 3000 km from Anhui, Henan, Shaanxi on the southern margin of the North China Craton (NCC), Gansu and Ningxia of the west margin of NCC, and the Qilian Mountain and Qaidam (Oulongbuluke) to Quruqtagh of Xinjiang, and even to the central Asia and reaching the Middle East in the Arabian Peninsula. Besides, it has also been widely reported on other continents, such as Europe and North American. Therefore, the Ediacaran glaciation was probably another episodic “snowball Earth” event.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-3: Climatic cooling events, glaciations, and glacial sedimentology
Presentation Preference: Oral Preferred

Multiple cycles of Ediacaran glacial dynamic evolution in North China Craton

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Keywords: Ediacaran, Luoquan Formation, Glacial dynamic evolution, North China Craton

A series of diamictites of late Ediacaran are widespread across Southeast–Central Asia, with the Luoquan Formation particularly well preserved along the southern margin of the North China Craton (NCC). A basal unconformity, comprising abundant striations and p-forms, such as Muschelbruch, steep-sided cavetto interpreted to have been produced subglacially, was cut into the Mesoproterozoic basement, which indicate a near north to south direction of glacier movement. Although the thickness of the Luoquan Formation varies greatly from north to south, the succession of Luoquan Formation at each outcrop evolves from massive or stratified diamictite at the base to laminated fine-siltstone with dropstones upward, and with or without siltstone (i.e., Dongpo Formation) capped on the top. However, special case occurred at Yiyang section in the northwest, which contains two sets of fining upward succession from massive diamictite to laminated pebbly sandstone, and then to dropstone bearing siltstone. Therefore, the Luoquan glacier in the southern NCC showed multiple cycles of dynamic evolution, and the first set of glacial advance-retreat cycle may corresponds to the formation of extensive subglacial bedforms and landscapes.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-3: Climatic cooling events, glaciations, and glacial sedimentology
Presentation Preference: Oral Preferred

Cap dolostone indicating the earliest Ediacaran paleogeomorphology of the Yangtze Craton

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Keywords: Ediacaran, Cap dolostone, Paleogeomorphology, Yangtze Craton

The cap dolostone is a type of carbonate with global distribution, significant carbon isotope negative drift and special sedimentary structures in the aftermath of the Snowball Earth. It is traditionally believed that the cap dolostone can be found in wide depositional environments from continental shelves, slopes to basins. However, the research on the cap dolostone blanketing the Marinoan Nantuo Formation in the Yangtze Craton (YC) of South China shows that the cap dolostone is only deposited in the continental shelf or shallow water ramp settings; the so-called "cap dolostone" of deep-water origin such as formed in the slope and basin environments is a misunderstanding. Meanwhile, because the western YC is located at the paleo-uplift area, where the marine transgression in the early Ediacaran cannot reach, the cap dolostone was generally absent. Therefore, at the beginning of Ediacaran, the paleogeomorphology of the YC was characterized by the uplift in the west, and the extensive & flat shallow water (ramp) environment in the middle and east. In particular, the cap dolostone facies changed into deep-water cherts in distally steeper ramp (basin) in the southeast margin of YC.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-3: Climatic cooling events, glaciations, and glacial sedimentology
Presentation Preference: Oral Preferred

Late Eocene signals of oncoming Icehouse and changing ocean circulation, Antarctica

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Keywords: Prydz Bay, East Antarctic Ice Sheet, Eocene-Oligocene transition, clinoforms, Mass-transport deposits

The end of the Eocene greenhouse world marked the most dramatic phase in the long-term cooling trend of the Cenozoic time. Here we interpreted seismic data from offshore Prydz Bay, Antarctica, provide new insight on the Paleogene stratigraphic transition from greenhouse to icehouse conditions and ocean circulation changes. Despite the lack of Paleogene sediment cores to provide precise chronology, we identify a prominent Paleogene transitional phase (Greenhouse to Icehouse) preserved in the deep-water sedimentary record by correlating from shelf to the continental slope based on 75,000km of multi/single channel seismic reflection data. The occurrence of mega-Mass Transport Deposits (MTDs) on the slope suggests significant instability and collapse of the upper part of the continental margin during deposition of glacio-fluvial braid-plain sand on the outer shelf (stratigraphic unit III in Ocean Drilling Program Site 1166). A later phase of the transition is represented by the growth of a well-defined set of Latest Eocene continental slope clinoforms. These were constructed largely by sediment delivered to the margin by marine-terminating glaciers on the shelf. The identification of the MTDs and prograding clinoforms helps define the transition interval (late-mid Eocene to Eocene-Oligocene boundary) of ice sheet dynamics, prior to amalgamation of a continent-wide ice sheet. A marked migration of the earlier margin depocenter toward the west and northwest, attested by onset of drift sedimentation, dominated the full glacial phase, strongly suggest a more vigorous ocean circulation as the earth has entered to the icehouse since the E-O boundary.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-3: Climatic cooling events, glaciations, and glacial sedimentology
Presentation Preference: Oral Preferred

Sedimentary evolution of Neoproterozoic greenhouse-icehouse transition in northern Yangtze Craton

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Keywords: Late Tonian, Sturtian glaciation, Northern Yangtze Craton, Sedimentary sequences, Sedimentary evolution, greenhouse-icehouse transition

Sea-level reconstructions provide us with snowball Earth scenario depicted by global ice sheets and low sea levels. The sea-level falls under the control of the Sturtian glaciation, caused unconformity (sedimentary discontinuity) between the glacial rock series and underlying strata in many cratons such as South Australia, Scotland, and Denmark. However, the Yangtze Craton shows a unique and continuously deposited sedimentary sequence of clastic rocks. In that context, this study explores this process through detailed sedimentological analyzes of six outcrops of Liantuo and Gucheng formations in the Shennongjia area, northern Yangtze Craton. The facies sequences of the Liantuo and Gucheng formations record transition from alluvial fan-braided river to shallow sea, and finally turn to glacial systems: (1) Beginning at ~770 Ma, the rapid subsidence of the northern Yangtze Craton was indicated by conglomerates and sandstones cover, which is interpreted as fan-braided fluvial facies; (2) At 750 Ma, the geological record demonstrates a fluvial to shallow marine facies transition; (3) After 720 Ma, Shennongjia or even the northern Yangtze Craton entered the glaciomarine environment with gradual development of the ice sheet. A model of sedimentary evolution from Late Tonian to the early Cryogenian of the Yangtze Craton is proposed under the constraints of chronology, driven by the tectonic-climate duality, which further deepens and expands our understanding of the climate and environment at the beginning of snowball Earth.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-3: Climatic cooling events, glaciations, and glacial sedimentology
Presentation Preference: Oral Preferred

A high-frequency sea-level change in the aftermath of the Marinoan glaciation

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Keywords: Fischer Plots, Sea-level change, Ediacaran, Doushantuo Formation, high-frequency cycles, Sedimentary facies

The rapid rise of glacioeustatic sea-level is the most extreme paleoenvironment alteration in the aftermath of the Snowball Earth. Although geologists conducted a lot of multi-subdiscipline research on this issue previously, there still exist potential for further discussions of the process in detail. The practice for decades years proved that the Fischer plot is a simple and robust tool to illustrate the fluctuations of accommodation patterns v.s. cycles sets or strata depth which could be interpreted as relative sea-level changes (e.g. Goldhammer et al., 1990; Sadler et al., 1993). This research simulates the Fischer plot to unravel the sea-level change in the aftermath of Marinoan glaciation by measuring the lower Ediacaran Doushantuo Formation in Shennongjia, South China. The result shows that 131 five order-cycles and 9 three order-cycles help us propose a two-stage variation of ice melting-forced sea-level change, i.e., (1) early high-frequency and slow to rapid stepwise rising, and (2) followed by stable decreasing in the latter. In addition, the vertical sedimentary facies of the lower Doushantuo Formation display, in ascending order, (1) intertidal carbonate rock, (2) subtidal clastics with turbidite and (3) intertidal lagoon fine clastics, indicating the process of the relative waxing and waning of sea-level. Such interpretation of the Fischer plot and the sedimentary facies' vertical evolution is beneficial to study the high-frequency sea-level change and paleogeographic reconstruction of post-Marinoan deglaciation.

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Session T1-3: Climatic cooling events, glaciations, and glacial sedimentology
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

The Carbon Cycle and Climate Fluctuations in the Early Permian Kungurian: Evidence from the Putaoling Section in Lower Yangtze Region

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Keywords: Kungurian, carbon isotope, carbon cycle, atmospheric carbon dioxide concentration, Lower Yangtze Region

The Early Permian Kungurian is in the climate transition period from the Late Paleozoic Ice Room to the Early Mesozoic Super Greenhouse, accompanied by global events such as the increase in atmospheric carbon dioxide concentration, ocean hypoxia, and decline in biodiversity. It is an important window and case study of the synergistic evolution of the global carbon cycle and climate environment. This study couples organic carbon isotopes (δ13Corg) and inorganic carbon isotopes (δ13Ccarb) and calculates Δ13C through stratigraphic, sedimentological and sedimentary geochemical studies of continuous sections of carbonate rocks of Putaoling Section at Chaohu in the Lower Yangzi region of South China, thereby indicating changes in the marine environment, carbon cycle anomalies and the evolution of biodiversity. The data show a simultaneous negative drift (KCIE event) of δ13Ccarb and δ13Corg in the Kungurian S. subsymmertricus dentate belt with a magnitude of about 1‰ and can be compared and related to other marine Kungurian profiles in South China. The simultaneous negative bias of δ13Ccarb and δ13Corg indicates the global carbon cycle anomaly caused by the input of a large number of lighter carbon isotopes in the Kungurian, which may be associated with the large igneous provinces associated with the mantle column on the northern margin of Gondwana and the release of methane hydrates, ultimately leading to higher greenhouse gas concentrations represented by atmospheric CO2 (pCO2). Excessive greenhouse gases rapidly exchange with the ocean and lead to lower ocean pH, potentially inhibiting calcification and cementation of reefs. Increasing seawater temperature will reduce oxygen solubility, making it easier to form an anoxic reducing environment, which may affect biodiversity. The environment of massive death of plankton and anoxic acidification is very conducive to the preservation of organic matter, which is also an important reason for the generally high TOC during this period. Anomalous carbon isotope fluctuations in the upper part of the Kungurian may be associated with global sea-level fall and upwelling currents.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-3: Climatic cooling events, glaciations, and glacial sedimentology
Presentation Preference: Oral Preferred

What does a glacial deposit really look like, and what is "normal" in Earth's sedimentary record of glaciation?

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Keywords: Glaciation, Cryogenian, Late Palaeozoic, Ordovician, Uniformitarianism

When we look at modern, Alpine glacial landscapes, we are struck by the abundance of chaotic and poorly sorted material, bearing large boulders. This material is diamict: unsorted, boulder-bearing material that is fashioned into a variety of familiar glacial landforms called moraines, and sometimes streamlined structures (drumlins). Earth has experienced many glaciations, and has a rich record of diamictites stretching from about 2.2 Ga to the present day. However, even superficial investigation reveals that the records of many glacial periods such as the Cryogenian and Late Ordovician are greatly contrasting. Cryogenian rocks crop out spectacularly in places like South Australia, Namibia, Scotland and the western USA. Glacially striated pavements below these are strikingly rare, in spite of these being associated with a so-called "snowball Earth". Spectacular, thick diamictites are interbedded with abundant dropstone-bearing strata and thus testify to a glacial influence, but not all diamictites are glacial and many record mass failures of slopes in a marine environment. By contrast, there is a high abundance of these features recording subglacial erosion in Late Ordovician and Late Carboniferous records. Huge networks of palaeo-ice streams can be mapped from satellite data, to allow detailed ice sheet reconstruction. The deposits of the Late Ordovician glaciation are predominantly sandstone, supercritical flow deposits are abundant, and most of the subglacial record records shearing of soft-sediment rather than "traditional" scratches on bedrock. Examples of these deposits are in Morocco, Algeria, Libya and Saudi Arabia. The Late Carboniferous record includes palaeo-fjord systems (e.g. in Namibia and Argentina) with polished bedrock surfaces that closely resemble Pleistocene fjord systems. Approaching the glacial record often requires "out of the box" thinking, because the present is not always the key to the past. This begs the question as to which glacial period, if any, is truly representative in terms of a glacial sedimentary record on Earth. So, do we really know what a glacial deposit looks like?

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-3: Climatic cooling events, glaciations, and glacial sedimentology
Presentation Preference: Oral Preferred

Precambrian red beds: their temporal and spatial distributions and association with glaciations

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Keywords: Red bed, Precambrian, Distribution, Sedimentary environment, Glaciations, Formation mechanism

Red bed is one of the most important witnesses of significant geological events. Making fully understanding of their sedimentary environments and forming mechanisms provides a great contribution for us to better understand the Earth's history and life evolution through time. Herein we make a statistic of the Precambrian red beds in more than 70 outcrops from nearly 30 countries and areas, including their lithology, sedimentary environment, areal distribution, and age data. 12 red bed sets are recognized with 5 of them considered as globally distributed, and the others are regional or local distributed. Globally distributed ones could act as paleoenvironment indicators, while the local ones are mainly dominated by local sedimentary environment and have little international significance. Lithologically, these red beds include red conglomerate and sandstone deposited in terrestrial (aeolian, alluvial, and fluvial) settings, red siltstone, muds, and carbonates deposited in shallow marine (dominately tidal and glacial marine) settings, and red mudstone, limestone, or dolostone deposited in shallow marine to bathyal transition areas. The terrestrial and shallow marine red beds are the dominating ones, while the red beds in shallow marine to bathyal transition areas are few and mainly concentrated in Ediacaran strata. Chronological coupling of the red beds deposition with the occurrences of glaciations, global eustatic sea-level changes, flourish of photoautotrophs (e.g., cyanobacteria), as well as the $\delta^{13}C$ and $^{87}Sr/^{86}Sr$ isotope indicate that the Paleoproterozoic Rhyacian red bed (Set 1) and Neoproterozoic Cryogenian and Ediacaran red beds (Sets 10-12) are closely related to the Paleoproterozoic and Neoproterozoic glaciations, Great Oxidation Event, and Neoproterozoic Oxygenation Event. The photosynthesizing of cyanobacteria is the most plausible oxygen producing mechanism which can increase and sustain significant levels of O_2 in atmosphere. The occurrence of glaciations decreased the water transmittance and prevented photosynthetic production of O_2 to oxidize Fe^{2+}, acting as a protector for oceanic Fe^{2+} accumulation. While melting of glaciers made the light available again for phototrophs and restarted the photosynthetic O_2 production to form red beds. In general, researches on Precambrian red beds are of great importance in decoding the systematical changes in paleoenvironment and shed light on the analysis of paleoevents like glaciations, and more attention should be given to them.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-3: Climatic cooling events, glaciations, and glacial sedimentology
Presentation Preference: Oral Preferred

Sedimentary Characteristics of the Late Paleozoic Ice Age in the Shenzha Area of the Lhasa Block

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Keywords: Sedimentary Characteristics, Late Paleozoic Ice Age, Lhasa Block

The Late Paleozoic ice age, as the glacial event with the widest influence range and the richest geological record since the Phanerozoic, recorded the complete greenhouse-icehouse-greenhouse climate change process, which is of great significance for us to understand the evolution of earth climate. Although a large number of studies have been carried out on the spatial-temporal evolution and controlling factors of the Late Paleozoic ice age, little is known about the records of the Late Paleozoic ice age in Lhasa block. In view of this, we have conducted a detailed sedimentary study on the Late Paleozoic ice age records in the Shenzha area of the Lhasa block. The Late Paleozoic ice age records of Lhasa block are mainly present at the upper part of Yongzhu Formation and Laga Formation, with the age constraint of Late Carboniferous-Permian. Twenty lithofacies types and eighteen lithofacies associations are recognized, which are arranged into eight sedimentary facies, including tidal flat facies, shore facies, glacial facies, shallow sea shelf facies, ice river facies, ice lake facies, outwash fan facies and carbonate platform facies, among which glacial facies is dominated by ice-rafting deposit, subglacial deposit and subglacial foreland deposit. Vertical sedimentary environment changes indicate the transition from early marine glaciers to late terrestrial glaciers, representing a continuous retreat of glaciers to land, consistent with an overall global warming trend from the Late Carboniferous to the Early Permian. In addition, multiple glacial-interglacial sedimentary sequences of the Laga Formation reflect that the Lhasa block has experienced multiple glacier evolution cycles, which can be compared with Late Paleozoic glacial record in Australian.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-3: Climatic cooling events, glaciations, and glacial sedimentology
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Heinrich event 6 recorded in a cave stalagmite from southeast China

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Keywords: speleothem, paleoclimate, Asia monsoon, Heinrich event

A stalagmite from Youqin Cave (southeast China), which is composed predominantly of columnar calcites with no evident diagenetic modifications, captured the Dansgaard-Oeschger Events (DO17 and DO16) and the Heinrich Event (H6) by the abrupt shifts in the δ18O records between 66.2 and 57.2 ka. The millennial-scale climate changes recorded in the stalagmite were tied to the fluctuations in the intensity of the Indian and East Asian monsoons. A comparison with climate records in Greenland ice cores and oceanic sediments suggests that during H6 the strength of the Asian monsoon was reduced. Compared with stalagmites collected from south China and North India, the centennial-scale δ18O variations in the Youqin stalagmite within the H6 are more dramatic than those in the stalagmites further inland. The contrast between stalagmites from different localities implies that during H6 (1) the East Asian monsoon had more influences on southeast China than the Indian monsoon; and (2) the centennial-scale δ18O fluctuations were possibly associated with the El Niño-Southern Oscillations that affected the area. Paleoclimate changes recorded by the stalagmite from Youqin Cave in the East Asian monsoon region provide important information for understanding global climate changes during the last glaciation period.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-3: Climatic cooling events, glaciations, and glacial sedimentology
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

The subsurface core-based paleosols and lacustrine sedimentary characteristics of the Eocene-Oligocene transition, Dongying Depression, Bohai Bay Basin, East China

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Keywords: Lacustrine basin, Eocene Oligocene transition, Bohai Bay Basin, East Asia

The Eocene-Oligocene transition (EOT) is an interest in geosciences field, which is characterized by cooling and arid climate feature. That climate varies in terrestrial settings, as reported by sedimentary records worldwide. However, the discussions are limited in the East Asia area since the lack of ideal outcrops in regions, which makes the inadequate knowledge of sedimentary records and monsoon-like climate patterns during the EOT in the East Asia. Thanks to the new subsurface cores collections. This study conduct the first time subsurface core description of paleosols, which were formed during the EOT in lacustrine basin of East China (Dongying Depression, Bohai Bay Basin). Based on petrographic analysis, the paleosols illustrate calcite precipitation nodules, with erosion surfaces and elements leaching making ferro-glaebules and nodules coatings. The calcareous and Fe-Mn horizons are developed, with appears of gleyed horizons. The main types are aridisols and oxisols. The subsequent paleosol named vertisol is characterized by the cracks and slickensides during wet and dry years occurred in seasonally arid paleoclimate. The leaching depth of calcareous horizon was used to estimate precipitation, with results between 105 mm and 178 mm annually, showing arid conditions in lake basin. The paleosols features are recorded in the second member of Shahejie Formation in three distinct wells located in the basin. Integrating the constraints of high resolution astronomical in region, the arid types of paleosols were firmly evaluated forming during the EOT. The palynological characteristics have xerophytic species, such as Labiatae and Ephedripites, separating from the Polypodiaceae and Alnipollenites existed in lower sediments developed in humid period. The geochemical elements support the rising of Mg/Ca and higher contains of Fe/Mn, illustrating arid conditions in terrestrial environments. The sedimentary records of lacustrine basin during the EOT were analyzed based on 15 cored wells, over 100 wells logs and seismic facies. The facies show the delta-lake sedimentary system is characterized by distributary channels developed in delta fronts before the EOT. The later weaken provenance inputs without thick sand deposits reflects the climate changing. The thin sheets and siltstone with calcite nodules appear in cores and within well correlations. The purple and brown-to-red clays were observed, which are similar to gleyed horizons of paleosols, showing seasonally fluctuations within shallow water levels shrinking after humid age. The sand isometric map of the changing time show banks and shoals extend quasi-parallel to the lake shore. The sedimentary features recovery in the upper intervals to some extent, with limited scale of sandbodies developed in delta-lake settings. Besides, the statistical map during the EOT also show the spit-like deposits, which are common in modern lakes influenced by regional prevailing winds. The scientific discussions on monsoon-like climate in the Eocene provide a possible interpretation that the dominant northwest winds during arid time influence sediments, with seasonally southeast humid vapor input the basin as well. The paleosols formed in uplifts within the basin are possible responses to the tectonic extension climax (42-32.8 Ma) in subduction of paleo-pacific ocean and Asian terra, which already left erosion records in regions.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-3: Climatic cooling events, glaciations, and glacial sedimentology
Presentation Preference: Oral Preferred

Recognising cold-based glaciation in the rock record: striated bedrock surfaces of the > 540 million year old Luoquan Formation of China

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Keywords: Glaciation, Ediacaran, Luoquan, North China Craton

When preserved from deep time glaciation, subglacially striated bedrock surfaces allow the interpretation of past ice characteristics that are often elusive from the study of sediments alone. Salient amongst these is the thermal regime, which has a profound influence upon ice behaviour and consequent sediment erosion, transport and deposition. Typically, striated bedrock surfaces are linked to ice at its pressure-temperature melting point, indicating a locally warm-based thermal regime. Conversely, a cold-based thermal regime is defined by ice frozen to the substrate and is linked to minimal erosion. Cold-based erosional forms have been identified in Antarctica but their recognition is next to impossible if imprinted upon a surface previously or subsequently affected by warm-based erosion (e.g. striation). In the ancient record this is especially problematic, as it is typically only through the recognition of characteristic warm-based features that a surface can be confirmed as subglacial at all. Consequently, it is likely that there is an observational bias in the rock record toward warm-based over cold-based ice. This study, through careful geomorphologic analysis of unusually well preserved striated surfaces of the North China Craton from the Ediacaran Period (c. 635 – 540 Ma), presents rare examples that record dominant cold-based and more limited warm-based erosion on the same subglacial surface. It is hoped that this approach may benefit other workers interested in identifying cold-based as well as the more obvious warm-based subglacial conditions from the record of deep time glaciation.

ID: T1-31454

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-3: Climatic cooling events, glaciations, and glacial sedimentology
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Magnetic Study of Sediments from core ARC7-P24 in Chukchi Sea, Northwest Ice Ocean

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Keywords: Arctic Ocean, Magnetic stratigraphy, Environmental Magnetics,element cycle, Beaufort Gyer

Abstract

The unique geographical location and sedimentary environment make the stratigraphic division and comparison of deep-sea sediments in the Arctic Ocean much more difficult than other sea areas(Mei et al.,2015Zhang et al.,2021).Therefore, the geochronological studies of the Arctic Ocean sediments are relatively scarce, which in turn increases the difficulty of conducting core environmental climate studies on a time scale.

In this paper, XRF element scanning, magnetic stratigraphy, and environmental magnetic analysis were performed on the P24-hole columnar samples (water depth 1662 m, column length 285 cm) collected at the Chukchi Sea Station in the Northwest Ice Ocean during China's seventh Arctic scientific expedition.The results of magnetostratigraphy show that the core P24 recorded two geomagnetic drift events in Laschamp and Norwegian-Greenland Sea when the Brunhes positive polarity. Combined with the cycles of Mn and Ca elements in the core, the chronological framework of the MIS5 in the P24 core was established.Environmental magnetic studies have shown that the main magnetic-carrying mineral in the P24 core is magnetite.The change of magnetite content is controlled by the change of provenance input controlled by the intensity of Beaufort Gyer during glacial and interglacial periods. During the interglacial period, the Beaufort Gyer strengthened, and the magnetic-bearing minerals in the icebergs or large ice blocks in the Canadian Arctic Islands were transported to the Chukchi Sea and unloaded to the seabed, resulting in an increase in indicators such as magnetic susceptibility;During the glacial period, the Beaufort Gyer weakened significantly, and the transported magnetic minerals decreased, resulting in a significant decrease in indicators such as magnetic susceptibility.

In conclusion, this study provides a reliable age scale for the core of the P24 hole in the Chukchi Sea of the Northwest Ice Ocean, and provides a new basis for the study of environmental climate change in this region on a time scale.

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ID: T1-31804

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-3: Climatic cooling events, glaciations, and glacial sedimentology
Presentation Preference: Oral Preferred

The late Paleozoic Ice Age Orutanda fjord in Namibia: the importance of gravitational resedimentation filling an overdeepened basin

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Keywords: Dwyka Group, Kaokoveld, glacial, mass wasting, subaqueous density flows

The filling of fjords is complex as it is controlled by glacier dynamics, sediment supply, relative sea-level changes, and topography. The latter makes fjords noticeable as overdeepenings and steep flanking slopes encourage downslope resedimentation of glacially-transported debris through the entire spectrum of gravitational mass movements and sediment density flows. Various paleofjords left sculpted by Gondwanan glaciers during the late Paleozoic Ice Age (LPIA; 362-256 Ma) have been demonstrated, most prevalently in Argentina, Brazil, and Namibia. This work presents the fjord morphology and depositional history of a glacial-deglacial cycle recorded in the Dwyka Group hosted in the Orutanda fjord in northwestern Namibia. Three stages are defined for the fjord evolution: glaciation, early deglaciation, and late deglaciation. The Orutanda fjord is roughly N-S oriented, 19 km long, 3.7 km wide, and has a maximum preserved depth of 470 m. The analysis of cross sections and the longitudinal profile demonstrate an overdeepened basin created after the convergence of a tributary glacier. The glacial trough was eroded during the glaciation stage by a southward advancing, wet-based glacier estimated to be between 90-200 m thick, with ice thickness varying according to the longitudinal position in the fjord. Following the erosion and total occupation of the trough by the glacier, the early deglaciation stage encompasses the progressive retreat of the tidewater glacier, flooding of the fjord, and sedimentation in an overdeepened basin. Proglacial sedimentation is recorded only by laminated mudstones and iceberg-rafted debris. Sedimentation was dominated by intense paraglacial downslope gravitational resedimentation of the glacially-transported debris accumulated in the flanking slopes. This resulted in coalescing debrites-turbidites lobes on the fjord's floor with sediment pathways perpendicular to the fjord axis. Slumps entirely composed of deformed debrites and turbidites indicate that these resedimented facies were prone to renewed downslope mass wasting. During late deglaciation, the Orutanda glacier became land based and the fjord experienced the instalment and progradation of a fjord-head delta. The axial southward progradation of the fjord-head delta is recorded only from slumps and turbidites derived from the failure of the fjord-head delta front and delta plain. The depositional record in the Orutanda fjord showcases a deep-time stratigraphic example of a fjord fill that is composed almost entirely from products of subaqueous gravitational resedimentation. An additional outcome is the successive resedimentation episodes which the glacial debris underwent until their final deposition on the fjord's floor. Recognizing an accurate genesis for glacial facies is fundamental for the recognition of glaciation in the stratigraphic record as well as for more detailed analyses on the reconstruction of former ice margin positions, ice thickness estimations, and the nature of fjords stratigraphic architecture.

Session T1-4: Understanding the Mesozoic greenhouse world

ID: T1-40034

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-4: Understanding the Mesozoic greenhouse world
Presentation Preference: Oral Preferred

A newly discovered Cretaceous erg in the Turpan-Hami Basin, NW China: Climatic and geographic insights into the Cretaceous and future greenhouse world

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Keywords: erg, greenhouse world, cliamte

Desertification, extending the area of desert and intensifying storms, has already hindered human sustainable development, and it will grow more serious along with the intensification of global warming in the future. Because of the similar geographic configuration and climatic circumstances, the Cretaceous world, known as a key greenhouse period of Earth's history, acts as a relevant model to comprehend the future greenhouse world. Here, we reacquainted the Early Cretaceous terrestrial deposits of the Liushuquan Formation (K1l) and Dahaidao Formation (K1d) in the Hami Basin, NW China. We found that the K1l, originally considered to be aqueous deposits, is composed of > 300 m of successive aeolian deposits and confirmed as representing a typical intermountain erg environment. The Liushuquan paleo-erg was the northernmost early Cretaceous erg discovered in Asia and was regulated by the subtropical high-pressure zones, the uplift of adjacent mountains, and regional topography. Paleoclimate evolution derived from paleogeography, paleoecology, and chemical weathering conditions indicates a marked transition from a hot and arid to a hotter and more humid climate from the early to mid-Cretaceous world, which would be attributed to the continuous rise of atmospheric CO2 concentrations and subsequent drastic shrinking of the Hadley circulation. Considering the Cretaceous climate and geography, we suggest that the climate will be hotter and drier and that the Kumutag desert has the potential to expand in the future greenhouse world.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-4: Understanding the Mesozoic greenhouse world
Presentation Preference: Oral Preferred

Significance of turritella dominated assemblage (TDA) within mid-Cretaceous carbonates of Bagh Group, central India: Evidence of sedimentological non-uniformitarianism

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Keywords: Carbonates, Sedimentological non-uniformitarianism, Cretaceous, Turritella, TDA

The Turritella dominated assemblage (TDA) in modern times are heterogeneous in nature, mostly reported in siliciclastic sediments within a relatively narrow range of environmental conditions. The TDAs are often useful indicators of different ecological parameters like depth, salinity, nutrient flux and temperature in establishing modern environments (Marincovich and Kase,1986; Thewissen et al. 1994; Kollman et al., 2002; Martinez and del Rio, 2002). However, the environmental conditions favorable for such assemblages had changed overtime and are poorly understood. The occurrence of TDA in carbonates is almost absent in modern environments. The modern carbonates are commonly accumulated under the abundance of carbonate producing organisms under low silicilastic supply. Such accumulations occur today in dominantly two environments, warm-low nutrient (WLN- called as tropical; found in low-latitudes) and cool-high nutrient (CHN- temperate, nontropical; found in high-latitudes) conditions. The accumulation of carbonates in warm-high nutrient (WHN) conditions, which is rare to absent in the present world, is observed from the Cretaceous successions, when the ocean chemistry was significantly different from present oceanic conditions.

The present work is the report of a TDA from the mid-Cretaceous Nodular limestone Formation, Bagh Group, central India. The Nodular Limestone is divided into six facies, which are litho-bioclastic wackestone-packstone facies, bioclastic lime-mudstone facies, mudstone facies, lithoclastic wackestone facies, TDA bearing mudstone facies and bioclastic wackestone facies. The TDA bearing lithounit varies in thickness between 10 and 15 cm with abundant turritelline fossils, which are well preserved as molds and casts within the horizon. Based on previous studies on TDAs and sparse data on carbonate dominated TDAs, it was assumed that turritellines are found predominantly in siliciclastic sediments of Cretaceous and Cenozoic, as the stratigraphic distribution and record of TDAs in carbonates are limited in the past as well as in the present (Beauchamp, 1984; Cooley, 1985; McCartan et al., 1985; Allmon, 1988; Allmon and Dockery, 1992; Spizuco and Allmon, 1992; Allmon and Knight, 1993; Allmon, 1996; Allmon, 2004; Allmon, 2007; Allmon and Cohen, 2008). The assemblage described here, adds a significant amount of knowledge about the occurrence and depositional environment, which favoured growth of turritellines within the mid-Cretaceous carbonates. The present assemblage would contribute to the understanding of palaeoecological and paleoenvironmental interactions of TDAs within carbonates by acknowledging the limiting factors like temperature, oxygen, depth, salinity and substrate using geochemical and paleo-redox proxies. Moreover, indicators of variable sediment supply with respect to sea level fluctuations were also explored as one of the possible explanations for the formation of these condensed turritelline dominated sections.

It is evident that the principle of sedimentological uniformitarianism does not hold for TDAs, as the ecological and environmental distribution and occurrence of TDAs from the past Cretaceous period to recent time had changed. The temporal change in the sedimentological association of TDAs cannot be neglected and may coincide with the global climatic change from greenhouse to icehouse conditions during the Oligocene epoch (Allmon and Knight, 1993; Prothero et al., 2003; Allmon, 2007).

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-4: Understanding the Mesozoic greenhouse world
Presentation Preference: Oral Preferred

Active El Niño-Southern Oscillation in the Early Cretaceous greenhouse

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Keywords: ENSO, Early Cretaceous, varve, climate simulation, northeast China

The El Niño-Southern Oscillation (ENSO) is the dominant mode of interannual climate fluctuation and generates teleconnections impacting global climate variability today. Its behavior in past greenhouse climates provides a useful perspective for understanding future ENSO under global warming. Despite evidence of active ENSO since the Late Cretaceous, whether ENSO operated at earlier times is unknown. Here we present evidence from annually-resolved lacustrine sediments in northeast China, showing signals of interannual precipitation variability 120 million years ago, with major frequency bands of 2.0-2.7 and 3.5-4.0 years. A coupled climate simulation of the Early Cretaceous generates ENSO with similar periodicities in tropical Pacific sea-surface temperatures and atmospheric teleconnection to northeast China precipitation. The simulated Early Cretaceous ENSO is higher in frequency and amplitude than ENSO of the modern climate. Our geological and modeling evidence suggests that ENSO, stronger than in the present-day, operated in the Early Cretaceous greenhouse climate.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-4: Understanding the Mesozoic greenhouse world
Presentation Preference: Oral Preferred

Evolution of atmospheric circulation across the Cretaceous–Paleogene (K–Pg) boundary interval in low-latitude East Asia

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Keywords: Global monsoon, Atmospheric circulation, K–Pg, Low-latitude East Asia, Terrestrial records

The Cretaceous–Paleogene (K–Pg) boundary interval is an important time interval for deep-time paleoclimatic research, and most records of this interval are derived from marine sections. In this study, we conduct high-resolution magnetic and geochemical analyses in a terrestrial sedimentary succession from the Nanxiong Basin (Southeast China). We combine this data with previous work to compare these results with global marine and other terrestrial records. We find that the magnetic and geochemical parameters record a sequence of global climatic changes across the K–Pg boundary interval. Moreover, during the Maastrichtian cold “greenhouse” time interval, the climate changes in the studied area are consistent with the benthic foraminiferal $\delta^{18}O$ record from the North Atlantic, and we observe no correlation between the $\delta^{13}Ccarb$ and $\delta^{18}Ocarb$; in contrast, during the Danian “greenhouse” time interval, the climate changes in the studied area are consistent with the benthic foraminiferal $\delta^{18}O$ records from both the Pacific and the North Atlantic, and we observe a positive correlation between $\delta^{13}Ccarb$ and $\delta^{18}Ocarb$. We suggest that the observed changes are likely linked to the transformation of atmospheric circulation in low-latitude East Asia. These new insights have implications for “global monsoon” research and understanding the causes of the mass extinction.

ID: T1-40538

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-4: Understanding the Mesozoic greenhouse world
Presentation Preference: Oral Preferred

Organic matter enrichment driven by global warming prior to and at the base of OAE 1a in southern Tibet, eastern Tethys

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Keywords: Lower Aptian, OAE 1a, Global warming events, Depositional environment, Organic matter accumulation

Global warming events in geological history are usually accompanied by the widely distributed source rock deposition. However, the mechanism of organic matter (OM) enrichment under global warming remains unclear. The Lower Aptian (Early Cretaceous), especially the Oceanic Anoxic Event 1a (OAE 1a) interval was an episode of global warming, and OM-rich sediments also showed a wide distribution in this time. During this interval, OM-rich rocks were formed in southern Tibet, which could provide a chance to reveal the mechanism of OM accumulation under global warming. Here, we present geochemical and mineralogical date to investigate paleoenvironmental conditions and the mechanism of OM enrichment prior to and at the base of OAE 1a in the Gucuo area of southern Tibet, eastern Tethys. Several geochemical proxies (MoEF, UEF, and Th/U) reflect changing redox conditions took place prior to and at the base of OAE 1a. Oxygen contents in the water mass tend to decrease prior to OAE 1a (may from oxic to suboxic conditions). At the onset of OAE 1a, a brief anoxic waterbody prevailed. After that, oxygen contents gradually increase (may from suboxic to oxic conditions). Productivity-related Ba/Al and Babio are indicative of a high biotic productivity during the sedimentation. The low values of B/Ga reveal a freshwater to brackish water condition, suggesting massive freshwater injection occurred prior to and at the base of OAE1a. Both of the CIAcorr values and Ga/Rb–K2O/Al2O3 and SiO2–Al2O3+K2O+Na2O bivariate diagrams reflect a warm-humid climate existed prior to and at the base of OAE1a. Combined with previous researches, a warm-humid climate in the study area was controlled by global warming during this interval. For one thing, a warming climate promoted the prosperity of aquatic organisms; for another thing, enhanced runoff and massive freshwater infusion under a warming climate enhanced fluvial delivery of nutrients to ocean, which would raise bioproductivity of surficial water. A high biotic productivity created massive OM, which contributed to OM accumulation. This study underscores that a high bioproductivity driven by global warming plays an essential role during the OM-rich sediments deposition.

ID: T1-40630

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-4: Understanding the Mesozoic greenhouse world
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Intensive peatland wildfires during the Aptian-Albian oceanic anoxic event (OAE1b): Evidence from borehole SK-2 in the Songliao Basin, NE China

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Keywords: Lower Cretaceous, OAE1b, Peatland, Wildfire, Coals

The Cretaceous has been considered a “high-fire” world accompanied by widespread by-products of combustion in the rock record. The mid-Cretaceous oceanic anoxic event 1b (OAE1b) is marked by one of the major perturbations in the global carbon cycle characterized by deposition of organic-rich sediments in both marine and terrestrial settings. However, our understanding is still limited on changes in wildfire activity during OAE1b period. Here, we carried out a comprehensive analysis, including organic carbon isotope ($\delta^{13}C_{org}$), total organic carbon (TOC), coal petrology, trace elements, and pyrolytic polycyclic aromatic hydrocarbons (pyroPAHs), of coal seams in the middle Aptian to early Albian Shahezi Formation from borehole SK-2 of Songliao Basin, NE China. Two negative $\delta^{13}C_{org}$ excursions in the Shahezi Formation can be corresponded with the Jacob/113 and Kilian sub-events of OAE1b. Moreover, the intensive peatland wildfires have been identified during the sub-event periods of OAE1b based on the co-occurrence of high abundance of charcoal and pyroPAHs at that time. In addition, Sr/Ba, Sr/Cu and Sr/Rb ratios demonstrate that enhanced peatland wildfires were controlled by dryer climate conditions owing to episodic northward migration of arid zones in East Asia related to rising global temperature during the sub-events of OAE1b. The climate-driven extensive wildfire activity in the mid-latitude terrestrial ecosystems can be a contributing factor for OAE1b through increased flux of nutrients fueled primary producers in the lake and marine environments leading to more speculative anoxia allowing the deposition of organic-rich sediments. Our results provide essential understanding of the importance of wildfires in driving mechanism of OAEs in Earth’s history.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-4: Understanding the Mesozoic greenhouse world
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Origin and preservation of organic matter in the Lower Cretaceous lacustrine sediments in the Liupanshan Basin, northwestern China

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Keywords: Early Cretaceous, Lacustrine sediments, Liupanshan Basin, Organic matter enrichment, Aliphatic biomarkers

Understanding the burial of organic matter in terrestrial sediments is improtant for reveal the carbon cycle in the Early Cretaceous. Here, total organic carbon (TOC) content, C/N ratio, n-alkane distribution, and δ13C composition of individual hydrocarbons of outcrop samples were employed to reveal the origin and preservation of high abundance of organic matter in the Madongshan Formation of Huoshizhai section in the Liupanshan Basin. Results show that the variations in TOC value of those samples in the studied profile can be divided into three stages. Stage I, TOC value is less than 1.45%. Short-chain n-alkanes are enriched in those samples, the δ13C value of n-C14 to n-C19 varies in a more wide range and is heavier than medium-chain n-alkanes (n-C20 to n-C24) and high carbon numbered n-alkanes >C24, and the C/N ratio ranges from 10 to 20. Stage II, TOC value measurably increases to the maximum value of 5.86%. The n-alkane distributions are mainly composed of two peaks of low (n-C18, n-C19) and medium (n-C23) carbon numbered n-alkanes, and some samples are characterized by the signal peak of n-C23. The δ13C value of medium molecular weight varies in a relatively narrow range and is clearly more negative than that of the low and high carbon numbered n-alkanes, and the C/N ratio is between 20 to 50. Stage III, TOC value tends to decrease. The percent of high molecular weight increase significantly in the n-alkane distributions, and presenting a clear odd-over-even carbon number predominance in those alkanes. Meanwhile, the δ13C composition of the high molecular weight odd and even n-alkanes in most samples have a saw-toothed carbon isotopic shape, and the C/N ratio decrease significantly and with an average value around 20. Those characteristics indicate that the predominant source of organic matter in the Madongshan Formation changes from aquatic algae to terrestrial plants. In addition, the high advantage of phytane and the detection of gammacerane in the whole samples may propose that those samples deposited in a salinity stratified water column associated with anoxic bottom waters.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-4: Understanding the Mesozoic greenhouse world
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Toarcian Ocean Anoxic Event in the eastern Tethys

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Keywords: Toarcian Oceanic anoxic event, carbonate and organic carbon isotopes, Total organic carbon, Qiangtang Basin, Eastern Tethys

The Early Toarcian "Oceanic Anoxic Event" (T-OAE) is a very significant paleoenvironmental perturbation of the Mesozoic that coincided with marked disruptions to both the climate system and marine ecosystems. This event is associated with widespread burial of marine carbon and a large negative carbon-isotope excursion (CIE) in carbonates, organic matter, and fossil wood. These features have been attributed to a large-scale injection of isotopically light carbon into the ocean-atmosphere system, possibly from the release of volcanogenic CO2 from the emplacement of the Karoo-Ferrar Large Igneous Province (LIP) in southern Gondwana and/or from dissociation of methane hydrates. The T-OAE has been well documented in the western Tethyan and Boreal realms. Only a few studies on the T-OAE have been reported from the northwest, central, and northeast Panthalassic Ocean. Therefore, the global expression of the T-OAE needs to be established through analysis of Early Toarcian rocks in other paleogeographic locations. In the eastern Tethys, Our studies present high-resolution carbon-isotope data, bulk geochemistry, and mineral characterization from various setting in the Qiangtang Basin. The Toarcian carbon-isotope excursion has been observed in the Biluoco section, Sewa section, Wenquan section, and northern Qiangtang depression (well QTKT-1). These data suggest that the T-OAE was extensive in the Qiangtang Basin. The Toarcian carbon-isotope profiles from the Qiangtang Basin, eastern Tethys are compatible with those in contemporaneous strata in the western Tethyan and Boreal realms, supporting the global expression of the T-OAE.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-4: Understanding the Mesozoic greenhouse world
Presentation Preference: Oral Preferred

Terrestrial carbon cycle and atmospheric CO2 concentration: Insights for prelusion and aftermath of the Chicxulub impact and Deccan eruption

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Keywords: carbon cycle, atmospheric CO2, Deccan Trap,Chicxulub impact, paleoclimate, Cretaceous-Paleogene boundary

The end-Cretaceous mass extinction has traditionally been attributed to the coeval catastrophic events of the Chicxulub asteroid impact and Deccan large igneous province volcanism. To decipher the driver and examine the climate conditions across the Cretaceous-Paleogene boundary (KPB), we conducted carbon isotope analyses of pedogenic carbonates in the Sichuan and Nanxiong basins, South China, in order to reconstruct atmospheric CO_2 concentrations (pCO_2) spanning 76–62 Ma. Combined with data from the Songliao Basin (north-east China) and Tornillo Basin (USA), $\delta^{13}C$ data and pCO_2 display high-frequency and high-amplitude fluctuations. Kernel smoothed results show a slight decreasing tendency with some early pre-KPB fluctuations and major post-KPB oscillations. In the 67–64 Ma interval, multiple breakpoints of $\delta^{13}C$ and pCO_2 are recognized in four stages, which represent rapid transient climate and carbon cycle events. Two breakpoints at 66.6 Ma and 66.2 Ma, along with breakpoints after the KPB (66.03 Ma), are not consistent with the onset of Deccan Traps volcanism (~66.3-66.4 Ma) and post-KPB duration (~66.0−65.6 Ma), implying the Deccan Traps degassing may not have played a major role in climate change around the KPB. The turnover breakpoint at ~65.90−66.0 Ma is coincident with the Chicxulub impact, supporting major transient climate and carbon cycle change associated with bolide impact, although the role of the Chicxulub impact on longer term climate and carbon cycle change after the KPB is uncertain. A gradual increase in $\delta^{13}C$ and pCO^2 from ~65.4 Ma may represent the onset of recovery of the terrestrial ecosystem. By comparing to the marine system, we propose that most of the major carbon cycle and climate changes do not correlate with the onset and cessation of Deccan Traps volcanism or the Chicxulub impact. We also suggest that ecosystem recovery within the terrestrial realm was a more difficult and erratic process compared to the marine ecosystem in the aftermath of the KPB.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-4: Understanding the Mesozoic greenhouse world
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Association of eolian facies and alluvial facies indicating widespread intermountain ergs in the Late Cretaceous South China

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Keywords: Alluvial-aeolian system, Late Cretaceous, Intermountain erg, South China

The Cretaceous is a period under typical greenhouse. In past, variable Cretaceous climate and the Late Cretaceous cooling have been verified by huge evidence from marine sediments and biota. And more and more terrestrial materials have been discovered and reported to support the hypothesis. Of them, the climate-sensitive eolian sandstones have been found and reported in the Cretaceous terrestrial sequences in South China. In these new findings, eolian sandstones were described and discussed on eolian facies and paleowind direction, few are involved in the association of the coarse alluvial facies.

In our recent investigation, we noted that some eolian facies are often associated with alluvial facies in the Late Cretaceous terrestrial sequences in South China. We then carried out field observation plus lithological texture identification under microscope. Results show that: sandstones are generally fine-to-medium grained (mean φ=2.53-3.59) and well-sorted, with a dominant composition of quartz, arranged in massive cross-bedded tabular bodies. The dip directions of foresets are usually NE. In SEM photos, the subrounded to rounded quartz grains displaying surface textures such as dish-shaped impact scars. The well- sorted sandstones commonly covered or interlayered cobbles and pebbles which juxtaposed singly in lineation, or interbedded with coarse sand matrix supported pebble to cobble conglomerates under slightly eroded surfaces. Locally, clast supported conglomerates deeply scoured into the well-sorted sandstones.

We interpreted the sandstone and conglomerate assemblages as two lithofacies and multiple sublithofacies. The lithofaceis are aeolian facies subdivided as aeolian dunes, interdunes, aeolian sandsheets and gobi deposits due to deflation, and alluvial deposits subdivided as ephemeral channels, pebble to cobble sheetfloods and debris flow deposits. Above features indicate that the sandstones are eolian and conglomerates are arid alluvial in origin. Taking into the spatial range of these eolian and arid alluvial facies with shape and size of the basins that occupy the facies association, we propose that the eolian facies associated with alluvial facies in the Late Cretaceous sequences are widespread intermountain ergs in South China, and they could not be the general desert in a relatively large and continuous distribution. The multiple alternative of eolian and arid alluvial facies indicates a (semi-) arid climate sustained in the middle Late Cretaceous in South China.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-4: Understanding the Mesozoic greenhouse world
Presentation Preference: Oral Preferred

Understanding the onset of Oceanic Anoxic Event 2 (OAE2) in the Cretaceous Hot Greenhouse climate

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Keywords: Os isotope, volcanism, Cenomanian-Turonian boundary, Tibet

Oceanic anoxic event 2 (OAE2) occurred across the Cenomanian-Turonian boundary during the Cretaceous hot greenhouse climate and represents a large abrupt oceanographic- atmospheric event in a greenhouse world. The initiation of OAE2 has attracted extensive attentions and is generally believed to be associated with submarine volcanism. Although proxy records from the Northern Hemisphere show a large osmium isotope excursion indicative of volcanism apparently preceding the carbon isotope excursion (CIE) of OAE2, the timing and mechanism of the global initiation of OAE2 remain elusive in part due to the lack of detailed osmium-isotope proxy records across the OAE2 intervals in the Southern Hemisphere. Here we report a high-resolution initial osmium isotope (187Os/188Osi, Osi) and δ13Corg record from a highly expanded OAE2 interval in southern Tibet, China that was deposited in the northern margin of India Plate in eastern Tethys in the Southern Hemisphere. The Osi record documents three distinct Osi shifts toward unradiogenic compositions with increasing amplitudes at ~95.1 Ma, ~94.8 Ma, and ~94.5 Ma, respectively, indicating episodic, intensifying volcanism with the highest intensity episode at 94.5 Ma. In addition, the large Osi negative excursion at ~94.5 Ma is followed by an 200 kyr Osi minimum interval concomitant with a cooling interval as revealed by an overall broad minimum interval of the difference of the paired δ13Ccarb and δ13Corg. This cooling interval is broadly synchronous with the Plenus Cold Event (PCE) recorded in the Northern Hemisphere. Furthermore, the large Osi negative excursion paradoxically lags the onset of OAE2 by 50 kyr at the Tibetan section. Comparison with and re-examination of the expanded OAE2 record of the Yezo Group (Japan) and those from the western interior seaway (WIS) in North America reveal the regional difference in the phasing relationship between the large Osi excursions and the CIEs of OAE2. Intriguingly, the large Osi excursions occurred during a near synchronous global transgression at ~94.5 Ma that increased the connectivity of global oceans. Taken together, these results suggest that enhanced ocean connectivity was essential to spreading the perturbation of submarine volcanism to world oceans to trigger the global onset of OAE2 at ~94.5 Ma.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-4: Understanding the Mesozoic greenhouse world
Presentation Preference: Oral Preferred

Deccan volcanic activity and its links to the end-Cretaceous extinction in northern China

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Keywords: Deccan Traps volcanism, End-Cretaceous mass extinction, Hg chemostratigraphy, Hg isotope, Northern China

The Cretaceous-Paleogene (K-Pg) boundary mass extinction is commonly attributed to the Chicxulub impact and/or the Deccan Traps (DT) volcanism, but the underlying trigger remains uncertain. The lack of detailed identification of the DT eruptive pluses impedes the full assessment of their relationship to the K-Pg boundary mass extinction. Here we present the first mercury (Hg) chemostratigraphy records on the paleo Asian plate, coupled with climatic and biotic data, to constrain the effects of the DT on the Late Cretaceous climate change and mass extinction. In northern China, a total Hg (THg) spike follows warming caused by the DT volcanism and corresponds to the significant species losses. Our study suggests that this most intense pulse of the DT (~50 kyr duration) occurred just before the K-Pg boundary and suggests that it contributed to the end-Cretaceous mass extinction in northern China.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-4: Understanding the Mesozoic greenhouse world
Presentation Preference: Oral Preferred

A new prospect to study paleoenvironment of the Late Cretaceous red beds

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Keywords: Red beds, Late Cretaceous, Paleoenvironment, Paleosols

The Cretaceous red beds in southeastern China are conventionally regarded as lacustrine-fluvial sediments in basin, while their paleoenvironmental implication is still in debate. In present study, the late Cretaceous paleoenvironment documented by red beds (Liancheng and Guanzhaishan section) in the western Fujian province were investigated based on environmental magnetism, grain size, geochemistry of the paleosols. This study shows that: (i) The red beds in the western Fujian, mostly in form of interbedded siltstone with gravels, are dominated by fine silt particles with minor clay and sand. The dominant magnetic carrier in red beds is hematite, which attributes to low magnetic susceptibility in the two sections. (ii) The weathering degree, reflected by chemical index of alteration (CIA), is moderate as those formed in warm and humid climate. In addition, the rare earth elements (REE) of red beds show enriched light rare earth element (LREE), depleted heavy rare earth elements (HREE), positive Ce anomaly and negative Eu anomaly, which resembles that of average upper continental crust (UCC), thus indicating thoroughly mixing sediments. (iii) Although paleosols were recognized in the red beds, in particularly GZS section, these paleosols were weakly developed with no apparent B horizon (e. g. Bk and Bt) in paleosols profile. The conflict between moderate chemical weathering degree and weak pedogenesis infers that the red bed sediments had experienced to an extent chemical weathering in source area before deposition. The red sediments were hardly chemically weathered after deposition. It should be noted that only the red beds are not enough to diagnose paleoenvironment variations, while the paleosols must also be taken it into account, which can provide an alternative prospect in studying Cretaceous red beds. (iv) The late Cretaceous paleoenvironment in western Fujian was suspected to be arid and semiarid. The hematite in red beds were mainly derived from source area, indicating dry oxidizing environment, rather than aqueous condition.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-4: Understanding the Mesozoic greenhouse world
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Sedimentology and carbon isotope record of an Oxfordian carbonate ramp system, Lower Saxony Basin, Germany

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Keywords: Oxfordian, Lower Saxony Basin, Chemostratigraphy

During the Oxfordian, the Lower Saxony Basin was covered by a shallow epicontinental sea, in which a thick succession of alternating marine limestones and marls was deposited. Due to the scarcity of biostratigraphic markers and numerous sedimentary gaps, the stratigraphic dating is still uncertain and hampers further studies on a basin-wide scale.

The Bisperode section located south of Hannover, Germany, contains a ~125 m thick succession of limestone and marl of the Korallenoolith Formation (middle–upper Oxfordian). The succession features 7 superordinate facies types, composed of 13 different microfacies types. A total of fifteen small-scale and nine medium-scale sequences are identified as transgressive-regressive cycles. The depositional model is interpreted to represent a patch reef-bearing ramp that shifted to an ooid-dominated carbonate ramp.

Chemostratigraphy has been verified as a reliable means of contrasting and calibrating biostratigraphic schemes on local and global scales. A high-resolution carbon isotope record was obtained from 257 bulk rock samples (at a spacing of ~50 cm). For comparison, an additional 164 drilled powder samples were obtained in the lower part of (7.0 to 48.5 m) the section (at a spacing of ~25 cm). Values from the bulk rock sample show the same trend as those of the drilled powder. Carbon isotope values vary between -0.1 and +3.1 ‰ and show some distinct long-term variations across the section, although, different depositional environments display facies dependent carbon isotope ratios. The new chemostratigraphic data enable correlation with the previous carbon isotope records (Konrad core, Eulenflucht core, and Steinbergen section). Based on this, a composite high-resolution carbon isotope stratigraphic record for Oxfordian successions in the Lower Saxony Basin can be established. Bulk geochemistry parameters of mineral data provide additional information and complement the sedimentological data.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-4: Understanding the Mesozoic greenhouse world
Presentation Preference: Oral Preferred

Mid-latitude precipitation in East Asia influenced by a fluctuating greenhouse climate during the latest Cretaceous through the earliest Paleogene

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Keywords: Cretaceous, Songliao Basin, greenhouse climate, precipitation, East Asia, paleosol

Deep-time records from greenhouse climate periods (e.g., the Late Cretaceous) provide a reference point for understanding how high atmospheric CO2 concentrations influence precipitation in the mid-latitude Northern Hemisphere (e.g., East Asia). In this study, we quantitatively reconstruct mean annual precipitation (MAP) in East Asia during the latest Cretaceous through the earliest Paleogene (~76-65.5 Ma), based on a well-studied paleosol sequence from the Sifangtai and Mingshui Formations from the SK-1n scientific borehole in the Songliao Basin, northeastern China. We use several proxies, depth to the calcic horizon (DTC) and two elemental geochemistry proxies in the paleosol B horizon (CIA-K, CALMAG), which all show clear changes in the MAP associated with warming and cooling events. In the warming period (e.g., at ~69.5-68.5 Ma), an increase in the land-sea thermal contrast led to an expanded, enhanced, poleward-shifted thermal low-pressure system over the East Asian continent, which triggered an enhanced hydrological cycle and increasing MAP in the Songliao Basin. During the cooling period (e.g., at ~72.5-69.5 Ma and ~68.5-66.5 Ma), weakened East Asian monsoon and strengthened equatorward-shifted westerlies allowed for colder and arid air masses to encroach upon the Songliao Basin, which led to decreased MAP. Changes in MAP across the K-Pg boundary coincide with climate fluctuations and catastrophic geological events. Furthermore, our work compares three warming intervals in deep-time (middle Maastrichtian, late Maastrichtian and earliest Paleogene) with Shared Socio-economic Pathway scenarios used by the IPCC for the end of the 21st century, and indicate MAP increases in East Asia with ongoing anthropogenic CO2 emissions.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-4: Understanding the Mesozoic greenhouse world
Presentation Preference: Oral Preferred

The Cretaceous (early Albian to early Campanian) biostratigraphy and paleotemperature reconstruction of the eastern Tethys: Calcareous nannofossil evidences from southern Tibet, China

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Keywords: Cretaceous, Eastern Tethys, Southern Tibet, Calcareous nannofossils, Biostratigraphy, Paleoclimate

Studies of geochemical proxies, e.g., carbonate $\delta^{18}O$ and TEX_{86} have documented that the Earth's climate significantly changed during the Cretaceous Period. However, the knowledge about the sea surface temperature (SST) history of the eastern Tethys was limited owing to the diagenetic alteration of carbonate and organic biomarkers. Based on calcareous nannofossil records of the Nirang section, this paper studies the biostratigraphy and SST evolution of the Cretaceous in the Tethys Himalayas of southern Tibet. There are 131 species identified from the studied succession. Twelve bioevents were recognized, allowing us to assign an early Albian to early Campanian age (CC8 to CC18 biozones) of the section. Meanwhile, a disconformity within 81-71Ma was identified in the early Campanian–early Maastrichtian. The SST evolution was analyzed by calcareous nannofossils Modified Temperature Index (MTI). The MTI results reveal that the long-term SST changes in the Tethys Himalayas of southern Tibet experienced a progressively warming from early Albian to early Turonian followed by rapid cooling in middle Turonian, and a warmth persisted interval till early Campanian. Short-term warming and cooling intervals, e.g., rapid warming in early Albian and latest Albian, cooling in the late Albian, peak warmth at Cenomanian–Turonian transition, and cooling in the middle Turonian are recorded in the study area too. The SST history of eastern Tethys can be well correlated to neighboring Exmouth Plateau and southern high latitude deep- sea sites. However, the compilation of TEX_{86} data indicates a substantial cooling during the Coniacian to Campanian. We suggest that the north drift of the Indian continent towards the equator is likely responsible for sustained warmth in the Tethys Himalayas during late Turonian to early Campanian, although the paleoclimate could be cooling.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-4: Understanding the Mesozoic greenhouse world
Presentation Preference: Oral Preferred

A high-resolution record of paleoenvironmental changes across the Pliensbachian-Toarcian boundary from Yorkshire, UK

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Keywords: Mercury, Organic carbon-isotope, Carbon cycle, Pliensbachian-Toarcian, Sea level

The Toarcian Oceanic Anoxic Event (T-OAE; ~183 Ma ago) in the Early Jurassic Period was one of the largest perturbations to the climate system of the past 250 Ma. It is recorded in sedimentary rocks as a pronounced negative carbon-isotope excursion (CIE) in the major biospheric reservoirs of carbon, suggesting a major release of 12C-enriched carbon to the ocean-atmosphere system. Across the Pliensbachian-Toarcian boundary (PTB), a smaller negative CIE has been recorded from many sections worldwide. Like the later T-OAE, the PTB event was associated with seawater warming and biotic extinction. Both events were likely temporally coincident with Karoo-Ferrar Large Igneous Province emplacement. Consequently, carbon effusion related to large-scale volcanism has been suggested as a causal driver of the PTB event and T-OAE. Nevertheless, the precise nature and global significance of the PTB event is unclear. Here, we present new high-resolution sedimentological and geochemical data from bulk organic-rich rocks spanning the late Pliensbachian to early Toarcian from Yorkshire (UK). We show that the negative CIE (magnitude of ~4‰) across the PTB was followed by a hitherto unrecognized and smaller negative CIE (magnitude of ~2‰) in the Dactylioceras tenuicostatum ammonite Zone. Both perturbations coincide with evidence for sea-level fall and elevated organic carbon and mercury concentrations. In addition, the tenuicostatum CIE was coeval with storm deposits and evidence for seawater deoxygenation. Our preliminary research indicates that both events were superimposed on a complex pattern of sea-level change. Changes in the flux of terrestrial organic matter related to sea level change may have been the cause of the observed mercury anomalies, rather than volcanism. The cause and significance of the tenuicostatum CIE remains unclear, but our study adds new detail for understanding the pattern of paleoenvironmental change during this interval of the Early Jurassic.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-4: Understanding the Mesozoic greenhouse world
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

High-resolution sedimentation rate determined by cyclostratigraphy in an Aptian pre-salt lacustrine carbonate system, offshore Brazil

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Keywords: sedimentation rate, cyclostratigraphy, lacustrine carbonate system, Brazil

The discovery of large-scale oilfields in the offshore Basins has revived interest in the exploration of the Aptian pre-salt carbonate systems in the Brazilian southeastern continental margin. Aptian lacustrine carbonate systems are characterized by special texture and mineral composition whose distribution and correlation have been broadly discussed in the last decade. Power spectral, Fourier transform, and correlation coefficient analyses of the gamma-ray logging data from an exploration borehole reveal strong astronomical signals of long eccentricity, short eccentricity, and obliquity cycles during Early Cretaceous. On the basis of the long eccentricity (405 kyr) tuning 4.5 astronomical time scales results, the carbonate systems above the basalt strata covers a 1.8 Ma period from 113.0 Ma to 114.8 Ma. The high-resolution sedimentation rates of the carbonate strata vary from 9.5 cm/kyr to 12.09 cm/kyr. This result is in good agreement with the paleontological ostracod biozones ages and the basalt Ar-Ar ages. This case study supports the cyclostratigraphic interpretation of a Cretaceous magnetic susceptibility series and provides new insights into changes of the depositional setting in an Aptian pre-salt lacustrine carbonate system.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-4: Understanding the Mesozoic greenhouse world
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Climate simulation supports ENSO activity from the Late Cretaceous California

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Keywords: Climate Simulation, Greenhouse Climate, ENSO, Terrigenous Laminae

Using climate simulation, we provide a new explanation of teleconnections between late Cretaceous El Niño – Southern Oscillation (ENSO) variability and participation proxy data from annually-resolved terrigenous laminae of Marca Shale, California persented by Davies et al. (2011). Our coupled climate simulation (first published by Zhang et al. (2019)) of the Late Cretaceous generates ENSO with similar periodicities in tropical Pacific sea-surface temperatures (SST) and atmospheric teleconnection to California precipitation. We think the teleconneection between tropical Pacific SST and participation of California is similar with them in Holocene(Du et al., 2020), when tropical Pacific SST changed the Aleutian Low and the Sub-tropical High, caused a longitudinal moving of Westerlies, then influenced the participation of California. Our evidence suggests that ENSO operated in the Late Cretaceous greenhouse climate.

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SSession T1-5: Data-driven paleogeographical reconstruction

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-5: Data-driven paleogeographical reconstruction
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Reconstruction of Quantitative Lithofacies Palaeogeography Based on Latent Class Analysis from Observed Samples

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Keywords: data–driven, latent structural analysis, quantitative palaeogeography

The conventional quantitative lithofacies palaeogeography mapping method is summarized as single factor analysis and multiple factor comprehensive. It has been widely accepted and very often used in the compilation of lithofacies palaeogeography maps. However, the procedure requires high experiences and the final map can't avoid certain degree of bias based on the experience of the geologist performing the multi-factor comprehensive mapping. This stems from the fact that there is no mathematical principle involved to achieve the single factor superposition. Therefore, it is necessary to deploy a mathematical relationship when performing the lithological palaeogeography map comprehension to achieve a superior data–driven approach and avoid any possible objective bias.

This study proposes a quantitative lithofacies palaeogeography analysis method based on latent class analysis that can provide a solid mathematical theory for the traditional lithofacies palaeogeography mapping procedure. Latent class analysis is a class of latent structural analysis methods proposed in the 1950s by Lazarsfeld and Henry and improved by Goodman (Lazarsfeld and Henry, 1968; Goodman, 1974). The proposed workflow can be divided into the following four integrated steps:

First step is to design of the questions before a questionnaire survey in sociological research, which is the basis for all subsequent analysis work. The lithofacies paleogeography analysis identifies the possible investigative factors for the specific research target area, such as the formation thickness, certain lithology content, etc. Each factor will be looked at as a manifest variable in later latent analysis.

Second step is to count the outcomes of all the observation locations or samples to get the spatial distribution characteristics of each manifest variable. All questions must be answered at each observation location that means all factors should be investigated from each sample. Only in this way can the spatial correlation of each factor (manifest variable) be built in the same probability statistics space.

In third step, it is to transform the manifest variables to latent variables. Using the latent classes to integrate multiple manifest variables will change the data analysis space from a higher statistic dimension into a lower one. This will reveal geological features embedded in multiple manifest variables.

The final step is lithofacies palaeogeography mapping. The latent class analysis model obtained in the previous step is used to explain each observation location sample outcome.

One case study presented in this study shows that the latent class analysis will make the superposition of multiple factors automatically, and the final obtained map reflects the distribution characteristics from the observations. The synthesis procedure based on a rigorous mathematical principle presents an improvement on the classic single factor analysis and multiple factor comprehensive method by extracting and characterizing the geological patterns embedded in all the observations.Thus, the conventional single factor analysis and multifactor integration method is now transformed with probability theory based latent analysis theory.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-5: Data-driven paleogeographical reconstruction
Presentation Preference: Oral Preferred

Provenance of Lower Jurassic sediments in the South China Continental Margin: Evidence from U-Pb ages of detrital zircons

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Keywords: Chi-square test, Detrital Zircon geochronology, South China Craton, Source to sink

In the Early Jurassic, a large-scale transgression occurred on the South China Continental Margin (SCCM), affected by the initiation of Paleo-Pacific subduction. This transgression significantly influenced the source areas and transport mode of Lower Jurassic sediments in the SCCM. This study presented 640 new detrital zircon ages to discuss the Early Jurassic source to sink system in the SCCM. The Chi-square test and multidimensional scaling (MDS) indicated that the major sinks can be divided into the western, central, and eastern SCCM. The Yunkai Terrane and Hainan Island were primary source areas for the western SCCM. The Wuyi Terrane and Nanling Tectonic Belt provided abundant detrital materials for the eastern SCCM. It should be noted that the central SCCM was a vast shallow sea in the Early Jurassic due to the large-scale transgression. Thus, the coastal currents and drowned pre-Jurassic river valleys controlled sediment delivery to the central SCCM. Overall, the Lower Jurassic sediments distribution system in the SCCM was significantly affected by Paleo-Pacific subduction.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-5: Data-driven paleogeographical reconstruction
Presentation Preference: Oral Preferred

Provenance of flysch and molasse separated by basal ~360Ma unconformity from Chinese Tianshan area: Constraints on the Silurian to Mississippian tectono-paleogeographic evolution in the southwestern Central Asian Orogenic Belt

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Keywords: provenance, flysch and molasse, tectono-paleogeographic evolution, southwestern Central Asian Orogenic Belt

Tectono-paleogeographic reconstruction in the tectonic switching eras of the Central Asian Orogenic Belt (CAOB) could decipher its multiple accretionary process during Paleozoic. In the Dananhu-Harlik Arc, Yili-Central Tianshan Arc and the North Tianshan Complex between two arcs from the southwestern CAOB, the Latest Devonian to Early Carboniferous molasse or volcanic rocks unconformably overlie on the pre-Late Devonian flysch, volcanic rocks, metamorphic rocks and ophiolitic rocks. In this contribution, we focused on the provenance evolution from each side of the Ordovician to Early Devonian Dacaotan Ophiolite located in the northern North Tianshan Complex. In the north side of the Dacaotan Ophiolite, three Silurian to Middle Devonian flysch samples contain no or minor Precambrian age scatters, and respectively yield the major age ranges of 550-420Ma, 550-390Ma and 400-370Ma. The εHf(t) values of zircons with 370-480Ma ages in these samples yield values of 4.65 to 15.71. In contrast, in the south side of the Dacaotan Ophiolite, the ~420Ma flysch sample yield the age ranges of 420-500Ma, 850-1000Ma and 1200-1800Ma and the εHf(t) values of Paleozoic zircons ranging from -9.86 to 1.18, and the ~380Ma flysch samples contain the similar age ranges and the dominantly negative εHf(t) values (Chen et al., 2019). However, the Latest Devonian to Mississippian molasse in the two arcs and North Tianshan Complex commonly contains the 330-400 age ranges (Zhang et al., 2013; Liu et al., 2014). In the Dananhu-Harlik Arc, the detrital zircons with 400-330Ma ages have εHf(t) values that range between -9.92 to 15.36 (Li et al., 2020), whereas in the south side of the Dacaotan Ophiolite, the 400-330Ma zircons yield εHf(t) values ranging from 11.75 to 14.35. These new evidences and reviews suggest that the Dananhu-Harlik and Yili-Central Tianshan Arcs are two discrete arcs during the Silurian to Middle Devonian, and they were mutually amalgamated along the Dacaotan Suture in the Latest Devonian, leading to the formation of basal ~360Ma unconformity in the two arcs and the North Tianshan Complex, and the mutual transportation of crustal material across the suture of two arcs. Moreover, our other contribution shows that the similarity value of Middle Devonian rugosa coral fauna is predominantly higher than the Early Devonian rugosa coral fauna between these two arcs, suggesting that the Dananhu-Harlik Arc gradually moved closer to the Yili-Central Tianshan Arc during the Early to Middle Devonian. Comprehensively combining with the data about the ophiolites, magmatism, structural deformation, provenance, and paleobiogeography from the southwestern CAOB, we speculate that the bidirectional roll-back subduction of the North Tianshan Ocean led to the extension of the Kalamaili and South Tianshan back-arc oceanic basins and the convergence of the Dananhu-Harlik and Yili-Central Tianshan Arcs. After the arc-arc amalgamation, the ocean basins connected with the sutured North Tianshan Ocean and back-arc basins continuingly subducted until the Permian, leading to the formation of the Carboniferous to Permian intra-arc basin with immature oceanic crust in the composite arc.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-5: Data-driven paleogeographical reconstruction
Presentation Preference: Oral Preferred

Quantifying the relative contributions of Miocene rivers to the deep Gulf of Mexico using detrital zircon geochronology: Implications for the evolution of Gulf Basin circulation and regional drainage

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Keywords: deep sea, detrital zircon, Gulf of Mexico, Miocene, sediment mixing

Sediment routing from hinterland to the deep sea is complicated because it involves evolution of river drainage from source areas to coastal plains and sediment mixing on the shelf and slope by marine currents. Previous regional paleogeographic mapping in the Gulf of Mexico (GOM) has observed a >150 km offset between the middle Miocene paleo-Tennessee fluvial axis and the associated deep-sea fan depositional axis, indicating a complicated sediment pathway. We integrate new and published detrital zircon (DZ) U-Pb age data from fluvial, shelf and deep-sea deposits to examine the complex Miocene sediment routing system in the northern GOM. These data suggest an increase in sediment load derived from western North America (increased Western Cordillera terranes; <300 Ma zircon age component) from the early to middle Miocene in the deep-water Green Canyon protraction area. The early Miocene Green Canyon area received sediments mainly from fluvial axes located directly updip: the paleo-Mississippi River (44%–56%; characterized by Yavapai-Mazatzal, Mid-Continent and Western Cordillera sourced 1800–1600 Ma, 1500–1300 Ma and <300 Ma, respectively, and Grenville-Appalachian sourced 1300–950 Ma and 500–300 Ma age components) and smaller rivers and tributaries draining the Appalachian Mountains (e.g. paleo-Tennessee River, 18%–43%; mainly Grenville-Appalachian sourced 1300–9500 Ma and 500–300 Ma age components). In contrast, the middle Miocene Green Canyon deep-sea fan shows a strong DZ signal from the paleo-Red River (38%; increased <300 Ma zircon age component), which requires input of additional sediment sources from west of the paleo-Mississippi system. In addition, the paleo-Tennessee River, which was a major middle-Miocene sediment source for the central-eastern GOM due to uplift and increased erosion of the Appalachian Mountains, is underrepresented (34%; decreased 1300–950 Ma zircon age component) in the middle Miocene Green Canyon fan. We suggest that two mechanisms combined to produce the increased middle Miocene input from western sediment sources and restriction of locally up-dip Tennessee River sources: (1) regional drainage changes involving middle Miocene capture of the paleo-Red River and its tributaries by the paleo-Mississippi River, which at the same time lost some of its eastern tributaries owing to expansion of the paleo-Tennessee and (2) eastward (clockwise) marine transport of western-sourced sediment along the shelf or slope, which deflected the paleo-Tennessee signal >150 km eastward to feed the deep-sea fan further east, perhaps reflecting intensification of a precursor to the GOM Loop Current.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-5: Data-driven paleogeographical reconstruction
Presentation Preference: Oral Preferred

Online databases of geologic formations (Lexicons) of China, India, Vietnam and Thailand with one-click visualizations onto East Asia plate reconstructions

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Keywords: GPlates, Website, Southeast Asia, Paleogeography

Paleogeography is the merger of sediment and volcanic facies, depositional settings, tectonic plate movements, topography, climate patterns and ecosystems through time. The construction of paleogeographic maps on tectonic plate reconstruction models requires a team effort to compile databases, data-sharing standards and computer projection methods. Two goals of the Paleogeography working group of the International Union of Geological Sciences (IUGS) program for Deep-Time Digital Earth (DDE) are: (1) to interlink on-line national lexicons for all sedimentary and volcanic formations, and develop on-line ones for nations that currently lack these; (2) to target specific regions and intervals for testing/showcasing paleogeography output from the merger of these databases.

Following those goals, we developed new cloud-based lexicons and applied interactive visualization techniques to regions in East Asia. This has been a successful collaboration among computer-engineers, plate-modelers and stratigraphers in India (ONGC), China (Chengdu Univ. Tech., and Chinese Acad. Geol. Sci.), USA (Purdue Univ., and Paleomap Project), Australia (GPlates visualization team) and Vietnam (Vietnam Nat. Univ.). Independent online lexicons with map-based and stratigraphic-based user-interfaces have been developed for all Proterozoic to Quaternary formations on the Indian Plate (over 800), the majority of the Devonian through Neogene of China, (ca. 1700 as of April 2022), and partially for Thailand and Vietnam. A multi-database search system returns all geologic formations of a desired date or geologic stage from these 4 independent databases. With one-click, a user can plot the regional extent of one or of all of those regional formations on different plate reconstruction models of that desired age. In the future, the fillings of the formation polygons will be either appropriate lithologic facies patterns or color-coding of interpreted depositional environments

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-5: Data-driven paleogeographical reconstruction
Presentation Preference: Oral Preferred

Provenances of Shuangyingshan Clastic Rocks in Beishan Orogen and Implications for Continental Evolution

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Keywords: Central Asian orogenic belt, Beishan, Clastic rocks, Continental evolution

The formation and evolution of the continental crust is an essential part of solid earth science research. The accretionary orogenic belt is a critical area for the growth of the continental crust. Yet, the estimation of the actual content of the new crust is often affected by the different anatomical ideas of the orogenic belt. The growth mechanism of accretionary orogenic belts, especially the key question of whether the accretionary orogenic belt is a collage of micro-continents or an accretionary wedge accretionary arc-type growth, is still controversial. This research studied the clastic rocks in the Shuangyingshan area of Beishan, which is located on the southern margin of the Central Asian orogenic belt, and came up with the following findings:

(1) The detrital zircon LA-ICP-MS U-Pb chronology results show that the maximum deposition age of the four clastic rock samples collected from the YingMaotuo, Shajing, and Zelumu is 503Ma, 443Ma, 431Ma, and 539Ma. The maximum deposition age of Shuangyingshan clastic rocks in Beishan is Early Silurian. This result is against the so-called Beishan Precambrian complex.

(2) Microscopic observations of clastic rocks show that they are mainly composed of mineral debris such as quartz, feldspar, and detritus, indicating an inmatured source, probably the fore-arc accretionary complexes.

(3) Whole-rock major and trace element analysis shows that the clastic rocks are characterized by high Si, Al, Na+K, and low Mg. The La/Sc, Th/Sc, La/Co, Th/Co, and Th/Cr values of the studied samples point well to the felsic source region. The εHf(t) values of the clastic samples indicate that a large amount of juvenile crust is involved.

(4) The distribution spectrum of the detrital zircons of the Tarim Craton is entirely different from the Shuangyingshan area in Beishan, which indicates that the clastic rocks in the Shuangyingshan area cannot be supplied by a hypostatic microcontinent from the Tarim Craton.

This result supports the idea that the crust of the Beishan orogenic belt is growing in the form of successive accretionary wedges and accretionary arcs, rather than in the form of a simple collage of continents.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-5: Data-driven paleogeographical reconstruction
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Drivers for heterogeneity of interglacial precipitation intensity over Asia during the past 900, 000 years

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Keywords: interglacial intensity, sorting coefficient, Ili loess, mid-Brunhes transition, Northern Hemisphere ice volume

Quantifying the spatiotemporal characteristics of interglacial periods enhances our understanding of the current warm period and improves predictions of future climate change. However, the intensity of precipitation during interglacial periods varied across Asia, especially between interglacials that occurred before and after the mid-Brunhes transition (MBT, around 430 ka). In this study, we present a high-resolution eolian dust record documenting the past 900,000 years, which was retrieved from the thickest loess borehole sequence (202.49 m) in the Ili Basin, Central Asia and conduct modelling study. We propose that the sorting coefficient of Ili loess is a more sensitive proxy for wind intensity than commonly used mean grain size, and the sorting coefficient is further used to reflect Northern Hemisphere ice volume (NHIV). Supported by numerical modeling experiments and additional multiple lines of evidence, we suggest that increased NHIV during post-MBT interglacials relative to pre-MBT interglacials caused heterogeneous precipitation intensity during interglacials over Asia.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-5: Data-driven paleogeographical reconstruction
Presentation Preference: Oral Preferred

Climate paleogeography knowledge system and deep time paleoclimate classifications

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Keywords: Climate paleogeography, Knowledge system, Paleoclimate classification, Deep-Time Digital Earth program

The climate paleogeography, especially the climate classifications, helps to interpret the global and regional climate changes and intuitively compare the climate conditions in different regions. However, the application of climate classification in deep time (i.e., climate paleogeography) is prohibited due to the usually qualitatively constrained paleoclimate and the inconsistent descriptions and semantic heterogeneity of the climate types. In this study, a climate paleogeography knowledge system is established under the framework of the Deep-Time Digital Earth program (DDE). The hierarchical knowledge system consists of five paleoclimate classifications based on various strategies. The classifications are described and their strengths and weaknesses are fully evaluated in four aspects: "simplicity, applicability, quantifiability, and comparability". We also reconstruct the global climate distributions in the Late Cretaceous according to these classifications. The results are compared and the relationships among these climate types in different classifications are evaluated. Our study unifies scientific concepts from different paleoclimate classifications, which provides important theoretical basis for the application of paleoclimate classifications in deep time.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-5: Data-driven paleogeographical reconstruction
Presentation Preference: Oral Preferred

Climate data and model constraints on Cambrian palaeogeography

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Keywords: Cambrian, paleogeography, climate, model-data comparison, general circulation model

The Proterozoic/Phanerozoic transition was characterised by major changes in Earth's biosphere and step-changes in the nature of Earth's chemical cycles. Unfortunately, loose constraints on the palaeogeographic and climatic context hamper interpretation of the co-evolution of the biosphere and the physical environment over this interval. Cambrian palaeogeographies proposed in the literature can be highly variable. For example, different configurations have positioned Gondwana either spanning the full range of southern palaeolatitudes, or rotated 90° and occupying only tropical palaeolatitudes. Quantitative palaeoclimate data are becoming available for the early Cambrian Period, though these data remain scarce and do not yet present a coherent global picture. A more geographically extensive dataset is required to evaluate climatic hypotheses on a global scale. Here, we couple lithological indicators of palaeoclimate with general circulation model simulations to assess the (dis)agreement between data and model predictions of early Cambrian climate under contrasting palaeogeographies. The concordance between geological data and model simulations is scored to assess the relative merits of each palaeogeographic reconstruction. This study highlights the potential of coupling numerical climate models and qualitative palaeoclimate data to refine our understanding of the Cambrian world, and provide climatic and geographic context for the rise of animal-rich ecosystems.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-5: Data-driven paleogeographical reconstruction
Presentation Preference: Oral Preferred

Towards a Digital Twin of Earth – Combining tectonics, mantle flow, paleogeography, climate, the biosphere, and landscape evolution on geological timescales

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Keywords: paleogeography, digital twin, tectonics, geodynamics

The geological record, despite the spatial and temporal gaps and biases, provides the crucial time capsules that help us reconstruct the past state of Earth in deep time. Although a wide range of efforts are underway to construct a present-day Digital Twin of Earth (important for geo-hazards, etc.), fewer efforts have been focused on establishing a “Deep-time Digital Earth”. Here we describe the framework for a deep-time digital twin of our planet that captures processes from deep mantle flow to surface tectonics, eustasy and flexure, landscape evolution, and climate. These models require a range of geological data constraints and have the benefit of being able to “fill gaps” both in spatial and temporal domains, where regional data coverage is appropriate, while also providing an opportunity to evaluate uncertainties and competing geological interpretations.

The new generation of deep-time digital Earth models incorporate stratigraphic, igneous, metamorphic, and paleontological constraints for the tectonic and paleogeographic evolution of our planet for the Phanerozoic (with emerging models covering even older timeframes). Importantly, keeping track of data inputs and time-evolving data coverage is key to understanding uncertainty and targeting regions for additional data collection where the geological record may be under-sampled. We demonstrate how plate tectonic reconstructions in the community (py)GPlates (www.gplates.org) framework can be used to drive mantle flow models, and explore rigid and deforming plate evolution. These components of the solid Earth system can be linked to ocean-atmosphere climate simulations, as well as landscape evolution models (such as pyBadlands) to also explore the influence of eustasy, flexure, climate and even aspects of the biosphere (such as reef systems), all of which were previously prohibitive to consider in a self-consistent deep-time tectonic and paleogeographic context.

Given the cost of collecting and analysing geological data, these models are an important value-adding step that enables us to extract additional knowledge from previously disparate data collections. The “deep-time digital twins” of our planet also provide unprecedented opportunities for transdisciplinary discoveries ranging from basic Earth science to evolutionary biology, resource exploration, and understanding changes in planetary habitability.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-5: Data-driven paleogeographical reconstruction
Presentation Preference: Oral Preferred

A Reconstruction of palaeodrainage patterns for South-East Gondwana basins of peninsular India in the Palaeozoic-Mesozoic period

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Keywords: Palaeo-drainage, Detrital zircon, Geochronology, Palaeo-reconstruction, Gondwana, Mesozoic

Gondwana Supergroup is defined by continental rift-basin deposits, with minor marine inputs, formed between the late Carbonaceous and lower Cretaceous. Excellent outcrops of Gondwana sediments are exposed along three river valleys along the eastern margin of the Indian continent: Damodar Valley, Son-Mahanadi Valley, and Pranhita-Godavari Valley. These south-east Gondwana sedimentary strata reflect the reversal of the present drainage pattern of the basins (Damodar, Satpura, Son-Mahanadi, and Pranhita-Godavari basin) in the Mesozoic. The reversal of drainage patterns is related to the upliftment of plumes related to hotspot reactivity and plate reorganization. The present-day drainage pattern follows these same Permian grabens, but in the opposite direction. However, the exact timing of the drainage reversal during the Mesozoic is yet to be constrained.

The proposed study will focus on tracing provenance, tectonic settings, transport history, and for time stratigraphic correlation and sedimentary environment. The vertical differences of heavy mineral assemblages in sandstone will be examined for understanding the evolution process and the uplift-denudation process of the provenance area. Sandstones are mixtures of mineral grains and rock fragments coming from naturally disaggregated products of erosion of all types of rocks. Hence, the study of sandstones plays a vital role in searching the sources of sediments and reconstruction of tectonics. The petrographic study of sandstone will provide information about the lithologic composition, weathering, sediment recycling, and distance from the depositional site. The QFR plot will be made by using Gazzi-Dickinson point-counting method. The provenance and the tectonic setting of the sandstone will be interpreted by using QFR modal analysis techniques, and it can also differentiate between the textural and mineralogical maturity.

Detrital zircon U-Pb geochronology will be used for distinguishing provenance histories, age spectrum, correlating stratigraphic units, and crustal evolution. By using the Laser-ablation–inductively coupled plasma–mass spectrometry (LA-ICP-MS) it is proposed to estimate, U-Pb crystallization ages and Hf isotope ratios from detrital zircon of the Mesozoic sandstone. This combination of U-Pb ages and Hf isotopic compositions of single-grain detrital zircons makes it possible to determine, through each grain, not only the age but the nature and source of the host magma. By studying all sources of data from Gondwana basins of peninsular India, we will be able to correlate the sediment dispersal pattern, stratigraphic correlation, and crustal evolution of other Gondwana basins of the world.

Session T1-6: Astronomical forcing of Earth's paleoclimate and sedimentation systems

ID: T1-60248

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-6: Astronomical forcing of Earth's paleoclimate and sedimentation systems
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Astronomical climate changes trigger Late Devonian bio- and environmental events in South China

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Keywords: Cyclostratigraphy, orbital forcing, F–F mass extinction, sea level changes, Kellwasser events

One of the five great mass extinctions of the Phanerozoic is the Frasnian–Famennian (F–F) mass extinction, for which the causes have not yet been identified. In this study, cyclostratigraphic analysis of two F–F transition sections was carried out in South China: the Yangdi section, a marine slope facies, and the Lali section, a marine basin facies. Paleoclimate proxy data collected at high resolution along these sections include magnetic susceptibility and X-ray fluorescence geochemistry. Time series analysis and modeling of the proxy data reveal that frequencies comparable to those of the Earth's long and short orbital eccentricity, obliquity, and precession index characterize the two successions. Metronomic 405-kyr long orbital eccentricity cycles identified along the two sections were used to construct a floating astronomical time scale across the F–F transition, revealing that 1000 kyr separates the Lower and Upper Kellwasser horizons (LKH and UKH), and ~1600 kyr separates the maximum values of the LKH and UKH δ13C excursions. The estimated duration of the UKH is 150 kyr, during which the first, second, and third extinctions of the F–F biotic crisis lasted 120 kyr, 20 kyr, and 10 kyr, respectively. Sedimentary noise models of the magnetic susceptibility and Ca concentration time series indicate that changes in sedimentary noise correspond to sea level variations. Modeling suggests that the long orbital eccentricity cycles controlled sea surface temperatures, and that third-order eustatic changes were forced by the combined orbital eccentricity and obliquity variations. Finally, we propose an "astronomical climate change" model as a defining mechanism of the F–F biotic crisis.

ID: T1-60398

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-6: Astronomical forcing of Earth's paleoclimate and sedimentation systems
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Eocene hyperthermal events in the terrestrial system: Geochronological and astrochronological constraints in the Fushun Basin, NE China

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Keywords: Eocene,Astronomical orbital,Hyperthermal events,Organic matter enrichment,Terrestrial system

Frequent hyperthermal events during the Eocene (55-47 Ma), primarily characterised by carbon isotope excursions (CIEs), have been identified from marine records worldwide. However, only a few excursions have been recognised and described in continental deposits, thereby limiting the understanding of the effect of global warming on terrestrial systems. Thick, dark, organic-rich mudstone containing complete astronomical age information was deposited during the Palaeogene in the Fushun Basin. Based on U–Pb zircon dating and Milankovitch cycle analysis, the astronomical time scale (ATS) of the Fushun Basin was established. Based on the high-resolution chronostratigraphic framework, combined with the negative migration characteristics of organic carbon isotopes (δ13CTOC), three hyperthermal events were identified: Eocene Thermal Maximum 2 (ETM2), Eocene Thermal Maximum (ETM3) and long-term Early Eocene Climatic Optimum (EECO). In particular, several periods of short-term hyperthermal events were identified in the EECO period: L, M, N, O, P, Q, R, S, T, U, V, W, C22nH3, C22nH4, C22nH5, C21rH1, C21rH2, C21rH3, C21rH4, C21rH5, C21nH1 and C21nH2. The records of sea and land hyperthermal events show that the records corresponding to land basins are timelier and more sensitive.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-6: Astronomical forcing of Earth's paleoclimate and sedimentation systems
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Astronomical forcing of Miocene red-green mudstone rhythms in northeastern Tibet: an integrated study of magnetostratigraphy and cyclostratigraphy

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Keywords: Orbital eccentricity metronomes, cyclostratigraphic-calibrated GPTS, astronomical origin, Miocene red-green mudstones, northeastern Tibet

Studies of lacustrine cyclostratigraphy in northeastern Tibet have made great strides in reconstructing the regional precipitation and aridification, and disentangling paleoclimate signals arising from the uplift of the Tibetan Plateau during the Miocene Epoch. A major success has been the recognition of Milankovitch forcing in the cyclostratigraphy reaching back through the Cenozoic. However, this cyclostratigraphy needs detailed calibration between the orbital metronomes and the Geomagnetic Polarity Time Scale (GPTS) to improve the accuracy and precision of age models. The orbital eccentricity metronome (405-kyr cycle) is typically applied to develop an age calibration between cyclostratigraphy and the GPTS. However, 405-kyr cycles have been difficult to detect in Cenozoic cyclostratigraphy of northeastern Tibet. Here we present an analysis of Miocene red-green mudstone sections by considering lithological color rank series. We formulate binary color rankings for the red-green mudstone rhythms based on published lithology logs from 8 Ma to 22 Ma. Time-frequency analysis of the color rank series highlights predominant 405-kyr cycles, which were previously unnoticed in other paleoclimate proxies. Our results include a calibration between 405-kyr-tuned cyclostratigraphy and the GPTS, identifying the orbital eccentricity (405-kyr) metronome from E19 to E53 in the reconstructed color rank time series. The red and green mudstone layers correspond respectively to the maxima and minima of long orbital eccentricity (405-kyr) cycles. The red mudstones formed in floodplain environments corresponding to warm-humid climate, whereas green mudstones formed in high-energy marginal lake environments corresponding to cold-dry climate. We propose that intensified precipitation during maximum orbital eccentricity resulted in higher fluvial detrital input, leading to red mud deposition in the basin, whereas less precipitation during minimum orbital eccentricity resulted in lower detrital input, leading to green mud deposition in the basin.

ID: T1-60612

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-6: Astronomical forcing of Earth's paleoclimate and sedimentation systems
Presentation Preference: Oral Preferred

Accurate time scale recovery by estimating variable carbonate accumulation rates in oceanic sedimentary sequences

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Keywords: cyclostratigraphy, time scale, sedimentation rate

We present a two-component model for sediment accumulation rate and time scale recovery for oceanic sedimentary sequences. In this model, one component, typically the insoluble fraction, accumulates at a constant rate, and the other component, typically the carbonate fraction, varies. Using empirical weight percent of the variable component, an algorithmic solution is derived that determines the relationship between stratigraphic position and time. Artificial examples demonstrate that when the model assumptions are accurate the algorithm provides a near-exact solution. Algorithm performance is explored under a wide range of model assumptions. Finally, the algorithm is applied to well known oceanic sedimentary sequence datasets from the Late Quaternary icehouse and mid-Cretaceous greenhouse. We compare results with previous, independently determined time scales for the sequences. We discuss the potential application of this algorithm for a wide variety of sedimentary sequences.

ID: T1-60815

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-6: Astronomical forcing of Earth's paleoclimate and sedimentation systems
Presentation Preference: Oral Preferred

Organic carbon burial is paced by a ~173 kyr obliquity cycle in the middle to high latitudes

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Keywords: orbital cycle, nonlinear response, carbon burial, mid-high latitude

Earth's climate system is complex and inherently nonlinear, which can induce some extraneous cycles in paleoclimatic proxies at orbital time scales. The paleoenvironmental consequences of these extraneous cycles are debated owing to their complex origin. Here, we compile high-resolution datasets of total organic carbon (TOC) and stable carbon isotope (13Corg) datasets to investigate organic carbon burial processes in middle to high latitudes. Our results document a robust cyclicity of ~173 thousand years (ka) in both TOC and 13Corg. The ~173-ka obliquity–related forcing signal was amplified by internal climate feedbacks of the carbon cycle under different geographic and climate conditions, which control a series of sensitive climatic processes. In addition, our new and compiled records from multiple proxies confirm the presence of the obliquity amplitude modulation (AM) cycle during the Mesozoic and Cenozoic and indicate the usefulness of the ~173-ka cycle as geochronometer and for paleoclimatic interpretation.

ID: T1-60879

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-6: Astronomical forcing of Earth's paleoclimate and sedimentation systems
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Astronomical forcing of Eocene terrestrial successions in the Jianghan Basin (China) and its implications for Eastern Asian climate evolution.

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Keywords: East Asian monsoon, Eocene climate, Astronomical time scale, Orbital signal, Salt rhythm

East Asia experienced complex climate changes during the Eocene, among which the origin and development of the monsoon pattern is of great importance. Due to the lack of the constraints of a complete time frame and research of the sedimentary records, the evolution process of the East Asian climate is still unclear. In this study, the Eocene strata of continental sequence in the Qianjiang depression of the Jianghan Basin, in central China, were evaluated to explore the Eocene climate evolution characteristics in East Asia. A complete high-precision Eocene astronomical time scale from 55.34 Ma to 33.9 Ma was established. The study showed that the dominant orbital signals in the sedimentary records changed from eccentricity in the early–middle Eocene to obliquity in the middle–late Eocene. The enhancement of obliquity signal corresponded to the lithological change in the Qianjiang Depression which responded to the global cooling; moreover, we found that obliquity signal in the sedimentary records could indicate the emergence of the East Asian monsoon. We considered that the development of the salt layer may be the result of the monsoon effect, which can be further used as the indicator for the monsoon. Therefore, the initial appearance of salt layers may be related to the formation of the monsoon, and the large set of salt rhythmites deposits dominated by obliquity signal can indicate the stability of the East Asian monsoon. Using the floating astronomical time scale, we concluded that the East Asian monsoon first formed 46.65–43.71 Ma and stabilized 43.71 Ma. The complete time history of the evolution of the East Asian monsoon, the conjoint development characteristics of salt rhythmites and obliquity signal in this study can be a new perspective and basis for future studies on the East Asian monsoon.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-6: Astronomical forcing of Earth's paleoclimate and sedimentation systems
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Orbital forcing of late-Early Devonian storm events on a mixed carbonate-siliciclastic shelf, Longmenshan area, Sichuan Province, China

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Keywords: Hybrid deposits,Tempestite,Milankovitch,cyclicity,Emsian,Eifelian

The Yangmaba Formation of latest Early Devonian in the Longmenshan area of Sichuan Province, China, is a shelf facies consisting of clay-rich, of siliciclastic sand-rich, of carbonate-dominated and of hybrid mixed clastic-carbonate deposits. Storm deposits vary in their thickness, in their composition and in their abundance-per-meter within these mixed carbonate-siliciclastic deposits. Meter-scale statistics of the relative storm frequency (events-per-meter) and magnitude (bed thickness) were compiled in two coeval sections through each of the hybrid facies in the lower Yangmaba Formation, which spans approximately the entire Polygnathus patulus conodont zone of the uppermost Emsian Stage. Low-pass filtering, spectral analysis and Acycle interpretation of these tempestite statistics yield 3 ½ main oscillations in each section, with an average wavelength of ca. 23 m. These long-wavelength trends are semi-coincident with interpreted long-term variations in sea level, where shallower depths allowed a greater influence by storms. Superimposed on the long-wavelength cycles are medium-wavelength cycles of 5.5 to 6.3 m. The estimated ca. 1.5 Myr time-span of this conodont zone of the lower Yangmaba Formation and the approximate 1:4 ratios of these wavelengths indicate that frequency and intensity of major storms and the recording of tempestites in the sedimentary record were modulated by ca. 100-kyr and 95-kyr short-eccentricity orbital-climate oscillations superimposed on a main 405-kyr long-eccentricity cycle. These eccentricity-climate cycles governed storm intensity and regional sea level on this margin of the tropical Yangtze Platform of South China.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-6: Astronomical forcing of Earth's paleoclimate and sedimentation systems
Presentation Preference: Oral Preferred

Milankovitch climate control of hyperpycnal flow sedimentation in an Early Cretaceous succession (Ri Qing Wei Basin, China)

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Keywords: Early Cretaceous, cyclostratigraphy, Laiyang Formation, East Asian continental margin, Lingshandao Island

Milankovitch forcing exerts a major control on climate that is recorded in the sedimentary rock record. However, its influence on hyperpycnal flow sedimentation is largely unknown. Hyperpycnites, sediments resulting from hyperpycnal flow, which is related to climate by flood frequency and magnitude, may be valuable tools for deciphering Earth's paleoclimate. Their origin and distinctive layering have been explained by various mechanisms, including initial phase of slope re-adjustment, intermittent tectonically or gravity-driven surface deformation, sea-level fluctuations, and variations in sediment supply. Their potential link to paleoclimate variations remains unexplored. Here we use cyclostratigraphic analysis combined with high precision U-Pb dating to investigate the potential influence of Milankovitch forcing on their deposition. A continuous drill core of the 125-million-year-old Early Cretaceous Laiyang Formation (eastern China) reveals well-defined cyclic hyperpycnal flow patterns. The radioisotopic dating constrains the formation's sedimentation rate to 86 m Myr−1 and links the observed cycles to precession index, obliquity and orbital eccentricity cycles. We conclude that Milankovitch cycles exerted a primary control on hyperpycnal flow sedimentation.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-6: Astronomical forcing of Earth's paleoclimate and sedimentation systems
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Cyclostratigraphy of Pingliang Formation of Ordovician in the Qishan Section in SW Ordos, North China

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Keywords: Ordos Basin,Magnetic susceptibility,Cyclostratigraphy

Cyclostratigraphy of Pingliang Formation of Ordovician in the Qishan Section in SW Ordos, North China

Abstract

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Cyclostratigraphy is to establish a high-precision astronomical chronometer by identifying Milankovitch cycle signals in the sedimentary strata. The high-resolution astronomical chronometer of the Paleozoic has not been fully established, which is known as the "frontier" of cyclostratigraphy. The study of Ordovician cyclostratigraphy in South China has been basically completed, but the study of North China is still relatively few. The southwest margin of Ordos Basin is a relatively well-developed Ordovician strata in North China. In Qishan section of Baoji City, Shaanxi Province, the Ordovician strata is well-developed, completely exposed and relatively lightly affected by tectonic geological processes. It is an ideal section for researching Ordovician cyclostratigraphy.

This paper studies the cyclostratigraphy of Qishan section, mainly researching the cycle period of Pingliang Formation of Upper Ordovician. Through field survey and measurement, the 600m thick Pingliang Formation of Qishan section is determined, and 3715 samples are collected at the top (36m thick) and bottom (30.3m thick) of the section Pingliang Formation at an interval of 2-10cm for magnetic susceptibility measurement. Time series analysis shows that the magnetic susceptibility has cycle period of 2.34m, 1.65m, 0.58m, 0.35m and 0.3m at the top of the top section, corresponding to the short eccentricity, obliquity and precession. After depth-time conversion, the astronomical cycles of 135kyr, 86kyr, 31kyr, 19kyr and 17kyr are identified, including 16 short eccentricity cycles, and the calculated floating astronomical chronometer lasts about 2.16Ma. Here are 1.88m, 1.25m, 0.47m, 0.28m and 0.23m thick cycle period in the bottom section. After depth-time conversion, 133kyr, 87kyr, 36kyr, 20kyr and 17ky rastronomical cycles are identified, and there are also 16 short eccentricity cycles, and the floating astronomical age scale is 2.128Ma.

Key words: Ordos Basin; Pingliang Formation; Magnetic susceptibility; Cyclostratigraphy

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-6: Astronomical forcing of Earth's paleoclimate and sedimentation systems
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Milankovitch cycles of Quaternary strata and its indications for paleoenvironmental variations in the Qiongdongnan Basin, South China Sea

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Keywords: Qiongdongnan Basin, Milankovitch cycles, Quaternary, clay minerals, Paleoenvironmental variations

Milankovitch cycles affected paleoclimate, paleoenvironment, sea-level changes and the onset/termination of glacial/interglacial periods. The effects of astronomical cycles have been used to calculate paleo-water depth, obtain sediment supply rate, determine geological interface age and divide sedimentary sequences. The Qiongdongnan Basin (QDNB) is rich in oil and gas resources, but few studies have been done on astronomical cycles and paleoclimate in the QDNB. The Quaternary strata in QDNB are mainly fine-grained mudstone deposits and its sediments have stored significant information on sea-level changes and paleoenvironmental variations. Taking the Ledong Formation in QDNB as the research object, an integrated analysis of sedimentological data, well-logging, borehole dating data, clay minerals and major/ trace element composition provided a detailed description of the sea-level changes and paleoenvironmental variations. At first, the data from the Well-08 drilled through Quaternary strata in the QDNB has enabled the reconstruction of the evolution of sea level and environment. The signals of Milankovitch cycles in Quaternary strata were identified, and the results of the spectral analysis show that the fine sensitive component records the periodic change information of the Earth's orbital parameters (~405-, 100-, 33-, and 20-kyr). Additionally, the variation of clay mineral and major element compositions, like the ratio of Sr/Cu in this area shows an obvious glacial-interglacial cycle, which reveals that the paleoenvironment in the QDNB has undergone three periods since the Quaternary: late glacial period, early interglacial period and interglacial period. Besides, cold and dry conditions are usually characterized as an increase in the productivity and input of terrestrial increase during glacial periods combined with low sea level, clay minerals and major/ trace element composition. Conversely, during the interglacial period, sea level rises. At a highstand, terrigenous sediments supply is reduced, the clay minerals showed an increasing trend of kaolinite and a corresponding decrease of illite, which reflected the humid and hot environment. The results of this study show that the Milankovitch cycles, sea-level changes and clay mineral compositions changes of Quaternary strata in QDNB are highly consistent, which is of great significance to study the variations of paleoclimate and paleoenvironment in the basin.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-6: Astronomical forcing of Earth's paleoclimate and sedimentation systems
Presentation Preference: Oral Preferred

Astronomical forcing of the paleoclimate and paleoenvironment on lacustrine magnetic records of the Lower K1sh formation in the Early Cretaceous Songliao basin, northeastern China

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Keywords: SK-2 borehole, lacustrine, Early Cretaceous, cyclostratigraphy, paleoclimate

Continuous cores of the lower Cretaceous in Songliao Basin, northeastern China, have been drilled out by the International Continental Drilling Project of SK-2 borehole, providing unprecedented geological materials for investigations of the early Cretaceous continental paleoenvironment and paleoclimate. In this study, we systematically studied the lacustrine successions of the lower Shahezi Formation (K1sh) in depth 4542-5694 m using the techniques of environmental magnetism, microscopic imaging, geochemical stratigraphy and cyclostratigraphy. Magnetic analysis reveals that there is an inverse correlation between magnetic susceptibility (MS) and lithology, where mudstones hold the largest values, and sandstones hold the smallest. The main magnetism carriers in the lower K1sh are pseudo-single-domain (PSD) and/or multi-domain (MD) ferromagnetic minerals, whilst the mainly dominant minerals of MS are paramagnetic and ferromagnetic minerals. To further explore the genesis of the environmental and climatic variations, MS was utilized as an alternative proxy to proceed with cyclostratigraphic analysis. Sedimentary cycles of 113.04 m, 34.11 m, 13.34 m and 6.00m are significant in power spectrum, which are in ratio highly accordant with long eccentricity (405 kyr), short eccentricity (124 kyr), obliquity (47 kyr), and precession (21 kyr) cycles in Early Cretaceous, proving the considerable impact of astronomical cyclicity on sedimentary rhythmicity. Long eccentricity controlled sedimentary facies, short eccentricity and precession are regarded to have mutually shaped the lake level oscillations. It should be noted that semi-precession periods identified from MS and the U sequence is most likely to directly drive the sand-mudstone alternations with the seasonal discrepancies of summer insolation. Finally, by tuning the inferred long and short eccentricity cycles to 405 kyr and 124 kyr orbital eccentricity theoretical curves, we established floating astronomical time scales (FATS) of 3356.99 kyr and 3248.80 kyr respectively, both of which fall into the range of the published U-Pb ages. Sedimentation rate was estimated ranging from 27.50 cm/kyr to 28.91cm/kyr, confirming the rapid deposition characterized within the fault lacustrine basin. In summary, our study acquired experimentally detailed magnetic characteristics of the early Cretaceous terrestrial sediments, shed new light on the astronomically forced configurations of paleoclimate on these magnetic properties, and provided a preliminary geochronological constraint for further marine-terrestrial comparison towards coeval strata.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-6: Astronomical forcing of Earth's paleoclimate and sedimentation systems
Presentation Preference: Oral Preferred

Orbitally forced organic matter accumulation recorded in an Early Permian mid-latitude palaeolake

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Keywords: Organic matter accumulation, Cyclostratigraphy, Milankovitch cycles, Lucaogou Formation, Junggar Basin

Organic matter (OM) sequestration acts as a significant sink of the CO_2 in Earth's carbon cycle and is tightly associated to the climate and depositional environments. The contemporaneous changes in primary productivity, preservation conditions, and sedimentation rate in the OM enrichment have been intensively discussed. However, the dominant factors in different depositional settings and the orbitally-forced variations in the lacustrine OM accumulation remain poorly constrained. Here, we investigate the depositional environment and OM accumulation in response to the astronomical forcing recorded in the Lucaogou Formation in southern Junggar Basin, northwestern China. Sedimentological and cyclostratigraphic studies show that both shallow lake and semi-deep to deep lake deposits recorded significant Milankovitch signals including long eccentricity (405 kyr), short eccentricity (~90.9 kyr), obliquity (34.5–37.4 kyr), and precession cycles (22.8 kyr, 22.7 kyr, 21.3 kyr, and 17.3 kyr). A linkage among the lithofacies, natural gamma ray (NGR), and total organic carbon (TOC) content suggests that the depositional environment and OM accumulation were in pace with the astronomically forced hydrological cycle and lake-level changes during the Lucaogou Formation depositional period. This complicated interaction was likely resulted from the teleconnection between changes in ice volume and monsoonal intensity on Milankovitch time scale. In addition, OM sequestration is a dynamically cumulative process of supply and degradation. The anti-phase and in-phase relationships between TOC and NGR content from the restricted mudflat towards shallow lake and towards deep lake respectively suggested OM accumulation efficiency was low in the active shallow water, likely resulted from the enhanced degradation. Finally, we propose a depositional model for the OM sequestration in Lucaogou Formation and suggest that detailed sedimentological studies are essential for the cyclostratigraphic analysis.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-6: Astronomical forcing of Earth's paleoclimate and sedimentation systems
Presentation Preference: Oral Preferred

Using cyclostratigraphic evidence to define the unconformity caused by the Mesoproterozoic Qinyu Uplift in the North China Craton

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Keywords: Milankovitch cycles, North China Craton, Mesoproterozoic, The Qinyu Uplift, Geological unconformity, Weathering crust

In the Yanliao Basin of the North China Craton, the Mesoproterozoic Xiamaling Formation contacted unconformably with the underlying Tieling Formation. This unconformity was caused by the Qinyu Uplift. Underneath this unconformity, the Tieling Formation experienced variably weathering with more extensive erosion of carbonates in the west than in the northeast of the basin. To constrain the timing of the Qinyu Uplift and the duration of subsequent unconformity, cyclostratigraphic analysis was conducted on the Tieling carbonate rocks. Referencing the periodicities of the eccentricity, obliquity and precession obtained from the Mesoproterozoic Xiamaling and Hongshuizhuang Formations, Milankovitch cycles during the Tieling Formation were recognized. A bentonite located at the middle of the Tieling Formation was recognized from the core at the Beizhangzi section, and was considered to be contemporaneous with those found at the Jixian and Liujiagou sections, which had a consistent age of 1441 Ma. Then a deposition rate from the bentonite layer to the top interface of the Tieling Formation was calculated to be 1.65 ± 0.22 cm /kyr, and the duration time were ca. 9 million years. So the minimum age of the Tieling Formation was ca. 1432 Ma. Combined with our new 207Pb/206Pb weighted average age of 1418 ± 14 Ma obtained from the bottom of the Xiamaling Formation, the Qinyu Uplift was constrained to occur between 1432 Ma and 1418 Ma, older than the previously suggested age of 1400 Ma. The duration of this unconformity was suggested to be no less 14 million years, and might be longer in the western part.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-6: Astronomical forcing of Earth's paleoclimate and sedimentation systems
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Cyclostratigraphic constraints on the negative carbon isotope excursion from the upper Doushantuo Formation, South China

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Keywords: the Doushantuo Formation, Cyclostratigraphy, the Shuram Excursion, duration

The Ediacaran strata record a most remarkable $\delta^{13}C$ negative carbon isotope excursion of carbonate globally in geological history, named the Shuram Excursion (SE) (Fike et al., 2006). The driving mechanism of the evolution of metazoan life by this disturbance of the global carbon cycle has always been one of the Ediacaran research hotspots. However, due to the lack of chronological constraints, the origin of the SE is still obscure and this driving mechanism is thus unclear (Bristow and Kenedy, 2008). A few astrochronologic studies provide constrains for the duration of SE, mostly over 7 .7 Myr (Minguez and Kodama, 2017; Gong et al., 2020; Sui et al., 2019). Recently Li et al. (2022) reported a 6.1 ± 0.2 Myr duration from the Zhengjiatang section that preserves a complete SE, which is perhaps the best estimate so far. In contrast, stratigraphic hiatus/unconformity may exist within the reported SE in other successions globally, which causes an over-estimation.

To better understand the duration and origin of the SE, we carried out cyclostratigraphic studies on the SE of the Doushantuo Formation from the Nanxiangerwan section, not far away from the Zhengjiatang section. In this study, magnetic susceptibility (MS) is used as the palaeoclimate index. Rock magnetism and mineralogical analysis indicated that the MS was mainly contributed by the terrigenous inputs, which were controlled by climate changes. The spectral results by the multi-taper method (MTM) of the MS sequence of the upper Doushantuo Formation from the Nanxiangerwan section showed that the complete Milankovitch periods were recorded. After tuning to the target 405-kyr-period sequence, a floating astronomical scale was established. Then the duration of the SE was established as ~ 6.5 Myr. This is consistent with the latest Re-Os age constraints with a < 6.7 ± 5.6 Myr duration for the SE (Rooney et al., 2020), the 6.1 ± 0.2 Myr duration from the Zhengjiatang section (Li et al., 2022) and is similar to those estimated from North America, Australia and Oman. Therefore, this infers the global isochronism of the SE, perhaps with an origin of the (heterogeneous) oxidation of the global ocean.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-6: Astronomical forcing of Earth's paleoclimate and sedimentation systems
Presentation Preference: Oral Preferred

Biomarker evidence for deforestation and an obscuring short eccentricity (100 kyr) across the Triassic-Jurassic boundary in the high-palae-latitude Junggar Basin, NW China

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Keywords: biomarker, Triassic-Jurassic boundary, mass extinction, wildfire and deforestation, floating astronomical scale, obscuring short eccentricity

One of the five largest mass extinctions, the end-Triassic mass extinction (ETME) in 201.6 million years ago, occurred near to the Triassic-Jurassic boundary (TJB) (Hillebrandt, et al., 2013). Dramatic declines of marine and terrestrial ecosystems were approximately synchronous with the eruption of the Central Atlantic Magmatic Province (CAMP). The loss of marine biodiversity is linked to an extreme global warming, while the reasons for floral destruction on the land ecosystems remain in debate. Here, biomarker records of higher plants are reported from the terrestrial high-palae-latitude Junggar Basin, NW China. The strata around the ETME interval are marked by sharp increases in the abundances of cadalene, retene, pimanthrene and furans, which are synchronous with "fern spikes". These results are interpreted as ruins of land vegetation and an enhanced burial of higher plants, which are consistent with palynological evidence of the loss of floral diversity. Based on an integrated stratigraphic correlation, an increased burial of higher plants, wildfires and CAMP volcanisms are synchronous both in the Haojiagou section and other classic TJB sections globally. We propose that widespread deforestation may be due to the CAMP-derived acid rains and then massive rapid death of vegetation provides moisture-free fuels for wildfires, rather than an initially enhanced wildfires lead into the deforestation.

Moreover, a floating astronomical scale is established for the Haojiagou section based on magnetic susceptibility data, and compared with previous study on Lith Index (Sha et al., 2015), combined with Laskar astronomical cycle model (La2010) of this period, the astronomical chronological characteristics of this section were discussed and a short eccentricity 100 kyr was identified. The results show that the ETME-TJB duration is 291 kyr with magnetic susceptibility constraint and 288 kyr with Lith Index constraint. However. in the moving window spectrum analysis results, an obscuring short eccentricity (100 kyr) occurs in the ETME-TJB period and the obliquity signal is enhanced. According to La2010, no astronomical orbital anomalies during interval of 201.6Ma to 201.3Ma indicate that the obscuring eccentricity is not determined by astronomical cycles, but probably related to the environmental fluctuations on Earth surface systems

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-6: Astronomical forcing of Earth's paleoclimate and sedimentation systems
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Paleoceanography of the equatorial Pacific over the past 5 Myr: High resolution benthic foraminiferal δ18O and δ13C records at ODP Site 807

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Keywords: Western equatorial Pacific, Pliocene-Pleistocene, stable isotope

The western equatorial Pacific is pivotal to precisely understand the global climate change and its evolution over geological time. However, continuous paleoceanographic records with high time resolution and accurate age model over the last 5 Myr are few in this important ocean region. Here, we present a high time resolution (2-3 kyr) benthic foraminiferal d18O and d13C record from Ocean Drilling Program Site 807 in the western equatorial Pacific and establish an accurate age model for the past 5.025 Myr. Comparison of the benthic d13C records from the west and east equatorial Pacific, and the North and South Pacific reveals that organic matter oxidation is the most important factor determining the deep water d13C value along the flow path of the deep Pacific circulation over the past 5 Myr. From 4.0 Ma to 2.7 Ma, a rapid decrease in benthic d13C gradients (Dd13CW-E) between the west (Hole 807A) and east (ODP Site 849 and IODP Site U1338) equatorial Pacific potentially resulted from strong ventilation in the North Pacific during the warm Pliocene. The subsequent gentle decrease in benthic d13C gradients might indicate stratification in the North Pacific and reduction of biogenic flux with the intensification of the Northern Hemisphere Glaciation (NHG) at 2.7 Ma. Both the Dd18OW-E and Dd13CW-E are strongly paced by 405 kyr long eccentricity cycles and 41 kyr obliquity cycle, revealing the complex interplay of both high and low latitude climatic processes on deep Pacific circulation changes.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-6: Astronomical forcing of Earth's paleoclimate and sedimentation systems
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Milankovitch paleoclimatic, tectonic, and sedimentary signals in late Permian-Early Triassic fluvial-lacustrine records, Bogda Mountains, NW China

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Keywords: non-marine records, Milankovitch signals, late Permian-Early Triassic

Non-marine cyclostratigraphic records are a manifestation of repetitive changes of ancient continental environmental, paleoclimatic, tectonic, and ecosystem conditions. Stratigraphic sections in Bogda Mountains, the greater Turpan-Junggar intracontinental basin, NW China, provide detailed records of the late Permian-Early Triassic terrestrial paleoenvironmental and paleoclimatic evolution at the paleo-mid-latitude of NE Pangea.

In this study, lithology and interpreted depositional environments are used in quantitative analysis because the environmental shifts occurred probably mainly in response to climatic changes. The section was measured at a cm-dm scale to document the lithology, sedimentary texture and structure, fossils, and stratal geometry. The stratigraphic thickness of the South Taodonggou section is 283 m. Many previous studies used astronomical tuning methods to estimate and reduce the distorting effects of long-term variable sedimentation rates of sedimentary records. However, the short-term sedimentation rate variation of different lithofacies should also be considered. The gamma analysis of Kominz and Bond (1990) estimates the facies-dependent thickness-time conversion factors (gammas) to convert and tune the thickness series into time series before spectral analysis. Multi-taper method (MTM) power spectral analysis and evolutive MTM are used to characterize the frequency content of the gamma-untuned and tuned series.

There are four types of high-order cycles (HCs): meandering stream, lacustrine deltaic, and lakeplain-littoral (subgroups 1 and 2). To obtain consistent gammas for each lithofacies, gamma analysis is conducted for each type of HCs. The gamma results suggest that environmental lithofacies in the South Taodonggou section have approximately constant time-thickness relations. Six normalization schemes are experimented. The spectra of the gamma-untuned and six gamma-tuned series of the South Taodonggou section have several statistically significant peaks which are compared with the line spectrum of Milankovitch climatic cycles at 244-249 Ma (Berger et al., 1992; Hinnov, 2000). Five peaks above or close to the 99% confident limit in the spectra of gamma-tuned series 3 all match with the line spectrum. Thus, the spectra of gamma-tuned series 3 is chosen for calibration with Milankovitch climatic cycles. The peak at frequency 0.0127 is assigned to the long-obliquity of a period of 40.5 kyr. The short-eccentricity peaks are at periods of 117.4 and 86 kyr, the long-obliquity at 40.5 kyr, the long-precession index at 20.7 and 19.9 kyr. Two low-amplitude peaks may also match with the Milankovitch peaks. They are the long (29.6 kyr) and short-obliquity (24.3 kyr) cycles. The good match of the spectrum of the third gamma-tuned series with that of Milankovitch cycles, suggesting that the cyclic sedimentation of the South Taodonggou section was significantly influenced by Milankovitch climatic forcing. The stratigraphic completeness of the South Taodonggou section is estimated to be 27% as the ratio between depositional duration and total duration.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-6: Astronomical forcing of Earth's paleoclimate and sedimentation systems
Presentation Preference: Oral Preferred

Astronomically forced lake level fluctuations during the Toarcian Oceanic Anoxic Event (Sichuan Basin, China)

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Keywords: Toarcian-Oceanic-Anoxic-Event, Sichuan Basin, Astronomical forcing

The Toarcian Oceanic Anoxic Event (T-OAE) is characterized by one of the largest carbon cycle perturbations of the Mesozoic, with associated climatic and environmental change, most notably the widespread development of anoxia in marginal marine basins. On land, an enhanced hydrological cycle led to the development of major lakes, or significantly elevated lake levels, in continental basins in China, such as in the Sichuan, Tarim and Junggar basins. Stratified lake watercolumns and the development of anoxic–euxinic lake bottom water conditions initiated a negative feedback mechanism in Earth's climate system through increased lacustrine (lake) carbon burial.

The sheer size of these lakes possibly allowed for lacustrine carbon burial to have a significant impact on Earth's carbon cycling at that time.

Here, we show new geochemical data from the Sichuan Basin and show that lake levels rose at the onset of the T-OAE. Importantly however, lake levels were likely not stable, but rather fluctuated on astronomical time-scales, possibly in response to periodic changes in the hydrological cycle (and monsoon intensity) and the transport of moisture into continental interiors. Furthermore, the lacustrine climate records spanning the T-OAE provide crucial continental constraints on the duration of the T-OAE, which remains heavily debated based on marine climate archives.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-6: Astronomical forcing of Earth's paleoclimate and sedimentation systems
Presentation Preference: Oral Preferred

Collapse of coal forests triggered the demise of the late Paleozoic icehouse

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Keywords: late Paleozoic icehouse, carbon burial, climate change, coal forest, obliquity forcing

The demise of late Paleozoic icehouse is Earth's first icehouse-to-greenhouse transition in an extensively vegetated world. In this paper, an astronomically forced teleconnection on a global scale is made to delineate a dynamic carbon sequestration history and its impact on icehouse termination. After a loss of coal forests in tropical Euramerica, floral survival became linked with 1.28 Myr obliquity cycles between low-latitude North China and high-latitude Gondwana from ~299.2–295.5 Ma. The expansion of coal forests enhanced carbon burial that increased O2 and lowered CO2 levels in the atmosphere, elevating atmospheric O2/CO2 to the point of crossing a threshold and triggering the collapse of coal forests at ~295 Ma. Following the sharply decline of coal forests, the lack of efficient carbon sinks on land, in combination with the reduced weatherability in the arid continent interiors, was unable to consume the excess CO2 from vegetation fires, leading to the termination of the late Paleozoic icehouse at ~295 Ma. A deep-time example is provided here on how a vegetated icehouse crossed a threshold, entering into a greenhouse without anthropogenic impacts.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-6: Astronomical forcing of Earth's paleoclimate and sedimentation systems
Presentation Preference: Oral Preferred

Sedimentary noise modeling of lake-level change and astronomical forcing in the Late Triassic Newark Basin of North America

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Keywords: groundwater, lake level, sea level, astronomical forcing, Late Triassic

Two different hypotheses, glacioeustasy and groundwater aquifer eustasy, have been proposed to explain short-term, high-amplitude sea-level oscillations during past greenhouse-dominated intervals. However, the veracity of aquifer eustasy on long-term, high amplitude sea level has never been rigorously tested. We test these competing hypotheses using an objective approach of sedimentary noise modeling for the lake-level reconstruction. Statistical tuning and astronomical calibration of paleoclimate and paleoenvironment proxies (depth rank, rock color, gamma ray, and sonic velocity) from the lacustrine Newark Basin enable the construction of a 31.55-Myr long astronomical time scale (ATS) for the Late Triassic that is comparable to classic Newark ATS previously presented. Using this timescale, sedimentary noise modeling in the lacustrine Newark Basin is carried out through the Late Triassic. Lake level fluctuations reconstructed by sedimentary noise modeling and principal component analysis reveal that million-year scale lake-level variations were linked to astronomical forcing with periods of ~3.3 Myr, ~1.8 Myr, and ~1.2 Myr. Our results demonstrate that astronomical forcing, as a driver of groundwater dynamics, may have an impact on global sea-level changes in the Late Triassic. This study thus emphasizes the importance of high-resolution, objective reconstruction of sea- and lake-levels for further testing the hypotheses of glacioeustasy and aquifer eustasy under a warming condition.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-6: Astronomical forcing of Earth's paleoclimate and sedimentation systems
Presentation Preference: Oral Preferred

Downhole gamma ray data to reconstruct an age-depth model of the lacustrine deposits of Chalco basin, Central Mexico

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Keywords: Quaternary, Tropical North America, Borehole Logging, Magnetic Susceptibility

Understanding the evolution of lower latitude climate from the most recent glacial periods of the latest Pleistocene to post glacial warmth in the continental tropical regions has been obstructed by a lack of long and continuous time series. Here we examine sediments from Lake Chalco, located in the Valley of Mexico, central Mexico (19°30'N, 99°W). The basin represents a hydrological closed system surrounded by the Trans-Mexican Volcanic Belt aging from the Oligocene to the present. We use borehole logging to conduct a cyclostratigraphic analysis of the Lake Chalco sediments, and incorporate other available dating information. More than 400 m of sediments are logged for several geophysical properties including magnetic susceptibility and spectral gamma radiation.

Gamma radiation can be used to identify elemental isotopes in the geological record, which is used for stratigraphic correlation and paleoclimatic investigations. Among the lake deposit of Chalco sub-basin, 388 total tephra layers (≥1 mm in thickness) were reported from the core description. Tephra layers with specific gamma ray signatures, presenting a challenge for extracting the primary signals caused by environmental and climatic agents. Here, we apply a tailored protocol to identify tephra layers embedded in other sediments using high-resolution gamma ray spectroscopy. This facilitates dividing the overall sediment column into representative horizons of tephra and non-tephra.

After extracting the non-volcanic primary signal, we apply a suite of evolutive cyclostratigraphic methods to the Lake Chalco logging data, with a focus on gamma ray data. The high-resolution results suggest that the Lake Chalco sediments contain several rhythmic alterations with a quasi-cyclic pattern comparable with the Pleistocene benthic stack. This allow us to calculate a ~500-kyr time span for the sediment deposition in Lake Chalco. By using cyclostratigraphic analysis on data captured by geophysical downhole logging, we demonstrate the potentially broad applicability of this method for downhole logging data and provide further insight into the sedimentation history of Lake Chalco.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-6: Astronomical forcing of Earth's paleoclimate and sedimentation systems
Presentation Preference: Oral Preferred

Chemo- and Cyclostratigraphic records of the Albian from the Tethyan Himalaya of southern Tibet, China

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Keywords: Albian, OAEs, Cyclostratigraphy, Carbon cycle, Terrigenous input, Southern Tibet

The Albian age is characterized by frequent short-lived perturbations of the global carbon cycle, including a series of Oceanic Anoxic Events (OAEs). Carbon isotope Excursions (CIEs) document these OAEs in detail. A strong influence of orbital forcing on oceanographic and climatic conditions in the Albian has been documented, but the relationship between orbital changes and the carbon cycle is still unclear. The Albian CIEs are well recorded globally, except in the eastern Tethys. The major forcing mechanisms of Mesozoic carbon cycling have long remained a conundrum. Here, we present bulk carbon ($\delta^{13}C_{carb}$) and oxygen ($\delta^{18}O_{carb}$) isotope data, magnetic susceptibility (MS), and total organic carbon (TOC) data from the Nirang Section in the Tethyan Himalaya of southern Tibet, China. The $\delta^{13}C_{carb}$ record for the first time documents the long-term secular variations in $\delta^{13}C$ during the Albian in the Tethyan Himalaya. The $\delta^{13}C$ curve obtained in Nirang can be correlated well with reference sections in other basins. OAE1b and 1c were identified as troughs in $\delta^{13}C$ profile in the lowermost and upper part of the section. Cyclostratigraphic analysis of MS, $\delta^{13}C_{carb}$ and TOC content from the Nirang section reveals the imprint of the orbital cycles of eccentricity (~100 kyr and ~405 kyr) and a long-term amplitude modulation of either obliquity or eccentricity (1.2 Myr). A detected ~1.1 Myr periodicity is the most significant cycle, providing strong evidence for astronomically paced climate change in the eastern Tethys during the Albian. The band-pass filters of the ~1.1 Myr periodicity in MS and TOC display a close correspondence, suggesting that the productivity and/or preservation potential of organic matter was likely controlled by orbitally forced changes in terrigenous input. Increasing $\delta^{13}C$ values correspond to higher values of MS and TOC content and vice versa, indicating that the $\delta^{13}C$ values of the eastern Tethys during the Albian were influenced by the intensity of the terrigenous flux and the subsequent burial of organic matter paced by orbital change. This work implies that cyclic changes in carbon reservoirs in the low latitudes during the Albian were controlled by seasonal variations in terrigenous input driven by the influence of orbital cycles on regional hydrological processes.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-6: Astronomical forcing of Earth's paleoclimate and sedimentation systems
Presentation Preference: Oral Preferred

Orbital forcing of carbon sink and hydrologic cycle during the Middle Triassic greenhouse climate in China

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Keywords: Middle Triassic, Milankovitch Cycles, Grand Cycles, Tethys, organic-rich

Exploring the relationship between continental organic-rich deposits and orbital forcing of climate is critical for understanding the roles of orbital forcing played in the Triassic. The Middle Triassic Yanchang Formation (FM) serves as the major source rock in the Ordos Basin, the largest petroliferous basin in China, and provides a unique record for improving our understanding of continental paleoclimate and ecological system in the Triassic hothouse world. Here, three wells (F-75, D-81 and Y-1) of the Yanchang FM in the Ordo Basin are evaluated for paleoclimate change from astronomical forcing. We establish a high-resolution age framework for the Yanchang FM derived from integrated, high-precision U-Pb zircon geochronology using chemical abrasion-isotope dilution-thermal ionization mass spectrometry (CA-ID-TIMS) on interstratified ash beds and cyclostratigraphy based on centimeter-scale multiple proxies for paleoclimate, including magnetic susceptibility (MS), gamma-ray spectral (GRS), X-ray fluorescence (XRF). We procure insights into the dominants of redox cycles in the lacustrine organic-rich shales and detrital input cycles in the deltaic sediments by deciphering the imprint of astronomical cycles on multiple proxies for paleoclimate. The redox cycles in organic-rich shales are largely driven by monsoonal dynamics of Tethys on the bands of precession and eccentricity. The major organic-forming intervals of the Yanchang FM, Zhangjiatan Shale and Lijiapan Shale, spanned ca. 241.1–240.9 Ma and 244.4–243.6 Ma, respectively, which coincided with the periodic humid intervals during the Middle Triassic. These periodic events are compared with Middle Triassic records of global sea level, temperature, biotic evolution and biogenic silica (BSi) flux suggests that the long-eccentricity (~3.3 Ma) forcing was involved in the repeated climatic and biotic upheavals that took place throughout the Middle Triassic. Moreover, the regional lake-level changes inferred from sequence stratigraphy and sedimentary noise modelling are anti-phased with the contemporaneous global sea-level changes. This supports the hypothesis that long-obliquity (~1.2 Ma) astronomically forced water mass exchange between land and ocean reservoirs during the Middle Triassic.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-6: Astronomical forcing of Earth's paleoclimate and sedimentation systems
Presentation Preference: Oral Preferred

Downhole logging data properties and its suitability for application of cyclostratigraphy and time series analysis

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Keywords: downhole logging, cyclostratigraphy, time series analysis

Extensive borehole logging datasets have been gathered for commercial and scientific purposes, but studies exploring their potential through applying time series analysis remain sparse. Typically, fast available logging data are relatively complete and may contain valuable paleoenvironmental information related to orbital forcing. There is, however, complexity in cyclostratigraphy and time series analyses being the reason why scientists often avoid these valuable tools. Here, we summarize the most relevant properties of borehole logging data and pitfalls in the context of time series analysis and cyclostratigraphy. In comparison to interpretation of data from core- or outcrop analysis, it is important to be aware of potential issues such as the effect of variation in borehole diameter and the influences of drilling fluids, and that presented logs may consist of merged results logged in several depth sections.

Session T1-8: Astronomically forced climate warming events and hydrocarbon generation

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-8: Astronomically forced climate warming events and hydrocarbon generation
Presentation Preference: Oral Preferred

Terrestrial sedimentary responses to astronomically forced climate changes during the Early Eocene in the Jianghan Basin, China

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Keywords: Terrestrial basin, Cyclostratigraphy, Early Eocene Climatic Optimum (EECO), Astronomical forcing

The Eocene is a transitional period from bipolar ice-free conditions (greenhouse climate) to bipolar ice sheets (icehouse climate), representing an important period in the Earth's history. It is enigmatic and interesting due to critical thermal events that occurred during the global cooling, such as the Early Eocene Climatic Optimum (EECO) and the Middle Eocene Climatic Optimum (MECO), which have been documented in the marine sediments but are still rarely reported in terrestrial basins. A continuous terrestrial succession of the Eocene Xingouzui Formation in the Jianghan Basin was investigated to understand the terrestrial sedimentary responses to astronomically forced climate changes, especially the Early Eocene Climatic Optimum (EECO). In this work, high-resolution gamma-ray (GR) logs were utilized for the cyclostratigraphy analysis of the Xingouzui Formation. Time series analysis reveals evidence for 405-kyr eccentricity cycles in the GR series, which is supported by statistical modeling of optimal sedimentation rates. An astronomical time scale (ATS) is constructed by tuning the GR data to this 405-kyr eccentricity cycle. This accurate timescale is critical for understanding the processes controlling organic carbon burial as well as paleoclimatic and paleoenvironmental background conditions. The results show that the terrestrial paleoclimate record is consistent with a time frame based on marine records, and highlights the major role of the EECO event in shaping East Asian paleoenvironments. A carbonate and evaporite mineral-rich interval developed in the Xingouzui Formation is closely associated with the EECO recorded in the deep-sea oxygen isotopes record, which is a continental record during warming. We further discuss the role of astronomically forced climate changes in controlling the depositional processes of lacustrine fine-grained sedimentary rocks during the EECO event. The results indicate strong astronomical forcing of the cyclic variations in organic matter abundance, mineral content, and lithofacies. The alternating cycle of dry/wet climate in the Early Eocene in the Jianghan Basin is driven by the eccentricity cycles. The Xingouzui Formation is the main target layer of shale oil exploration in the Jianghan Basin; therefore, our study is conducive to the comprehensive prediction of favorable shale oil layers.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-8: Astronomically forced climate warming events and hydrocarbon generation
Presentation Preference: Oral Preferred

Mesoproterozoic earth orbital period and the evolution of the earth-moon system

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Keywords: earth orbit parameters, Mesoproterozoic strata, Milankovitch signal, North China

The periodic variation of earth orbit parameters results in a multi-scale rhythm of sediment by controlling the surface climate and sea level changes. The identification of sediment cycle period can also be used to calculate the orbital parameters of geological history and to establish astronomical chronology scales with a resolution of 100,000 or even 10,000 years. There is relatively good tronomical time tuning for the Cenozoic strata and Mesozoic strata (Hinnov, 2018), while there are not so much evidences for Paleozoic studies, even scarce for Precambrian. North China holds the most continuous Mesoproterozoic strata (Wang et al., 2017). The deposition time from Changchanggou Formation to Xiamaling Formation is 1.65~1.35 billion year in the Yanliao Basin, and the stratum has good rhythmic characteristics, covering nearly 8000m, providing an excellent case for the study of Mesoproterozoic astronomical chronology. The periodic astronomical cycle of Milankovitch signal of eccentricity, obliquity and precession is identified from the studies of Hongshuizhuang, Tieling and Xiamaling formation, confirming the earliest Milankovitch cycle and its controlling on the climate changes. The long eccentricity is 405kyr, short eccentricity is 128kyr, obliquity and precession is 28kyr and 14kyr by the spectral analysis of magnetic susceptibility, greyscale data, Cu/Al, Si, Zi/Al, and Ti/Al for Xiamaling Formation sedimentation, recording all of the major periods expected from the orbital forcing of solar insolation on Earth like today and much of the Phanerozoic Eon (Zhang et al., 2015). The Tieling formation records the same long eccentricity of 405kyr, eccentricity from 86~130kyr, and the obliquity of 22.5kyr (Lyu et al., 2021), and Hongshuizhuang formation holds a same long and short eccentricity, obliquity of 20-28.5kyr and precession of 14-16kyr (Cheng et al., 2020). Meyers and Malinverno (2018) got dominant climatic precession cycles of 14 kyr and eccentricity cycles of 131 kyr by using a Bayesian inversion approach to quantitatively link astronomical theory with Xiamaling geologic data, almost similar with data of Zhang et al (2015). So the short eccentricity is short than the modern of 100kyr, and the obliquity and precession obtained from the Mesoproterozoic were obviously smaller than modern of 42 kyr and 23 kyr, which might reflect the closer distance between the earth and the moon and the shorter daytime (Meyers and Malinverno, 2018). Anyway, the Mesoproterozoic climate changes cause the same organic matter burial heterogeneity with Phanerozoic by affecting seawater circulation, seasonal/trade wind intensity and terrigenous input. The discovery of the earth orbit parameters from the North China provide critical constraints for further modifying astronomical solutions for the early Earth and restoring the length of the daytime, and changes the idea of 21-hour resonance in atmospheric thermal tidal forcing during 18-8Ga (Bartlett and Stevenson,2016).

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-8: Astronomically forced climate warming events and hydrocarbon generation
Presentation Preference: Oral Preferred

Astronomically forced warming events and organic carbon burial

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Keywords: astronomical, warming events, organic carbon burial, climate changes

Stratigraphic records are essential for deciphering past climate variability and understanding causality of climate events in Earth history. Some geological records during warming events such as the ocean anoxic events (OAEs), Early Eocene Climatic Optimum (EECO), and Middle Eocene Climate Optimum (MECO) reveal a close relationship between increased surface temperatures and enhanced organic carbon burial in sedimentary basins driven at orbital eccentricity time scales. There are some evidences reveal that the organic carbon burial occurred at the minima of the 405 kyr and ~2.4 Myr long eccentricity cycles and ~1.2 Myr long obliquity cycle with global cooling and decline of atmospheric CO2. However, how the orbitally forced climate changes and driven the carbon cycle variations and what is the mechanisms of the organic carbon burial and source rock formation that remain poorly understood. Here, we present an example of EECO and MECO events recorded at North China oil-bearing basins that reveal the relationship between the astronomically forced climate changes and source rock formation, feedback of carbon cycle on climate changes.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-8: Astronomically forced climate warming events and hydrocarbon generation
Presentation Preference: Oral Preferred

Multi-scale orbitally and sub-orbitally driven climatic and environmental contributions to source rock formation across the Cenomanian and Turonian, Texas, USA.

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Keywords: Cenomanian, Eagle Ford, source rocks

Modelling source rock petroleum potential requires an understanding of organic matter content, type and geographic extent. These parameters are generally constrained by abundant well and core data in heavily explored and developed basins. However, in frontier basins with sparse data, or in the search of source rock sweet spots in unconventional tight oil and gas plays, prediction of source rock character and extent away from data points is critical. To predict multi-scaled vertical and horizontal source rock heterogeneities (deci-meter to micro-meter) away from well control, we need to understand the impact of the primary forcing mechanisms for source rock formation and preservation.

We present an integrated multidisciplinary study from a continuously cored section of the entire Eagle Ford Group (Boquillas Formation) from the Shell Iona-1 and other research boreholes and surface sections (Texas, USA). The Eagle Ford Group is a prolific source rock along the US Gulf Coast and Gulf of Mexico and was deposited during the Cenomanian to Turonian Stages of the Late Cretaceous, a Greenhouse Climate state period characterized by extreme warmth. The sedimentary succession is characterized by sub-meter scale limestone–marlstone couplets which preserve unambiguous primary environmental signals. Integrated sedimentological, paleobiological and geochemical analyses support greater water-mass ventilation and current activity promoting increased silica/carbonate productivity during the deposition of limestone beds compared to deposition of marlstone beds which reflect greater organic matter productivity and preservation. Astrochronological analysis indicates that these environmental variations occur on multiple orbital timescales. In particular, we propose that obliquity and precession forcing on the latitudinal distribution of solar insolation are consistent with the observed lithological and environmental variations in this mid-latitude epicontinental sea setting. We also present a conceptual model that illustrates the geographic variation in orbital expression on sedimentary successions and associated impact on organic matter type and quality prediction.

As part of the multi-scaled understanding of source rock deposition, we also analyzed exceptionally well-preserved, millimeter-scale laminations from the organic-rich marlstone beds of the lower Eagle Ford. Sedimentological, geochemical, and micropaleontological data indicate that individual pairs of light-dark laminae record alternations in the extent of water-column mixing and oxygenation with sub-orbital periodicities (80–100 yr, 200–230 yr, 350–500 yr, 1650 yr, 4843 yr and 10,784 yr periodicities). The centennial to millennial variations are reminiscent of those found in Holocene total solar irradiance variability, and the 10,784 yr anoxia cycle may be a manifestation of semi-precession-influenced Tethyan oxygen minimum zone waters entering the seaway.

This multi-scaled integrated approach highlights the impact of astronomically forced global and regional climate change on source rock formation and preservation and guides a quantitative approach to modelling petroleum potential and hydrocarbon generation across orbital timescales.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-8: Astronomically forced climate warming events and hydrocarbon generation
Presentation Preference: Oral Preferred

Paleoenvironmental Trends, Cycles and Events at the Onset of Cretaceous Oceanic Anoxic Event 2 Recorded at Demerara Rise, Equatorial Atlantic Ocean

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Keywords: Ocean oxygenation, organic-rich laminated black shale, source rock, XRF core scan, photolog, Cenomanian-Turonian boundary

Oceanic Anoxic Event 2 (OAE2) that took place across the Cenomanian-Turonian transition (~94 Ma) is marked by high rates of carbon burial in the oceans and a positive marine carbon isotope excursion, and has been associated with Large Igneous Province volcanism, super-greenhouse conditions, and widespread oceanic anoxia. To investigate paleoenvironmental conditions at the onset of OAE2, high-resolution XRF and color line core scanning was undertaken on the OAE2 black shales from ODP Site 1261, Demerara Rise, western equatorial Atlantic Ocean. Analysis of a composite grayscale scan of the original Site 1261 core photographs detected Milankovitch cycles throughout the OAE2 interval, indicating an average accumulation rate of 1.071 cm/kyr. Eight elements, Ca, S, Si, Fe, K, Ti, Al, and P were scanned at 100-micron resolution (but are stratigraphically smoothed due to the 200-micron wide XRF aperture), and color attributes R, B, G, a*, b*, and l* were logged at 70-micron resolution. A thin volcanic ash marks the start of the carbon isotope excursion and onset of OAE2. The elements are related to detrital influx, primary productivity, nutrient supply and redox conditions (anoxia/euxinia), and reveal strongly changing relationships with the onset of OAE2. The color line scans corroborate XRF elemental cm-scale variations, and with their higher resolution capture significant sub-mm-scale variability, bringing very high-frequency (decadal-centennial scale) paleoenvironmental dynamics of the OAE2 western Atlantic margin into sharp focus. These deposits are a major source rock for recently discovered reservoirs in offshore Guyana and Suriname.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-8: Astronomically forced climate warming events and hydrocarbon generation
Presentation Preference: Oral Preferred

Climatic variability during the Late Devonian Kellwasser Crisis on astronomical and millennial timescales

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Keywords: Late Devonian, Kellwasser Crisis, astronomical forcing, anoxic black shales, Rhenish Massif, XRF

The Late Devonian (ca. 379–359 Ma) was characterised by a series of widespread marine anoxic events, documented in the rock record by black shales and limestones. The greatest of these, the Kellwasser Crisis at the Frasnian-Famennian boundary, was associated with one of the "Big five" Phanerozoic mass extinctions. Despite decades of research, it remains controversial what triggered the Kellwasser Crisis and why the Late Devonian ocean was particularly sensitive to widespread anoxia. De Vleeschouwer et al. (2017) hypothesised that the exact timing of tipping the Devonian system into oceanic anoxia could have been related to a particular sequence of astronomical forcing configurations. First, a long-term eccentricity minimum (or "node") creates relatively stable climate conditions for several tens of thousands of years, during which thick continental regoliths are formed. Then, a rapid increase in eccentricity intensifies climate variability and triggers the release of nutrients from the continents into the oceans. To test this hypothesis, we have generated high-resolution elemental records of the Winsenberg roadcut (eastern Rhenish Massif, Germany), employing a number of different X-Ray Fluoresence (XRF) methods. The Winsenberg section is 12 m thick and reflects a deeper outer shelf environment just southeast of the Brilon Reef Complex. It features well-expressed Lower and Upper Kellwasser black shales/limestones (LKW and UKW) that are 150 and 80 cm thick, respectively. While rhythmically bedded carbonates crop out in between the two Kellwasser intervals, the 72-cm thick Usseln Limestone occurs directly below the LKW. This limestone bed contains strongly-expressed cm-scale rhythmical variations in carbonate content and can be traced through much of the Rhenish Massif (Gereke, 2007). Lithologic cyclicity is smaller in scale but also more evident in the Usseln Limestone, compared to the stratigraphic interval in between the two Kellwasser shales. This distinction dictates a difference in XRF analytical approach: while the interval between the LKW and UKW was analysed at a cm-scale using a portable XRF analyser, the Usseln Limestone was XRF-imaged at mm-scale resolution using µXRF elemental mapping. These combined methods allow for a detailed investigation of Winsenberg's environmental response throughout the Kellwasser Crisis, on both astronomical and millennial timescales. On astronomical timescales, the stable 405-kyr eccentricity 'metronome' cycle defines an astrochronological framework that is largely in line with other globally-distributed astrochronologies. The Winsenberg floating chronology will form the basis for testing the eccentricity minimum hypothesis, which is a work in progress. The µXRF images of the Usseln Limestone are combined with petrographic thin-section analysis to show that diagenetic processes did not superimpose the primary rhythm of millennial-scale climate variability. Our results indicate that the Late Devonian Earth system was highly variable on short timescales immediately prior to the Kellwasser Crisis, and the Usseln Limestone provides a unique sedimentary archive to analyse the imprint of these rapid climatic fluctuations in the rock record.

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Session T1-9: The Mesozoic-Paleogene hyperthermal events (IGCP739)

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-9: The Mesozoic-Paleogene hyperthermal events (IGCP739)
Presentation Preference: Oral Preferred

Milankovitch cycles to detect the relation between the abundance of nummulites and the Middle Eocene peak warming: Cyclostratigraphy of the carbonate oil reservoir, Siouf member, in central Tunisia

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Keywords: Astrochronology, Petroleum geology, δ13C and δ18O isotopes, Parasequences, Integrated stratigraphy, Paleoclimate change.

The middle Eocene witnessed several episodes of rapid warming, leading to changes in the sedimentary facies and microfossils content. These changes culminated during the Middle Eocene Climatic Optimum (MECO), an episode of global warming that led to the widespread deposition of nummulitic limestone of the Reneiche / Siouf member (Mb.) in central and NE Tunisia. The Siouf Mb. is a lateral equivalent to the Reneiche Mb., both are the leading oil reservoirs in central Tunisia, Kerkennah, and the Gulf of Gabes. This early Bartonian nummulitic limestone member has yielded exceedingly well-developed oil reservoir proprieties. However, the potential links between the occurrences of these exceptionally developed nummulites and the MECO remain poorly investigated. We have used a multi-proxy approach (Sedimentology, biostratigraphy, stable isotopes, and cyclostratigraphy) to place our findings in a well-defined temporal context. We constrain the factors that led to the fast change toward a short-lived nummulitic limestone shelf. The MECO interval is unambiguously identified here at the Reneiche / Siouf Mb. by the biostratigraphic age (lower SBZ17 and E12) and a 3‰ negative δ18O excursion in the shallow-water carbonate platform.
We interpret the coincidence between the MECO and the Reneiche/Siouf Mb. as an indication for a link between the re-appearance of nummulites and the intense warming event. Nummulites appear in low abundance during the Lower Reneiche Limestone unit (LRL, Bey et al., 2015) from 40.52 to 40.18 Ma, then show transient increase reaching maximum abundance at the Upper Reneiche Limestone unit (URL, 40.11 to 40 Ma). Our data show that the abundance peak of nummulites and the negative values of δ18O in the URL post-dated the Middle Eocene third-order maximum flooding surface by 350 kyr, took place during the MECO peak warming from 40.07 to 40 Ma. Our results indicate that the development of the nummulitic limestone oil reservoir is directly related to the onset of the MECO warming event rather than to the sea level. Mesotrophic environment and arid to semi-arid climate during the MECO with a correspondingly high eustatic sea level favored the deposition of the Siouf / Reineche Mb. in central and NE Tunisia from 40.54 Ma to 39.8 Ma.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-9: The Mesozoic-Paleogene hyperthermal events (IGCP739)
Presentation Preference: Oral Preferred

The Helmstedt Lignite Mining District in Northern Germany – An important archive for the Paleogene greenhouse

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Keywords: Eocene, PETM, EECO, palynology, carbon isotopes, thermal event

Long-term effects of present global warming on ecosystems on timescales beyond those covered by the human record are mostly a matter of speculation. However, the reaction of ecosystems to global warming on different timescales can be inferred from detailed studies of long-term greenhouse periods and short-term warming events repeatedly known from the geologic past. The Early Eocene Climatic Optimum (EECO) and its superposed short-term warming events such as the Paleocene-Eocene Thermal Maximum (PETM) represent the last greenhouse period before today. It is especially suited for comparisons to the presently developing greenhouse since fauna and flora already reached an evolutionary state similar to today.

The Paleogene succession of the former Helmstedt Lignite Mining District in northern Germany is situated in an estuary at the southern edge of the proto-North Sea. It includes the late Paleocene to lower Eocene Schöningen Formation and the middle Eocene Helmstedt Formation, thus uniquely covering the entire Paleogene greenhouse phase and its gentle demise. Due to the interaction between changes in sea level, salt withdrawal in the subsurface and climate-related changes in runoff from the hinterland the area was subject to frequent changes between marine and terrestrial conditions, repeatedly leading to peat formation. The more than 200 m thick succession with about 13 lignite seams of up to 15 m thickness offers the rare opportunity to study late Paleocene–middle Eocene near-coastal sedimentary systems and to trace the long-term changes and short-term perturbations of the climate on the diversity and composition of plant communities across 10 million years by using pollen and spores as proxies. Changes in vegetation concur with strong differences in petrologic composition of the lignite seams between the two formations, especially with regard to charcoal content. In the Schöningen Formation fusain layers and dispersed fusain are common whereas the lignites of the Helmstedt Formation are nearly devoid of fusain. In both formations the lignite seams are separated by more or less marine interbeds in the lower part while they are associated mainly with fluvial sediments in the upper part.

Bulk organic carbon isotopic data from the Schöningen Formation show different negative carbon isotope excursions reflecting massive short-term carbon cycle perturbations, which can be related to long- and short-term hyperthermals of the early Eocene such as the EECO and the PETM. Palynological analysis proved that shifts in $\delta^{13}C_{TOC}$ values are correlated with changes in the peat forming wetland vegetation. Rapidly changing palynofloras at the PETM may be attributed to the thermal event. However, also during times outside hyperthermals strong changes in the palynofloras occur, which may be related to changing hydrologic conditions, nutrient resources and effects of peat aggradation that influenced the mire forest.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-9: The Mesozoic-Paleogene hyperthermal events (IGCP739)
Presentation Preference: Oral Preferred

Nitrogen cycle perturbations linked to chemocline collapse during the Jenkyns Event (early Toarcian OAE)

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Keywords: Stable isotope, Nitrogen cycle, Chemocline, Black shale, Ordos Basin

Marine nitrogen cycle perturbations during the Jenkyns Event (Toarcian Oceanic Anoxic Event, ~183 Ma) have been documented by nitrogen isotope ($\delta^{15}N$) signals. These signals emphasize the impact of seawater redox changes on the biogeochemical nitrogen cycle. However, to date there have been no studies on the lacustrine nitrogen cycle during the Jenkyns Event. In this study, we report the first $\delta^{15}N_{bulk}$ data from the Anya section of the Ordos Basin, North China and establish a model of the lacustrine nitrogen cycle through the Jenkyns Event. Based on the co-variation of $\delta^{15}N_{bulk}$ values with independent proxies for redox change (C_{org}/P ratios and $\delta^{34}S_{py}$) from this study and previous work, three phases of Anya deposition are identified: (1) Prior to, and during the early part of the Jenkyns Event, a positive excursion in $\delta^{15}N_{bulk}$ values (~+3.9 to +7.4‰) across a black shale interval occurred. This positive excursion indicates that nitrogen loss (via partial denitrification and/or anammox) was dominant. (2) A negative excursion in $\delta^{15}N_{bulk}$ (~+7.4 to +2.5‰) correlates with a negative $\delta^{13}C_{org}$ excursion that demarcates the main phase of the Jenkyns Event. This negative excursion can be attributed to the predominance of nitrogen fixation (nitrification and nitrate assimilation) within oxygen-rich water, where chemocline collapse promoted upwelling of ^{15}N-enriched ammonium. However, ^{15}N-enriched ammonium is more likely to be oxidized in oxygen-rich water and then incorporated into the pool of dissolved inorganic nitrogen (DIN). Additionally, an increased input of land plants (Type III kerogen) and a change in the hypolimnion's redox conditions (anoxic to dysoxic-oxic) suggest that chemocline collapse was most likely related to an enhanced hydrological cycle during the Jenkyns Event. (3) Following the chemocline collapse, a positive excursion in $\delta^{15}N_{bulk}$ (~+2.5 to +6.4‰) occurs in the later Jenkyns Event and its recovery phase, implying that nitrogen loss was once again prevalent. However, a dysoxic-oxic hypolimnion may have been formed as a result of lake level falls during lake regression, which may explain the subsequent stabilization of $\delta^{15}N_{bulk}$. This study suggests that chemocline collapse may play a significant role in the biogeochemical nitrogen cycle in lacustrine systems, and contributes to our understanding of the terrestrial response to the Jenkyns Event.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-9: The Mesozoic-Paleogene hyperthermal events (IGCP739)
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Clay Mineral Constrains on Global Continental Weathering During the Paleocene-Eocene Thermal Maximum

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Keywords: Paleocene-Eocene thermal maximum, Polecat Bench, smectite, paleoclimatology, continental weathering

The Paleocene-Eocene Thermal Maximum (PETM), ~ 56 million years ago, is a geologically short-term greenhouse gas-induced global warming event. The drawdown mechanisms and rates of the high CO_2 concentrations in the atmosphere-ocean system during the event remain enigmatic. Continental chemical weathering is thought to be an important process removing CO_2 from the atmosphere, although the rates of weathering and drawdown change remain unknown. World-wide, enhanced physical weathering is observed during the event, while evidence for enhanced chemical weathering remains scarce. Here, we test chemical weathering and physical weathering changes in the PETM interval in a proximal continental setting using high-resolution clay mineralogy measurements in floodplain strata. The records from the Bighorn basin, Wyoming, a Laramide foreland basin, reveal a 30-kyr lagged increase of smectites during the body of the PETM that is prolonged for at least 50-kyr after the event. Altogether, this increase can only be explained as the result of an increase of physical weathering and erosion of smectite-rich Cretaceous bentonites in the catchments. The lagged response after the PETM onset most likely relates to the time it takes before the signal fully propagates through the catchments and upstream, basinal channel and floodplain sediments.

We observe significant grain-size sorting smectites with smectites enriched in coarse-grained sediments. However, sedimentation rates and average grain sizes remain similar in the PETM. Therefore, the smectite increase cannot be explained by grain size sorting. In-situ pedogenesis after deposition at the study site was insignificantly different in the PETM from pre-PETM soils, also not being able to explain the observed trends.

Global warming during the PETM could have generated enhanced climate seasonality with contrasting precipitation regimes during the different seasons. This may have led to drier summers causing lower vegetation covers reducing cohesiveness of catchment laterites and basinal soils. More frequent rainstorms then likely intensified the denudation of smectite-rich sediments, which at the same enhanced sediment recycling within the source-to-sink system. The prolonged nature of the smectite enhanced after the PETM event may again relate to post-PETM signal propagation times, which are even lower than after the onset of the PETM due to lower recycling rates after the event. Our result suggest that chemical weathering rates are not significantly altered during transient hyperthermal events of less than 200 kyr or are overruled by physical weathering and erosion changes. Our data therefore suggest that chemical weathering changes might not play as a strong additional role as negative feedback mechanism to reduce greenhouse-gas warming.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-9: The Mesozoic-Paleogene hyperthermal events (IGCP739)
Presentation Preference: Oral Preferred

Complex environmental perturbations related to the early Aptian OAE 1a – insights from a pelagic succession from the western Tethys (Subbetic Zone, SE Spain)

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Keywords: Early Aptian Oceanic Anoxic Event, Subbetic basin, accelerated environmental changes, inorganic and organic proxies, local palaeogeography, global anoxic conditions

The early Aptian Oceanic Anoxic Event (OAE 1a) represents a major perturbation in the global carbon cycle associated with a light-carbon input into the climate system, from volcanogenic (Ontong-Java Plateau) and/or methanogenic sources, originating significant environmental, biotic and sedimentary changes. The global signature of this event is a negative followed by a positive carbon stable isotope excursion (CIE), which correlates with the widespread massive accumulation of organic matter in all major ocean basins. Besides the global environmental perturbation that characterizes the OAE 1a, local factors are a key aspect to take into account when discussing the global signals on marine successions. Here, we combine new biomarker and elemental data with published high-resolution C-isotope stratigraphy, TOC content and biostratigraphy from an early Aptian pelagic succession in the western Tethys, La Frontera section (Subbetic basin, SE Spain), in order to provide new insights into the relative roles of variations in terrestrial inputs, primary productivity and degree of oxygenation of marine waters during and after the OAE 1a. This section is further compared with a published equivalent record from a nearby succession deposited on a slightly different palaeogeographic context (Carbonero section), in order to discuss the local vs. global controls on the geochemical signal.

In La Frontera section, analyses of the distribution of selected biomarkers (n-alkanes, acyclic isoprenoids, steranes and hopanes) together with the record of redox-sensitive trace elements, has revealed three intervals of accelerated environmental change that correlate with those previously observed in the Carbonero section. These episodes occurred during intervals of rapid change in the C-isotope values. In La Frontera section, the first episode, which coincides with the negative C-isotope excursion at the onset of the OAE 1a (isotope segment C3), is characterized by a weak deoxygenation and environmental stress. The second episode, which took place at the end of the positive shift globally assigned to the C4 segment, represents the major environmental and biotic perturbation of the succession, with development of anoxia/dysoxia and increased continental inputs and productivity. The third interval of rapid perturbations during the OAE 1a occurred in the lower part of C6 segment, in this case showing a moderate increase in marine productivity, weak development of anoxia/dysoxia and no evidences of increased continental inputs. Despite the correlation of these episodes with those observed in the Carbonero section, interesting differences can be noticed regarding the magnitude of these perturbations. At Carbonero, the three intervals have similar intensity in the geochemical signal, whereas at La Frontera the second episode (C4) shows a signal clearly stronger than the others. These differences can be explained by the effect of the local palaeogeography, with variations in subsidence rates that originated more restricted water circulation at the Carbonero section. However, the major episode of accelerated environmental change recorded at the end of C4 segment in both sites would indicate that this interval represents intensified global anoxic conditions. Interestingly, organic and inorganic proxies in both localities show that environmental perturbations persisted after the OAE 1a, indicating a protracted environmental perturbation in the Subbetic basin.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-9: The Mesozoic-Paleogene hyperthermal events (IGCP739)
Presentation Preference: Oral Preferred

Glauconite authigenesis during the warm climatic events of Paleogene: Case studies from shallow marine sections of Western India

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Keywords: Paleogene, hyperthermal events, glauconite, oxygen-depleted shelf, rectilinear benthic foraminifera, transgressive deposits

This study explores authigenic mineralization associated with Paleogene warm climatic intervals within passive continental margin sediments in western India, represented by continental to marginal marine to shallow open marine sedimentary packages. These sedimentary packages are punctuated by -cm to -m thick glauconitic shale units, ubiquitous in transgressive shallow marine deposits of Cambay, Kutch, Jaisalmer, and Barmer basins. The Paleogene sediments, having extremely precise biostratigraphic age constraints, represents one of the warmest periods in the Cenozoic era. High-resolution biostratigraphic data, integrated with carbon isotope signatures, demarcate the Paleogene hyperthermal events and reveal an exceptionally high abundance of glauconite corresponding to the warming events. Although most of these glauconites are confined within the upper Paleocene-lower Eocene sediments, glauconite deposits also occur within the middle Eocene and upper Oligocene sediments. In all of these basins, glauconitic shales alternate with limestone/marl and/or grey shale unit representing an open shallow marine depositional setting. Green shale shows fine silt to fine sand-sized glauconite pellets, associated with glauconite infillings within the pores of bioclasts, randomly dispersed in a clayey matrix. The geochemical composition of glauconite varies widely, encompassing the entire maturity spectrum of glauconite minerals. The K_2O content of the glauconite pellets varies from 4 to 8 wt%, while the infillings variety is invariably poorer in K_2O. The glauconites within the upper Paleocene-lower Eocene sediments manifest high Al_2O_3 content (> 10 wt%) while the glauconites within the middle Eocene and lower Oligocene show considerably low Al_2O_3 (< 8 wt%). Despite the highly variable maturity and the Al_2O_3 content, these glauconites are rich in Fe_2O_3(total), exceeding 20 wt% in most of the cases. The glauconitic shales show minor bioturbation and are rich in rectilinear benthic foraminifera, indicative of the oxygen-depleted bottom-water conditions. The unusual composition of upper Paleocene-lower Eocene glauconites relates to their formation within kaolinite substrates during the extremely warm climatic interval. Contrary to this, during the middle Eocene and Late Oligocene, the waning phase of Paleogene warm climatic conditions, glauconite formed by the initial authigenic precipitation of Fe-smectite/ Fe-Al-smectite and its subsequent maturation. The warm climatic condition enhanced the precipitation and runoff, which supplied enhanced nutrients including K, Fe, Al, Si, and Mg into the shallow marine environment, facilitating prolific organic growth and enriching the seawater with cations. The decomposition of organic matter might have resulted in an oxygen-depleted bottom water condition, which was suitable for the mobility and fixation of iron into the glauconite structure. The glauconite formed abundantly during hyperthermal events because of the convergence of favorable factors such as rapid transgression, reduced sedimentation rate, warm seawater condition, enhanced continental weathering, and enhanced supply of nutrients favoring dysoxic shallow shelves.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-9: The Mesozoic-Paleogene hyperthermal events (IGCP739)
Presentation Preference: Oral Preferred

Increased river discharge across the PETM recorded in coastal-plain strata of southern Kazakhstan

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Keywords: PETM, Central Asia, fluvial style, braided, meandering

The lower Paleogene sedimentary record of the uraniferous Chu-Sarysu Basin preserves a complex succession of coarse fluvial channel-belt deposits interstratified with finer floodplain and delta-plain strata that were deposited on a large subtropical coastal plain at the eastern margin of the Turan Platform. Two laterally extensive, ~25 m-thick sandstone bodies floored by prominent erosion surfaces are recorded below and above the Paleocene–Eocene boundary, respectively, and reflect laterally amalgamated channel fills partitioned by local abandonment mudstone facies. Sedimentary analysis indicates that sandstone bodies consist of multi-storey channel fills exhibiting a variety of architectural elements. The lower sandstone body comprises fining-upward grain-size trends and an abundance of rippled, organic-rich levee deposits characteristic of meandering-channel fills. In contrast, the upper sandstone body is dominated by stacked tabular cross-sets of coarser lithologies suggestive of braided-river deposits. This abrupt geomorphic change from meandering to braided fluvial style suggests a widespread increase in river discharge on the coastal plain arguably controlled by allogenic forcing. Base-level changes linked to a fluctuating water table are unlikely during greenhouse conditions of the early Paleogene, whereas the south Kazakh domain of the Turan Platform had been peneplained and uniformly subsiding since the Late Cretaceous. It is herein proposed that Paleocene–Eocene fluvial systems in the Chu-Sarysu Basin predominantly responded to intensified rainfall and runoff associated with extreme global warming. This study comes within a growing body of sedimentological evidence indicating that the PETM induced increased atmospheric humidity and an enhanced hydrological cycle. These rapid climatic changes led to increased channel-discharge regimes and sediment fluxes that are reflected in coeval sedimentary records worldwide and, for the first time, showcased in coastal-plain deposits of central Asia.

This dataset was collected within the framework of a reservoir and Uranium mineralisation modelling study on Paleogene deposits of the Chu-Sarysu Basin, logistically and financially supported by KATCO JV LLP.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-9: The Mesozoic-Paleogene hyperthermal events (IGCP739)
Presentation Preference: Oral Preferred

Cretaceous Oceanic Anoxic Events in Turkey: Collaboration of oceanic, climatic and tectonic changes

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Keywords: Cretaceous OAE, Black Shales, Pontides, Taurides, Arabian Platform, Turkey

Occurrences of black shale deposits in Mid-Barremian, Aptian, Cenomanian/Turonian stages in different basins in Turkey are recorded as Cretaceous oceanic anoxic events. The Mid-Barremian black shales (MBE) have been recorded within turbidite succession in deep marine setting in central Sakarya zone of Pontides (Yilmaz et al., 2012). 2 ‰ shifts in carbon isotope curve is recorded in parallel with European basins, but with low TOC value. The Aptian black shales (OAE1a) are recorded in pelagic carbonate slope environments in central Sakarya zone of Pontides and represented by a negative carbon isotope shift with 2 ‰, and TOC around 2% (Yilmaz et al, 2004; Hu et al, 2012). In Sakarya zone of Pontides, OAE2 is recorded in pelagic slope carbonates (Yilmaz et al, 2010) with carbon isotope curve more than 1 ‰ positive shift and >2 % TOC. Another OAE2 was recorded in Antalya Nappes of Taurides without carbon isotope curve but TOC >20% (Yurtsever et al. 2003, Bozcu et al. 2011).

Platform equivalents of OAE 2 have been recorded on the Arabian Platform carbonates in SE Turkey (Mulayim et al., 2019; 2020). In the north of Arabian Platform, there is a sudden change from upper Cenomanian shallow water platform carbonates to lower Turonian hemipelagic shales/clayey limestones with high organic carbon content. Stable isotope content of the transition is well recorded with change around +1,9 ‰, and the temperature difference is calculated around 2,2 °C (Yılmaz et al, 2020). Interesting point of the OAE 2 on Arabian Platform is to follow a drowning phase and covered by black shales in lower Turonian.

The OAE1a and OAE2 levels recorded in Turkey can easily be correlated with European examples and mainly controlled by sea level and tectonics in large-scale and climate and oceanographic changes in small-scale. The most extensive distribution of the OAE records in Turkey belong to OAE1a and OAE2, and display potential for source rocks for hydrocarbon exploration.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-9: The Mesozoic-Paleogene hyperthermal events (IGCP739)
Presentation Preference: Oral Preferred

A sulfur-isotope record of long-term oceanic anoxia in the Toarcian and possible protracted cease of gypsum deposition

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Keywords: Toarcian Oceanic Anoxic Event, Sulfur isotopes, Long-term anoxia, Stepwise deoxygenation, Tibetan Himalaya

The early Toarcian of the Early Jurassic saw a long-term positive carbon-isotope excursion (CIE) abruptly interrupted by a significant negative shift, associated with rapid global warming and an oceanic anoxic event (T-OAE, 183 Ma). However, the detailed processes and mechanisms behind ocean deoxygenation are unclear. Here, we present high-resolution carbonate-associated sulfate-sulfur isotope data (δ34SCAS), from the Tibetan Himalaya, spanning the Toarcian interval. The δ34SCAS record shows a large positive shift from ~+20‰ to ~+40‰ which persists to nearly the end of the Toarcian. This confirms that the oceans were spatially heterogeneous with respect to their sulfate-sulfur isotope composition and suggests major pyrite burial associated with widespread development of anoxic/euxinic bottom waters during the early Toarcian. Box modelling results and sedimentary evidence suggest that large amounts of pyrite burial likely occurred in the near-equatorial deep-sea floor of the Panthalassa/Tethys. Additionally, the high-resolution δ34S data presented here provide strong evidence for two major phases of the early Toarcian ocean deoxygenation and this process was likely terminated around the end of the T-OAE nCIE. Box modelling also indicates that the persistent positive δ34S of seawater in the aftermath of the event was likely maintained by a long term downwards shift in the relative proportion of gypsum burial. This was likely driven by the forcing of seawater to below gypsum saturation point driven by a combination of massive evaporite burial of sulfate prior to the event and increased pyrite burial during it.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-9: The Mesozoic-Paleogene hyperthermal events (IGCP739)
Presentation Preference: Oral Preferred

Mercury evidence for combustion of organic-rich sediments during the end-Triassic crisis

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Keywords: Mercury isotope, Jurassic, pelagic sediments, extinction

The sources of isotopically light carbon released during the end-Triassic mass extinction remain in debate. Here, we use mercury (Hg) concentrations and isotopes from a pelagic Triassic–Jurassic boundary section (Katsuyama, Japan) to track changes in Hg cycling. Because of its location in the central Panthalassa, far from terrigenous runoff, Hg enrichments at Katsuyama record atmospheric Hg deposition. These enrichments are characterized by negative mass independent fractionation (MIF) of odd Hg isotopes, providing evidence of their derivation from terrestrial organic-rich sediments ($\Delta^{199}Hg < 0‰$) rather than from deep-Earth volcanic gases ($\Delta^{199}Hg \sim 0‰$). Our data thus provide evidence that combustion of sedimentary organic matter by igneous intrusions and/or wildfires played a significant role in the environmental perturbations accompanying the event. This process has a modern analog in anthropogenic combustion of fossil fuels from crustal reservoirs.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-9: The Mesozoic-Paleogene hyperthermal events (IGCP739)
Presentation Preference: Oral Preferred

The first record of OAE2 and high resolution integrated stratigraphy of the Cenomonian-Turonian succession, Sulaiman Range, Pakistan

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Keywords: Pakistan, Cretaceous, calcareous nannoplankton, Goru Formation, OAE2, planktonic foraminifera

High-resolution planktonic foraminiferal and calcareous nannoplankton biostratigraphy is provided for the pelagic succession of the Goru Formation from Murree Brewery Section of the Sulaiman Range, Pakistan. The Goru Formation in the studied section spans over the Middle Albian (Biticinella breggiensis; CC8 Zone) to Late Turonian stages (Marginotruncana sigali; CC12 Zone). Lithologically, the Goru Formation is predominantly composed of the carbonate-rich mudstones and a 0.5m black shale interval representing OAE2 followed by red colored marl/limestones (potentially Cretaceous Oceanic Red Beds, CORBS). Biostratigraphically, The Cenomanian/Turonian (C/T) boundary is identified based on the First Appearance Datum (FAD) of calcareous nannoplankton Quadrum gartneri and the FAD of the planktic foraminifera Helvetoglobotruncana helvetica. The Carbon and oxygen isotopic analysis on the carbonate fraction is also presented. A prominent negative δ13C isotopic excursion of 6 ‰ occurs at the bottom of the black shale interval, this is followed by a positive isotopic excursion of 5.8‰ representing the Cenomanian-Turonian boundary (CTB) immediately above the black shale interval. A change to more negative δ18O values from the uppermost Cenomanian into the lowermost Turonian may be the result of warming. Similar to other Tethyan sections, the onset of the OAE2 predates the CTB in Murree Brewery Section as recorded in many European sections. A major turnover in the deep-dwelling planktonic foraminifera (Rotaliporas) occurred during the Cenomanian-Turonian boundary Interval. The single-keeled Rotaliporas was succeeded by the double-keeled Globotruncanids. Three dissolution resistant calcareous nannoplankton taxa are dominant i.e. Watznaueria barnesae, Eiffellithus turriseiffelii, Eprolithus floralis within the studied interval. High species richness and high abundance of the tropical species Watznaueria barnesae, suggest warm tropical waters. The two abundant species, tropical W. barnesae and cool water E. floralis alternate in abundance in the early and middle Turonian, suggesting changing climatic conditions.

Reference

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-9: The Mesozoic-Paleogene hyperthermal events (IGCP739)
Presentation Preference: Oral Preferred

Enhanced storm-induced turbiditic events during early Paleogene hyperthermals (Arabian continental margin, SW Iran)

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Keywords: Paleogene hyperthermal, Carbonate microfacies, Calciturbidite, Condensed glauco-phosphorite, SW Iran, Neo-Tethyan ocean

Early Paleogene hyperthermal episodes including the Paleocene-Eocene Thermal Maximum (PETM) have long been viewed as analogues of the Anthropocene global warming. Few studies, however, have analyzed the environmental consequences of such climatic anomalies in deep-water turbidite-rich successions. This integrated sedimentological, biostratigraphic, and stable-isotope study of the Paleogene Pabdeh Formation, deposited along the Arabian continental margin of southwestern Iran, allowed us to document the geological response of hyperthermal events in deep Neo-Tethyan Ocean. The late Thanetian event (Pre-Onset Excursion or long-term late Paleocene climatic perturbation), the Early Eocene Climate Optimum, and the Middle Eocene Thermal Maximum were successfully identified within the Pabdeh Formation. The PETM event could not be documented because the Paleocene/Eocene boundary corresponds to a prolonged non-depositional hiatus marked by a glauco-phosphorite interval. Based on high-resolution microfacies analysis, three different processes in a carbonate slope to basin-margin environment were distinguished including pelagic settling, upwelling-condensation-reworking, and storm-induced turbiditic deposition. Detailed sedimentological analysis revealed an anomalous abundance of storm-induced proximal to distal turbidites represented by packstones with deep-water and reworked shallow-water bioclasts occurring during the hyperthermal intervals. A close causal link between climate warming and tropical storms during the early Paleogene hyperthermal events is thus envisaged. As a principal mechanism, we propose that rapid warming in response to massive carbon release triggered pronounced sedimentological changes along low-latitude tropical margins, leading to generation of storm-induced calciturbidite and re-deposition in the deep sea during hothouse stages.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-9: The Mesozoic-Paleogene hyperthermal events (IGCP739)
Presentation Preference: Oral Preferred

Biogeochemical responses to global warming during the Paleocene-Eocene Thermal Maximum in the eastern Tethys

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Keywords: PETM, North Atlantic Igneous Province, eastern Tethys

The Paleocene-Eocene Thermal Maximum (PETM; 56 Ma) represents a rapid and sustained climate perturbation event that coincides with the emplacement of the North Atlantic Igneous Province (NAIP). Although proxies for chemical weathering, biological productivity, and oceanic deoxygenation are commonly used in the deep oceans, the role of the eastern Tethys, a subtropical shallow marine environment, in regulating the carbon cycle dynamics and climate feedbacks is poorly understood. Here we present geochemical data from the Tarim Basin, northwestern China to assess the environmental responses of the eastern Tethys to the PETM. An increase in chemical weathering proxies (chemical index of alteration, chemical index of weathering, modified chemical index of alteration, and plagioclase index of alteration) indicates enhanced terrestrial input shortly after the PETM onset, possibly due to an intensified chemical and physical weathering. The PETM onset is also characterized by an increase in Mo and V concentrations, indicating an expansion of oceanic anoxia. At the same time, primary productivity appears to increase abruptly, presumably due to an increased riverine flux of nutrients (Ni, Fe, and P) that stimulated marine productivity. The ecosystem stress imposed by elevated nutrient fluxes and anoxia expansion is likely amplified by simultaneously intensified chemical and physical weathering, highlighting the importance of integrating geochemical proxies in tracking the environmental responses to climate changes.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-9: The Mesozoic-Paleogene hyperthermal events (IGCP739)
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

New constraints on the PETM record in shallow-marine carbonates from the Adriatic Carbonate Platform, NE Italy

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Keywords: PETM, Mercury, shallow-water carbonates, Dinarides, NAIP

The Paleocene-Eocene Thermal Maximum (PETM; ~ 56 Ma) was an interval of extreme transient climate change, associated with global warming and a massive perturbation of the global carbon cycle (e.g., Zachos et al., 2003). This latter is testified by a sharp Negative Carbon Isotope Excursion (N-CIE) in the global marine and terrestrial $d^{13}C$ records, linked to the injection of large volumes of isotopically light carbon into the ocean-atmosphere system. The source of such ^{13}C-depleted carbon is still a matter of debate. The emplacement of the North Atlantic Igneous Province (NAIP) with the release of huge amounts of CO_2 is suspected to be one of the factors that may have caused such a relevant change in the composition of the atmosphere/ocean carbon reservoirs and the associated abrupt climate perturbation. Research is increasingly exploring mercury (Hg) anomalies as tracers of volcanism during the Paleocene-Eocene interval mostly in deep-water and subordinately in shallow-water settings (e.g., Tremblin et al., 2022 and references therein), arguing about their possible relationship to the NAIP emplacement and its impact on the PETM onset and duration.

The aim of this contribution is to present an integrated study of sedimentology, stratigraphy (bio and chemo), and geochemistry of the deposits belonging to the Adriatic Carbonate Platform cropping out in the Classical Karst area of Friuli Region (NE Italy), encompassing the PETM event. In particular, here we show paired new carbon- and oxygen-isotope data combined with Hg concentrations and TOC analyses from two shallow-water marine carbonate sections across the Paleocene-Eocene boundary.

The two investigated sections were deposited during the migration of the foreland basin related to the Dinaric orogeny and are today exposed in the Classical Karst area near Trieste (Italy) for about 50 and 300 meters, respectively, of Paleocene-Eocene platform carbonates evolving upward to hemipelagic marls and then to siliciclastic deposits. Vertical facies evolution of the carbonate platform indicates that an initial inner- to mid-ramp setting underwent a relative deepening and then was followed by multiple emersion episodes intercalated by proximal marine deposition (i.e., innermost to inner ramp environments). This latter was followed by a return to open marine facies which then persisted until the final drowning of the Adriatic platform that in our study area occurred in the late early Eocene.

Our results show in both sections a negative excursion in the carbon-isotope record that, associated with biostratigraphic data, can be correlated with the PETM N-CIE and is comparable to other coeval $d^{13}C$ records, both in shape and amplitude. These negative shifts are associated with anomalies in Hg concentration, strengthening the hypothesis that magmatism effectively occurred during this time interval, and its effects are also recorded in shallow-water deposits. These findings corroborate the hypothesis that vulcanism (the NAIP?) might have played a key role in climate change at the PETM.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-9: The Mesozoic-Paleogene hyperthermal events (IGCP739)
Presentation Preference: Oral Preferred

Evidence of Hg enrichment at the SPBE from Lower Jurassic continental succession of the Sichuan Basin, China

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Keywords: Hg enrichment, volcanism, pXRF, climate change,SPBE

In the Early Jurassic, there is a globally recognized perturbation of the carbon cycle occurred at the Sinemurian-Pliensbachian transition, named“Sinemurian-Pliensbachian Boundary Event” (SPBE, ~ 192.5 Ma). The SPBE is associated with environmental and climate perturbations such as increased runoff, changes in marine shallow water carbonate production, enhanced preservation of organic matter and dysoxic conditions in the oceans. Evidence mainly comes from the marine realm, while other sedimentary settings around the world has been less investigated. Recent works have highlighted the presence of a prominent negative perturbation of the $\delta^{13}C_{org}$ in Lower Jurassic lacustrine succession of the Sichuan Basin, which has been correlated to the SPBE (Franceschi et al., 2022). The causes of the SPBE are still unclear, but a potential link to late phases of volcanism of the Central Atlantic Magmatic Province has been hypothesized based on mercury (Hg) enrichments observed in Sinemurian – Pliensbachian marine successions of the Western Tethys (Shöllhorn et al., 2020). Studies have put forward the hypothesis of a warming trend in the lower Pliensbachian that may have culminated in short-lived hyperthermals (e.g. Silva et al., 2015). In this contribution, we present Hg and TOC content data from the Lower Jurassic lacustrine succession of the Sichuan Basin (Eastern Tethys) in the Dacao section where a high resolution $\delta^{13}C_{org}$ record is already available (Franceschi et al., 2022). Results highlight Hg enrichments coincident with the negative $\delta^{13}C_{org}$ shift that is interpreted as the SPBE. The relative low correlation with TOC data, suggests that Hg could be volcanogenic. This, together with the fact that the Hg enrichment at the Sinemurian-Pliensbachian transition is documented in the continental realm, strengthen the hypothesis of a global-scale link between the SPBE and volcanic activity. Preliminary results of elemental analysis carried out with pXRF further reveals enrichment trends in elements such those of the group of clay minerals that may be compatible with variations in runoff intensity caused by climate change to more humid conditions at the SPBE. Our results provide clues as to how climate changes associated with the SPBE may have been linked to volcanic activity and have had global extent.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-9: The Mesozoic-Paleogene hyperthermal events (IGCP739)
Presentation Preference: Oral Preferred

The Carnian Pluvial Episode in the western Sichuan Basin (South China)

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Keywords: CPE, Late Triassic, biostratigraphy, chemostratigraphy, Ma'antang Formation

The Carnian Pluvial Episode (CPE; early Late Triassic) was a global perturbation of the C-cycle associated with a marked enhancement of the hydrological cycle, and consequent increase terrigenous sediment and freshwater input to the shallow marine sedimentary environments. Within the CPE interval, negative shifts in the $\delta^{13}C$ of marine and terrestrial organic matter and marine carbonates testify to multiple injection of large amounts of CO_2 into the atmosphere – ocean system, likely linked to the emplacement of the Wrangellia Large Igneous Province. The CPE coincided with a crisis of shallow water carbonate production and with a major biological turnover both in the marine and terrestrial realms. The environmental effects of the CPE have been widely documented in the western Tethys, but much less data are available from other areas. In the last decade, the western Sichuan Basin (China) became a reference locality for the study of the effects of the CPE in the eastern Tethys. However, research has also given rise to debate on the bio-, magneto- and chemostratigraphy of the Carnian successions. To resolve the existing controversies on this key CPE study area, we review the current knowledge on biostratigraphy, petrology and geochemistry of the successions in the Sichuan Basin, and provides an updated bio- and chrono-stratigraphic framework. Furthermore, we highlight the open questions and outline future research directions about the CPE in the area.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-9: The Mesozoic-Paleogene hyperthermal events (IGCP739)
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Coeval changes of carbonate platform environment and carbon isotope at Permian-Triassic boundaries in South China and Lhasa block

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Keywords: Permian-Triassic boundary,Carbonate platform,Carbon isotope,Carbonate microfacies

The Permian-Triassic boundary (PTB) has experienced the largest biological extinction in the geological history, and there has been a significant global carbon isotope excursion, accompanied by the development of unconformity, anachronistic facies and Occurrence of hyperthermal event. However, there are absence of detailed studies in carbonate platform environment in response to the carbon isotopic excursion around the PTB. This study measured three carbonate platform sections throughout the PTB located on the South China (Liangfengya section near Chongqing, Taiping section in Guangxi) and Lhasa block (Wenbudangsang section near Gaize). High-precision carbonate microfacies and carbon apposition stratigraphic analysis were carried out, and 14 types of carbonate microfacies were recognized. Carbonate microfacies show that during the latest Permian, the Liangfengya section and the Taiping section are in the inner ramp environment as a whole, and the Wenbudangsang section is in the outer ramp environment. The carbonate carbon isotopes during PTB can be divided into four stages: NC1 (before carbon isotope excursion event), NC2 (carbon isotope excursion event initiation stage), NC3 (carbon isotope excursion event continuous stage) and NC4 (after carbon isotope excursion event). Comprehensive studies on sedimentary microfacies, carbon isotope changes and fossil records show that there is an evolutionary sequence of NC2 with unconformity development and anachronistic facies development followed by the NC3 stage. Taking the duration of NC2 stage in the Meishan section as the standard (~58 kyr), the occurrence time of sedimentary events in different sedimentary sections is restored by stratigraphic thickness interpolation. The hard ground structure first appeared in the Liangfengya section at ~ 9kyr later the start of NC2 stage, and the last appeared in the Wenbudansang section at ~ 46kyr later the start of NC2 stage. Stratigraphic loss occurs at ~ 6kyr later the start of NC2 stage in areas where microbialites are not developed, and at ~ 37kyr later the start of carbon isotope negative bias in areas where microbialites are developed. At the same time, the emergence of hard ground structure or stratum loss is often accompanied by the development of anachronistic facies, in which the main development of microbialites and oolitic limestone is concentrated in NC2 stage, and the main development of dolomite is in NC3 stage. Compared with the PTB , with the intensification of the earth's temperature increase, the carbonate platform in the shallow sea environment will take the lead in the sudden change of the marine environment, spread to the deep-water environment ~ 37kyr later, and accompanied by the emergence of microbialites and oolitic limestone.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-9: The Mesozoic-Paleogene hyperthermal events (IGCP739)
Presentation Preference: Oral Preferred

Ocean deoxygenation across the end-Triassic mass extinction

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Keywords: ocean oxygen scarcity, redox proxies, western Tethys, eastern Panthalassa, end-Triassic extinction

The role of ocean deoxygenation as a cause of the end–Triassic marine mass extinction is widely debated. Here we present multi-redox proxy data (carbonate-associated sulfate $\delta^{34}S$, I/(Ca+Mg), Fe speciation and trace metals) at sections across the shallow to deep-water marine realms of the western Tethys and eastern Panthalassa. Results show local dissolved oxygen decline in the near-surface ocean of low-latitude Tethys across the extinction, synchronous with the global-scale spread of deeper anoxic waters on continental shelves and slopes. Further, persistent euxinic conditions prevailed across the Triassic–Jurassic boundary in many semi-enclosed basins of the NW European epicontinental sea, coinciding precisely with the major phase of benthic faunal loss at the regional scale. Hence, the coincidence of extreme redox shifts with the extinction losses on a global scale implicates oxygen scarcity as an important factor in the crisis.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-9: The Mesozoic-Paleogene hyperthermal events (IGCP739)
Presentation Preference: Oral Preferred

REDUCED PLATE MOTION CONTROLLED TIMING OF EARLY JURASSIC KAROO-FERRAR LARGE IGNEOUS PROVINCE VOLCANISM

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Keywords: Plate motion, Toarcian, Karoo-Ferrar, Large Igneous Provicne volcanism, LIP

Large igneous province (LIP) emplacement is commonly associated with mantle plume upwelling, leading to surficial magmatism, proposed to have driven past global change events by volcanic carbon emission. One of Earth's largest past environmental perturbations, the Early Jurassic Toarcian oceanic anoxic event (T-OAE; ~183 Ma), has been linked to emplacement of the Karoo-Ferrar LIP. However, the role of mantle plumes in controlling the onset and timing of LIP magmatism is poorly understood.

Here, utilizing global plate reconstruction models, and Lower Toarcian sedimentary mercury (Hg) concentrations from the Mochras borehole (Wales, UK), we demonstrate (1) that the Early Toarcian OAE occurred coevally with Karoo-Ferrar LIP emplacement, and (2) suggest that the timing and duration of LIP-emplacement was governed by a reduction in local Pangean plate motion associated with a reversal in plate movement direction.

With this, we present a new model that mechanistically links Earth's interior and surficial processes, and we show that this mechanism is consistent with the timing of several of the largest LIP volcanic events throughout Earth history and thus, by inference, the timing of many of Earth's past global climate change and mass extinction events.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-9: The Mesozoic-Paleogene hyperthermal events (IGCP739)
Presentation Preference: Oral Preferred

Towards a consistent extraterrestrial 3He chronology of the Paleocene-Eocene Thermal Maximum

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Keywords: Paleocene-Eocene, extraterrestrial helium isotopes, cyclostratigraphy, hyperthermal event

The Paleocene-Eocene Thermal Maximum (PETM) was one of the most severe episodes of rapid greenhouse warming of the geological past. Identifying the key drivers of the carbon cycle across the PETM requires an accurate, highly resolved chronology of the event and its characteristic phases. The duration of these various phases estimated by cyclostratigraphic and extraterrestrial ^{3}He ($^{3}He_{ET}$) methods, however, vary greatly, hindering a detailed understanding of the impact of rapid warming on Earth System dynamics. To reconstruct sedimentation rates across the PETM, we present new high-resolution $^{3}He_{ET}$ contents measured at CRPG and Caltech of nannofossil ooze spanning the Paleocene-Eocene boundary at ODP Site 1209 (North Pacific). The measured $^{3}He/^{4}He$ ratios approach those measured in modern interplanetary dust particles and show that >99.9% of sedimentary ^{3}He is of extraterrestrial source. Cycle-based age models imply $^{3}He_{ET}$ fluxes of 0.31 ± 0.02 pcc/cm^{2}/ka before and after the PETM, supporting the hypothesis of a constant flux across the event. Assuming this flux remained constant through the PETM, our $^{3}He_{ET}$ -based sedimentation rates reveal an episode of extreme condensation across the PETM onset and indicate that the interval of anomalously ^{13}C-depleted values (body/core) lasted ~185 ka. The termination of the PETM core coincided with a surprisingly fast (<30ka) increase of carbonate fluxes, which remained elevated for ~80 ka, in line with other oceanic records. Based on these results and a comprehensive reassessment of previous $^{3}He_{ET}$ and cyclostratigraphic records, we construct an integrated and globally consistent age model for the PETM in continental, shallow marine, and deep-sea settings. The implications of the new chronology for the causes and consequences of the PETM will be discussed.

Reference
No

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-9: The Mesozoic-Paleogene hyperthermal events (IGCP739)
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Stepwise increasing paleotemperatures in the Late Jurassic-Early Cretaceous epeiric basin of the Eastern Russian Platform

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Keywords: Paleotemperature, Late Jurassic, Early Cretaceous, epeiric basin, Eastern Russian Platform

Aside from the long-term periods of warm climate, several hyperthermal events are identified in the Jurassic and Cretaceous (Foster et al., 2018), most of which are associated with oceanic anoxic events (OAEs) and black shale accumulation. In the Eastern Russian Platform (North-Eastern Peri-Tethys), several Mesozoic black shale formations are widely occurred, among those the Middle Volgian (Upper Jurassic) Promzino formation and the OAE 1a-related Lower Aptian (Lower Cretaceous) Ulyanovsk formation are known. To reconstruct paleotemperatures and the depositional environments, the stable oxygen and carbon isotopes of biogenic carbonates (more than 200 ammonite, bivalve, and benthic foraminifer shells and belemnite rostra) from the Upper Jurassic-Lower Cretaceous succession were analyzed. The lack of significant diagenetic alterations of carbonates as well as their mineralogy were preliminarily established using element geochemistry, Raman spectrometry, and electron microscopy data.

Based on the first results of the $\delta^{18}O$ analysis, a paleotemperature curve was constructed using equations from (Grossman, Ku, 1986; Anderson, Arthur, 1983). This curve shows quite a warm climate in the Late Jurassic in study region, with water column temperatures ranging in 17–25 °C. Noteworthy, temperatures calculated for benthic foraminifer shells are generally similar to those for ammonites suggesting a low temperature gradient in water column and hence a weak water stratification. Slight positive temperature excursion during the deposition of the Promzino black shales does not match the hyperthermal event (18–23 °C) which is confirmed by temperatures curve constructed for the temperate belt of the Northern hemisphere (Veizer, Prokoph, 2015). Rather abrupt warming of almost 4 °C is reported for the Russian Platform in the Later Jurassic (Price, Rogov, 2009), but the maximum temperature obtained (20 °C) is much lower than that typical for hyperthermal event. Interestingly, our results show an unexpected cold snap (10 °C) in the uppermost Promzino formation which could be probably caused by the strong phase of volcanic activity (Rentgarten, Kuznetsova, 1967). Nevertheless, warm climate reconstructed could maintain high productivity in the highly restricted basin in the Middle Volgian (Zorina et al., 2020) which is among major factors contributing to the enhanced preservation of the organic matter in the Eastern Russian Platform.

Trend of temperature evolution during the Early Cretaceous is partly similar to the global one, but temperatures reconstructed for the study basin in the Later Hauterivian and Barremian generally exceed the global values by more than 5 °C with occasional drop to 8 °C detected in the Later Hauterivian. This discrepancy could be explained by the specificity of basin circulation and strong phases of volcanic activity (Zorina et al., 2020). Rapid rise in temperature to 30–35 °C in the Late Barremian–Early Aptian (combination of our data with those from Zakharov et al., 2013) reflects hyperthermal event OAE 1a. Most probably, the extremely hot climate induced intensification of desalination of surface water and development of thermohaline stratification in the water column, which in turn caused anoxia and the organic matter accumulation (Erbacher et al., 2001).

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Session T1-10: Sedimentology of mass extinctions and biotic crises

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-10: Sedimentology of mass extinctions and biotic crises
Presentation Preference: Oral Preferred

New insights into the terrestrial end-Permian biotic crisis from eastern Australia

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Keywords: Permo-Triassic, eastern Australia, biotic crisis, coastal plain

This talk summarises results from a multi-disciplinary project that aimed to elucidate responses of lowland terrestrial settings in high paleolatitudes to end-Permian environmental stresses. The study focused on an extensive, north-south-elongate basin system in eastern Australia that preserves a stratigraphically complete succession of late Permian to Middle Triassic age. A suite of high-precision, CA-IDTIMS U-Pb ages from zircons in tuffs provides tight constraints on the timing of events. The succession accumulated on a broad, coastal alluvial plain in a retroarc foreland basin. The Permian succession preserves abundant coal. Abrupt extirpation of the Glossopteris flora is recorded at the top of the uppermost coal seam in the succession, but this event took place some 200-600 kyr before the marine extinction event as determined at the Meishan Permo-Triassic boundary GSSP. Above the uppermost coal is a distinctive dark grey shale ("Marker Mudstone" in the Bowen Basin of Queensland, Frazer Beach Member in the Sydney Basin of New South Wales) that preserves mainly algae, fungi, amorphous organic matter and charcoal fragments. Elements of a new macro- and microflora then become apparent gradually through the overlying strata. These strata are initially drab grey like the underlying Permian succession, but progressively change to stronger hues upward. Chemical Index of Alteration data indicate a major increase through the Permian-Triassic transition, δ13Corg values describe a negative excursion, and there are transient spikes in nickel concentrations in mudrocks across the boundary. Climate models suggest a shift towards warmer and more seasonal climates across the boundary, and this is supported by sedimentological data that indicate fluvial sediment dispersal under increasingly flashy discharge regimes. Deep tetrapod burrows were found subtending from the base of a sharp-bounded sandstone bed at one locality.

No significant, long-term change in overall depositional environment, average grain-size, or sediment dispersal direction is recorded across the boundary, with mobile fluvial systems active both before and after the floral extirpation. However, the Marker Mudstone/Frazer Beach Member record widespread ponding of surface water caused by an excess of water availability following demise of the Glossopteris flora. Presence of charcoal indicates abundant wildfires, and the proliferation of algae and fungi indicates that lakes became eutrophic and were inhospitable to aerobic life. Above this, stratal color changes and together with the deep tetrapod burrows, suggest that the Early Triassic climate entailed periods of drought and/or seasonal drying of the landscape. Geochemical and modelling data indicate a change to a warmer, seasonal, and more humid climate. Floral extirpation was likely caused by climate and fire regimes passing a tipping point, possibly in conjunction with poisoning by airborne volcanigenic heavy metal toxins. The palaeoenvironmental changes across the Permo-Triassic boundary in eastern Australia are comparable to, but slightly less extreme than, those documented from lower palaeolatitudes, suggesting flattening of latitudinal temperature gradients at this time.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-10: Sedimentology of mass extinctions and biotic crises
Presentation Preference: Oral Preferred

Disruption of terrestrial plant ecosystem in Miocene (sub) tropics: a palynological perspective from Fotan Formation, Southeast China

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Keywords: palynology, fern spike, ecosystem disturbance, Miocene, Southeast China

The palynological records on "fern spike", i.e., forest was transiently replaced by fern-dominant vegetation and then rapidly recovered, were documented in the geological past around the world, especially following the massive extinction (e.g. Triassic/Jurassic and Cretaceous/Tertiary boundaries). Fern spikes represent the initial colonization by pioneer species following massive destruction of vegetation.

Here, two fern spikes were recognized in the palynological sequences of MP-1 section (late Early–early Middle Miocene) and HK section (late Middle–Late Miocene) from the Fotan Formation in Zhangpu County, Fujian Province, Southeast China, which is the first report about fern spike events in this area.

Based on the appearances of fern spikes and the law of vegetation succession, we found that at least two catastrophic events occurred in our study area during the Miocene, which are considered to be caused mainly by the contemporaneous flood basalt volcanism. Along with the fern spikes we observed the increased runoff and the bloom of *Concentricystes* (algae) as a result of enhanced nutrient inputs after the ecosystem disturbances. Besides, in comparison with MP-1 section, the fern spike in HK section is characterized by 1) the higher abundance and diversity in terms of the composition of fern spores, 2) the appearance of fungal spike, 3) the longer time of duration, and 4) the much higher degree of prosperity of *Concentricystes*, suggesting that the severity of the catastrophic event occurred during the deposition of HK section is greater than that of MP-1 section.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-10: Sedimentology of mass extinctions and biotic crises
Presentation Preference: Oral Preferred

Proxy records of terrestrial climatic and environmental change through the End-Permian Extinction in the high palaeolatitudes of southeastern Gondwana

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Keywords: extinction, paleoclimate, Australia

Rapid climatic and environmental change were major contributors to the End-Permian Extinction (EPE). Although well-constrained for the marine realm, relatively few records document the pace, nature, and magnitude of climatic and environmental change across the EPE in terrestrial environments. The Bowen and Sydney basins in eastern Australia were major depocenters within a narrow, north-south-elongate basin system that stretched along the southeastern margin of Gondwana. These basins preserve a stratigraphically complete, upper Permian to Middle Triassic succession, which accumulated on a broad, coastal alluvial plain in a retroarc foreland basin setting. A continental volcanic arc produced numerous zircon-bearing tuff beds, which has facilitated the development of a high-resolution chronostratigraphic framework. We generated geochemical proxy records for pCO2, chemical weathering, and land surface temperature (LST). Regional climate simulations provide additional context. Through the latter half of the Changhsingian, Chemical Index of Alteration (CIA) profiles show increases from long-term averages of c. 70 in the Bowen Basin and c. 75 in the Sydney Basin to 80–85 regionally, suggesting an increase in LSTs from 12–14 °C and 14–16 °C, respectively, to 20–21°C along the entire continental margin. Consistently humid, temperate, broad-leafed Glossopteris forest-mire ecosystems thrived through this interval, despite gradual warming and increasingly seasonal climate. The EPE horizon, evident as the abrupt disappearance of coal-forming forest communities and elevated levels of charcoal in sediments, is marked by a peak in CIA and LST values of 85–90 and 22–23°C, respectively, indicating that the extinction coincided with an episode of intense chemical weathering and peak warmth. These results suggest that a tipping point was reached, which crossed a tolerance threshold for the forest-mire ecosystems that had long dominated the landscape. CIA profiles indicate that erosion following the collapse of vegetation was relatively short-lived in what was a low-gradient landscape. Although the post-EPE climate was 10–14°C warmer and landscapes were no longer persistently wet, results point to overall higher but more seasonal precipitation consistent with an intensification of a monsoonal climate regime in southeastern Gondwana. Aridification, often linked to the EPE, developed gradually in this region, perhaps facilitating the persistence of refugia for moisture-loving terrestrial flora. In the immediate aftermath of the extinction, the region was dominated by flora indicative of more open vegetation with adaptations to periodic water stress. Consistently humid conditions supporting coal-forming vegetation only re-established in the region some 5–10 million years later, during the Middle Triassic.

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Session T1-10: Sedimentology of mass extinctions and biotic crises
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A biotic crisis driven by an abrupt shift to well oxygenated oligotrophic conditions and a collapse of primary productivity in the epicontinental sea ecosystems during the CTBE

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Keywords: CTBE, OAE-2, epicontinental sea, Foraminifera, Dinoflagellata, δ15Norg

The Cenomanian-Turonian Boundary Event (CTBE), also referred to as the Oceanic Anoxic Event 2 (OAE-2), was investigated in a section representing the shallow epicontinental sea of the Central European Basin in Poland. This event was one of the strongest biotic crises of the Mesozoic, which impoverished marine biota, benthic foraminifera in particular. The crisis is expressed in the section examined by significant changes in foraminiferal and organic dinoflagellate assemblages, which indicate a switch to highly oligotrophic conditions associated with a collapse of primary production concomitant with the onset of the OAE-2. This switch correlated with a significant shift in N isotope signature in bulk organic matter, which we analyzed in detail. Yet, despite these biotic and isotopic changes, lithology and depositional conditions remained unchanged throughout the event, which suggests an environmental control on these variations.

Expansion of anoxic conditions in the basinal settings is accompanied by a sudden decrease of δ15Norg values (< −2‰) and high organic primary productivity during the OAE-2. These depleted δ15Norg values are thought to be chiefly driven by the assimilation of recycled ammonium, not nitrate, by primary producers, which was delivered to the photic zone from anoxic bottom waters. High production rate of this 15N-depleted biomass boosted by denitrification and anammox in such “ammonium ocean” caused the residual 15N enrichment in the remaining fixed N pool in the surface layer. Unlike the basinal settings, we observe a drastic increase of δ15Norg values to > +5‰ in the epicontinental setting examined during the OAE-2, which indicates that productivity was dominated by nitrate (and nitrite) and that the ammonium from the ocean did not reach the epicontinental setting. Instead, we propose that the shallow oceanic waters, with strongly 15N-enriched nitrate spread laterally onto epicontinental settings. Yet, our micropaleontological data show that fully oxic and low-productivity conditions occurred at that time in the area, so at such low level of bioavailable N, the additional delivery of strongly 15N-enriched nitrate was able to increase the overall δ15N of organic matter deposited in the epicontinental basin. Our integrated foraminiferal and dinoflagellate cyst study, supplied with N isotopic data, indicate that the biota were impacted by an abrupt shift to well oxygenated oligotrophic conditions and a collapse of primary productivity in the epicontinental Central European Basin. Because the event was concurrent with the development of extensive and extreme oceanic bottom water anoxia that reached the photic zone in oceanic settings, we infer that the biotic crisis in the shelf seas during the OAE-2, and possibly during other OAEs, was triggered by this anomalous nutrient cycling in Earth's oceans.

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Session T1-10: Sedimentology of mass extinctions and biotic crises
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Paleozoic ironstone suggests redox stratification played a role in Ordovician and Silurian biotic crises

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Keywords: extinction, ironstone, ocean oxygenation, ocean anoxic events, Paleozoic, redox stratification

Variable oceanic redox and expanding shelfal anoxia have been increasingly invoked as the causal mechanism in several biotic crises (extinctions) and contemporaneous isotopic excursions that occurred during the early and middle Paleozoic. However, the exact drivers of these anoxic events remain poorly constrained. In this study, sedimentologic, stratigraphic, and geochemical analyses of five Ordovician and Silurian ironstone-bearing successions are used to provide insights into the oceanic redox structure during the early Paleozoic. Eu anomaly and $^{87}Sr/^{86}Sr$ data indicate that ironstone formed from marine fluids with a component of mid-ocean ridge hydrothermal waters that remained largely unmixed during transport over thousands of kilometers to continental margins and epeiric seas. These results suggest that areas of the deep oceans must have been oxygen deficient, thereby supporting the buildup of hydrothermal fluids. Thus, ironstone provides novel evidence that redox stratification, with oxygenated surface oceans above anoxic deep waters, must have at least transiently existed through the Ordovician and Silurian. Furthermore, these data suggest that ironstone is a previously unrecognized proxy of Paleozoic oceanic oxygenation, one that supports the hypothesis that Paleozoic oceans did not become as well ventilated as modern oceans until at least the Devonian. The interpretation of protracted deep-ocean oxygenation and open-ocean redox stratification has important implications for the co-evolution of the biosphere. We propose that widespread transport of deep anoxic water, and with it both toxic and bioessential trace elements, onto oxygenated continental shelves represents a previously unrecognized driver of, or contributor to, numerous Ordovician-Silurian biotic crises and anoxic events. If sub-redoxcline, anoxic, trace-element-rich waters spread from deep oceans onto outer continental shelves, the expected effects would have included elevated primary productivity, expanded neritic oxygen minimum zones, benthic oxygen deficiency, enhanced organic matter burial, modified regional biologic pumps, abrupt facies changes, locally ferruginous or euxinic bottom water leading to sedimentary metal enrichment (e.g., ironstone or elevated pyrite burial), and resultant $\delta^{13}C$ and $\delta^{34}S$ excursions. Each of the aforementioned effects is widely documented for many of the Late Ordovician (i.e., Hirnantian) and Silurian biotic crises (e.g., the Ireviken, Lau, Klonk). Furthermore, the oceanographic and climatic shifts (i.e., glacioeustasy, intensified upwelling, changes in circulation patterns, etc.) interpreted as coincident with these early Paleozoic extinction events are all means by which sub-redoxcline waters could have readily spread into shallower environments. This spread would have occurred either directly through upwelling or indirectly through shoaling of the redoxcline such that it impinged above the shelf-slope break. Thus, the redox stratification model provides novel insights into the underlying oceanographic redox state during the early Paleozoic, which when combined with previously interpreted climatic and oceanographic triggers for early Paleozoic anoxic events, readily explains their widely documented sedimentary and geochemical records.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-10: Sedimentology of mass extinctions and biotic crises
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SEDIMENTARY RESPONSE TO ABRUPT CLIMATE CHANGE ACROSS THE HYPERTHERMAL PERMIAN-TRIASSIC BOUNDARY ON LAND, NORTH CHINA

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Keywords: sedimentary response, Permian–Triassic boundary, hyperthermal, paleoenvironment, warming, North China

The Permian-Triassic boundary (PTB, ~252 Ma) witnessed the largest hyperthermal event ever, with the most drastic environmental changes and the most severe biotic extinction worldwide, both on land and in the oceans. The climate heated rapidly in low-latitude areas, caused by a huge and sharp input of greenhouse gases related to large igneous province volcanism (Siberia LIPs) and synchronous massive volcanism worldwide. This study investigates the sedimentary response to environmental changes across the terrestrial PTB in the eastern Ordos Basin, North China. The PTB is indicated by the die-off of tetrapods and plants, decreased bioturbation levels in the uppermost Sunjiagou Formation, and the bloom of microbially-induced sedimentary structures (MISS) in the Liujiagou Formation, supported by the sharp negative shift of carbon isotope and synchronous geochemical proxies. The abrupt sedimentary transition from Lopingian meandering rivers to Induan braided river-aeolian facies to Olenekian shallow lacustrine setting documents palaeoenvironmental changes from semi-arid to arid and then to semi-humid conditions, which is synchronous with the collapse and delayed recovery in palaeoecosystems and is likely to be one of the direct causes. Similar sedimentary responses to extreme climate crises on land have been reported elsewhere worldwide at the PTB (e.g. South Africa, Russia, NE Spain) and across other similar deep-time hyperthermal events (e.g. Paleocene–Eocene Thermal Maximum). Exploring their common features could test the idea that there is a ‘hyperthermal blueprint’ or common pattern to such events through geological time, but at different magnitudes that could inform our understanding of the current, Anthropocene climate crisis. Such a sedimentary response under a regime of warming, aridity and intermittent heavy precipitation on land may not only accumulate or amplify the signals of abnormalities and consequences in shallow marine settings but also connect the land and ocean.

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Session T1-10: Sedimentology of mass extinctions and biotic crises
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Tracing anoxic events across mud-dominated epicontinental seas during the Middle to Upper Devonian in the Illinois Basin, North America

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Keywords: Kellwaser event, black shales, axonia, Late Devonian

Anoxic conditions in epicontinental watermasses have been implicated as one of the key drivers for deposition of black shales in the geologic record. However, there are several mechanisms that can trigger anoxia, and distinguishing among them is a significant challenge for the reconstruction of depositional conditions in ancient mud-dominated systems. In this study, we reconstructed the general evolution of watermass conditions through deposition of the organic-rich Late Devonian New Albany Shale (NAS) in the Illinois Basin, USA. Through a detailed sedimentological and geochemical characterization of three cores, we establish a general sequence evolution of the NAS that we extrapolate to 50 wells across the basin using gamma ray logs. The three studied cores have been divided into three stages based on detrital proxies (Zr, Al), carbonate proxies (Ca), and redox-sensitive proxies (Mo, U). Moreover, each stage is characterized by a distinctive facies association arrangement. Our results suggest that deposition of the NAS occurred in three stages (two prograding, and one retrograding), characterized by the occurrence of four variably-related anoxic pulses. The first anoxic pulse was triggered by initial flooding of the basin at the base of a depositional sequence. The second anoxic pulse occurs in the middle of this prograding sequence and is likely related to the Lower Kellwasser Event based on scarce available biostratigraphy. The third anoxic pulse is related to basin flooding at the base of a second prograding sequence and can be confidently assigned to the Upper Kellwasser Event based on biostratigraphy and the presence of a positive carbon isotope excursion in organic matter. The fourth anoxic pulse occurs in a general retrogradational context when black shale deposition reached its maximum areal extent in the basin. This signal matches the expression of the global Hangenberg Event in the Williston Basin (North Dakota, USA), but further bio- and chemostratigraphic constraints are needed to confirm the placement of this event in the Illinois Basin. Overall, we find that anoxia in the epicontinental Illinois Basin was triggered by a variety of different mechanisms through deposition of the NAS. In some cases, anoxia is a local response to changes in relative sea level and, in other cases, basin anoxia is related to global anoxic events with no change in relative sea level. In some instances, however, these two mechanisms are related likely because anoxia in multiple epicontinental seas worldwide is triggered by the same eustatic forcings. We suggest that a similar approach may be useful in reconstructing the conditions that led to black shale deposition in other epicontinental seas of the geologic past.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-10: Sedimentology of mass extinctions and biotic crises
Presentation Preference: Oral Preferred

The disturbance of terrestrial ecosystems during the Permian-Triassic transition in South and North China

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Keywords: Terrestrial, Permian-Triassic mass extinction, South China, North China

The Permian-Triassic mass extinction (PTME) had a catastrophic impact on both marine and terrestrial ecosystems and was the most severe crisis of the Phanerozoic. It is widely attributed to the global environmental changes caused by the contemporaneous volcanism. The timing and nature of the terrestrial crisis is unclear. The terrestrial sediments in South China record increased abundance of fossil charcoal coincident with the onset of a negative carbon isotope excursion (CIE) and the loss of tropical rainforest vegetation, both of which occurred immediately before the peak of Hg concentrations. We find a significant peak of spore tetrads of lycopsid plants coeval with increases in metal concentrations above the main terrestrial extinction interval in South China, which suggests that survivor lycophyte plants were under huge stress after the loss of the Permian forests. However, the crisis of conifer and the dramatic decrease of total organic carbon content in North China occurred before the negative CIE and significantly preceded the increase of Hg content. These evidences probably suggest that the crisis of different terrestrial ecosystems is asynchronous. To obtain a more complete understanding of the specific processes and driving mechanisms of terrestrial PTME, high-resolution and in-depth studies are urgently needed to reveal the biological and environmental evolution in the terrestrial record.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-10: Sedimentology of mass extinctions and biotic crises
Presentation Preference: Oral Preferred

The timing of forest fire at the K-Pg boundary; evidence from the Pacific margin of Baja California, Mexico

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Keywords: Cretaceous-Paleogene, Impact, Forest fire

Impact of the Chicxulub bolide that brought the Mesozoic to a close is widely recorded by a layer of highly distinctive deposits, including the products of catastrophic sedimentation around the Gulf of Mexico and the North Atlantic, as well as globally-distributed bolide- and target-sourced ejecta from the impact site itself. These deposits also include soot, the origin of which has ascribed either to combustion of inorganic material at the target site, or to wild fires occurring at or close to the time of impact, or subsequently due to ignition of forest killed by the immediate after-effects of the impact (Morgan et al., 2022, and references therein). We describe a section from a mid-slope succession on the Pacific margin of Mexico, about 2500 km from the impact site, which on the basis of faunal and floral changes, radiometric dating, and an iridium anomaly, clearly represents a Cretaceous-Palaeogene (K-Pg) boundary section. The deposit consists largely of debrites that contain not only re-sedimented shallow marine faunas but also large sections of silicified tree trunks with charred bark and cambium but pristine xylem, and no evidence of decay or bio-erosion (Cevallos-Ferriz et al., 2021). Raman spectroscopy of the charcoal indicates temperatures up to more than 1000 C. The presence of fossil wood within deepwater deposits implies its incorporation into a debris flow whose matrix yield strength exceeded the buoyancy of the wood.

The adjacent slope and coastal succession shows widespread and large-scale sliding at the K-Pg boundary. We interpret the presence of shallow marine and terrestrial material within debrite of the K-Pg boundary section to indicate resedimentation by the back-wash of a slide-generated tsunami. Adopting upper crustal P wave velocities of 6 to 8 km s^{-1} (e.g. Rosalia et al., 2019) depending on the ray path, arrival times of the first seismic shocks from the impact would have been no more than 5 to 7 seconds post-impact. Based on historic seismogenic mass failures (e.g. Løvholt et al., 2019), sliding would have occurred almost immediately, and the associated tsunami would have arrived within minutes to tens of minutes. Since the trees incorporated into the debris flow by the tsunami were already charred, the high-temperature event responsible must already have occurred by this time, i.e. within minutes to tens of minutes of the impact. This rules out secondary burning of dead trees in the days to months following impact. Numerical modelling of the impact plume or 'fireball' (Svetsov and Shuvalov, 2018), and re-entry of ejecta into the atmosphere (Morgan et al., 2013) indicate substantial heat flux within seconds to minutes of impact. Experimental evidence (Belcher et al., 2015) appeared to indicate

that sustained heat flux would be required to ignite live wood, and that the required conditions would only be achieved relatively close to the impact site (in contrast to the estimates of Svetsov and Shuvalov, 2018). However, our evidence shows that heating sufficient to very rapidly ignite live trees occurred almost immediately after impact at distances of at least 2500 km from the impact site.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-10: Sedimentology of mass extinctions and biotic crises
Presentation Preference: Oral Preferred

A New Liberation Lagerstätte from Southwest China during Carnian Pluvial Episode

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Keywords: Liberation Lagerstätte, Carnian Pluvial Episode, Xiaowa formation, South China

We report the Luxi biota, a new Liberation Lagerstätte from the Triassic Carnian Xiaowa Formations in Yunnan, South China, with close faunal links to the biota of Cassian Formation in Italy. The biota described from the marls of the Julian 2 siltstone were deposited during a major, Tethyan-wide climate crisis - the so-called Carnian Pluvial Episode(CPE) - characterized by an amount of terrigenous clastics input the marine and a demise of carbonate platforms. The biodiversity of the Luxi biota includes Cephalopoda (Ammonitida, Phragmoteuthida, Orthocerida, Nautilida and Belemnitida), Gastropoda, Bivalvia, Brachiopoda, Crinoidea and plant fossils. The fossil community from three different lithological parts of the Xiaowa Formation exhibits different preservation forms and combinations in each part. In the lower part, abundant compressed Trachyceras multituberculatum and Halobia yunnanensis were found in black mud-limestone; The middle part is dominated by the lime-siltstone. At the base of the middle part contains three-dimensional preserved Sinobelemnitidae and Michelinoceras with a few pyritized ammonoids(Austrotrachyceras, Sirenites). However, Sinobelemnitidae rapidly disappeared and replaced by some gastropods such as Anulifera, Zygopleura, Neritaria etc.. Based on electronic microscope scanning, some gastropods preserve the protoconch and all protoconches indicate these gastropods were a nonplanktotrophic lifestyle during the larval stage. Besides the gastropods, a few phragmoteuthids(Phragmoteuthis), bivalves(Halobia, Monotis) and brachiopods(Norella, Neoretzia) with low fossilized are also found in this part; The upper part is black shell. It contains a large amount of three-dimensional preserved ammonoids (Austrotrachyceras, Neoprotrachyceras, Sirenites, Yakutosirenites, Anasirenites), brachiopods and crinoid stems. This important discovery indicate (1) bio-community change accompany by the environmental fluctuation during CPE. To be more specific, the three parts of Luxi biota represent a planktotrophic biotic combination transferred to a benthic biotic combination during terrigenous clastics inputting. The benthic biotic combination returned to planktotrophic biotic combination after terrigenous clastics inputting. (2)Due to fossilization has been affected by the carbonate production crisis and an amount of terrigenous clastics inputting, some vulnerable and delicate parts of fossils can be preserved. It provides favorable conditions for the formation of Liberation Lagerstätte.

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Session T1-11: Paleoclimate in shallow-marine environments

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-11: Reading paleoclimate signals across timescales and environments
Presentation Preference: Oral Preferred

A middle Wuchiapingian hydroclimate induced acceleration in basaltic landscape erosion in paleotropical South China

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Keywords: basaltic landscape, erosion, weathering, early Late Permian, hydroclimate change

Chemical weathering and physical erosion are major factors affecting landscape evolution and shaping Earth`s surface. Modern observations and measurements along with modelling suggest significant effects of hydroclimate on catchment erosion and weathering. But to reveal the hydroclimate influences on catchment-averaged erosion and weathering from geological records is challenging. Here we present proxy data on the provenance, source weathering and paleowater salinity from the early Late Permian sedimentary successions in western South China. The analyzed successions are dominated by basaltic mudrocks and sandstones derived from the Emeishan large igneous province. A negative organic carbon isotope excursion (CIE) was observed from all the studied three successions. Based on this CIE, these studied estuary-deltaic successions can be correlated with deep-water and shallow marine successions in South China and with terrestrial successions in eastern Australia where the last Permian glacial-deglacial cycle was recorded. Reported high-precision tuffaceous zircon U-Pb ages support these stratigraphic correlations and constrain this early Late Permian CIE at around 258-257 Ma, corresponding to the middle Wuchiapingian deglaciation. Through this strata interval with CIE, mudrock chemical and mineral compositions consistently demonstrate a decrease in source chemical weathering intensity and detrital zircon data suggest a prominent unroofing of the Emeishan volcanic provenance. Using proposed relationships of chemical weathering rate with land surface temperature and with denudation (total erosion) rate for present-day basaltic landscapes, the denudation rates of the Emeishan basaltic landscape were calculated based on the published seawater temperatures from South China and show high values (~300 t/km^2/yr) in the interval with CIE than in the underlying and overlying intervals (both are ~200 t/km^2/yr). During the acceleration interval, denudation rate is negatively correlated (r^2 = 0.56) with mudrock B/Ga ratio which shows a distinct decrease from >6 to < 3. This decrease in mudrock B/Ga ratio reflected a marine to freshwater facies change and suggest an enlargement in freshwater influx for these middle Wuchiapingian estuary-deltaic environments in South China. Such water salinity changes along with the co-increased sandstone proportion in studied successions and occurrences of terrigenous clastic depositions in deep-water and shallow marine successions support an enhancement in fluvial sediment and freshwater supply, which were possibly related to strengthened rainfalls. It follows that the erosion acceleration of basaltic landscapes was likely associated with hydroclimate change in South China during the middle Wuchiapingian warming. Landscape evolution modelling supports this hypothesized causal linkage and further indicates an increase of precipitation by ~2-3 times for the observed acceleration in landscape erosion.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-11: Reading paleoclimate signals across timescales and environments
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

The Late Miocene Carbon Isotope Shift driven by synergetic terrestrial processes: A box-model study

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Keywords: carbon cycle, box-model, late Miocene, carbon isotope, atmospheric CO2

As the most significant carbon isotope excursion in the past 10 Ma, the Late Miocene Carbon Isotope Shift (LMCIS, 7.65 to 6.5 Ma) offers a great opportunity to investigate the carbon-climate dynamics in a warmer-than-today world. However, the driving mechanisms of the LMCIS remain controversial. In this study, we used a 7-box biogeochemical model to simulate the long-term seawater $\delta^{13}C$ and atmospheric CO_2 changes during the late Miocene. Based on the quantitative parameterization of two terrestrial processes (C_4-grasses expansion and enhanced weathering input) during the late Miocene, our results show that the synergy between the two terrestrial processes may ultimately result in the LMCIS via the perturbation of the land-sea carbon fluxes. Moreover, our results reveal that the re-partitioning of alkalinity and nutrients between the land and the ocean may have influenced the long-term atmospheric CO^2 change during the late Miocene.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-11: Reading paleoclimate signals across timescales and environments
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Rapid climatic fluctuation during the Guadalupian-Lopingian transition: recorded by weathering index of geochemical acid-insoluble residua of carbonate rock, South China

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Keywords: Acid-insoluble residua, Continental weathering, Climatic fluctuations, The GLB transition, South China

The Guadalupian-Lopingian boundary (GLB) transition was regarded as a gradual warming period with the termination of the Late Paleozoic Ice Age (LPIA). However, the glacial-nonglacial cycles from Eastern Australia imply that the period was also influenced by climatic fluctuations. We here report on a GLB section of the South China Block confined by the conodont biostratigraphy to constrain weathering intensity and the associated climatic fluctuation during this critical interval. The chemical weathering indices were estimated by analyses of acid-insolubles residua extracted from carbonate rocks. Two weak weathering unitsUnit 1 and 3, Early Capitanian and Early Wuchiapingianand two strong weathering unitsUnit 2 and 4, Late Capitanian and Middle Wuchiapingianare identified. δ 13 C carb generally follow well the variation tracks of weathering indices. Two weak weathering units (Unit 1 and 3) correspond to the P3 glacial and the P4 glacial in high-latitude region of Australia. The strong weathering unit (Unit 2) is closely related to the eruption of the Emeishan Large Igneous Province (ELIP). These climatic fluctuations of the GLB transition also influenced the biodiversity. The CIA-converted land surface temperature and reported seawater temperature reflect the synchronous response of continental climate and marine conditions. The high temperature associated with the peak of the ELIP may be responsible for the GLB extinction.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-11: Reading paleoclimate signals across timescales and environments
Presentation Preference: Oral Preferred

Tectonic quiescence triggered the early Paleoproterozoic glacial climate and the onset of the Great Oxidation Event

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Keywords: Paleoproterozoic, Chemical weathering, Snowball Earth, Great Oxidation Event

The Great Oxidation Event (GOE), a milestone event in the evolutionary history of habitable Earth, generally coincided with the Paleoproterozoic glacial climate. However, the causal-effect relationships between these two events remain controversial. Here, we investigate the continental chemical weathering, which is the critical link between these two events, by compiling a global data set of the chemical index of alteration (CIA) in this interval from 2600 to 2000 Ma. Our results demonstrate that the time period from ~2430 to 2340 Ma is generally characterized by limited continental chemical weathering, coinciding with the glacial climate and tectonic quiescence revealed by the compiled data of U-Th-Pb ages of zircons and volume of the large igneous province (LIP). The limited continental chemical weathering suggests that the nutrients fluxed into the ocean would be very low, which would restrict O_2 production. Therefore, we proposed that both the glacial climate and onset of the GOE were attributed to tectonic quiescence, which decreases the CO_2 and reducing gases released into the atmosphere. The resurgence of the tectonic activity ~ 2340 Ma could trigger the termination of glacial climate, result in a significant increase in the continental chemical weathering, and, consequently, promote the large increase in pO_2 indicated by the high $\delta^{13}C$ values in the interval from ~2250 to 2060 Ma.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-11: Reading paleoclimate signals across timescales and environments
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Isotopic and elemental characteristics of the Ediacaran Doushantuo Formation, South China: New insights for great oxygenation events

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Keywords: continental weathering, Neoproterozoic oceanic oxygenation, Yangtze Platform, isotope

The Ediacaran Period (635-542 Ma), a critical period throughout Earth history, witnessed major marine carbon cycle perturbations, great oxygenation events, biological systems innovations, and regional Ediacaran glaciation events. However, the origin of these negative carbon isotope anomalies and great oxygenation events remain highly debated. Here, we present high-resolution carbon and strontium isotope, and elemental records of drill core samples from the Ediacaran Doushantuo Formation, Yichang City, Hubei Province, South China. The δ13C profiles display five negative carbon isotope excursions (EN1, EN1-1, EN1-2, EN2 and EN3), which consist of three major negative excursions (EN1, EN2 and EN3) and two minor, local negative excursions (EN1-1 and EN1-2). Both EN2 and EN3 excursions display highly basin-scale spatial heterogeneity along the shelf-to-basin transect across the Yangtze Platform. Overall, Doushantuo Formation δ13Ccarb values in deeper intrashelf basin sections are ca. 3-5‰ lower than those in the shallower intrashelf basin, shelf margin and upper slope sections, and are ca. 5-10‰ lower than those in the inner shelf sections, respectively. High spatial heterogeneity in the magnitude and timing of EN2 and EN3 excursion across the proximal to distal transect reflects dynamic oxidation in the surface ocean between elevated oxidant availability with limited spatiotemporal distribution and reduced carbon from the subsurface dissolved organic carbon (DOC) pool. Elevated oxidant availability during the EN2 and EN3 is primarily associated with the long-term late Neoproterozoic oxidation event combined with enhanced continental weathering. Doushantuo Formation 87Sr/86Sr records exhibit two significantly positive 87Sr/86Sr excursions (P1 and P2), roughly coinciding with the EN2 and EN3 excursions. Elevated 87Sr/86Sr ratios during the P1 and P2 events are likely linked to the overall rise in continental weathering rates during the assembly of Gondwana at ca. 0.6-0.5 Ga. Additionally, redox-sensitive trace elements (Mo, U and V) also display significantly enrichments within EN2 and EN3 excursions, which indicates oceanic oxygenation events. A compilation of δ13C, 87Sr/86Sr, and redox-sensitive trace elements record during the Ediacaran suggests that increasing continental weathering provokes oceanic oxygenation that leading to negative carbon isotope anomalies.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-11: Reading paleoclimate signals across timescales and environments
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Coupled conodont δ18OPO4 and 87Sr/86Sr records indicate hydroclimate changes in North China at the Permo-Carboniferous transition

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Keywords: Permo-Carboniferous transition, oxygen isotope, strontium isotopes, conodont, paleoclimate

The significance of chemical proxies from semi-restricted marine depositions are debated. Recent studies have shown decoupling of epicontinental isotopic records from open-marine ones and suggested superposition of regional hydro-climate factors, such as freshening, coastal upwelling, temperature, and salinity. We analyzed oxygen and strontium isotopes of conodont apatite (genera Streptognathodus) from Permo-Carboniferous epicontinental successions in southern North China and tested how the connection of epicontinental isotope variability in the sea to large-scale ocean-atmosphere processes. Average δ18O values are around 16.7 ‰ and decrease from 18.0 ‰ to 16.2 ‰ from the early Gzhelian to Asselian. These δ18OPO4 values are consistently lower than that of contemporary open-marine successions. The strontium isotope ratios are between 0.70825 and 0.70948, with an average value of ~0.70858. The 87Sr/86Sr values are consistently higher than the corresponding open-marine records. Optical observations and trace element characters suggest no significant diagenetic influences on the analyzed conodont domains. It is therefore that the obtained δ18O and 87Sr/86Sr values could reflect the oxygen and strontium isotopic features of the seawaters from which these conodont apatites were precipitated. We hypothesized an extensive effects on the epicontinental sea waters from fluvial discharges which supply freshwaters with low δ18O and high 87Sr/86Sr due to the drainages in Proterozoic basements of North China. This study emphasized the linkage of hydroclimate conditions to the biogeochemical evolutions in epicontinental seas and highlighted the cautions to interpret chemical proxies from shallow marine records.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-11: Reading paleoclimate signals across timescales and environments
Presentation Preference: Oral Preferred

A three-billion-year history of continental weathering

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Keywords: weathering, continental crust, geological carbon cycle, zircon, oxygen isotopes

Chemical weathering has profound influence on the Earth's habitability because it releases vital nutrients to sustain the biosphere and regulates climate through interaction with carbon cycle. However, reconstructions of continental weathering through the Earth's history are scarce. Based on a novel big-data algorithm applied to the O-U-Pb-Hf isotopic compositions of over 5,000 grains of globally distributed detrital zircons, this work deconvolves a three-billion-year history of continental weathering rate from the time-integrated weathering-alteration of crustal $\delta^{18}O$ registered by detrital zircons with varying temporal and spatial coverage.

Zircon can record the oxygen isotopic composition ($\delta^{18}O$) of its parent crust at the time of crystallization, the value of which principally reflects the time-integrated effect of crustal alteration. The Hf isotopes and U-Pb isotopes of zircon constrain the alteration history between crust generation and zircon crystallization. A new algorithm is introduced to reconstruct the average $\delta^{18}O$ alteration rate of continental crust ($R_{\delta 18O\text{-}CC}$) through time by solving a set of linear equations based on a large population of detrital zircons with varying temporal coverage across the history of crustal alteration. The reconstructed $R_{\delta 18O\text{-}CC}$ shows an overall bell-shape long-term evolution centered at 2 Ga superposed with variations that are coupled with supercontinental assembly cycles. The long-term evolution of the reconstructed $R_{\delta 18O\text{-}CC}$ seems to be correlated with solid-earth CO_2 degassing expected from the age distribution of deleted mantle and the supercontinental cycles. Thus, the $R_{\delta 18O\text{-}CC}$ is interpreted to reflect weathering considering the control of solid-earth CO_2 degassing on the total weathering flux of continental crust. This work demonstrates the great potential that weathering history may have in reconstructing the operation of the Earth system across deep-time.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-11: Reading paleoclimate signals across timescales and environments
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Environmental co-evolution in South China during the Cryogenic interglacial: Evidence from trace element geochemistry

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Keywords: Cryogenic interglaciation, element geochemistry, volcanism, chemical weathering,material cycling

Earth witnessed two global glaciation events (named Sturtian and Marinoan) during the Neoproterozoic Cryogenian. The Cryogenian interglaciation, occurring between these two glacial events, was a key period for the formation of manganese resources and polymetallic black shales in the world. However, the formation mechanism and environmental changes of this interglacial period remain poorly understood. This study investigates the elemental geochemistry of the Cryogenic glacial-interglacial sequence (Tieshiao and Datangpo Formations) in the Wuhe Section, Guizhou, SW China, and demonstrates that: (1) the Cryogenic interglaciation was driven by large volcanism, which not only directly released large amounts of volcanic components (e.g., Hg, V andTl) into the ocean, but also triggered global warming, leading to enhanced continental chemical weathering and the input of terrigenous substances (e.g., Y, Nb, Ta, Zr and Hf) into the ocean. Volcanism and terrigenous weathering introduced abundant nutrients into the ocean, enhancing marine productivity and the oxygenation of surface seawater, leading to precipitation of Mn from seawater to cause large-scale manganese ore formation in this period; (2) Elements (e.g., In, Sn, Ag, Cu, Zn, Pb and Bi) enriched in submarine hydrothermal fluids show low anomalies during the Cryogenic interglaciation, suggesting that the Cryogenic interglaciation was not driven by submarine volcanism, but more likely by large-scale terrestrial volcanism. Results of this study reveal a close coupling of the evolution of the "ocean-atmosphere-land" system during the Cryogenic interglaciation.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-11: Reading paleoclimate signals across timescales and environments
Presentation Preference: Oral Preferred

Clay minerals as weathering and paleoclimatic proxies across the Carnian Pluvial Episode (Late Triassic): a composite section from the Dolomites (Italy)

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Keywords: Clays, Paleoclimate, Triassic, Carnian, CPE, Dolomites

Clay minerals are weathering products par excellence and their formation can be linked to the climate; thus they could be helpful in paleoclimatic reconstructions. The Carnian Pluvial Episode (CPE) is a multi-pulses climatic perturbation associated with almost four negative Carbon isotopic shifts (Dal Corso et al., 2020). The CPE triggered many important consequences on the sedimentary, environment and global ecosystem evolution of the Late Triassic. Several sedimentological, geochemical and paleontological features have been studied to detect changes related to the climatic episode, and the Dolomites have been representing a helpful source of data on this topic (Dal Corso et al., 2018). Nevertheless, through more than 20 years of studies in the Dolomites, clay minerals were not considered yet.

Here we provide the first paleoclimatic study of clay sediments based on mineralogical data (bulk and clay fraction) and geochemical analysis for Dolomites successions, which encompass not only the syn-CPE succession, but also the pre- and post- event stratigraphic intervals. We sampled clayey beds and interbeds from the San Cassiano Fm., Heiligkreuz Fm. and Travenanzes Fm., obtaining a composite section which covers the earliest (Julian) to late (Tuvalian) Carnian time span. Collected samples were XRD-analysed both as “bulk” powders and oriented mounts. Diffraction patterns of the “bulks” were Rietveld-fitted to achieve phase quantitative analyses while oriented mounts allowed complete identification of clay minerals. ICP-OES analyses were conducted for major, minor and trace elements. This approach combines complementary data from mineralogy and geochemistry, allowing to provide a complete picture on the weathering processes and rate occurred across the CPE. Obtained analysed have been integrated to sedimentological and palynological data to improve the paleoclimatic reconstruction.

Interestingly, the samples from the uppermost San Cassiano Fm. and the first two members of the Heiligkreuz Fm. (Alpe di Specie and Borca mbs.) displayed the same clay assemblage, dominated by Illite-Smectite mixed-layer (I/S), followed by Illite, Kaolinite and also Chlorite in several samples. Within this interval, we observed a maximum in the ratio of clay minerals vs. carbonates located few meters above the first Negative Carbon Isotope Excursion (NCIE) detected by Dal Corso et al. (2018), suggesting that clays might record the environmental change connected to the first pulse of the CPE later than other proxies (e.g., palynomorphs).

Samples from the overlying Dibona Mb. (above the second NCIE) show a higher dominance of siliciclastics/carbonates ratio (confirmed also by geochemistry) and contain two different species of mixed-layer phase: the disordered I/S and the regular mixed-layer (Rectorite). In suborder, we found Illite and Kaolinite while Chlorite is absent. The mineralogy of the clay fraction leads to consider this association as representing a humid paleoclimate, if provenance changes are excluded.

The climatic configuration was reversed within the Travenazes Fm., whose samples are dominated by Illite and I/S (prevailing Illite), followed by Chlorite. Kaolinite is absent. These features allowed us to interpret the sharp change in clay mineralogy as a further witness of the return to arid condition in the late Tuvalian, after the CPE.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-11: Reading paleoclimate signals across timescales and environments
Presentation Preference: Oral Preferred

Palaeovegetation and palaeoclimate evolution in the late Oligocene-early Pliocene shales in the Ying-Qiong Basin, South China Sea

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Keywords: higher plant-derived biomarkers, palynological records, palaeovegetation, palaeoclimate, East Asian monsoon

The sedimentary rocks of the Yinggehai-Qiongdongnan Basin in the northern South China Sea preserve important records of the complicated interactions between terrigenous sediments and the East Asian monsoon climate. It remains obscure how higher plant-derived biomarkers and the inferred floral changes respond to the East Asian monsoon climate in the South China Sea. The late Oligocene-early Pliocene palaeovegetation and palaeoclimate in the Ying-Qiong Basin, South China Sea were comprehensively reconstructed using higher plant-derived biomarkers, palynological records, kerogen maceral compositions, and trace elements of shales. During the period from about 24.9−18.3 Ma, there are trends of higher relative abundances of plant-derived biomarkers including oleanane, des-A-oleanane, rearranged oleananes, taraxastane, bicadinanes, high molecular weight n-alkanes (Cn ≥ 27), C19 tricyclic terpane, and C29 ααα 20R sterane in the younger sediments. Similarly, over this period, there are records of increasing amounts of tropical/subtropical angiosperms and pteridophytes in the younger sediments, and lesser amounts of temperate Pinus and Alnus species. The bloom of the dominant tropical-subtropical higher plants and the large influx of terrigenous organic matter during this period were likely associated with extra precipitation under a warming climate. This warming and more humid climate is related to the establishment of the East Asian monsoon in the South China Sea at about 24.9 Ma in the late Oligocene, which was likely caused by uplift of the northern Himalaya-Tibetan Plateau.

During the period from about 8.2−2.7 Ma (corresponding to the deposition of the upper Huangliu Formation to the lower Yinggehai Formation), there was a remarkable decline of inferred higher plant inputs and vitrinite proportion in the kerogen. The temperate species Pinus and Alnus became more dominant, and ferns became less abundant in the lower Yinggehai Formation compared to the underlying late Miocene sediments. Various higher plant-derived aromatic hydrocarbons including cadalene, retene, 1,2,7-trimethylnaphthalene, 1-methylphenanthrene (1-MP), 1,7-dimethylphenanthrene (1,7-DMP), 6-isopropyl-1-isohexyl-2-methylnaphthalene (ip-iHMN) and other polycyclic aromatic hydrocarbons (PAHs) were identified. Higher plant parameters suggest that the relative abundance of total terrigenous organic matter in the early Pliocene was lower than in the angiosperm-dominated organic matter in the late Miocene Huangliu Formation. Various gymnosperm/angiosperm indices including retene/(retene + cadalene), 1-MP/9-MP, and 1,7-DMP /(1,3- + 3,9- + 2,10 + 3,10-DMP), and the higher plant index, indicate that gymnosperms made a larger contribution to the organic matter when the lower Yinggehai Formation was deposited during the early Pliocene. Combustion-derived PAHs including fluoranthene, benzo[a]anthracene, benzofluoranthenes, and coronene predominate over petrogenic PAHs, indicating that there were more wildfires during deposition of the lower Yinggehai Formation and the upper Meishan Formation. In contrast, there is a mixed input of combustion-derived and petrogenic PAHs in the Huangliu Formation. As also supported by increasing abundances of Pinus and Alnus in palynological records, the combustion-derived PAHs, the gymnosperm/angiosperm parameters, and the trace element proxies provide unequivocal evidence for a weakened East Asian summer monsoon during a cooling climate from the late Miocene to the early Pliocene in the South China Sea.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-11: Reading paleoclimate signals across timescales and environments
Presentation Preference: Oral Preferred

Provenance and depositional environment in Shuicheng area, western Guizhou Province, China—Evidence from paleontology and geochemistry

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Keywords: Changhsingian, Calcareous algae, Foraminifera, Palaeoclimate, paleoceanography, Provenance background

Well-developed marine carbonate of the the Late Permian Changhsingian in the Shuicheng area of western Guizhou, with abundant biological fossils such as calcareous algae, foraminifera, brachiopods, gastropods, bivalves, cephalopods, crinoids, echinoids, sponges and ostracods. Based on the systematic paleontological and geochemical analysis, we studied the water medium conditions, palaeoclimate, paleoceanography and provenance background of the late sedimentary period of Changxing Formation in the area. The results show that six fossil assemblages can be delineated from the bottom to top in the Changhsingian vertical sedimentary sedimentary sequence: the Foraminifera-Calcareous algae-Brachiopoda assemblage, the Foraminifera-Brachiopoda-Bivalve assemblage, the Bivalve-Gastropoda-Crinoida assemblage, the Foraminifera-Calcareous algae-Bivalve assemblage, and the Foraminifera-Bivalve-Brachiopoda and Foraminifera-Calcareous algae-Ostracoda assemblages. Among them, calcareous algae and planktonic foraminifera are the most abundant and diverse. The trace elements of Rb, Cs, Ba and Tl are relatively depleted, while the Trace elements of Nb are relatively enriched. The trace elements abundance of Li, Be, Sc, V, Cr, Co, Ni, Cu, Zn, Ga, Sr, Zr, Sn, Hf, Ta, Pb, Th and U are closer the average of the upper crust. Chondrite—normalized REE patterns show that the rocks are enriched in LREE and relatively depleted in HREE, with Eu weak negative anomaly and Ce no anomaly. Study area Changxing Formation main sedimentary period was mainly in warm humid climateparalic sedimentary environment and anoxic environmentthus in favor of abundant calcareous algae and foraminifera growing. A sudden dry and hot climate in the late period, with a sudden rise in the water column, an increase in salinity and temperature, and the emergence of clusters of relatively heat-tolerant ostracods, while other organisms declined sharply or even disappeared. ∑REE-La/Yb discrimination diagram indicate that the Provenance is mainly influended by volcanism during the Emeishan stage, diagenetic parent material is basalt. According to discrimination diagrams of La-Th-Sc, Th-Sc-Zr/10 and Th-Co-Zr/10source materials of the Changxing Formation was mainly deposited in a continental island arc setting and clastic materials from an oceanic island arc were partly added during the late depositional period

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-11: Reading paleoclimate signals across timescales and environments
Presentation Preference: Oral Preferred

Hydroclimate dynamics in the Plio-Pleistocene Western Pacific

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Keywords: cyclostratigraphy, shallow-marine, climate, monsoon, tropical cyclone, Taiwan

The Plio-Pleistocene stratigraphic record of shallow-marine environments from the Western Foreland Basin (WFB), Taiwan, is an excellent climate archive because of its high temporal completeness promoted through high rates of accommodation creation and sedimentation. To date, only a limited interval of early Pleistocene shallow-marine strata (~220 kyrs) has been astrochronologically tuned, revealing traceable climate oscillations.

Here, we astrochronologically tuned the Chinshui Shale and the lower part of the Cholan Formation of the WFB, extending the record of climate oscillations from 3.7 to 1.9 Ma. These strata are tuned to a tropical deep-sea stable oxygen isotope ($\delta^{18}O$) record with an established time scale. The Chinshui Shale is mudstone-dominated and was deposited mostly in offshore settings. The Cholan Formation comprises mainly heterolithic strata deposited in shallower marine settings (i.e., offshore transition and nearshore environment). In this study, we use two borehole gamma-ray profiles from the Chinshui Shale and the Cholan Formation. High gamma-ray values reflect clay-rich mudstone intervals and correlate to lower values of $\delta^{18}O$ in the reference record. Low gamma-ray values point to sandstone-dominated packages and correlate with higher values of $\delta^{18}O$.

Our results show that alternating mudstone-dominated to sandstone-dominated successions during the late Pliocene to early Pleistocene are orbitally paced, and the stratigraphic record of WFB is effectively “complete” for the studied time frame between 3.7 to 1.9 Ma. The results also allow us to i) tune the upper Pliocene–lower Pleistocene Chinshui Shale and lower part of the Cholan Formation, ii) refine the magneto-biostratigraphic framework established for this time interval in the WFB of Taiwan, and iii) lay the groundwork for connecting climatic changes in Taiwan during this time to global climate change impacts.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-11: Reading paleoclimate signals across timescales and environments
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Geochemical characteristics of Early Cambrian elements and their Paleoenvironmental Significance in the western margin of the upper Yangtze River

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Keywords: sedimentary environment,δCe negative anomaly,Redox index,Early Cambrian,Upper Yangtze Region

The petrology and element geochemistry of well js1 in the Early Cambrian Maidiping-Qiongzhusi Formation in the western margin of the upper Yangtze are studied, and the characteristics of elemental geochemistry and sedimentary environment of Maidiping-Qiongzhusi Formation were discussed, so as to provide a theoretical basis for determining the paleoenvironmental evolution of Maidiping-Qiongzhusi Formation and shale gas exploration evaluation.The comprehensive analysis of geochemical characteristic parameters such as organic carbon, whole rock host, trace and rare earth elements shows that the characteristic parameters such as $Al_2O_3/(Al_2O_3+ Fe_2O_3)$, MnO/TiO_2, Zn-Ni-Co, U-Th and Y/Ho of Maidiping-Qiongzhusi Formation in JS1 well area indicate that it belongs to the continental margin sedimentary environment affected by terrigenous debris, and the parent source mainly comes from the mixing of sedimentary rocks and granite. The ree results show that light rare earth elements (LREE) is enriched relative to heavy rare earth elements (HREE) in Maidiping Formation $(La:Yb)_N$=6.05, slightly to the right, and the average δEu is slightly less than 1, indicating normal seawater deposition, shallow water, and not significantly affected by hydrothermal action. The Qiongzhusi Formation has obvious light rare earth elements differentiation $(La:Yb)_N$=7.69), LREE enrichment, HREE depletion, and obvious right dip, with weak negative δCe and δEu anomalies, and transient or intermittent hydrothermal activity disturbance. The comparison of δCe anomaly characteristics (δCe=0.36) and regional geochemical parameters shows that the water body of Maidiping Formation is dominated by oxidation conditions, and the sedimentary evolution process is tidal flat facies and shelf facies regionally, while the sedimentary environment of Qiongzhusi Formation is shallow water and deep water shelf facies of reduction-weak oxidation-weak reduction environment.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-11: Reading paleoclimate signals across timescales and environments
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Geochemical Analysis of Sedimentary Environment of Laiyang Group in Taolin Area, Riqingwei Basin

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Keywords: Riqingwei Basin, Laiyang Group, Sedimentary Environment

The Early Cretaceous marine sedimentary strata in the coastal area of eastern Shandong Province are scattered among rift continental basins. The study shows that a large-scale NE-trending rift basin, named the Riqingwei Basin, was during the Late Mesozoic. However, the sedimentary environment of the basin is still controversial. In this study, 14 siliceous sandstone samples from the Early Cretaceous Laiyang Group in the Taolin section of the Riqingwei Basin were taken as the research objects, and the evolution of sedimentary paleoenvironment was studied by petrology and elemental geochemistry. The geochemical indicators of the samples constrain the paleoenvironmental characteristics. 1) The CIA value of 70 % of the samplesCIA =50-60, reflecting the weak chemical weathering conditions and stable tectonic background in the source area. The PIA value of the samplePIA=36-74, which was lower than that of PAAS, indicating that the weathering degree of the source area was low. The SiO_2 / Al_2O_3 ratio in the study sample fluctuated between 2.84 and 4.11, indicating that the source composition was immature. 2) According to (Fe + Mn) / Ti and MnO / TiO_2 values, The Laiyang period in the study area was formed in the marginal sea environment and some strata were affected by hot water. 3) The Sr / Cu values of the studied samples were greater than 5 and the C values of 70 % the samples were 0.3~0.6; at the same time, the ancient water temperature calculation shows that the max sedimentary temperature of Laiyang period is 28.4 ℃, which generally reflects the climatic conditions of hot and drought. 4) The V / (V + Ni) values of the studied samples were greater than 0.46, and the Ceanom values (Ceanom=-0.032~-0.056), indicating that the sedimentary environment was in anoxic condition. 5) The 100MgO / Al_2O_3 values of the studied samples are greater than 10, CaO / (Fe + CaO) values are 0.10 ~ 0.54, Sr / Ba values are 0.14 ~ 0.67, indicating that the sedimentary environment is a marine environment with low to medium salinity. 6) The MnO / Fe value of the samples in the study area are 0.005 ~ 0.015, indicating the acidic or weak acidic sedimentary water conditions. The ∑REE of the samples is high, the REE distribution curve is gentle weak right-leaning type, the difference of light and heavy rare earth elements is not obvious, and there are Eu positive anomalies and Ce weak positive anomalies. The value of LREE / HREE (10.2-11.97), and the La / Ce ratio of some samples is less than 1. It shows that the Laiyang Group belongs to seawater deposition and is affected by hot water. In summary, the siliceous sandstone of Laiyang Group in Taolin area is mainly formed in the marine sedimentary environment of hot and drought, weak acidity, hypoxia and affected by hot water.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-11: Reading paleoclimate signals across timescales and environments
Presentation Preference: Oral Preferred

Bio-geochemical and depositional framework of siliciclastic sediments from an oxygenated Neoproterozoic epeiric shelf under warm and humid climate in the backdrop of Neoproterozoic Oxygenation Event (NOE)

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Keywords: Warm and humid climate, Neoproterozoic Oxygenation Event, Shallow epeiric platform or seaway.

Major, trace and stable isotopic investigations have been carried out on siliciclastic fine-grained sediments of Cave-temple Arenite Member of Neoproterozoic Badami Group of Karnataka, southern India. U-Th-Pb isotopic constraints of overlying limestone units of Konkankoppa Member provided an apparent age of this Basin as 960 Ma (Joy et al., 2019). Age of mafic intrusive from underlying Mesoproterozoic sequence (Pillai et al., 2018) and recent works on tectono-sedimentological and paleogeographic models (Samanta et al., 2021) also suggest an age of 900-800 Ma for initial Badami sediments and correlate it to break-up of Rodinia Supercontinent. The whole succession of the studied Member is composed of three sedimentary cycles, where the middle cycle is a fluvio-marine one. State-of-the-art facies study and sequence stratigraphic analyses have been used to reconstruct the palaeogeographies of the studied marine succession. The sequence model reveals a marine siliciclastic deposition related to a shallow epeiric platform or seaway, where the marine inundation took place from the western margin of the Basin. Depositional environment varies from sand-dominated, shallow waters of upper-shore regimes to comparatively deeper waters of outer shelf, where sediments are muddy and rich in authigenic clays, like ferric-illite and glauconites. Major oxide composition of shales, siltstones and clay rich sandstones have been utilized to infer Chemical Index of Alteration (CIA) and probable climatic condition during marine transgression and regression. Where, the underlying fluvio-alluvial cycle was deposited in a semi-arid to semi-humid condition (Samanta et al., 2021), the studied marine sediments were deposited in a warm and humid climate that preferred pronounce chemical weathering. Biogenically induced trace metals and stable carbon isotopic values have been used to infer the palaeo-productivity of the marine water column. Bi-metal ratios and REE pattern reveal a redox stratification within the water column. Where, shallow marine sediments of inner shelf deposited in an oxic water column, deeper muddy sediments from offshore-transition and outer shelf deposited within suboxic to anoxic-euxinic waters. Shallow marine sandstones bear ample evidences of microbial proliferation, as MRS (Microbially Related Structures), within photic zone. $\delta^{13}C_{org}$ (VPDB) values also infer that shallow water was dominated with photo-autotrophs ($\delta^{13}C_{org}$ values between –22‰ to –25‰), where deeper water might have been a niche for anaerobic and sulphur reducing chemoautotrophs ($\delta^{13}C_{org}$ values <–25‰) (Kodina et al., 1996; Hayes et al., 1999). Presence of clustered framboidal pyrites within deeper most black shales from the outer shelf also supports this contention. This present climatic interpretation, redox stratification of ocean water with an oxic shallow marine milieu and a variation in biotic community with water depth, altogether point towards a warm and humid climate with significant oxygen distribution within the atmosphere and the shallow marine water column, in equilibrium with the atmosphere. Also, the entire sedimentological and bio-geochemical framework reveal that the sedimentation took place during the warmer periods after Super-continental break up and was under an oxygenated environment, in the backdrop of Neoproterozoic Oxygenation Event (NOE).

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-11: Reading paleoclimate signals across timescales and environments
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Sedimentology and sequence stratigraphy of the Aalenian from Southern Germany

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Keywords: Middle Jurassic, sea-level change, sedimentation rate, depositional environment

Middle Jurassic sedimentary deposits in southern Germany have accumulated in a shallow-marine shelf environment and are typically dominated by thick clayey lithologies with increasing occurrences of sandstones in the upper parts. The sedimentary evolution and paleoclimatic significance of these often poorly exposed deposits remain largely unexplored. Here we present a suite of high-resolution x-ray fluorescence (XRF) core scanning data from southern Germany covering the entire Aalenian stage. The overall objective of this study is to identify Transgressive-Regressive cycles based on the analysis of three cores obtained during scientific drilling campaigns in 2019-2021. Cores have been analyzed with an Avaatech XRF Core Scanner at a 10 mm sampling interval, an energy of 10 keV and a current of 500 µA to measure element intensities ranging from aluminium through iron. Resulting trends in elemental ratios indicative for subtle grain-size variations such as Si/Al are used to reconstruct shoreline trajectories and establish a sequence stratigraphic framework. Particularly the thick and largely homogenous Opalinuston Formation appears suitable in that respect, likely resulting from extraordinarily high sedimentation rates during the lower Aalenian in southern Germany, thus providing a complete but unexplored archive of paleoclimatic signals. For the upper Aalenian, a fennoscandian sandstone provenance resulting from uplift of the North Sea dome has been suggested. Such an exotic source area has important implications regarding transport processes and, consequently, the underground architecture of upper Aalenian sandstones. Accordingly, this project will also investigate sediment provenance in order to provide a holistic view of the sedimentary evolution of the South German Basin during the Aalenian.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-11: Reading paleoclimate signals across timescales and environments
Presentation Preference: Oral Preferred

Great Blue Hole (Lighthouse Reef, Belize, Central America): a late Holocene high-resolution storm and climate archive

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Keywords: Holocene, climate dynamics, cyclone frequency, SST

Marine sinkholes, such as the 320 m wide and 125 m deep Great Blue Hole (Lighthouse Reef Atoll, Belize, Central America) are very special geomorphological features of modern reef systems. The former Pleistocene karst cavity was inundated 7.8 kyrs BP by the Caribbean Sea, in the course of the Holocene sea-level rise. Because of anoxic bottom-water conditions and, hence, undisturbed annually-layered sediments, this Belizean sinkhole is a unique sedimentary archive for the understanding of Holocene climate variability and accountable meteorological and oceanographic phenomena. As the Great Blue Hole is located within the Atlantic hurricane belt, the cavern acts as a giant sediment trap for both fair-weather and storm sedimentation. By analysing the 8.55 m long sediment core BH6, frequency variations of tropical cyclones were reconstructed with annual resolution 1885 years through the Common Era, a time window, which is key for studying climatic variations and their effects on human society. As an innovation step, a multi-proxy approach based on textural, compositional and geochemical data was applied, in order to ensure a more reliable differentiation between fair-weather sediments and tempestites. The gained data indicate a likely connection between long-term storm activity patterns and the responses of important climate phenomena to the Common Era climate variability. During five investigated climate intervals, the modes of the El-Niño-Southern-Oscillation (ENSO), the North Atlantic Oscillation (NAO) and the Atlantic Multidecadal Oscillation (AMO) exercised a major control on cyclone activity by internally modulating the thermodynamic environment (sea-surface temperature and vertical wind shear stress dynamics) for enhanced/suppressed storm formation, both on millennial and multi-decadal scales. The beginning of the Medieval Warm Period (1400-900 CE) was an exceptional time period of the Common Era record. At that time, a southward migration of the Intertropical Convergence Zone (ITCU) caused, in combination with hydro-climate changes, a shift in the tropical Atlantic cyclone regime. The storm activity in the south-western Caribbean changed in general from a stable and less active stage (900-100 CE) to a more active and variable state (modern-1100 CE). Additional geochemical analyses of the sediment layers were carried out, in order to more accurately estimate the role of sea surface temperatures (SST) within this positive feedback mechanisms of climate variability, atmospheric and oceanographic boundary conditions and cyclone frequency patterns. Stable isotope measurements (δ18O) of the varved sediments allowed to provide a continuous and 1885 years long SST curve with annual resolution. The relative SST curve was supplemented with absolute SSTs, using a molecular proxy application (TEX86). Over the investigated time series, oxygen isotopes (δ18O) and TEX86 data imply a general SST rise of 0.5°C to 1.3°C, within the south-western Caribbean. Our δ18O data further indicate an obvious variability on multi-decadal time scales. The δ18O variations occur with 32-64 years periodicities. This signal is clearly an evidence of a SST modulation, controlled by AMO variability and phase changes (50-70 years). This in turn confirms the observed relationship between storm frequency and the reactions of the above-mentioned climate phenomena to the Common Era climate variability.

Session T1-12: Deep-time lacustrine sedimentology: Paleoclimate evolution, depositional processes and geo-resources exploration

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-12: Deep-time lacustrine sedimentology: Paleoclimate evolution, depositional processes and geo-resources exploration
Presentation Preference: Oral Preferred

Simulation of Diagenesis Events Based on Digital Rock Techniques

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Keywords: Digital rock technique, Diagenesis, Discrete element method, Cementation, Dissolution, Pore system

Sedimentary rocks form after the sediments experience a series of diagenesis events, such as deposition, cementation, and dissolution. It is of great difficulty to quantitively simulate the diagenesis events using computationally numerical techniques since these events involve chemical and physical reactions between the fluids and minerals. In this paper, some novel methods based on digital rock techniques are presented to address the issues. The discrete element method is used to simulate the packing of mineral particles, and the dilation operation and quartet structure generate set algorithms are utilized to simulate the cementation and dissolution. The new digital rocks are generated after the original rock undergoes a diagenesis event. Besides, the effects of diagenesis events and diagenesis pathways on rock properties are comprehensively analyzed. The results show that cementation can decrease the porosity, fractal dimension, pore/throat radius, coordination number, correlation of pore space, permeability, and velocity values of the rocks and increase the tortuosity and formation factor of pore space. Comparing the cementation, the dissolution makes a reverse effect on rock properties. The diagenesis pathway also has an impact on the physical properties of digital rocks. In a word, the study will present a comprehensive simulation workflow about deposition and diagenesis and help us to better understand the variations of the flow and mechanical properties of rocks without conducting extensive experiments if rocks experience different diagenesis processes along different pathways.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-12: Deep-time lacustrine sedimentology: Paleoclimate evolution, depositional processes and geo-resources exploration
Presentation Preference: Oral Preferred

Sedimentological response of late Triassic Carnian Pluvial Episode (CPE) in lacustrine basin: A case study from Yanchang Formation of Ordos Basin

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Keywords: Carnian Pluvial Episode,Climate Change,lacustrine response,late triassic,Ordos Basin

The Carnian Pluvial Episode (CPE event) is one of the most significant climate abrupt events on Earth in the Triassic, and the abrupt climate environment has an important control effect on the sediment characteristics of inland lake basins.In this paper, the most important petroliferous basin on land in my country: the Triassic Yanchang Formation in the Ordos Basin is taken as an example. Based on the latest research progress on global paleoclimate, event sedimentation, source rock development mechanism and heterogeneous integration surface in terrestrial basins, based on full reference at home and abroad, and through rethinking and researching some sedimentation and accumulation problems of the Yanchang Formation, the following three points of understanding have been obtained: The Carnian period of the Middle-Upper Triassic Yanchang Formation in the basin has been redefined, and the sedimentary response to the CPE event of the Yanchang Formation has been clarified. The top boundary is equivalent to the stratigraphic boundary between the Chang 4+5 member and the Chang 3 member, and the CPE event roughly corresponds to the deposition of the "Chang 7 member black shale event"; During the Carnian and CPE events, the Yanchang Formation sedimentary lake basin showed the characteristics of "rapid lacustrine transgression and oscillating slow retreat", which is very conducive to the development of high-quality source rocks; Affected by the paleo-climate and CPE events in the Carnian period, the Yanchang Formation developed two upper and lower xenoconformity formed due to abrupt climate and environment, and they both had a significant control effect on the distribution of oil and gas. This research is of positive significance for in-depth discussion of the formation and evolution mechanism of Yanchang Formation lake basin, sedimentary sequence filling and evolution characteristics, and guiding the practice of oil and gas exploration.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-12: Deep-time lacustrine sedimentology: Paleoclimate evolution, depositional processes and geo-resources exploration
Presentation Preference: Oral Preferred

Main controlling factors to organic matter enrichment in the shales of Permian Lucaogou Formation, Jimsar Sag

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Keywords: organic matter enrichment, shale, laminae combinations, Lucaogou Formation, Jimsar Sag

The organic matters distribution characteristics and the enrichment controlling factors in the shales of Permian Lucaogou Formation were studied by integration using cores observation, thin sections identification, x-ray diffraction, rock pyrolysis analysis and element geochemistry analysis. The results showed that the rock types mainly consist of silty dolomite, micrite dolomite, tuffaceous dolomite, dolomitic siltstone, silty tuff and tuffaceous siltstone. There are three major laminae types in the research area, the tuff laminae, terrestrial debris laminae and carbonated texture laminae. The main types of laminae combinations are the “tuff texture + carbonate” binary laminae combination, “tuff texture + terrestrial debris” binary laminae combination, and “carbonated texture + terrestrial debris” binary laminae combination. In general, the rocks mixed with pyroclastic and chemical sediments are the most conducive to organic matter enrichment, and the higher the content of pyroclastic components, the more organic matter accumulation. Microscopically, organic matter is mainly concentrated in the tuff laminae. The content in the carbonate laminae is low, and almost no organic matter is visible in terrestrial detrital laminae. The organic-rich lithofacies are mainly laminar tuffaceous siltstone and tuffaceous dolomite, the organic matter distribution continuously in strip-shapes. The laminated dolomitic siltstone and silty dolomite mainly contain the scattered organic matter, and they show relatively low organic matter content. The massive micrite dolomite and siltstone are characterized by organic-poor features. The main controlling factors to organic matter enrichment in different lithofacies are significantly different. Productivity is the main controlling factor to organic enrichment of silty dolomite and micrite dolomite, while the organic matter in silty and tuffaceous dolomite is mainly controlled by redox environment. The higher specific surface area of clay minerals can easily absorb organic matter to form stable organoclay complex, which allows the organic matter to be effectively preserved in dolomitic siltstone and tuffaceous siltstone.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-12: Deep-time lacustrine sedimentology: Paleoclimate evolution, depositional processes and geo-resources exploration
Presentation Preference: Oral Preferred

Characteristics and controlling factors of glutenite reservoir rock quality of retrogradational fan delta: A case study of the Upper Wuerhe Formation of the Mahu Sag, the Junggar Basin

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Keywords: retrogradational fan delta, glutenite, reservoir rock quality, controlling factor, Junggar Basin

The glutenite reservoir rock of the fan delta facies is associated with a complex sedimentary environment and high heterogeneity, and by far the characteristics and controlling factors of the reservoir rock quality have not been well understood. By comprehensively investigating the lithofacies, petrology, physical properties and diagenesis of the Upper Wuerhe Formation of the Mahu Sag, the Junggar Basin, it is concluded that the Upper Wuerhe Formation develops three major groups of lithofacies, totally consisting of 11 sub-types, and reservoir rock properties of different lithofacies are greatly varied. This research shows that the lithofacies attributed to the tractive current and density current have well-sorted rock particles, low mud content, well-developed secondary dissolved pores, and thus high overall reservoir rock quality. On the contrary, the lithofacies based on debris flow and sheet flow, are observed with high mud content, suppressed development of intergranular and dissolved pores, and thus poor reservoir rock quality. The system tract controls the macro variation of the reservoir rock quality. The best quality is found in the highstand system tract, followed by those of the lake transgression and at last lowstand system tracts. The micro variation of the reservoir rock quality is determined by the mud content, rock particle size and dissolution. The muddy matrix mainly damages the pore connectivity, and presents the strongest correlation with permeability. The reservoir rock with concentrated particle sizes and well-sorted particles has quality better than those of reservoir rocks composed of excessively large or small particles. Dissolution effectively improves the storage capability of the reservoir rock, resulting in an average porosity increment by 4.2%.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
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A novel approach for studying Source-to-Sink system using stratigraphic forward modelling

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Keywords: Source-to-Sink system, stratigraphic forward modelling, basin analysis, provenance tracing, sediment routing system, depositional processes

The study of source-to-sink (S2S) system has become an integral part of depositional system and basin analysis. Conventionally S2S analysis mostly invokes comparing heavy mineral assemblages, elemental compositions and geochronology of certain minerals (e.g., zircon) from sources and sinks. This approach, however, depends heavily on the availability of outcrop, core or cutting samples from both the provenance (source) and basin (sink) areas, and is not always applicable. This is especially true, when analyzing ancient S2S or in exploration frontier basins, where the provenance may have already been eroded away or buried, or few samples are available from limited subsurface drillings. The other challenging issue with the conventional approach is that the interpretation of the mineralogical, geochemical and geochronological data from individual provenances may not be unique or the data do not have the spatial-temporal resolution to differentiate sediment provenances.

Here, we propose an alternative approach for S2S analysis using stratigraphic forward modeling (SFM), which allows us to study the sediment transport process of the S2S system quantitatively and reproduce the dynamic evolution of the sediment routing system. The procedure involves the reconstruction of a 3D stratigraphic model for the basin (sink) to be investigated using a hydrodynamics-based sedimentary modelling program that mimics the depositional processes during the basin-fill process. Once the model is calibrated and validated with available seismic, well log or core data, it can then be used to generate lithological, sedimentary facies and chronological information at each grid cell. Such information can be extracted to quantitatively determine the contribution from individual sediment provenances, achieving a quantitative analysis of the S2S system. The animated SFM also allows the visualization of the S2S depositional process in 3D. The construction of a SFM requires four major input parameters including (1) initial topography, (2) tectonic movement, (3) base-level change and (4) sediment supply. These input data can be derived from our existing understanding of regional geology (e.g., conceptual model, published literatures), available seismic, well log and core data, and modern analogues. For S2S analysis, it is crucial to preset the sediment supply parameter comprising source locations, sediment compositions, discharge rates, etc. A novel method is designed to preset sediment supply from multiple sources in which the sediment at each source is being released alternatingly to chronologically differentiate the relative contributions from different sources at any given grid cells in the basin at a given time step (duration). A conceptual sedimentary basin model of 80x98 km in dimension with three sediment provenances was used to demonstrate the effectiveness of this novel approach for S2S analysis. SFM also allows us to better analyze and understand the coupling relationship between the dynamic evolution of the S2S system and the internal and external dynamic geological processes such as tectonic subsidence, base level change and paleoclimate.

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Sedimentary evolution of the southwestern Tarim Basin during the Cretaceous in response to basin-range coupling: New insights from basin and landscape dynamics modelling

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Keywords: sedimentary evolution, basin-range coupling, Badlands, Tarim Basin

Sedimentary basin evolution can be reconstructed through modelling the landscape dynamics processes in response to basin-range coupling. In tectonically active regions, it is difficult to effectively restore the paleogeography and paleogeomorphology using conventional methods due to strong tectonic deformation after the initial sedimentary deposition. Several conceptual models have been proposed regarding the sedimentary evolution during the Cretaceous in the southwestern Tarim Basin, China. However, none of them can adequately account for all the research results of the stratigraphic architecture, paleogeography and sedimentary facies in a quantitative way. This study presents the first attempt to simulate the stratigraphic and sedimentary evolution of the southwestern Tarim Basin during the Cretaceous in three dimensions using a basin and landscape evolution modelling approach. The *Badlands* software was used to simulate the landscape evolution and sedimentation in response to basin-range coupling. The program is able to generate a more refined landscape model by simulating the tectonic process, climatic changes, base level oscillation and sediment flux. A 3D stratigraphic model of the Early Cretaceous is built by using seismic profiles, structurally balanced cross-sections, well and outcrop data. Relevant parameters such as base-level change, tectonic movement, rainfall, sediment and erosion were assigned to the numerical model to simulate the coupling effect of the orogenic belt denudation and basin sedimentary fill. The simulation results show that: (1) the presence of paleo-uplift within the basin can better match the present-day observed sediment thickness and distribution. (2) sedimentary provenance was sourced primarily from the West Kunlun orogenic belt with the Makit Slope to the north and the paleo-uplift within the basin only providing limited amount of sediment volumetrically. (3) there were no lakes in the basin during the Early Cretaceous, and a major river system developed in the basin along the trend of the orogenic belt east-westward. The 3D stratigraphic model has offered some new insights on the spatial distribution of the Cretaceous reservoir beds in the southwest Tarim Basin for further petroleum exploration.

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Jurassic basin types and paleogeographic pattern in southwest Depression of Tarim Basin

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Keywords: 3D digital outcrop,structural differences,prototype basin,paleogeographic

The Tarim Basin belongs to the rejuvenated foreland basin, which is characterized by multi-stage superimposition. The southwest depression is affected by the Pamir salient and the tectonic compression deformation is intense. Therefore, it is of great significance to accurately recover the prototype basin of southwest depression for exploration. In this paper, the UAV is used for the first time to build a macroscopic 3-D geological model in the region.,and the distribution and filling characteristics of the southwest depression basin are studied on the basis of 1-D drilling, 2-D outcrop and 3-D seismic data. It is pointed out that there is no “Jurassic pan-lake basin” in the Jurassic which connects the vast area in front of West Kunlun mountain, and based on this, the differential distribution model of Jurassic basin in Southwest Depression is established. Research suggests that large scale intracontinental orogeny developed in southwest Depression of Triassic, and large scale thrust fold belt developed along piedmont under compression environment. The thermochronology data show that the tectonic activity in the west was earlier than that in the east, and the different tectonic activity caused the folding belt to disappear gradually in an arc eastward. During the Jurassic sedimentary period, the southwest depression was dominated by extensional environment, and the orogenic belt root collapsed, resulting in the development of faulted basins between fold belt and orogenic belt. The fold belt became a high palaeogeomorphic position, which separated Jurassic deposits and provided sediments for foreland depressions. The paleogeographic pattern of "fault lake basin in the west and depression in the east" was formed by the fold belt as the boundary. The lake basin types mainly include fault lake basin, small intermountain lake basin within the fold belt and discontinuous depression lake basin.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
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Paleoclimate evolution recorded by the Paleocene-Eocene salt-lake sediments in Eastern China and its driving mechanism

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Keywords: Paleocene-Eocene, paleoclimate evolution, East Asian monsoon, driving mechanism, Dongying Depression

The Paleocene-Eocene with complex paleoclimate changes is a key period for understanding the evolution of the Paleogene paleoclimate in East Asia. Previous studies focused on this period were mainly based on sedimentological data from Central and Western Asia, the sediments of the Dongying Depression in Eastern China provide a stratigraphic sequence of red-bed clastic rocks, gypsum-salt rocks and shallow-semi-deep lacustrine mudstones with abundant sporopollen fossils and stratigraphic data during the Paleocene-Eocene, which was a period highly sensitive to paleoclimate changes. Selecting the Kongdian Formation (Ek)-the third member of the Shahejie Formation (Es3) of the Dongying Depression as the study object, the evolutional characteristics and the Driving Mechanism of the Paleocene-Eocene climate are investigated by a comprehensive analysis of sedimentological data, geochemical indicators, paleontological data and Milankovitch cycle analysis.

The results indicate that the paleoclimate evolution during the period of the Ek-Es3 member in the Dongying Depression can be divided into eight stages, in which the trends of paleoclimate change in stages 1–4 were similar to those in Central and Western China. The paleoclimate reached the hottest period in the Cenozoic after warming and drying during the first stage, and then showed a long-term drying and cooling trend with the Middle Eocene Climate Optimum (MECO) in the fourth stage. Affected by the uplift of the Tibetean Plateau and the regression of the Tarim Sea, the trends in stages 5-8 are clearly distinct from those in Central and Western China. In the fifth stage, although the paleoclimate in the study area was dry during stage 5, the paleoclimate in eastern East Asia began to evolve towards humid condition. In the sixth stage, the paleoclimate in the study area became oscillatory humid, and the latitudinal zonal paleoclimate pattern started to fall apart. The paleoclimate pattern changed from latitudinal zonation to east/humid and west/arid during stages 7-8, suggesting that the East Asian summer monsoon became prevalent and dominated the climate in eastern China from that time.

Based on the investigation of Paleocene-Eocene global atmospheric evolution and tectonic activities, and the analysis of sedimentary cycles at different scales, it is found that the driving mechanism for the paleoclimate evolution in the study area can be divided into two categories. The dominant mode of eccentricity under the background of planetary wind system during the 1-6 stages and the short eccentricity and precession control mode under the background of East Asian monsoon during the 7-8 stages. The paleoclimate is relatively dry and mainly controlled by the planetary wind system during stages 1-6, and the climatic characteristics reflected by meter scale sedimentary cycle is mainly driven by the eccentricity cycle. In addition, precession and obliquity cycle also have an important driving effect on the development of sedimentary cycle under the modulation of eccentricity. In stages 7-8, the East Asian monsoon became prevalent and dominated the climate in East Asia, while the paleoclimate reflected by the meter scale sedimentary cycle was mainly controlled by the short eccentricity and precession period.

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Controlling factors on formation of different quality lacustrine organic-rich shales and forming regularity of shale oil

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Keywords: Lacustrine, organic-rich shale, different quality, accumulation mechanism, shale oil, differential evolution

Unconventional energy resources of oil shale and shale oil become the substitutable field for conventional energy resource. Stronger heterogeneity on organic matter abundance, maceral components, and hydrocaron generation existed in lacustrine organi-rich shale (ORS) deposition, which included high-, fair- and low-quality. Based on the comparative analysis of the organic geochemical characteristics of the ORS from the first member of the Qingshankou Formation (Kqn1) in the Songliao Basin, the third member of the Shahejie Formation (Es3) to the third member of the Dongying Formation (Ed3) in the Bohaiwan Bay Basin, the paleoclimate Es3 to Ed3 in the Bohai Bay basin trended from warm-humid, semi-arid, arid, to warm-humid, along which the bottom water changed from freshwater-brackish, brackish, to fresh-brackish water, and varied from weak reduction–reduction, strong reduction, to reduction-weak reduction. OM of ORS is dominated by aquatic algae with a few exinite, and its productivity varied in different periods. The development of Es3 and Ed3 high-quality ORSs was controlled by productivity-driven, while the ORS of Es1-2 was decided by a combination of preservation conditions dominated and paleoproductivity supplemented. Meanwhile, sag-controlled fault influenced the thick scale of ORS development but not the quality. The sedimentary sand obviously inhibited the development of high-quality ORS. The high-quality ORS of the Kqn1 in the Songliao Basin was controlled by the high paleo-lacustrine productivity under warm and humid conditions and string anoxic reduction conditions with semi-saline water, and dominated by lamalginite and telalginite with supplemented exinite.

Lower mature samples of high-, fair- and low-quality OPSs of the Kqn1 were selected to conduct a thermal simulation experiment to identify the differences in shale oil generation from different quality of ORSs.The results indicate that the high-quality ORS dominated by telalginites or telalginite-lamalginites preferentially starts to generate hydrocarbons and still has high hydrocarbon generation capacity during high thermal stage; fair-quality ORS with low clay mineral content dominated by lamalginites reaches peak hydrocarbon generation and produces movable shale oil earlier, followed by high-quality ORS, low-quality ORS subsequently. High-quality ORS enter the shale oil stage when Ro value above 0.54% (burial depth >1283.3m). Fair- and low-quality ORSs generate shale oil when Ro>0.58% (burial depth >1332.8m). The hydrocarbon production evolution process of ORS could be divided into three stages: early low maturation stage (Ro < 0.58%), major oil production stage (0.58% < Ro < 0.97%), and oil/gas production stage (Ro > 0.97%).

Overall, strong basin-controlled and sag-controlled faults under warm and humid paleoclimate greatly affected the development scale of ORS. The distribution of sedimentary sand had an impact on quality and distribution range of ORS. The key factor was still the paleoproductivity or preservation conditions or both jointly controlling the quality of ORSs. And high-quality ORS containing abundant lamalginite and telalginite will preferentially enter the shale oil stage and arrived at the peak generation of shale oil earlier. Therefore, the sweet spot section of shale oil derived from high-quality will be buried more shallowly. The understanding is favorable to provide favorable theoretical support for the exploration and development of shale oil.

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Geochemical characteristics of calcite veins in the ultra-deep Bashijiqike Fm sandstones in the Kuqa Depression, western China: Implications for fluid evolution

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Keywords: Calcite veins, Fluid orign, Vein-forming environment, Minor and Rare Earth elements, Carbon and Oxygen isotopes

Subsurface fluid flow and fractures are usually simultaneously induced by tectonic movements. Vein-forming fluids would preferably enter into fractures and develop various veins, especially in ultra-deep tight sandstones. Therefore, geochemical signatures of fracture-filling cements could provide vital record on fluid evolution. The ultra-deep tight sandstones of the Cretaceous Bashijiqike Formation (K1bs) had experienced intensive compression since the Middle-Late Himalayan tectonic movement, producing various veins including quartz bridge, gypsum, calcite, dolomite and ankerite. Calcite veins occur widely. An integrated analysis including optical Cathodoluminescence (CL), Electron Microprobe Analysis (EPMA), LA-ICP-MS and Carbon and Oxygen stable isotopes were employed to determine the elemental compositions and abundances across calcite veins, their formation environments, material sources and precipitation periods. Calcite cements of the wall rocks and veins generally showed bright yellow, orange and dull yellow CL colors. Rare earth elements (REE), Mn and Fe can influence CL intensities and colors. REE and Mn are common CL activators, whereas Fe is a major CL quencher. Due to overlapping of REE and Mn in the CL spectroscopy, higher Mn (>2000 ppm) is stronger CL activator than REE (<200 ppm) in the K1bs Reservoirs. From vein walls to center, Mn and Sr concentrations are quite stable, while the Fe and Mg concentrations increased gradually. This implies that Mg and Fe were incorporated into the calcite lattice at a faster rate, that was also controlled by temperature, crystal growth rate and element concentrations. Post Archean Australian Shale (PAAS) normalized REE+Y patterns of calcite cements show similar characteristics with MREE being slight enriched, while LREE and HREE are slightly depleted. This indicates that pore-dominated and fracture-dominated calcite cements were deposited from marine sediment pore-waters in a weak zone. There was no obvious correlation between δCe and δEu indicated that late diagenesis had little effect on the REE fractionation, thus indicators calculated from PAAS Normalized REE could represent the calcite-forming environment. Some pore cement shows extremely negative δCe and positive δLa, which may be inherited from sea wear. In addition, both δGd and δEu showed slightly positive anomaly. Because Gd is constant from surface to the deep-sea water, a positive δGd is generally caused by the PAAS normalization method. Extreme positive δEu is always associated with hydrothermal fluid injection. Due to the lack of evidence on the hydrothermal mineral combination, Eu2+ from weathering feldspars may be responsible for the slight positive δEu. Using Carbon and Oxygen stable isotope and fluid inclusion homogenization temperatures, the oxygen isotope of the vein-forming fluids or sedimentary fluids can then be calculated by using the oxygen isotope fractionation equation for calcite. Both 13CPDB (-3.36~1.35‰) and 18Ofluid-SMOW (-1.10~2.91‰) indicated that sea water is the major source for the precipitation of the calcite veins.

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The Permian source-to-sink evolution and tectonics implications in Northwest Junggar Basin: Evidence from detrital zircon geochronology

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Keywords: Junggar Basin, Permian, provenance, U–Pb zircon geochronology, source-to-sink system, heavy mineral

The Junggar Basin, located in the NW China, is the main area for oil exploration. However, the study area lacks a complete research consisting of sequence stratigraphy, source area, transport process and deposition. The provenances of the large-scale fans developed in the system remain unclear, which needs further semi-quantitative analysis.

In this study, statistical analysis of heavy mineral assemblage and detailed petrographic investigation of gravel sized clasts, combined with detrital zircon U-Pb geochronology, were conducted from sediments in different periods to understand the sediment provenance and unravel the source-to-sink processes in the studied region. The source-to-sink systems were traced and the evolution was comprehensively analyzed and its significance for tectonic evolution was discussed.

The potential source area mainly exposes the Silurian, Devonian and Carboniferous igneous rocks and sedimentary rocks. Through heavy mineral assemblage and gravel composition analysis, it is clear that the parent rocks of the northwestern margin of Junggar Basin during the Permian are mainly intermediate-basic igneous rocks and intermediate-acid igneous rocks, mainly from the central West Junggar. There are a small amount of mixed remote sources in the northern Mahu Sag and Zhongguai Uplift, which come from the northern and southern parts of West Junggar respectively.

The detrital zircon dating results showed a dominant peak at 310-330 Ma and a secondary peak at 400-440 Ma in the northern Mahu Sag, only one dominant peak at 295-325 Ma in the central Mahu Sag, multiple peaks at 270-350 Ma in the southern Mahu Sag, and multiple peaks at 370-450 Ma in the Zhongguai Uplift. The detrital zircons from core samples reveal marked spatial changes in their age signatures that correlate with the nearby potentially source terranes. The U-Pb detrital zircons data reveal that the Permian to Carboniferous ages as the main contributor, while Silurian to Devonian ages are subsidiary.

The results reveal that the study areas displayed similar zircon U-Pb ages and gravel composition of conglomerate with the discharged basins, which reflects the control of sediment sources in river catchments, and also implies the continuous source supplies and transport pathways for sediments since the early Permian.

Based on a comprehensive analysis, the Northwestern Junggar Basin was divided into four major source-to-sink systems, with central West Junggar as the main provenance and northern and southern West Junggar as the secondary provenance.

The evolution of the source-to-sink systems shows inheritance and evolves from a single provenance into a complex provenance. In the Lower Wuerhe and Upper Wuerhe Formations, the proportion of sediment supply from the southern and northern West Junggar is higher. The variations of U-Pb detrital zircon data are the response of source-to-sink system to the transformation from extension fault to compression depression during the Late Permian. During the late Permian-early Triassic, Junggar Basin may have developed compressional thrust, leading to the uplift of West Junggar. And the tectonic activity in the southern West Junggar is stronger than that in the northern West Junggar.

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Sequence stratigraphy, depositional environment and associated lithofacies of lacustrine shale: A case from the Upper Fourth Member of Shahejie Formation, Dongying Depression, Bohai Bay Basin

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Keywords: Lithofacies (assemblages), Shale oil, Sequence stratigraphy, Dongying Depression, Bohai Bay Basin

The lithofacies assemblages in the lacustrine shale of the Shahejie Formation in the Dongying Depression have different compositions due to the complex depositional climate, lake water conditions, and sediment supply. Hence, the lithofacies types and depositional conditions were analyzed based on parasequence division and lithofacies classification. According to gamma ray (GR) integrated prediction error filter analysis (INPEFA), handheld x-ray fluorescence (XRF) measurements, mineral composition, total organic carbon (TOC) content, and sedimentary structures, six parasequences (P1 to P6 from bottom to top) were identified, and seven lithofacies are recognized: (1) organic-poor thin-bedded calcareous mudstone, (2) organic-poor laminated calcareous mudstone, (3) intermediate-organic laminated calcareous mudstone, (4) organic-rich laminated calcareous mudstone, (5) organic-rich calcareous shale, (6) organic-rich laminated carbonate-bearing mudstone, and (7) laminated silty mudstone.

When the climate became warm and wet, the water level of the lake increased with a decrease in salinity, and the corresponding lithofacies assemblages in the P1 to P2 parasequences gradually changed from organic-poor thin-bedded and laminated calcareous mudstone to intermediate-organic and organic-rich calcareous shale. When the climate became humid and warmer, resulting in an increasing water level and terrigenous input, the lithofacies assemblages in the P3 to P4 parasequences changed from organic-rich calcareous shale and laminated carbonate-bearing mudstone to laminated silty mudstone and calcareous mudstone. At the end, the climate became slightly drier and cooler with a decrease in the water level, and the P5 and P6 parasequences were dominated by intermediate-organic and organic-poor laminated calcareous mudstones.

Through elemental analysis and lithofacies observation, we found that the redox conditions of the water may have changed over time. Among the parasequences, the water column of the P2 parasequence was mainly stratified by salinity, that of the P4 parasequence was mainly stratified by temperature, and that of the P3 parasequence was in transition. The synergistic effect of various factors played a key role in the enrichment of organic matter.

This study highlights the depositional processes of the lithofacies assemblages in a lacustrine shale and contributes to the understanding of shale oil accumulation in lacustrine shale.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-12: Deep-time lacustrine sedimentology: Paleoclimate evolution, depositional processes and geo-resources exploration
Presentation Preference: Oral Preferred

Occurrence, genesis and significance of analcime in Paleogene lacustrine shale in Cangdong depression, Bohai Bay Basin, China

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Keywords: Analcime, Genetic mechanism, Distribution characteristics, Fluids-rock interaction

Natural analcime, an aluminosilicate mineral with multiple genetic mechanisms, widely occurs in fine-grained sedimentary rocks. The assemblage relationship with different authigenic minerals as well as distribution in both plane and vertical can indirect indicate the paleoenvironment, paleostructure and diagenetic fluids evolution. In past 30 years, analcime has been proved to be an important component of high-quality oil and gas reservoirs, which can improve reservoir porosity through a precipitation-dissolution mechanism under the influence of mass organic acids released by source rocks.

The content of analcime ranges from 4.4% to 59%, with an average of 12.9% in the shale of Paleogene Kongdian Formation, Cangdong Depression, Bohai Bay Basin. Based on this, scanning electron microscope, CL microscope, X-ray fluorescence spectrometry, Raman spectroscopy, fluid inclusion microthermometry and laser ablation inductively coupled plasma mass spectrometry were utilized to analyse the occurrence, genesis and distribution of analcime in Ek2 (the most analcime-rich member). The results show that: (1) The occurrence of analcime in shale and interbeded silty bands include dispersed micritic, sparry filling and bedding laminae. (2) The content of analcime has a negative correlation with the clay minerals, symbiosis with hydrothermal minerals include dolomite, pyrite and barite. (3) The distribution of analcime is controlled by both of fault and salinity. (4) The fluid inclusion thermometry results indicate the reservoir was modified by multiple phases of hydrothermal fluids. (5) The REE distribution pattern of analcime is similar to adjacent volcanic rocks, and the differences reflect the influence of diagenetic fluid. Combined with the characteristics of “weak intensity, low amplitude and high frequency” of Cenozoic fissure-erupted magma activity in Cangdong Depression, concluded that analcime was formed in a "closed-semi-closed" lake basin environment under the influence of high-frequency hydrothermal fluids, dominated by hydrothermal and diagenetic fluids driven "water-rock" reactions. The formation mechanism include: non-tuffaceous materials conversion, hydrothermal deposition mineralization, and alkaline lake or pore water precipitation. The last two are closely related to the formation of analcime laminae, which has the greatest contribution to improve shale reservoir porosity and connectivity.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-12: Deep-time lacustrine sedimentology: Paleoclimate evolution, depositional processes and geo-resources exploration
Presentation Preference: Oral Preferred

Weak strike slip in Yangjiang-Yitong fault zone and its sedimentary structural response and petroleum geological significance

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Keywords: Yangjiang-Yitong fault zone, Yangjiang depression, Fault reservoir control, Extension-strike slip, Magmatism

Previous studies on the Yangjiang-Yitong fault zone mainly focus on the identification marks, development stages and temporal and spatial distribution, and lack of research on the impact of the fault zone on the sedimentary filling and oil and gas geological significance of Cenozoic basins (depressions). The Yangjiang east sag in Pearl River Mouth Basin is located in the north section of Yangjiang-Yitong fault zone. Plenty of oil and gas exploration work has been carried out in recent years, which provides data basis and oil and gas exploration perspective for the study of Yangjiang-Yitong fault zone.

Researchers in this paper recognize that Yangjiang-Yitong fault zone is a large-scale weak strike slip fault zone. The fault zone has an important influence on the source sink system, sedimentary filling and oil and gas accumulation in Yangjiang east sag. To sum up, there are three main points.

First, it promoted the rifting evolution process and the formation of accommodation space of Yangjiang east sag, which was "strongly extensional depression in the early Wenchang period and extensional-strike slip joint depression control in the late Wenchang period".

Second, it formed the sedimentary filling and source rock development mechanism of "multi-stage rifting center superposition, endogenous thick lacustrine sedimentation, magmatic warming promoting hydrocarbon generation and expulsion". Yangjiang-Yitong fault zone limits the scope of rifting, superimposes the rifting centers of different rifting episodes in Yangjiang east sag, promotes the formation of accommodation space and is conducive to the formation of medium and deep lacustrine environment. The basement on the Yangjiang-Yitong fault zone is broken, forming a paleogeographic pattern of alternating depression and uplift. It is dominated by the material source in the basin, and the superposition of multi sequence high-quality source rocks in the under compensation environment. The fault zone was activated twice in Eocene and Miocene, and the magma was abnormally developed. The deep heat flow brought by it greatly reduced the hydrocarbon generation and expulsion threshold and enhanced the oil and gas resource potential of Yangjiang east sag.

Third, it promotes the fault reservoir control mechanism and oil and gas distribution law of "weak strike slip faults control traps, differences control migration, and fault segmentation controls sealing" in Yangjiang east sag. After activation in Miocene, Yangjiang-Yitong fault zone developed a series of NW-NWW trending, tensional and torsional faults, which controlled the development of main traps, vertical transportation and lateral sealing of oil and gas, and then controlled the distribution pattern of oil and gas.

Based on the recognition of the weak strike slip property of Yangjiang-Yitong fault zone and its oil and gas geological significance, it has improved the confidence in the oil and gas exploration of the whole Yangjiang-Yitong fault zone and promoted the exploration process of Yangjiang east sag. At present, many high-quality oil fields have been found in Yangjiang East sag.

Scientific Themes: Theme 1: Deep-time Climate & Environment
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Presentation Preference: Oral Preferred

Multi-source deposition of lacustrine carbonate-rich fine-grained sediments and hydrocarbon accumulation in the Upper Es4 Member in Dongying Depression

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Keywords: Dongying Sag, the Upper Es4 Member, carbonate deposits; multiple sources; hydrocarbon accumulation

Lacustrine carbonate-rich fine-grained sediments are widely distributed in the Upper Es4 Member of Dongying Depression. They are rich in organic matter and important target for unconventional oil and gas resources. The geological data and methods including cores, thin sections, X-ray analysis, SEM, EMPA and trace element analysis were integrated to study the source and formation mechanisms of carbonate-rich fine-grained sediments during the warm and humid climate, microorganism bloomed and induced to form the calcite. The strong rifting led to deep hydrothermal upwelling which resulted into thermogenic ankerite. The hydrothermal mineral form into combination of ankerite-gypsum-barite-quartz-pyrite. Ternary diagram of Ni-Co-Zn of the study object also indicated thermogenic source. Glauconite, coccolithophores and trace fossils Paleodictyon are found in carbonate deposits in the study area which indicated transgression. The storage space includes interparticle pores, intraparticle pores, lamina fissures and fractures. Hydrothermal fluids upwelled along the fractures and contribute to the maturation of organic matter thus it is beneficial to the development of high quality source rocks.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-12: Deep-time lacustrine sedimentology: Paleoclimate evolution, depositional processes and geo-resources exploration
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Identification and reconstruction of multi-scale bedding fractures in shale reservoir

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Keywords: Fractures fill, Fluid inclusions, Bedding fracture opening, Bedding fracture filling

Bedding fracture in shale reservoir is one of the important factors affecting the development of shale oil and gas reservoir. Whether bedding fracture is effective or not directly affects the production of shale oil and gas. Through the field outcrop, core observation and water immersion experiment analysis, it is clear that the bedding fractures of shale reservoir layers exist in the natural state. Imaging logging, wet light identification, microscopic imaging gray analysis and other technologies are used to jointly identify multi-scale bedding fractures on opening. Imaging logging can identify bedding fractures with an opening of more than 5mm, and the density can reach 14 / M; The immersion test method is to identify that the density of bedding seam can reach 1813.5 pieces / m, and the number of bubbles is positively correlated with the number of bedding and natural micro cracks. The density of micro crack seam can be calculated quantitatively by using TOC and silica content. The imaging logging is calibrated by comparing the argillaceous strip, low angle fracture and imaging logging on the core. The bedding fracture with the opening position greater than 5mm has a good response on the imaging logging, and there is no response on the imaging logging for the foliation fracture with the opening position less than 5mm on the core. However, according to this mode, it is inferred that the bedding fracture in the lower part of the underground state is open. Combined with the distribution of calcite veins and the growth mode of calcite veins observed in the core of the study area, four stages of foliation fracture development are proposed. The first stage is the original stage, with sedimentary formation layer; The second stage is the primary stage, and some cracks open along the bedding plane; The third stage is the growth stage. The open cracks continue to grow or merge to form large-scale cracks, or close and disappear; The fourth stage is the old age stage. Some cracks continue to open, and some cracks form calcite filling cracks due to recrystallization. The research results have extensive reference significance for re understanding the size of shale gas reservoir space and exploration and development.

Scientific Themes: Theme 1: Deep-time Climate & Environment
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Presentation Preference: Oral Preferred

Proportional relationship between the flux of catchment-fluvial segment and their sedimentary response to diverse bedrock types in subtropical lacustrine rift basins

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Keywords: Source-to-sink system, Bedrock type, Catchment area, Sediment discharge, Sandy sediment flux

Sedimentary features of a source-to-sink (S2S) system produce distinct responses to diverse bedrock types (i.e., silicate and carbonate rocks) in the catchment; these majorly influence the sediment flux, volume, and grain size in the sink area. By comparing a modern S2S system of Holocene Erhai Lake Basin (ELB) (in southwestern China) and an ancient S2S of Eocene western Offshore Bohai Bay Basin (OBBB) (in eastern China), we investigated the differences and proportional ranges among sandy sediment flux (Q_f) and sediment discharge (Q_s) from catchment associated with diverse bedrock types in a humid and subtropical lacustrine rift basin by combining with the Google-topographic-map, BQART-model, and seismic-geomorphology analysis. Based on geomorphological and 3D visualization analysis, we identified the differences among multiscale catchment-fluvial segments and their sedimentary responses in S2S systems, and then extracted parameters of catchment-unit area (A), catchment relief (R), and total sediment discharge (Q_s, calculated by BQART model). Furthermore, we analyzed sediment-dispersal patterns and sandy sediment fluxes in the nearshore (Q_f) using regional geologic data, outcrops and the Google Earth database in the Holocene ELB, and using seismic geomorphology in the Eocene western OBBB. Finally, quantitative analysis of the modern and ancient S2S segments was used to investigate the total sandy sediment flux (Q_f), which is supplied by > 60% of the entire sediment discharge (Q_s) for catchments with silicate bedrocks (e.g., metamorphic rock and granite), while the ratio Q_f/Q_s corresponding to carbonate bedrocks is less than 30%. Additionally, the ratio Q_f/Q_s for catchments with mixed silicate carbonate bedrocks ranges between 30% and 60%. These results not only provide a new perspective for investigating sandy sediments in a subtropical lacustrine rift basin, but also yield implications for better understanding of continental S2S system theory for diverse bedrock types.

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Presentation Preference: Oral Preferred

Genetic mechanism and significance of sparry calcite in lacustrine deep-water fine-grained sedimentary rocks

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Keywords: Fine-grained sedimentary rocks, shale oil, sparry calcite, diagenesis

Sparry calcite is widely developed in lacustrine deep-water fine-grained sedimentary rocks, which is one of the important reservoirs of shale oil. Taking the fine-grained sedimentary rocks of the upper fourth sub-member and the lower third sub-member of Shahejie Formation(Es_4^s-Es_3^x) in Jiyang depression as an example, by means of thin section observation, inclusion test, field emission scanning electron microscope observation, laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) analysis, micro-area carbon oxygen isotope analysis, etc., the research shows that the sparry calcite in the Es_4^s-Es_3^x lacustrine deep-water fine-grained sedimentary rocks in Jiyang depression is mainly formed in the middle diagenetic stage. The temperature range is 90 ~ 120 ℃, and the pressure range is 45 ~ 60MPa. According to the aspect ratio of crystal, sparry calcite can be divided into granular, columnar and fibrous. According to the enrichment of albite, quartz and other impurity minerals, granular sparry calcite is further divided into impurity-rich granular sparry calcite and impurity-poor granular sparry calcite. Columnar/fibrous sparry calcite (collectively referred to as “beef” sparry calcite) is also further divided into clay basement and carbonate basement. The development of sparry calcite is the result of the synergistic effect of the thermal evolution of organic matter, the transformation of clay minerals and the dissolution of unstable minerals such as early calcite and feldspar. Impurity-rich granular sparry calcite characterized by poor iron is the main type of sparry calcite in the study area. The material components are mainly derived from the dissolution of early micritic calcite in situ. It is formed by recrystallization driven by organic acid and carbonic acid. The occurrence, structure, mineral composition and element content inherit the characteristics of early calcite to a great extent; The development of beef sparry calcite is controlled by the mechanism of crystallization force and abnormal overpressure. The beef sparry calcite with carbonate basement is poor in iron, and the material components are mainly derived from the dissolution of basement carbonate. The variation range and trend of element content inherit the characteristics of the basement to a certain extent; The beef sparry calcite with clay basement is rich in iron, which is the result of the coupling of clay mineral transformation, calcareous bioclastic dissolution and organic matter thermal evolution. The genetic mechanism of different types of sparry calcite indicates the formation and evolution of shale oil reservoir and the law of generation, migration and accumulation of shale oil.

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Dynamic evolution model and exploration significance of sedimentary system of steep slope zone in Paleogene in Panyu 4 sag, Pearl River Mouth Basin

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Keywords: Panyu 4 sag, Sedimentary system, Dynamic evolution model, Paleogene, Steep slope zone

Panyu 4 sag, as a hydrocarbon-rich sag, a series of oil fields in Neogene have been discovered successively. The proved reserves have already exceeded 100 million tons. The drilled wells analysis shows that the development and distribution law of high-quality reservoirs is the key factor restricting the Paleogene exploration in this area. In this paper, by analyzing the formation and evolution process of the paleogeomorphology , and the dynamic mechanism of the development of paleovalley system in the Paleogene steep slope zone of Panyu 4 sag, the sedimentary system of the steep slope belt of Panyu 4 sag was reshaped. Also, the dynamic evolution model of of sedimentary system was established in the Paleogene steep slope belt Panyu 4 sag, which provides reference for the exploration of Paleogene and the study of dynamic sedimentary system in similar areas. The results are as follows: The staged activation of pre-existing faults controls the sedimentary pattern of the steep slope zone. During the sedimentary period of Wenchang Formation, the two groups of pre-existing faults were activated in stages under the influence of the regional stress field [1]. The NE trending pre-existing faults activated and controlled the sag in the early Wenchang Formation, which controlled the sedimentary pattern of the steep slope zone in the early stage of Wenchang Formation in Panyu 4 sag, dominated by the near-source gravity flow deposition. The NW trending pre-existing faults activated and controlled the channel in the middle Wenchang Formation. It controlled the sedimentary pattern of the steep slope zone in the middle and late stages of Wenchang Formation of the Panyu 4 sag, dominated by the traction flow deposition. The transition of the regional stress field triggers the transition of the sedimentary pattern. Affected by the change in subduction angle and direction of the Pacific plate to the Eurasian plate at around 43 Ma(in middle Wenchang period) [2] , a series of NWW trending valley systems developed in the uplift area of the steep slope zone of Panyu 4 sag. While the sections of sag-controlling fault and NE trending pre-existing fault were combined, the gradient of the steep slope zone became gentler. At the same time, influenced by the upward arch of the magma in the center of the sag, relatively shallow sedimentary environment developed in the steep slope zone[3-5]; In the Paleogene steep slope zone of Panyu 4 sag, the nearshore subaqueous fans sedimentary system developed in early Wenchang period, while the northern sub-sag was the dominant development area. The fan delta sedimentary system developed in the middle and late Wenchang period, while the South sub-sag was the main development area. With good reservoir conditions, the fan delta development area in the steep slope zone of upper Wenchang Formation in the south sub-sag is a favorable exploration area.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-12: Deep-time lacustrine sedimentology: Paleoclimate evolution, depositional processes and geo-resources exploration
Presentation Preference: Oral Preferred

Recognition and Sedimentary Responses of Milankovitch Cycles in Eocene Shahejie Formation, Dongying Depression, Bohai Bay Basin

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Keywords: Lacustrine shale, Milankovitch cycles, Sedimentary environment, Laminar combination, Dongying Depression

Several studies have revealed that the Eocene fine-grained sedimentary rocks in Bohai Bay Basin is driven by astronomical forces. However it is still not clarified how orbital cycles specifically control the deposition of fine-grained sedimentary rocks and the coupling relationship of paleoclimate- paleolake- sedimentation. In this study, a combination of core and thin section observation, X-ray diffraction, ICP-MS analysis, total organic carbon (TOC) content analysis and cyclostratigraphy analysis were conducted on the lacustrine shale of the Eocene Shahejie Formation (Es4u to Es3l) in the Dongying Depression of Bohai Bay Basin, in order to recognize the Milankovitch cycles and explore the controlling effect of eccentricity, obliquity and precession on the deposition of the lacustrine shale as well as the paleoclimate evolution. The related achievements are as follows: 1. Through pre-processing, sliding window spectrum analysis and multi-taper method (MTM) of the natural gamma ray data of the well NY1, good orbital signals were recognized. And through correlation coefficient method (COCO), the study interval is divided into two sections according to the change of accumulating rates. Filtered eccentricity, obliquity and precession signal curves were obtained for both sections. 2. For the lower Section, obliquity is the main controlling factor for shale deposition and precession is the secondary controlling factor. When obliquity reaches its maximum, the content of dolomite and clay in Shahejie Formation increases, while the content of calcite decreases and TOC also increases. At this point the laminar combinations are mainly dolomite/calcite lamina and organic-rich clay lamina. When obliquity reaches its minimum, the content of calcite increases, the content of dolomite and clay decreases and TOC decreases. At this point the laminar combinations are mainly calcite lamina and clay silt mixed lamina. 3. For the upper Section, eccentricity is the main controlling factor for shale deposition and precession is the secondary controlling factor. When eccentricity reaches its maximum, the content of clay and quartz in Shahejie Formation increases, while the content of carbonate minerals decreases and TOC also increases. At this point the laminar combinations are mainly calcite lamina and organic-rich clay silt lamina. When eccentricity reaches its minimum, the content of clay and quartz decreases, the content of carbonate minerals increases and TOC decreases. At this point the laminar interface is usually blurry. 4. According to a series of geochemistry data analysis, the chemical weathering index (CIA) for the lower section is relatively low, the Mg/Ca ratio and Ni/Co ratio are relatively high, which indicates that the paleo-environment was arid and reductive. For the upper section, CIA is relatively high and the Mg/Ca ratio and Ni/Co ratio are relatively low, indicating a humid and less reductive paleo-environment. The coupling relationship of paleoclimate-paleolake- sedimentation experienced a transition from the lower section to the upper section of the study interval, which is consistent with the shift from obliquity driven to eccentricity driven. The intensification of East Asia monsoons might be responsible for this transition.

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Session T1-12: Deep-time lacustrine sedimentology: Paleoclimate evolution, depositional processes and geo-resources exploration
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Origin of organic-rich lacustrine shales under constraint of astronomical forcing and volcanism

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Keywords: origin of lacustrine shale, astronomical forcing, volcanism, shale oil

As the continuous progress of shale oil exploration and development, lacustrine shales is gradually regarded as a favorable target. Laminated shales with TOC content up to 20% commonly developed in Triassic Chang 73 sub-member in Ordos Basin, which was considered as the key object for shale oil exploration and development. The origin of this laminated shales rich in organic matter has long been of great interest to geologists. In this study, microscopic petrological analysis, in-situ geochemical analysis, spectral and wavelet analysis were used to explore the origin of laminated shales in Chang 73 sub-member. Three types of laminae and two types of laminar combination were generally identified in Chang 73 sub-member. Organic-rich laminae (ORL) and tuff-rich laminae (TRL), with TOC content ranging from 6% to 12%, are mainly composed of clay minerals. They are considered to have high oil generation potential. Silt-grained felsic laminae (SSFL) of low-density turbidity current origin contains large amount of k-feldspar (up to 70% in content) with dissolution pores. These dissolution pores provided good spaces for oil accumulation. Therefore, laminar combination 1, consisting of interbedded ORL and TRL, has superior oil generation conditions but weak oil storage capacity. Laminar combination 2, consisting of interbedded ORL and TRL, has good ability of oil generation and accumulation. Tectonic activity was relatively weak during the sedimentary period of Chang 73 sub-member. Therefore, astronomical forcing and volcanism mainly control paleo-environment evolution and lake-level fluctuation, which further result in laminated shale deposition. In the period of low obliquity, lake-level falling occurs under control by cold and arid paleo-climate. The silt-grained particles carried by low-density turbidity current commonly transported to the center of lake. It induced large-scale deposition of laminar combination 1 during this period. In the period of high obliquity, warm and humid paleo-climate induces lake-level rise. Retrogradation of silt-grained particles carried by low-density turbidity current occurred during this period. SSFL is gradually replaced by TRL. Clay minerals are dominated in the sediments. Therefore, laminar combination 2 generally deposited in the period of high obliquity. In the background of periodic paleo-environmental evolution controlled by astronomical forcing, volcanism will lead to short-term disturbances on paleo-environmental evolution. It will further impact lake-level fluctuation and shale deposition. In the period of intense volcanic activity, massive CO2 release will trigger the greenhouse effect. Heavy rainfall induces lake-level rise even in the period of low obliquity, which result in large-scale deposition of laminar combination 2. Astronomical forcing and volcanism finally induce the alternate deposition of laminar combination 1 and 2, promoting shale oil generation and accumulation.

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Discussion on mixing of fine-grained sediments in lacustrine deep water, Dongying Sag , Bohai Bay Basin

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Keywords: fine-grained hybrid sedimentary,sedimentary environment,lithofacies,sedimentary fabric,Dongying sag,sedimentation

Take the example of fine-grained sedimentary rocks in the Lower Member 3 and Upper Member 4 of Shahejie Formation in Dongying Sag.Through core observation in cm-scale,detailed description of small-sized sedimentary structures,thin section identification,analysis of whole rock X-ray diffraction and trace elements test,fine-grained sediments occurrence and their mixed mode were studied,and the effect of basin fluid,climate and water properties on transfer,mixing and sedimentation of fine-grained rocks was analyzed.The mixing sedimentary mechanism of fine-grained rocks was discussed.The results indicate tha the depositional period of shale fine-grained migmatites in Dongying depression is generally characterized by the transformation of climate from semi humid to humid, from bottom to top, it shows the process of increasing injection amount of clastic material source,increasing water depth, decreasing salinity and decreasing reducibility; fine-grained sedimentary rocks in lacustrine deepwater are mixed in both components and structures under macroscopic and microscopic scales.The mixing sedimentation can be classified into homogeneous,lamina-overlapped and heterogeneous mixings with lamina-overlapped mixing the major type of fine-grained rocks.Based on the lamina contact relations,proportion and mineral occurence,the lamina mixing sedimentation is divided into:Lamina-overlapped mixing of sandmud and limestone,lamina-overlapped mixing of mud and limestone,laminate mixing of mud-sand sequence and limestone,lamina-overlapped mixing of limestone,mud and dolostone.The types of mixing sedimentation of fine-gained sediments are often influenced by multiple factors at the same time,and the climate and the hydrodynamic conditions are the main factors.The mixing sedimentation of fine-grained sediments varied in different fluids (turbidity current and bottom current).The climate causes changes of physical and chemical properties of water as well as layering of water body,which controls different types of flocculating settling and chemical deposition of fine-grained sediments.The mixing sedimentation types vary in different structural positions and water depths,and are even different vertically in the same structural position.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-12: Deep-time lacustrine sedimentology: Paleoclimate evolution, depositional processes and geo-resources exploration
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Paleoenvironmental study of Lucaogou Formation in Jimsar Sag, Junggar Basin

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Keywords: Jimusar Sag, Junggar Basin, trace element , paleoenvironmental, paleosalinity, paleoclimate

The Jimusar Sag in the Junggar Basin is a well-studied site in northwestern Xinjiang, China, and its study can provide rich information for the paleoenvironmental and paleogeographic evolution of the Northeast Pangea. In this study, core, thin section and XRF data were used to classify the lithology of Lucaogou Formation samples, and the concentrations of major and trace elements were analyzed using linear and multivariate statistical data of whole-rock elemental data. The results show that the lithology can be divided into two large cycles, the upper cycle is dominated by mudstone, and the lower cycle is dominated by sandstone. There are mixed layers of lime mudstone, lime mudstone, sandy dolomite and sandy limestone in the upper cycle, and dolomite sandstone, lime sandstone, dolomitic sandstone, lime sandstone, sandy dolomite, sandy Mixed layers of limestone. The main and trace element concentrations are mainly enriched in O, Na, Mg, Al, Si, K, Ca, Fe and other elements.

Further, we measure its paleoenvironmental characteristics based on various commonly used indices and elements, such as paleosalinity, paleoclimate, paleowater- depth, etc. Investigating previous literature found that in recent years, there is a lack of research on paleoenvironmental research using major trace elements on paleosalinity, a lack of combined research on weathering in paleoclimate, and a lack of data from paleotemperature and paleohumidity. For the study of paleosalinity, this paper adopts Sr/Ba, and considers the effect of inorganic carbon (replaced by CaO) on Sr and productivity on Ba. After removing the carbonate samples, as well as data with Sr values >1000 ppm and CaO >20 wt%, the correlation between CaO and Sr was significantly reduced. After that, we further judged the salinity of the Lucaogou Formation in the Jimusar Sag by combining carbon and oxygen isotopes. In the study of paleoclimate, this paper not only used the trace element index ratio to judge, but also combined with the transfer function of the main element and the carbon-oxygen isotope, used the CIA-K index to consider the effect of weathering, and then comprehensively analyzed the paleoclimate from the aspects of paleohydrology and paleoprecipitation. Finally, this paper analyzes the water depth through Fe/Mn, Mn/Ti and other indicators.

The study shows that the Lucaogou Formation in Jimsar Sag is dominated by saltwater-brackish water environment with a very small amount of freshwater environment. The climate is generally relatively hot and dry, with intermittent warm and humid climates. The water depth is always in a semideep-deep water environment. By comparing the curve changes and lithology changes of various paleosalinity and paleoclimate metrics, we find that sedimentary rock lithology is closely related to paleo-salinity. Carbonate rocks usually indicate a high salinity environment, and clastic rocks usually indicate a low salinity environment. The sharp fluctuations of the paleosalinity index curve are similar to the characteristics of lithological mixed sedimentation.However, most of the carbonate rocks in the Lucaogou Formation were deposited in situ, and the clastic materials in the clastic rocks may have been brought in with terrigenous freshwater that reduced the salinity of the lake.

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Main controls and geological sweet spot types in Paleogene shale oil rich areas of the Jiyang Depression, Bohai Bay basin, China

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Keywords: Paleogene ,Shale oil ,Shale reservoir, Sweet spot

The shale oil wells drilled in the early stage of the Jiyang Depression have achieved industrial-scale flflow, but the oil production in special exploration wells has been less than ideal. The area of continental shale oil and gas
accumulations has not been properly controlled, and geological sweet sections and sweet areas need to be systematically studied. In this study, shale reservoir characteristics are analyzed in detail based on thin sections,fifield emission scanning electron microscopy (FE-SEM) observations and mercury injection experiments of well core samples combined with X-ray diffffraction (XRD) and geochemical indicators. Key factors related to a high yield of shale oil are determined in addition to the shale oil production capacity, and the types of shale oil sweet spots are classifified, while the sweet spot distribution pattern is determined. The results show that the Paleogene shale in the Jiyang Depression is rich in carbonate minerals (mainly calcite and ferrocalcite, followed by dolomite and ferrodolomite) and has a low clastic content, high organic carbon content (2.0–7.0 wt%), and medium maturity (Ro = 0.51%–1.1%). An effffective reservoir space assemblage usually has a three-tier inter communication form within the porosity-fracture network. Laminar lithofacies that are rich in carbonates are the most favorable for containing continental shale oil reservoirs. Shale oil geological sweet spots can be roughly
divided into matrix shale oil, fracture shale oil, interlayer shale oil, and compound shale oil types. The key focus in locating shale oil wells is to fifind geological sweet spots that have an appropriate organic matter (OM) content,
interlayer development, light oil, and high pressure. This study demonstrates that favorable sweet spots are found to have the following conditions: a shale formation pressure coeffiffifficient of > 1.2, shale total organic carbon content of > 2%, organic-rich laminar lithofacies (including interlayer and single-interlayer thicknesses of > 2 cm), burial depth of > 3200 m, middle diagenetic stage B (Ro > 0.7%), and crude oil density of <0.89 g/cm3.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
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Lacustrine dolostone in the Songliao Basin: A novel mineralogical evidence for seawater intrusion

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Keywords: lacustrine, dolostone, Songliao Basin, seawater intrusion

Lacustrine dolostones are widely distributed in the black shale deposit in Qingshankou Member 1 in the Songliao Basin, northeast China, whereas little emphasis has been put on their petrogenesis and implications on paleo-lake water as well as continental weathering conditions. Here we reported the in-situ multielement imaging via Micro X-ray fluorescence and high spatial-resolution geochemical results of a dolostone nodule from the Qingshankou Member 1, of which the sedimentary and elemental signatures confirmed its protogenetic origin and effectiveness in recording the geochemical characteristics of paleo-lake during its formation.

According to in-situ multielement imaging results, the well-preserved laminated structures inside the nodule and the features with a magnesium-rich core wrapped with an iron-concentric outer layer and a manganese-concentric shell together indicate its primary form as dolomite and a gradual transformation into ankerite as well as manganese-ankerite. The elemental variation implies a varied bottom water redox condition, which involved from sulfidic to ferruginous and manganous zones. The extremely positive $\delta^{13}C$ values (up to +9.5 ‰) of the dolostone indicate the presence of microbial methanogenesis. And the supremely high $\delta^{26}Mg$ results (up to -0.85‰) demonstrate intensivecontinental weathering. Relatively low Y/Ho ratios, middle rare earth elements enrichment features and inconspicuous europium positive anomalies of this nodule point to a lake-water dominated source. However, the Sr isotope values in the core of the nodule (0.7076~0.7080) are close to the contemporaneous seawater (0.7074), whereas different from the modern river (0.7120) and the host black shale (0.7100). On the premise of excluding the influence of hydrothermal fluids, the significantly low Sr isotope values of the lacustrine dolomite might be caused by seawater interference during its dolomitization. Our findings demonstrated that the lacustrine dolomite within black shales is not only a faithful tracer of diagenetic water environment and continental weathering process, but also a novel fingerprint mineralogical evidence for episodic seawater intrusions in the Songliao Basin during late Cretaceous period, which supplemented other paleontological and geochemical records.

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Sedimentary environment and characteristics of Dalazi formation in the eastern depression of Yanji Basin

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Keywords: Yanji Basin, Dalazi formation, sedimentary characteristics, fan delta facies

The development period of the lower Cretaceous Dalazi formation in Yanji basin is the heyday of the development of Yanji Basin. A set of source rock is developed in the Dalazi formation in the east of the basin. This group is not only the main reservoir, but also an important exploration target. In order to better analyze the sedimentary law of Yanji Basin and predict the favorable facies belt, the sedimentary environment and sedimentary characteristics of Dalazi formation in the eastern sag are studied in detail by analyzing a large number of logging data, seismic data and observed core photos. The Dalazi formation as a whole is a set of sand mud interactive sedimentation of transgressive system, and the lake water depth is large. The histogram of mudstone color index shows that the mudstone color in this period is mostly dark. It is a reduction environment and the environment is relatively stable. Dark mudstone with large thickness and good oil generation conditions is deposited in some well areas. According to the analysis of composition maturity and heavy minerals, the sedimentary characteristics of this formation are multi provenance and near provenance, and the provenance direction mainly comes from the East. According to the sandstone triangle analysis, the lithology of reservoir sandstone is mainly lithic arkose, a few are arkose, and the sedimentary formation is fine clastic oil-bearing sedimentary formation. The sedimentary facies model of this period is: shore shallow lake facies—semi deep lake facies—fan delta facies. Based on the analysis of the sedimentary environment and characteristics of Dalazi Formation in the Eastern sag, as well as the oil and gas shows in YC2 well , it shows that there is a good oil and gas migration and accumulation system in this area, which is favorable for oil and gas accumulation and has a certain exploration prospect.

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Study on High-resolution Sequence Stratigraphic Structure Model of Dalazi Formation in Yanji Basin

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Keywords: Yanji Basin , Dalazi Formation , Maximum Entropy Spectrum , Astronomical Cycle , High-resolution Stratigraphic Framework

In the Dalazi Formation of Yanji Basin, fan delta facies and lacustrine facies are mainly developed, and alluvial fan facies are locally developed, of which the second member of Dalazi Formation is the key oil-bearing layer for exploration and development. In the process of stratigraphic correlation and division, it is found that the sandstone layer of the Dalazi Formation has a certain sedimentary thickness, and the sandstone has a certain continuity. The sand-mud interbeds frequently appear in this interval, and the stratification marks of the conventional logging curves are not obvious. In order to improve the accuracy of small layer division and correlation, based on high resolution sequence stratigraphy theory and astronomical cycle theory, the maximum entropy spectrum analysis, spectrum analysis and wavelet time-frequency analysis technology are used to process and analyze the natural gamma curve(GR) data. Sequence boundary is identified by combining the logging lithology information. According to the prediction error curve in the maximum entropy spectrum analysis, it is identified that the second member of the Dalazi Formation contains a long-term base level uplifting semi-cycle and a long-term base level subsiding semi-cycle. On this basis, the middle-term base level cycle and short-term base level cycle are identified by combining the spectrum analysis technology and wavelet time-frequency technology. Finally, the second member of Dalazi Formation in Yanji Basin is divided into 1 long-term base level cycle, 6 middle-term base level cycles and 16 short-term base level cycles, and the sequence stratigraphic division scheme is proposed. Based on this, the high-resolution stratigraphic framework is established, which provides accurate geological basis for the subsequent comprehensive reservoir evaluation and sand body prediction.

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Sedimentary evolution research of Tongfosi-Dalazi Formation, Eastern Depression of Yanji Basin

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Keywords: sedimentary evolution,cycle,maximum entropy spectrum,lake level,fan delta

Yanji Basin is a Mesozoic rift basin in eastern Jilin Province. The existing exploration data show that Tongfosi-Dallazi Formation is the most favorable area for oil and gas reservoir in Yanji Basin. The structural characteristics of the basin are complex, and large and small faults are developed. The sample analysis results show that the physical properties of sandstone reservoirs are generally deviated, which belongs to the type of medium porosity and low permeability reservoirs. The source rocks in the eastern depression are relatively developed, and the sandstone thickness is large, which has certain resource development potential. And in the eastern depression Yan12well in1280m still see oil and gas shows, porosity of12-13 %, permeability of$4 \times 10^{-3}\mu m^2$, indicating that there is a relatively good reservoir physical properties distribution area, but the specific distribution is not clear.

On the basis of basic geological research such as regional tectonic background and regional stratigraphic characteristics, the sedimentary evolution process of Tongfosi-Dallazi Formation in the eastern depression of Yanji Basin is described in detail in this paper : 1.Tongfosi-Dallazi Formation in Yanji Basin is divided into a third-order cycle and six fourth-order cycles by using sequence stratigraphy analysis ; 2.The maximum entropy spectrum analysis method is used to obtain the change rule of the lake level in the eastern depression of Yanji Basin : The basin mainly experienced a complete process of water inflow and water recession in the Tongfosi-Dalazi sedimentary period, in which the Tongfosi Formation and the first member of the Dalazi Formation are water inflow, the second member of the Dalazi Formation is the highest water level period, and the third member of the Dalazi Formation begins to reduce water level. 3.Sedimentary characteristics and sedimentary facies were studied. Fan delta facies and lacustrine facies were mainly developed in Tongfosi Formation and Dalazi Formation, in which fan delta facies identified fan delta plain and fan delta front subfacies. The lake facies can identify shallow lake, semi-deep lake-deep lake subfacies. The fan delta sedimentary system developed in the Tongfosi and Dalazi Formation, but the Dalazi Formation fan delta facies is the most developed, and the source supply is sufficient. The lacustrine sedimentary system is mainly developed in the Tongfosi Formation, and the Dalazi Formation is only developed in some areas of the basin.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-12: Deep-time lacustrine sedimentology: Paleoclimate evolution, depositional processes and geo-resources exploration
Presentation Preference: Oral Preferred

Identification and quantitative characterization of silty laminae and beds in lacustrine organic-rich shales

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Keywords: Silty laminae and beds, lacustrine shale, organic-rich shale, formation evaluation

Influenced by sedimentary environments such as sediment provenance, paleoclimate, the geochemistry of the water body and paleoproductivity, various laminae and beds are developed in the lacustrine organic-rich shales. Silty laminae and beds developed in the shale formation in the freshwater lake basin are important reservoir spaces and efficient channels for oil and gas migration. In addition, the identification and characterization of silty laminae and beds are critical to the sedimentary environment analysis, formation evaluation and sweet spot optimization. Researchers carried out a lot of studies on the drilled rock samples which contain silty laminae and beds, including core description, mineral composition analysis, scanning electron microscope, particle size, nitrogen adsorption and other experimental methods. Mathematic methods such as unsupervised clustering, fractals and joint characterization are used in the quantitative characterization of silty laminae and beds. However, drilled rock samples are limited and expensive, it is challenging to realize the fine evaluation of heterogeneous organic-rich shale formations.

Chang 7 member organic-rich shale formation in the Ordos basin is studied in this research. We used conventional logging and electric imaging logging to realize the identification and quantitative characterization of silty laminae and beds in lacustrine organic-rich shales. It mainly includes the following three steps:

(1) Lithology identification: the logging response characteristics of pure shale, silty laminae and beds, pyrite enriched layers and tuff layers in the organic-rich shale formation are analyzed. The criterion of lithology identification is established, and it can be clear that the silty laminae and beds with thickness greater than 1cm can be identified by the electric imaging logging.

(2) Identification of silty beds: the essence of silty beds identification based on the electric imaging logging is edge detection. A new method based on image processing and morphology is established, including the comprehensive process of electrical imaging logging, edge detection based on Sobel horizontal operator, and open operation. The silty laminae and beds with thickness greater than 1cm can be identified by this new method.

(3) Quantitative characterization of silty laminae and beds: based on the identification of organic-rich shales and silty beds, the thicknesses of silty beds are counted. It is clear that the distribution of the thickness of silty beds can be characterized by fractals. Therefore, the total thickness calculation model of silty laminae and beds can be established by the comprehensive analysis of electric imaging logging and drilled rock samples.

This research indicates that the silty laminae and beds identified by electrical imaging logging and core observation have a good consistency. This new method can be used in the uncored wells to realize the identification and quantitative characterization of silty laminae and beds. Moreover, the results are critical in the sedimentary environment analysis, formation evaluation and sweet spot optimization.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-12: Deep-time lacustrine sedimentology: Paleoclimate evolution, depositional processes and geo-resources exploration
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

A comparative study of lake level fluctuation based on sedimentary facies and hydrogen index: a case from the Cenozoic Nima Basin in Tibet

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Keywords: Nima Basin, Tibet, Lake level fluctuations,hydrogen index,sedimentary facies

Lake level fluctuations are extremely sensitive to regional and even global climate and environmental changes. Meanwhile, the source rocks are mostly developed and distributed during the lake-flooding period. Identifying the level fluctuations of ancient lakes is beneficial to the prediction and search of source rocks, and promotes the exploration and development of oil and gas resources. Therefore, it is significant to restore the indicators that record the level change of ancient lakes. In modern lakes, lake shorelines and lakeside terraces can directly reflect the fluctuation of lake levels. However, these geomorphological signatures are generally difficult to preserve in ancient lake deposits. Lake level fluctuations derived from traditional sedimentary facies changes are more intuitive, but the resolution is low. As an indicator of the redox environment, the hydrogen index can make up for the shortcomings of the above methods.

The Niubao Formation of Paleogene in the Nima Basin, Tibet, with clear outcrops, rich lithology, and fossils, is suitable for studying lake level fluctuations. Investigated the development horizon of source rocks in this section, this study discussed the relationship between source rocks and lake level and the superiority of hydrogen index in studying paleo-lake level fluctuations.

We discuss lake level and its controlling effect on source rocks by comparing the lake level fluctuation curves based on sedimentary facies and hydrogen index respectively. Through the research of sedimentary petrology, kerogen type, hydrogen index, and organic matter maturity of the samples, it was found that deep lacustrine facies has higher TOC compared to shallow and semi-deep lakes. The increase of lake paleo-depth plays a leading role in the quality of source rocks. However, when the lake level rises to a certain extent, the TOC of source rocks is mainly controlled by paleoproductivity. Compared with the lake level curve based on sedimentary facies, the hydrogen index also identifies lake level changes in similar lithologies. This more detailed method of describing the level fluctuations of ancient lakes is of great significance for guiding oil and gas exploration.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-12: Deep-time lacustrine sedimentology: Paleoclimate evolution, depositional processes and geo-resources exploration
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Distribution regularity of the coupling relationship between tight sandstone reservoir densification and oil and gas filling in the third member of Shahejie (Es3) Formation in Bohai Bay Basin

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Keywords: Tight oil and gas,Reservoir densification,Hydrocarbon charging,Bohai Bay Basin

The tight sandstone in the Bohai Bay basin is rich in oil and gas resources, mainly distributed in the third member of Shahejie Formation (Es3). The differential tectonic evolution leads to obvious differences in diagenetic evolution history and oil and gas filling history in different regions of the basin. However, there is still a lack of research on the relationship between reservoir densification process and oil and gas filling.

Based on the relationship between reservoir densification and oil and gas filling, tight sandstone oil and gas reservoirs can be divided into three types"Accumulation before tightness" type (type I) “Accumulation synchronization with tightness” type (type II) "Accumulation after tightness" type (type III).

Based on the time coupling relationship between reservoir densification and main hydrocarbon generation and expulsion period, the coupling relationship between diagenesis and accumulation of tight sandstone reservoir in the Es3 Formation is characterized by multi-layer ring distribution centered on Bozhong Depression. The outer ring area includes the north of Jizhong Depression and Changwei Depression. The sub outer ring area mainly includes Liaohe Depression, Linqing Depression and the north of Liaodongwan Depression. The middle ring area mainly includes the south of Jizhong Depression, Jiyang Depression and Huanghua Depression. The inner ring area is mainly Bozhong Depression.

Two periods of oil and gas charging occurred in the Es3 formation, respectively in the middle and late Paleogene and Neogene to Quaternary. From the periphery of the basin to the center, there is an evolution law of “early one-stage hydrocarbon charging” → “two-stage hydrocarbon charging, early mainly” → “two-stage hydrocarbon charging, late mainly” → “late one-stage charging”. The evolution of reservoir porosity in the Es3 Formation presents the characteristics of “compaction and cementation porosity reduction” → “dissolution porosity increase” → “cementation porosity reduction” → “weak dissolution porosity increase”.

The densification time of the reservoir from the outer ring to the center presents the evolution law of "middle Paleogene → middle to late Paleogene → late Paleogene to early Neogene → middle to Late Neogene". For the first stage of oil and gas filling in the middle and late Paleogene, from the outer ring to the middle ring, the coupling type presents the distribution law of " type III → type II or type III → type I or type II". For the second stage of oil and gas filling from Neogene to Quaternary, the whole basin is dominated by type III coupling relationship.

The outer ring and sub outer ring are mainly tight oil and gas reservoirs with type III coupling relationship, which is likely to form relatively dispersed continuous tight oil and gas accumulation; In addition to type III oil and gas reservoirs, tight oil and gas reservoirs with type I and type II coupling relationship are also developed in the middle ring and inner ring, which is likely to form relatively concentrated trap tight oil and gas accumulation, and the exploration is relatively favorable.

Scientific Themes: Theme 1: Deep-time Climate & Environment
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Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Tectonic and depositional evolution of Meso-Neo Proterozoic in Ordos Basin and its periphery

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Keywords: Ordos Basin and its periphery,Meso-Neo Proterozoic,property of prototype basin,tectonic and depositional evolution

The tectonic and sedimentary evolution of Meso-Neo Proterozoic in Ordos Basin and its periphery is ascertained in order to restore the original tectonic and sedimentary pattern and to explore oil and gas. In this paper, based on geological, seismic and logging data, the tectonic and depositional evolution of Meso-Neo Proterozoic have been studied in Ordos Basin and its periphery. The research shows that the Ordos Basin and its periphery underwent four tectonic and sedimentary evolutionary stages in Changchengian, Jixianian, Qingbaikou and Sinian Period of Meso-Neo Proterozoic. They are rift, passive continental margin, marginal subsidence and marginal depression, respectively.The Changchengian System was mainly composed of a set of terrestrial-littoral facies quartz sandstone, and developed braided river, delta, littoral shallow sea, shallow sea and deep sea sedimentary facies. The Jixianian System was mainly epeiric sea sedimentary facies with shallow water, including sand flat, dolomitic flat, flint dolomitic flat, open platform and shallow sea facies. Within Qingbaikou Period, the sedimentary environment of Ordos Basin and its periphery was retention marine basin and continental slope. There was glacial deposits in the Sinian System developed continental glacier, littoral sediment and shelf sedimentary facies.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-12: Deep-time lacustrine sedimentology: Paleoclimate evolution, depositional processes and geo-resources exploration
Presentation Preference: Oral Preferred

Environmental magnetism and cyclostratigraphic analysis of the lacustrine successions of the Lower K1sh formation in the Early Cretaceous Songliao basin, northeastern China

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Keywords: SK-2 borehole, lacustrine, Early Cretaceous, environmental magnetism, cyclostratigraphy

Continuous cores of the lower Cretaceous in Songliao Basin, northeastern China, have been drilled out by the International Continental Drilling Project of SK-2 borehole, providing unprecedented geological materials for investigations of the early Cretaceous continental paleoenvironment and paleoclimate. In this study, we systematically studied the lacustrine successions of the lower Shahezi Formation (K1sh) in depth 4542-5694 m using the techniques of environmental magnetism, microscopic imaging, geochemical stratigraphy and cyclostratigraphy. Magnetic analysis reveals that there is an inverse correlation between magnetic susceptibility (MS) and lithology, where mudstones hold the largest values, and sandstones hold the smallest. The main magnetism carriers in the lower K1sh are pseudo-single-domain (PSD) and/or multi-domain (MD) ferromagnetic minerals, whilst the mainly dominant minerals of MS are paramagnetic and ferromagnetic minerals. To further explore the genesis of the environmental and climatic variations, MS was utilized as an alternative proxy to proceed with cyclostratigraphic analysis. Sedimentary cycles of 113.04 m, 34.11 m, 13.34 m and 6.00m are significant in power spectrum, which are in ratio highly accordant with long eccentricity (405 kyr), short eccentricity (124 kyr), obliquity (47 kyr), and precession (21 kyr) cycles in Early Cretaceous, proving the considerable impact of astronomical cyclicity on sedimentary rhythmicity. Long eccentricity controlled sedimentary facies, short eccentricity and precession are regarded to have mutually shaped the lake level oscillations. It should be noted that semi-precession periods identified from MS and the U sequence is most likely to directly drive the sand-mudstone alternations with the seasonal discrepancies of summer insolation. Finally, by tuning the inferred long and short eccentricity cycles to 405 kyr and 124 kyr orbital eccentricity theoretical curves, we established floating astronomical time scales (FATS) of 3356.99 kyr and 3248.80 kyr respectively, both of which fall into the range of the published U-Pb ages. Sedimentation rate was estimated ranging from 27.50 cm/kyr to 28.91cm/kyr, confirming the rapid deposition characterized within the fault lacustrine basin. In summary, our study acquired experimentally detailed magnetic characteristics of the early Cretaceous terrestrial sediments, shed new light on the astronomically forced configurations of paleoclimate on these magnetic properties, and provided a preliminary geochronological constraint for further marine-terrestrial comparison towards coeval strata.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-12: Deep-time lacustrine sedimentology: Paleoclimate evolution, depositional processes and geo-resources exploration
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Establishment of an age-calibrated astronomical time scale for the Chang 7 Member of the Triassic Yanchang Formation within the Ordos Basin, Central China

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Keywords: Triassic time scale, Detrital zircons, Tuff zircons, Geochronology, Milankovitch cycles, Indosinian Orogeny

Astrochronology provides a method for developing highly detailed internal time scales for understanding Earth's history and rates of processes. During the Triassic, large continental lakes formed in the Ordos Basin of Central China. The lacustrine facies of the 7th Oil Member (Chang 7 Member) of the Yanchang Formation in the southern Ordos Basin displays cyclic changes in clay content, color and other properties. U–Pb geochronology of zircons from a basal tuff (ca. 239 Ma) and of detrital zircons from two sandstone beds within the reference Well N36 were used to constrain the stratigraphic ages and to identify possible provenance of the siliciclastics. Detailed time-series analysis was performed on the natural gamma (GR) logs and on the elemental concentrations of Fe and of Al. The resulting astronomical time scale for the Chang 7 Member, as constrained by the U-Pb dating, spans the interval from ca. 239 Ma through ca. 229 Ma; therefore, it was deposited during the Ladinian and Carnian (late Middle through earliest Late Triassic). The distribution of detrital zircon dates show that the Chang 7 Member in the southern Ordos Basin has multiple provenance characteristics. The southern Ordos Basin is far from this provenance area, which is reflected in the low sediment accumulation rate (0.5-2 cm/kyr). In contrast to underlying members, the lacustrine sediments of the Chang 7 Member hosts a large number of tuffs and seismites. This change is interpreted as a product of the initiation of collisional tectonics that formed the North Qinling orogenic belt on the southern margin of the Ordos Basin.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-12: Deep-time lacustrine sedimentology: Paleoclimate evolution, depositional processes and geo-resources exploration
Presentation Preference: Oral Preferred

Enrichment mechanism of organic matter in saline lacustrine basin

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Keywords: paleoenvironment,organic matter enrichment,saline depositional environment, lacustrine basin

The organic matter enrichment is the basis of oil and gas resources evaluation. The lacustrine shale oil and gas resources is rich from Mesozoic and Cenozoic in China. However, due to the small area of the lacustrine basin, the hydrological conditions of the lake is disturbed by the sedimentary environment and affect the balance of evaporation and precipitation resulting from the small area of lacustrine basin (Katz, 1995), which leading to the change of lake water properties and complex organic matter enrichment (Pedersen and Calvert, 1990). The Dongpu Depression is a typical continental faulted lacustrine basin in Bohai Bay Basin in China. During the sedimentary period of the lower sub-member of Es3 (Member 3 of the Shahejie Formation), the deposition environment of saline and fresh-water were developed in the north and south region, respectively. In the past 50 years of exploration and development, 93.7% of oil and 80% of natural gas have been found in salt water sedimentary environment (Zhang et al., 2017).

The shale deposited in the north region develop salt rocks (mean value: 8.24%) and carbonate minerals (mean value: 34.79%) with an average TOC of 1.17%. The shale in the south region develop rare salt rocks with an average TOC of 0.44%. The carbonate minerals are relatively few (with an average of 20.5%). Combined with the data analysis of major and trace elements, it is considered that the climate was arid during the sedimentary period of the lower sub-member of Es3. The salinity of the ancient lake in the northern region is high, and halophilic algae such as dinoflagellate are developed, which increases the paleoproductivity in this period. In the southern region, the salinity of ancient lake is low, green algae are mainly developed, the degree of chemical weathering is medium, and the terrigenous input is high.

According to the further analysis of the organic matter enrichment mechanism of the saline sedimentary environment in the north, it is found that the TOC shows an obvious positive correlation with the paleoproductivity, which increases first and then decreases with the paleosalinity, reaching the maximum when the paleosalinity is 11 ‰. Based on the palynological analysis, it is found that when the salinity of the northern region is 12 ‰ ~ 13 ‰ and the TOC content is as low as 0.2%, the sporopollen development mainly includes Ephedra and Podocarpidites. It may be that the seasonal arid climate leads to the increasing terrigenous input, which is not conducive to the enrichment of organic matter. When the salinity is 10 ‰ ~ 12 ‰, the TOC content exceeds 1.5%, the dinoflagellate and acritarcha algae are developed. In addition, the humid climate and stable ancient lake leads to the anoxic bottom water, which is conducive to the enrichment of organic matter.

Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-12: Deep-time lacustrine sedimentology: Paleoclimate evolution, depositional processes and geo-resources exploration
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Pore evolution characteristics and shale oil enrichment model of sandstone bearing shale series

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Keywords: sandstone bearing,shale oil,Pore evolution,enrichment model

In recent years, China has found huge shale oil resources in sandstone bearing shale series, which has greatly increased China's shale oil production. This kind of shale oil has attracted the attention of academic and industrial circles. We found shale series with the same characteristics in the north of Dongying Sag, Bohai Bay Basin, and analyzed its mineral composition, reservoir physical properties and oil characteristic. The result shows that this kind of lithofacies is mainly developed in the ancient steep slope area in Dongying sag. Although the sandstone layer is close to the organic-bearing or organic-rich shale, some sandstone layers didn’t storage oil prioritily. This is because the intergranular pore cementation in the diagenetic evolution process is earlier than the generation of oil. The shale series in the deep-water area is more rich in organic matter and clay mineral, the number of micropores and mesopores is greater than that of shallow water shale series. Sandstone provides limited porosity, so although more sandstone is developed in shallow water shale series, deep water shale series has higher porosity. However, sandstone significantly improves the permeability. Due to the development of more macropores, shallow water shale oil has high gas oil ratio and free hydrocarbon content. Therefore, the shale oil in shallow water shale series has higher fluidity than that in deep water shale series. On this basis, the pore evolution model and shale oil enrichment model of sandstone bearing shale in this area are proposed.

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Session T1-12: Deep-time lacustrine sedimentology: Paleoclimate evolution, depositional processes and geo-resources exploration
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Analysis of provenance and tectonic background of Lower Cambrian black shale in Western Hunan and Hubei

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Keywords: Cambrian,Western Hunan and Hubei,Geochemistry,Black shale,Material source,tectonic setting

Based on the geochemical analysis of the black shale of Niutitang Formation in Gucheng Village (GCC) section and Yanwutan (YWT) section in Western Hunan and Hubei, the provenance and tectonic background of the black shale of Lower Cambrian in Western Hunan and Hubei are discussed. According to the combination ratio characteristics of major, trace and rare earth elements, the provenance background of the two sections is of mixed origin. The tectonic background is dominated by passive continental margin in GCC section and continental island arc in YWT section. There are great differences in sedimentary and mineral characteristics between the two sections. Niutitang Formation in GCC section is stratified. Niu1 member is siliceous shale and argillaceous shale, Niu2 member is micritic limestone, and Niu3 member is limestone and mudstone; The Niutitang Formation of YWT section is not stratified, mainly developing carbonaceous tabular shale, and the lower part is enriched with pyrite, nickel, cobalt, vanadium and other metals and phosphorus nodules. The quartz mineral content in YWT section is much higher than that in GCC section, and pyrite is also more developed than that in GCC section. The main reason for the difference of characteristics is the different tectonic background, followed by the influence of hydrothermal activities and the different depth of water body.

Scientific Themes: Theme 1: Deep-time Climate & Environment
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Presentation Preference: Oral Preferred

Study on Chang 8 sedimentary system and sand body distribution law in Huanxian-Heqi area

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Keywords: Material source, Lake shoreline,Sedimentary microfacies, Sand body, Sand reservoir

Study on Chang 8 sedimentary system and sand body distribution law in Huanxian-Heqi area

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Ordos Basin is the most important oil and gas resource exploration and development base in China at present. Recently, a major breakthrough has been made in the exploration of Chang-8 oil reservoir group in Huanxian-Heqi area, and oil-rich sand belt has been found. Although the lithology, sedimentary structure, structure and fossil characteristics of cores in the early stage determined that Chang-8 oil reservoir group has shallow water sedimentary characteristics,However, the unclear understanding of the provenance, sedimentary system types and sand body distribution characteristics of Yanchang 8 reservoir group restricts the further exploration. Based on the analysis of lithology, sedimentary structure, structure and fossil characteristics in Huanxian-Heqi area, this study systematically carried out the work of provenance, sedimentary system, sand body distribution law and so on.

The sedimentary center of Ordos Basin is distributed in NW-SE direction, and Huanxian-Heqi area is located in the southwest of the sedimentary center, which is mainly influenced by the western and southwest provenances from the regional background analysis. During the long sedimentary period, the ancient water depth of the lake basin was high in the central and western parts and low in the eastern part. Compared with the Chang 82period, the Chang 81lake basin has expanded in scope and the water body has gradually deepened. Expansion to the south is obvious.The bottom shape of the lake is higher in the west and southwest, and lower in the middle and east. During the 82period, the delta plain was mainly located in the west and south of Huanxian-Heqi area, with braided channel and flood plain deposits, which were distributed from southwest to northeast. Delta front deposits are located in the northeast direction of the plain, and underwater distributary channels are mainly developed.The water depth extending to Huanxian-Heqi-Wujiao-Baima-Haojiajian area gradually increased, and developed into estuary dam, far sand dam and sheet sand deposit. The water depth of Chang 81period is higher than that of Chang 82, and the delta plain is mainly located in the west of Huanxian-Heqi area. Delta front deposits are located in the central and eastern part of the study area, and underwater distributary channels are mainly developed.The Zhonghuan County-Hedao-Heqi-Wujiao-Haojiajian area is distributed on the outside of the delta front, with deep water body, with far sand bar and sheet sand.

The favorable reservoir sand bodies in Chang 82section are mainly the superimposed sand bodies of underwater distributary channel, mouth bar and far bar in delta front; The water depth of Chang 81section in Huan-Heqi area is longer than that of 82section, and the favorable area moves southward. The reservoir sand bodies are mainly the superimposed sand bodies of underwater distributary channel, estuary bar and far sand bar in delta front.

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Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Study on Reservoir Characteristics in Eastern Sag of Yanji Basin

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Keywords: yanji basin, rock formation function, pore structure, physical characteristics, heterogeneity

Reservoir characteristics are the key factors affecting the distribution and accumulation of oil and gas, which are of great significance to the exploration and development of oil and gas reservoirs. This paper analyzes and evaluates the reservoir characteristics of Tongfosi-Dalazi Formation in eastern Yanji Basin. Through thin-section observation and analysis, the contact relationship, morphological change and content of diagenesis products of rock debris were analyzed for various types of diagenesis in the study area to study the distribution and development of secondary pores; Combined with the existing physical property data, the distribution law and correlation of porosity and permeability in the study area are analyzed to find the layers with better physical property conditions; Based on the characteristics of mercury injection curve, the pore types and structure of different layers are analyzed, and the reservoir performance in the study area is judged by combining with the physical property data; The heterogeneity of the study area is evaluated by using the characterization parameters of permeability heterogeneity, and then the connectivity of sand bodies is studied to reveal the law of oil-water movement.

The results show that the sandstone reservoir rocks in the study area are feldspathic sandstone, lithic feldspathic sandstone and feldspathic lithic sandstone. The main diagenesis types include compaction, cementation and dissolution. The physical property of reservoir is characterized by low porosity and low permeability. The pore type is dominated by secondary pores with strong heterogeneity. This paper makes an objective and general expression of the overall reservoir capacity, and correct reservoir evaluation is of great significance to oil and gas exploration.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-12: Deep-time lacustrine sedimentology: Paleoclimate evolution, depositional processes and geo-resources exploration
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Mineralogical and geochemical characterization of calcareous shale in the lacustrine basin: Implications for paleosalinity, paleoclimate, and paleoredox conditions

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Keywords: Shale lithofacies, paleosalinity, paleoclimate, depositional environment, Shahejie Formation, Bohai Bay Basin

Shale is an important self-sourced reservoir rock in many sedimentary basins worldwide. In this research work, a geochemical history of variations of sedimentary environment in the lacustrine basin is analyzed based on extensive shale samples collected from the lower 3rd member (Es_3^L) and upper 4th member (Es_4^U) of the Paleogene Shahejie Formation in the Boxing Sag (Dongying Depression, East Coast of China). The representative shale samples were analyzed for total organic carbon (TOC) contents, mineralogical composition, the concentration of different elements (major, minor, and trace), kerogen types and vitrinite reflectance (R_o), and different sedimentary structures to understand the evolution of the depositional settings and their effect on the distribution of shale lithofacies in this basin. The TOC content in this shale is ranging from 0.08% to 13.6% (average 2.45%). R_o values range from 0.55–1.19% (avg. 0.85%) with type-I to type-II kerogens. The studied shale is composed of calcite (average 37.83%), dolomite (avg. 10.47%), quartz (avg. 23.8%), plagioclase (avg. 3.91%), clay (20.84%), and pyrite (2.85%). Seven lithofacies have been determined including mixed shale, calcareous shale, laminated limestone, argillaceous shale, dolomitic shale, siliceous shale, and siliceous dolomite based on mineral composition, TOC contents, and sedimentary structures. Different geochemical proxies including Sr/Ba, Ca/Ca+Fe, C-values, CIA values, Ti/Al, Al/Al+Fe, Al/Ti, V/V+Ni, Ni/Co, and Fe/Ca+Mg were used to interpret salinity, paleoclimate, detrital influx, provenance, paleoredox and water depth of the depositional environment in the studied shale. The detailed interpretation of the sedimentary environment suggested that during the deposition of Es_3^L shale, the terrigenous influx was high in shallow to a deep open lacustrine system with higher primary biogenic productivity. Semi-humid climatic conditions with higher precipitation rates prevailed during the deposition of this shale. On the other, relatively limited terrigenous input with low bioproductivity prevailed during the deposition of Es_4^U shale in the study area. Semiarid to humid climatic conditions with strong evaporation prevailed during the deposition of this shale. In this research work, a detailed depositional model of the Es_3^L– Es_4^U shale in Boxing Sag is established. The interpretations deduced from the current research work are likely to not only can expand the knowledge of shale lithofacies and genesis of lacustrine fine-grained sedimentary rocks, but can also offer a theoretical foundation for lacustrine shale oil exploration and development.

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Session T1-12: Deep-time lacustrine sedimentology: Paleoclimate evolution, depositional processes and geo-resources exploration
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Characteristics and distribution law of the lithofacies assemblages of fine-grained sedimentary rocks in the Ek2 in the Cangdong sag, Bohai Bay Basin, eastern China

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Keywords: Cangdong sag,Ek2 fine grained sedimentary rocks, Lithofacies;,Lithofacies assemblages, Distribution law

The thick fine-grained sedimentary rocks in the second member of the Kongdian Formation (Ek_2) in the Cangdong sag, Bohai Bay Basin, eastern China, are typical lacustrine source rocks and have recently been regarded as the main target for shale oil exploration. Fine-grained sedimentary rock with strong heterogeneity and poor plane continuity, is the basis for the accumulation of shale oil and gas. Therefore, it is of great significance to strengthen the study of lithology, lithofacies and lithofacies assemblages of fine-grained sedimentary rocks.

Based on the observation and description of cores from Well G108-8, Well GD12, and Well GD14, combined with analysis of thin sections and X-ray diffraction data, lithofacies of the Ek_2 fine-grained sedimentary rocks can be divided into six types, including laminated felsic fine-grained sedimentary facies according to mineral compositions and sedimentary structures, massive felsic fine-grained sedimentary rocks, laminated mixed fine-grained sedimentary rocks, massive mixed fine-grained sedimentary rocks, laminated carbonate fine-grained rocks, and massive carbonate fine-grained sedimentary rocks. Due to the vertical frequent alternation of lithofacies, lithofacies assemblages are proposed to describe the distribution law of the Ek_2 fine-grained sedimentary rocks, which can be named felsic lithofacies assemblages, felsic bedded with carbonate lithofacies assemblages, mixed lithofacies assemblages, carbonate bedded with felsic lithofacies assemblages, and carbonate lithofacies assemblages. The mineral compositions, sedimentary structures, and containing lithofacies types show significant differential among these lithofacies assemblages, which can be consisted with the evolution of sedimentary environment.

The method of combining the acoustic travel time (AC) log and density log is established to identify lithofacies assemblages in the study area, which can be used to study the distribution law. Lithofacies assemblages transformed from mixed to felsic bedded with carbonate in the lower part of the Ek_2^1, while from felsic to carbonate in the upper part of the Ek_2^1. From the margin to center of the lacustrine basin, lithofacies assemblages have two trends during the sedimentary period of Ek_{21}. Lithofacies assemblages present felsic, felsic bedded with carbonate, and mixed from the margin to center with the humid climate and strong detrital input. Furthermore, lithofacies assemblages present mixed, carbonate bedded with felsic, and carbonate from the margin to center with the arid climate and weak detrital input.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-12: Deep-time lacustrine sedimentology: Paleoclimate evolution, depositional processes and geo-resources exploration
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Compositional zoning in calcite cements records transgressions: Cretaceous terrestrial sandstones, Kuqa Depression, NW China

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Keywords: Compositional zoning, Calcite cements, Transgressions, Kuqa Depression

Concentric compositional zones of early calcite cements can reflect changes in fluid properties and are further indicative of changes in sedimentary environments. Concentric compositional zoning revealed by cathodoluminescence is common in early non-ferroan calcite cements in Cretaceous sandstones of the Kelasu thrust belt within the Kuqa Depression. Optical microscopy, cathodoluminescence (CL), LA-ICP-MS and stable-isotope analysis were used to investigate the petrographic and chemical characteristics of these calcite cements. In cathodoluminescence, the zoned cements consist of alternating brightly luminescent zones and non-luminescent zones. Concentrations of Fe^{2+} are both low in non-luminescent and brightly luminescent zones (<200ppm). Mn^{2+} Concentrations in brightly luminescent zones (880~3020ppm) are higher than Non-luminescent (<620ppm). Non-luminescent zones show negative δCe, while brightly luminescent zones show positive δCe. These data imply that non-luminescent zones precipitated in oxidizing diagenetic environments, and brightly luminescent zones precipitated in reductive environments. The $\delta^{13}C$ values of non-ferroan calcite cements range between -4.8‰ and 0.8‰ PDB, while the $\delta^{18}O$ values are between -14.9‰ and -6.6‰ PDB, which is interpreted to indicate precipitation from meteoric water. Kuqa Depression experienced multiple transgression-regression of Tethyan seawater from the Early Paleocene to Late Eocene. During transgression, seawater inundated the unconformity and prevented meteoric water from recharging the Cretaceous sandstone aquifer, causing the pore waters to tend to stagnate and become more reductive, and resulting the brightly luminescent zones to precipitate. During regression, oxygen-rich meteoric water from the Southern Tien Shan dissolved the surface-deposited carbonates and continuously recharged the sandstone aquifer along the unconformity, and causing non-luminescent zones to precipitate. Thus, a cycle from brightly luminescent zone to non-luminescent zone records once transgression-regression (The last cycle only includes a brightly luminescent zone). Four zoning cycles can be observed in Cretaceous sandstones of Dabei 12 well, which indicates that transgression may have occurred four times in this area. Three zoning cycles can be observed in Cretaceous sandstones of Bozi 9 well, implying that transgression may have happened three times in this area. Two zoning cycle can be identified in Cretaceous sandstones of Keshen 10 well, so this region may have experienced twice transgression.

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Scientific Themes: Theme 1: Deep-time Climate & Environment
Session T1-12: Deep-time lacustrine sedimentology: Paleoclimate evolution, depositional processes and geo-resources exploration
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Lithofacies and Sequence Studies of Lime-rich Fine-grained Sedimentary Rocks in the lower Es3 and upper Es4 Boxing Sag

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Keywords: Boxing sag,lime-rich fine-grained sedimentary rocks, lithofacies types,sequence stratigraphic division

It’s the basis of shale oil theory research and exploration and development to accurately divide the sequence and summarize the lithofacies characteristics and evolution law of the high-TOC lime-rich fine-grained sedimentary rocks in Boxing Sag.The study shows that the fine-grained sedimentary rocks in the Boxing subsag have the following characteristics: (1) The fine-grained sedimentary rocks in the study area are characterized by rich gray matter. CO isotopes of different lithofacies microareas show that the δ13C values (-6.257, -0.313) are consistent with the carbonate values of Ordovician system in North China. Therefore, it’s speculated that the gray matter may be mainly derived from the surrounding Ordovician uplift.2On the basis of mineral content, sedimentary structure and TOC content, fine-grained sedimentary rocks are divided into 11 lithofacies: organic-rich massive siliceous clastic type (carbonate type) mixed fine-grained sedimentary rocks, organic-bearing layers argillaceous dolomite, organic-rich lamellar (massive) (layered) carbonate-type mixed fine-grained sedimentary rock, organic-rich lamellar argillaceous limestone, organic-rich lamellar (layered) carbonate mixed fine-grained sedimentary rocks, organic-rich lamellar mudstone facies, and organic-rich layered siltstone facies. (3) Combined with seismic, logging, logging, geochemical parameters and other data, the sequence stratigraphic framework of the lower Es3-upper Es4 in Boxing subsag was established, and it was divided into two three parts. level sequence. Sequence one, the lake transgression domain and the highstand domain developed, which may be due to the erosion of the lowstand domain under the Es3; the highstand domain was divided into late highstand domain and early highstand domain by lithofacies assemblages and logging curves; sequence two,there are complete low-stand domain, lake transgression domain and high-stand domain. Then, the logging curve is processed by cyclolog software, and the lower part of Es3 is further divided into 10 sublayers (C1-C10), and the upper Es4 is divided into 9 sublayers (C1 -C9) (4) Lower Es3: A small amount of organic-rich massive clastic mixed fine-grained sedimentary rocks developed in the late high stand area, and a large amount of organic-rich massive (laminar) carbonate mixed fine-grained sedimentary rocks developed with the decrease of terrigenous input. When the content is higher, organic-rich layered carbonate-type mixed fine-grained sedimentary rocks develop; a large number of organic-rich layered carbonate-type mixed fine-grained sedimentary rocks develop in the early highstand, and a small amount of organic-rich layered carbonate-type mixed fine-grained sedimentary rocks develop when the water is shallow. The TOC content of the lake transgression area can reach up to 13.6%, and a large amount of organic-rich lamellar limestone and a small amount of organic-rich lamellar carbonate migmatite are developed. Upper Es4 member: a large number of interbedded siltstones interbedded with interbedded multi-stage siltstone containing organic intermittent lamellar argillaceous limestone and organic massive carbonate-type mixed fine-grained sedimentary rocks are developed in the high standing domain; The TOC content can reach 8.35%, which is similar to the lower Es3. In the low-stand region, the shallowest water body has strong evaporation, and many organic layered argillaceous dolomite and organic laminar mixed fine-grained sedimentary rocks are developed.

Scientific Themes: Theme 1: Deep-time Climate & Environment
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Obliquity-forced aquifer-eustasy during the late-Cretaceous greenhouse world

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Keywords: Songliao Basin, Astrochronology, Cretaceous, Aquifer-Eustasy

The mechanism of short-term and high-magnitude sea-level oscillation has long been debated between glacio- and aquifer-eustasy (Miller et al., 2005; Haq, 2014), largely due to the sparse robust evidence for the aquifer-eustasy, and the little knowledge about hydrological dynamics behind it. Non-marine/ continental greenhouse archives (e.g. lake level) and their temporal correlation to marine successions (e.g. sea level) could give clue to aquifer-eustasy (Wagreich et al., 2014). The Songliao Basin (SLB), in Northeast China, is one of the largest Mesozoic terrestrial inland basins and has deposited the near whole Cretaceous successions (Wang et al., 2013). The greenhouse Late Santonian-Early Campanian Lower Nenjiang Formation (K_2n^{1+2}), recovered from three boreholes in SLB provides a unique opportunity for validating and decoding the aquifer-eustasy. Initially the cyclostratigraphy of logging gamma ray (GR) and Thorium (Th) series from three boreholes was implemented, which in junction with the radioactive ages renewed the chronology framework of SLB. Using the astronomically tuned GR and Th series, the lake level of SLB, which is recovered from sedimentary noise modeling (Li et al., 2019) and presents the water table of groundwater reservoir, shows a clear out-of-phase relationship with the coeval sea level, validating the aquifer-eustasy hypothesis. The lake level shows prominent ~1.2Myr cycles and a well-coupled relationship with sea level and obliquity modulation, indicating that the orbital obliquity drove the lake level and modulated the water exchange between ocean and continent during the Cretaceous greenhouse period. The strong precipitation indicated by the negative excursion of Ostracods $\delta^{18}O$ (Chamberlain et al., 2013) well correlates to the high lake level, high obliquity, and low sea level, suggesting that during obliquity modulation maxima, more moisture was precipitated into the high-latitude continents, consequently recharging the aquifer and raising the lake level while drawing down the sea level and vice versa. The close correspondence between reported marine incursion layers (Hu et al., 2015) and lowstand of sea level casts a doubt on marine incursion hypothesis in the SLB, more work is needed to reconcile this paradox. Overall, this study gives robust geological evidence for aquifer-eustasy and firstly decodes its role on Cretaceous short-term eustasy.

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Theme2

Tectonics & Volcano-Sedimentology

Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks

ID: T2-10072

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Genesis and sedimentation of the Middle Proterozoic en echelon rift in the western margin of the North China Plate

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Keywords: Western margin of the North China Plate, En Echelon rift, Middle Proterozoic, Boundary transform fault, Formation mechanism

The en echelon rift located at the margin of continental plates is rare in the world, and its genetic mechanism has not been widely concerned. In the western margin of the North China Plate, a series of Mesoproterozoic rifts are developed in the Ordos Basin, which are characterized by en echelon distribution in the NE direction. At present, there are still different understandings about the genetic mechanism of this rift zone. This paper reviews the research progress of Columbia supercontinent, studies the characteristics of middle Proterozoic rift in Hangjinqi area, and puts forward a new interpretation scheme. Under the tectonic background of the Columbia supercontinent cracking, the western margin of the North China Plate moved relative to adjacent plate, resulting in the formation of boundary transform faults. Under the action of the translation shear, the localized extensional (T) faults developed in en echelon style, and a series of NW trending rift belts developed continuously. At the strike turning point at the end of the boundary transform fault, the associated T rupture strike shows NNE-NS-NNW deflection from east to west, and finally forms the diverging rift in the Hangjinqi area. The boundary transform fault is related to the spreading of the mid-ocean ridge within the supercontinent and is also subjected to the counterclockwise rotation of the North China plate. In this paper, the tectonic origin of the boundary shift fault is proposed, which explains the formation mechanism of the middle Proterozoic en echelon rift and the northern divergent rift on the western margin of the North China Plate. The Middle Proterozoic Yanlian rift in Ordos basin plays an important role in controlling stratigraphic deposition and hydrocarbon accumulation.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks
Presentation Preference: Oral Preferred

Detrital zircon U-Pb age characteristics of the Cambrian Jianchang Formation in eastern Liaoning, North China Craton and its geological significance

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Keywords: North China Craton, Detrital zircon, Jianchang Formation, provenance

The Jichang Formation (F.) in eastern Liaoning is mainly distributed in Benxi area and Dalian. The Jichang F. overlies the Kangjia F. or Qiaotou F. of the Late Mesoproterozoic-Early Neoproterozoic, in Benxi, and a layer of sandstone with a thickness of nearly 2m developed at the bottom, which is obviously different from the Dalian area. Scholars have mostly explored the relationship between the NCC and the two supercontinents, Rodinia and Gondwana, by analyzing the detrital zircon ages in the Precambrian strata of the NCC. In order to find more informations, we collected sandstone samples from the sandstone at the bottom of the Jichang F., which had never been studied before, and carried out a zircon LA-ICP-MS U-Pb chronology study. The dating results show that the detrital zircon ages in the sandstone of the Jichang F. have 5 peaks of 2490Ma, 2145Ma, 1824Ma, 1178Ma and 517Ma. It is worth noting that the above-mentioned age peaks greater than 1000Ma have been reported in the Xihe Group strata in the eastern Liaoning (Zhang et al., 2020; Zhao,2020;), indicating that many parts of the Precambrian zircon in the sandstone in the Jichang F. should have inherited the Xihe Group. These zircon ages are interpreted as being partly from the North China Craton itself, and other part comes from cratons such as Laurentia, Siberia, Baltica, Sao Fransico, etc (Zhao et al., 2020; Wang et al., 2021). The age of the youngest zircon is 513.4±12.9Ma, which limits the lower limit of the deposition of the Jianhang F., and its age is determined at Stage 4 of the Cambrian Second Series. At the same time, it also shows that the NCC had the mixing of new biological sources close to the age of stratigraphic deposition in the Cambrian. Some scholars have suggested that there may be at least two periods of magmatic activity at 520 Ma and 430 Ma in the deep part of the NCC, and 520 Ma coincides with the aggregation peak of the Gondwana supercontinent. Therefore, we speculate that the age peak of 517 Ma found in the Jiachang F. indicates a key node in the Early Paleozoic evolution of the NCC, probably related to a global tectonic event controlled by its deep processes.In addition, the age of 700-1000 Ma is not found in the detrital zircon ages of the Jiancahng F., but these ages have been found in the Jinxian Group and Early Cambrian strata in the Dalian area. Therefore, after the deposition of the Xihe Group and before the second Cambrian, the Benxi area began to expose the surface and did not accept deposition, while the Jinxian Group and the Early Cambrian strata were deposited in the Dalian area. Therefore, the magmatism during this period may not have affected the Benxi area, resulting in the sandstone provenance of the Jiachang F. have no such informations.

Reference

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks
Presentation Preference: Oral Preferred

Effects of Qinghai-Tibet Plateau Uplift on Paleogene-Neogene Sedimentary Evolution in the Southwestern Margin of Qaidam Basin

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Keywords: sedimentary evolution, Paleogene-Neogene, Qaidam Basin, Qinghai-Tibet Plateau

The stages and spatial differences of the uplift of the Qinghai-Tibet Plateau have important scientific significance for further understanding the uplift mechanism of the Qinghai-Tibet Plateau, discussing the effects of climate and environment, and guiding oil and gas exploration. This paper takes the Qaidam Basin located in the northeastern part of the Qinghai-Tibet Plateau as the research object, and conducts a comprehensive analysis of the distribution, evolution characteristics and differences of sedimentary systems. Combined with the research results on the uplift of the Qinghai-Tibet Plateau in recent years, this paper discusses the control effect of the Qinghai-Tibet Plateau uplift on the Paleogene-Neogene sedimentary differences in the Qaidam Basin. The research results show that five major provenance sedimentary systems developed in the Paleogene in the western Qaidam Basin, i.e., NBZL braided delta, QHQ-YYS fan delta, ALE-TMLK braided delta, QMTA-DCS braided delta and GS braided delta. While four major provenance sedimentary systems developed in the Neogene, i.e., NBZL braided delta, QHQ-YYS fan delta, Aral braided delta, and Gs braided delta. The NBZL braided delta sedimentary system exhibits the evolutionary characteristics of retrogression, the ALE-TMLK fan delta sedimentary system exhibits retrogression to progression, the ALE-TMLK braided delta sedimentary system exhibits regression to strong progression, and the GS braided delta sedimentary system shows the evolution characteristics of regression-progression. The QMTA-DCS braided delta sedimentary system developed in the Paleogene and not developed in the Neogene. It can be seen that due to the influence of the uplift of the Qinghai-Tibet Plateau, the distribution and sedimentary evolution of each provenance system in the western Qaidam Basin showed obvious differences. The uplift of the Qinghai-Tibet Plateau in the Paleogene was relatively small, and the ancient Kunlun Mountains in the southwestern margin of the basin provided provenance, forming the QMTA-DCS large-scale braided delta deposits. The Mantage Mountains blocked the direct flow of the ancient Kunlun Mountains water system into the Qaidam Basin, but went westward along the mountain through the Kunlun Mountain Pass, and merged into the Qaidam Basin along the Alar River and the Timurik River, forming the largest Alar braided delta sedimentary system in the region. In the KB and DCS areas, the petroleum exploration was suggested to focus on the Paleogene braided delta reservoirs and the Neogene shallow lake beach-bar reservoirs. It supports the discovery of the Paleogene braided delta oil reservoirs in the KB area and the Neogene coastal shallow lake beach-bar oil reservoirs in the ZHQ-WN area. In conclusion, the detailed first-hand data in this paper are of great significance for restoring the lithofacies and paleogeography of the Qaidam Basin, understanding the stages and spatial differences of the uplift of the Qinghai-Tibet Plateau, and guiding oil and gas exploration in the Qaidam Basin.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks
Presentation Preference: Oral Preferred

Neoproterozoic geodynamics of South China and implications on the Rodinia configuration: the Kunyang Group revisited

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Keywords: Sedimentary provenance, Kunyang Group, Detrital zircon geochronology, South China Block, Rodinia

The late Mesoproterozoic to early Neoproterozoic strata in the Yangtze Block hold a key position in deciphering the tectonic evolution of the South China Block and implicate upon the reconstruction of the Rodinia supercontinent. The sedimentological, geochronologic, and geochemical data on the Kunyang Group, southwestern Yangtze Block, were evaluated for a better understanding of the regional geodynamics and refinement in its paleoposition in the Rodinia supercontinent. Our findings constrain the deposition of the Kunyang Group sediments occurring during 1152 Ma and 1000 Ma, under a stable environment with alternating neritic and littoral facies sedimentation. In contrast, deposition of the Meidang Formation, traditionally thought to represent the upper part of the Kunyang Group, continued up to 866 Ma in an active setting at varying basin depths and hydrodynamic conditions. Moderate to high SiO2 contents (57.7-95.4 wt%), highly variable K2O/Na2O ratios (0.01-55.8), and critical trace element abundances (Zr: 57.6-578 ppm, Th: 1.95-28.3 ppm, Sc: 0.75-24.3 ppm), detrital zircon age distribution, sedimentological characteristics, and bimodal magmatism cumulatively underline a transition from continental rift to passive continental margin setting, followed by an active continental margin setting. The onset of oceanic subduction below the SW-NW margin of the Yangtze Block caused a hiatus in sedimentation, marked by an unconformity between the Kunyang Group and Meidang Formation.

Paleocurrent data, zircon U-Pb ages, and Lu-Hf isotopic characteristics indicate that the Kunyang Group received detritus from some interior sources and exotic terranes, such as the Gawler Craton in Australia, the Transantarctic Mountains in East Antarctica, and the Ongole domain in the Eastern Dharwar Craton of India. The Yangtze Block was likely located to the west of Australia and East Antarctica and north of India in the Rodinia supercontinent. Paleocurrent data also confirm an external location for the Yangtze Block in the Rodinia paleogeographic configuration.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks
Presentation Preference: Oral Preferred

Late Neoproterozoic–early Paleozoic basin evolution in the Cathaysia Block, South China: Implications of spatio-temporal provenance changes on the paleogeographic reconstructions in supercontinent cycles

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Keywords: Cathaysia Block,Detrital zircon ages,Provenance variation,Tectonic evolution,Gondwana

The role of the Cathaysia Block, South China and its linkage with orogenesis in the Rodinia and Gondwana supercontinents remain unresolved because of uncertainties in its position in supercontinent reconstruction(s) (Cawoood et al., 2017). Lithostratigraphic, geochronologic, geochemical (including isotopic) and paleocurrent data from late Neoproterozoic to early Paleozoic sub-basins in the Cathaysia Block reveal spatio-temporal, tectono-sedimentary and provenance diversity that show linkages with previously adjacent terranes and orogens in East Gondwana. The abundance of siliceous and conglomeratic rocks, local unconformities and pinch-out indicate that the basins were source from proximal late Cryogenian terranes, and experienced late Ediacaran transgression and middle Cambrian uplift. Cryogenian to early Ordovician strata all contain a major 1000-900 Ma (late Grenvillian) detrital zircon population, whereas 1300-1050 Ma (early Grenvillian) zircon populations are significant only in pre-late Ediacaran strata (Wang et al., 2018). A 850-700 Ma zircon population is most prominent in middle Cambrian strata, where it is sometimes associated with a 650-500 Ma (Pan-African) zircon peak.

The Grenvillian zircon population implies significant sediment input from eastern Indian (990-950 Ma) and western Australia (1300-1050 Ma) sources, underlining the fact that the Cathaysia Block was located between these two terranes in the northern part of East Gondwana (Yu et al., 2010). The diminishing contribution of early Grenvillian detritus in the late Ediacaran strata can be related to the Pinjarra Orogeny (550-520 Ma), whose uplift blocked the transport of detritus from Australia (Cawood et al., 2007). Middle Cambrian provenance variations with the abundance of 850-700 Ma zircons indicates derivation from the Wuyishan terrane of South China, supported by the associated change in the detritus from felsic and andesitic volcanic rocks to granitic rocks. Given that the Cathaysia Block was a passive continental margin, this provenance change was likely caused by the uplift of the southeastern Cathaysia Block, related to the far-field stress effects of the late phase of the Kuunga Orogeny (530-480 Ma) (Xu et al., 2016). The decrease in the abundance of early Grenvillian and Pan-African zircons implies that they were transported into the basins through independent drainage systems. This is consistent with the local and temporal variations in paleocurrent orientations during the Cambrian, further implying diverse and complex drainage system(s) in the southwestern Cathaysia Block during this period.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks
Presentation Preference: Oral Preferred

Linking the Paleozoic evolution of Hainan Island to Indochina and Australia: implications for the ocean-continental configuration of eastern Tethys Ocean

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Keywords: detrital zircon U-Pb-Hf isotopes, Hainan Island, Eastern Tethys Ocean, paleogeography

How was the northern margin of East Gondwana configured before and after the opening of Paleo-Tethys Ocean and where was the eastern extension of the branched Ailaoshan Ocean still have been debated. The Cambrian-Ordovician and Carboniferous successions in Hainan Island provide key records of tectonic evolution of the island with its surrounding terranes and their absolute and relative paleopositions to the northern margin of East Gondwana before and after the opening of Paleo-Tethys Ocean and further constrain on the eastern extension of the Ailaoshan Ocean. U-Pb ages and Hf isotopic compositions of detrital zircons from these successions reveal two distinct changes in sedimentary provenance. The first transition of sources, between the middle Cambrian and late Ordovician, reflects a shift from the local Precambrian basement of Hainan Island to a mixed detritus input that mainly supplied by the northern margin of East Gondwana. Integrated with the similarity in provenance of the Ordovician in the Hainan Island and Indochina, this transition implies the juxtaposition of Hainan Island and Indochina along the northern margin of East Gondwana by the late Ordovician. The second transition of sources is characterized by the presence of ca. 370 Ma juvenile arc affinity detritus derived from the subduction of Paleo-Tethys Ocean along the southern margin of the North Qiangtang-Indochina-Hainan continental silver and the disappearance of Gondwana-derived materials in the Lower Carboniferous, along with detritus input of mid-Mesoproterozoic basement in the island, which responded to the separation of the North Qiangtang-Indochina-Hainan continental silver from the northern margin of East Gondwana and the initial subduction of Paleo-Tethys Ocean. The tectonic evolution of Hainan Island and its surrounding terranes during the Paleozoic, integrated with regional tectonic framework, suggest that the Ailaoshan Ocean as a branch of Paleo-Tethys Ocean extended eastward to the north of Hainan Island and separated the North Qiangtang-Indochina-Hainan continental silver from the South China Block.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks
Presentation Preference: Oral Preferred

Neoproterozoic (Tonian and Cryogenian – early Cambrian) sedimentation in NW India: implications on the transition from Rodinia breakup and Gondwana assembly

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Keywords: Sedimentary provenance, Sindreth and Punagarh basins, Marwar Supergroup, NW India, Rodinia-Gondwana transition

The breakup of Rodinia and the assembly of Gondwana supercontinents during the Neoproterozoic era has been hailed as a major global event of redistribution of continental blocks. Tonian (Punagarh-Sindreth basins) and Cryogenian – early Cambrian (Marwar basin) sedimentary rocks in NW India were investigated to better understand the Neoproterozoic tectonic evolution of this region and Rodinia to Gondwana transition. The collinear (NNE – SSW trending) Punagarh and Sindreth basins received a dominantly felsic detritus with negligible heavy mineral sorting. Mild to weak chemical weathering in their source region for Punagarh and Sindreth sedimentary rocks is reflected in their low CIA (53.1-62.2) and high ICV (0.76-1.04) values. The clastic composition and geochemical characteristics of Punagarh and Sindreth rocks suggest a back-arc basin setting, and volcanic arc and cratonic interior region source for the sedimentary detritus. The Punagarh basin was proximal to the craton while the Sindreth basin was closer to the arc system. In contrast, the Cryogenian – early Cambrian Marwar Supergroup sedimentary rocks comprise mature quartz arenite with high CIA (77.8-94.8) and low ICV (0.18-1.00) values that suggest a strong chemical weathering in the source region, and significant physical sorting during transportation and sedimentation. The dominance of quartz (87-94%), Zr enrichment, and detritus derived from the cratonic basement indicate deposition of Marwar sediments in a tectonically stable basin, temporally coinciding with the Gondwana assembly. Collective inference of provenance and tectonic setting for Punagarh, Sindreth, and Marwar basins underline a transition from an active to a passive continental margin in NW India at ~760 Ma. The inference of a Neoproterozoic active continental margin in NW India is in agreement with the subduction of the peripheral Rodinia supercontinent during its breakup. Further, the passive continental margin sedimentation in the Marwar Basin suggests the presence of an open sea between NW India and western Gondwana during the Gondwana assembly.

Reference
None

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks
Presentation Preference: Oral Preferred

Carboniferous sedimentary records and geochemistry evidence related to the subduction initiation of the Paleo-Asian Ocean in eastern part of northern margin of North China Craton

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Keywords: North China Craton, passive continental margin, subduction initiation, the Paleo-Asian Ocean, Carboniferous

The tectonic setting of northern margin of the North China Craton (NCC) during Carboniferous has sparked fierce debate for a long time. In this study, we present new zircon U-Pb ages of Carboniferous sedimentary records in eastern Jilin Province (NE China) along the northern margin of the NCC. We systematically collected samples of metamorphic rhyolite (FY-1), underlying metamorphic greywacke(CD-1) and gabbro(HT-1) from the Changde metavolcanic rock sequence, and carried out LA-ICP-MS zircon U-Pb dating, zircon Hf isotope and geochemistry analysis for the three samples. (1) Previous research suggested that the age of the Changde metavolcanic rocks belonged to the pre-Devonian. However, the zircon U-Pb dating for Sample FY-1 in this study yields an age of 345.3 ± 2.3 Ma in the Early Carboniferous[1]. The $\varepsilon_{Hf}(t)$ values of Sample FY-1 are 3.46-12.2, and the two-stage model ages (T_{DM2}) are 571-1132 Ma, which indicate that the rock originated from the partial melting of the young lower crust. The Early Carboniferous metamorphic rhyolite shows enrichment of light rare earth elements and large ion lithophile elements, and depletion of heavy rare earth elements and high field strength elements. The geochemical characteristics and the discriminant diagrams of tectonic environment suggest that the metamorphic rhyolite is A-type rhyolite and formed in the post-collision extensional environment. (2) The detrital zircon U-Pb ages of Sample CD-1 contain abundant old ages including Carboniferous to Ordovician ages of 353-462 Ma and Neoproterozoic age of 861 Ma, and a small amount of Mesoproterozoic to Proterozoic ages of 2325-2456 Ma and Neoarchean detrital zircon ages. One of the youngest detrital zircons from Sample CD-1 is 351±7 Ma, further indicating that the metamorphic greywacke was deposited during the Early Carboniferous (ca. 351-345 Ma). The crystallization age curve and summary plot of detrital zircons show that Sample CD-1 was mainly deposited in a passive continental margin. (3) The youngest zircons of Sample HT-1 are concentrated in 245-247 Ma in the Middle Triassic with a few captured zircon ages of Carboniferous, Neoproterozoic and Neoarchean. The discriminant diagrams of tectonic setting show that the gabbro formed in an extensional setting. In addition, the final closure of the Paleo-Asian Ocean occurred during the Permo-Triassic suggested by our previous researches[2-3]. Therefore, it was a passive continental margin of the NCC during the Early Carboniferous[4-5]. In central Jilin Province, we also found that the provenance content of felsic magmatic rocks recorded by detrital heavy minerals in the Carboniferous strata is decreasing, whileas that of basic-intermediate magmatic rocks is increasing. The above results may reflect that the enhanced subduction process of the ancient ocean with the increase components of volcanic island arc in the Late Carboniferous. By collecting the results of previous ages of Carboniferous magmatic zircons, detrital zircons and zircon Hf isotope in the northern margin of the NCC[6-8], we further suggest that the timing of provenance change and tectonic setting change from passive continental margin to active continental margin environment is at ca. 320 Ma.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks
Presentation Preference: Oral Preferred

Paleotethyan evolution of NE Iran

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Keywords: Paleotethys, NE Iran, Subduction initiation, initial collision

The timings of the onset of oceanic spreading, subduction and collision are crucial in plate tectonic reconstructions, but not always straightforward to resolve. The evolution of the Paleo-Tethys Ocean dominated the Paleozoic-Early Mesozoic tectonics of West Asia, but the timeline of events is still poorly-constrained. In this study we present detrital zircon ages from NE Iran, in order to determine the timing of tectonic events in the region, and the wider implications for regional tectonics, paleogeography and climate change. Paleozoic clastic rocks record two major age peaks at ~800 Ma and ~600 Ma. The consistency in age patterns shows a dominant provenance from the Neoproterozoic basement of northern Gondwana. We interpret deposition on a long-lasting passive continental margin after the initial spreading of the Paleo-Tethys Ocean. Initial collision between the South Turan (Eurasia) and Central Iran (Gondwana) blocks caused coarse clastic deposition, the protolith of the Mashhad Phyllite, in a peripheral foreland basin on the Paleozoic passive margin. The Mashhad Phyllite yields major zircon age clusters at 450-250 Ma and 1900-1800 Ma, with a clear provenance from the active, Eurasian, margin. The Paleozoic ages reveal a long-lived subduction zone under the South Turan Block began in the latest Ordovician. Analysis of the age spectra allows us to constrain the timing of initial collision as no later than 228 Ma, which is also a constraint on the maximum depositional age of the Mashhad Phyllite. Based on our new results and previous data, we discuss the interaction between the Rheic and Paleo-Tethys oceans, and explain how a new subduction zone may have initiated after continental collision.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks
Presentation Preference: Oral Preferred

The Jan Mayen microcontinent: an understanding of its sediments, and relationship between tectonic evolution as the distal domain of volcanic passive margin, in the North Atlantic

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Keywords: Jan Mayen microcontinent, Volcanic passive margin,Stratigraphic correlation,Tectonic evolution

The Jan Mayen microcontinent (JMMC) is located in the central part of the Norwegian-Greenland Sea of the North Atlantic, conjugate with the Jameson Land basin on the Greenland continent margin and the Vøring basin on the Norwegian shelf margin of the Beltic continent in accordance with similar Paleozoic-Mesozoic stratigraphy. The JMMC extends southwards from the Jan Mayen Fracture zone towards northern Iceland and its architecture shows the characteristic of detachment faults which is similar to the Mesozoic fault system of the Vøring basin. The distribution of SDR, volcanic intrusion and explosion can be interpreted on the seismic data which indicates the JMMC is the distal domain of the Volcanic passive margin in the North Atlantic mostly during the Cenozoic age, also indicts the lithospheric extension and break while the embryonic oceanic crust generating through the detachment movements and mantle upwelling. The stratigraphic correlation, tectonic event records, and the faults architecture help to setup the tectonic evolution model by the analogic basin analysis and is supposed to start from the Paleozoic-Mesozoic orogeny to rifting, and then be influenced by the twice seafloor spreading of the age 55Ma and 25 Ma. The first seafloor spreading of 54Ma age caused the continental crust break-up and formed the volcanic passive margin between the Greenland and Beltic, especially the JMMC's separating from the conjugate Norwegian shelf margin. The second seafloor spreading of 25Ma age caused the oceanic ridge jump due to the Iceland mantle plume drifting off the Greenland and also caused the JMMC's separation from the Greenland continent as an 'abandoned orphan’floating on the oceanic crust.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Sedimentary Responses of Late Triassic Soft Sedimentary Deformation to Paleoearthquake Events in the Southwest of North China Plate

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Keywords: Seismic events, Trigger mechanism, Sedimentary sequence, Seismites, Chang-7 Member

The tectonic events caused by paleoearthquakes have a good response in sedimentary filling. Outcrops and cores from the Chang-7 Member of the Late Triassic Yanchang Formation, Ordos Basin in Northern China, yield a wide variety of soft sedimentary deformation structures (SSDSs), many of which are laterally extensive for more than 150 km. They include various types of folds, soft sediment liquefaction deformation (liquefied sandstone dyke, liquefied breccia), gravity-driven deformation (load structures, ball-and-pillow structures), hydraplastic deformation (loop bedding, convolute deformation) and brittle deformation (intrastratal faults and stair-step microfaults, microcracks). In most cases, deformation is represented by hybrid brittle-ductile structures exhibiting lateral variation in deformation style. These occur in delta front to semideep to deep lake sands and mudstones (shales).

From bottom to top, the sedimentary sequence of seismites in the Chang-7 Member is described as follows: underlying aseismic layer, microfissure and seismic breccias, stair-step microfaults, liquefied sandstone dyke, liquefied convolute deformation, seismically breccia and ball-and-pillow structure, liquefied homogeneous layer and overlying aseismic layer. The seismites recognized in outcrops and cores indicate earthquakes with magnitudes between 6 and 8, which are interpreted as a response to splicing collision orogenic events of the South China Block (SCB) and North China Block (NCB) during the Late Triassic period. Systematic study of the spatial and temporal distribution of these seismites improves the understanding of the tectonic context and evolutionary history of sedimentary basements. This study can provide a new perspective on the evolution of tectonic activities in the basin.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks
Presentation Preference: Oral Preferred

Neoproterozoic crustal thickness evolution in northern Tarim and the implications for breakup of Rodinia supercontinent

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Keywords: crustal thickness evolution, Tarim, Rodinia, supercontinent breakup

Understanding supercontinental cycles can help us better comprehend earth's evolution. The debate over the geodynamic drivers for breakup of supercontinents has focused on the “Bottom up” process related to mantle plumes or “Top down” process related to exterior subdution. We explore the crustal thickness by detrital zircon for Ediacaran sedimentary rocks and magma source based on the Hf - Nd isotope data from northern Tarim.The Hf - Nd isotope values decrease with crustal thickening and switch to increase with extensional thinning environment. The cyclic secular trends in thickness and isotope were attributed to alternating regimes of compression and extension resulting from advancing to retreating, and multistage accretion process is controlled by the outward migration of subduction zone. Crustal thickness recovery based on detrital zircon combined with isotope changes can play an important role in understanding the geodynamic drivers of crustal evolution and supercontinent cycle.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks
Presentation Preference: Oral Preferred

THE CLOSING TIME OF PALEO ASIAN OCEAN: EVIDENCE FROM SEDIMENTOLOGY

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Keywords: paleo Asian Ocean, Closing time, flysch, zoophycos ichnofacies,

The Central Asian orogenic belt is one of the largest accretionary orogenic belts in the world, formed in the paleo Asian Ocean subduction, arc and micro continental blocks of collage. The closing time of paleo Asian Ocean is a important scientific issues.

In this study, we discoveried a marine clastic rocks of the flysch formation duiring the end of Late Carboniferous and Early Permian period, in Xiwuqi area. The type of rocks are mainly feldspathic lithic sandstone developed grad bedding and parallel bedding.It is accompanied with the zoophycos ichnofacies.

U-Pb Ages of Sedimentary Rock indicated that the deposition forming time should yanger than 289Ma.The magmatic arc of detrital zircons mainly come from its north late Early Carboniferous and Late Carboniferous, Xilinhaote Xiwuqi area.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Zircon U-Pb age and geochemistry of volcanic rocks from the Carboniferous Baishan Formation in the Yuanbaoshan-Heishishan area in northern Beishan orogenic collage (NW China): implications for subduction process of the Paleo-Asian Ocean

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Keywords: Beishan orogenic collage, Baishan Formation, Yuanbaoshan area, Central Asian Orogenic Belt, Paleo-Asian Ocean

The Beishan orogenic collage in NW China is located in southernmost part of the Central Asian Orogenic Belt[1]. In the northern Beishan orogenic collage, the Carboniferous Baishan Formation, which consists of andesite, dacite, rhyolite and volcaniclastic rocks, is widely distributed along northern and southern sides of the Hongshishan-Baiheshan-Erlegen Ula SSZ ophiolite melange belt[2-3]. In this study, two zircon U-Pb isotopic ages of 300.0 ± 2.5Ma and 300.3 ± 1.9Ma in the Late Carboniferous were obtained from the andesite and breccia-bearing granite porphyry from the Baishan Formation in the Yuanbaoshan-Heishishan area, Inner Mongolia (NW China). The volcanic rocks are relatively enriched in large-ion lithophile elements (eg. Rb, K, Ba, and U) and light rare earth elements and depleted in high field-strength elements (eg. Nb, P, and Ti). They exhibit geochemical characteristics related with active continental margin volcanic arcs, which indicate that the subduction process of the Paleo-Asian Ocean has continued to the Late Carboniferous during the Late Paleozoic in the northern Beishan orogenic collage. Geochemical study further suggests that the magma source of the andesite in the Carboniferous Baishan Formation is a mantle wedge metasomatized by fluid in the subduction zone, and the breccia-bearing granite porphyry is mainly the product of the continental crust melting. The volcanic rocks from the Baishan Formation changed from neutral and calc-alkalic rock series in the northern part to intermediate-acid or acid and high potassium calc-alkalic rock series in the southern part along the ophiolite melange belt[3]. The distribution thus indicated a southern subducted polarity of the Paleo-Asian ocean plate in the northern Beishan orogenic collage in the Carboniferous based on previous research[4]and this study.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks
Presentation Preference: Oral Preferred

The change of sedimentary environment and provenance and its tectonic significance in the early-middle Jurassic in northeastern Sichuan Basin

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Keywords: heavy mineral composition, zircon U-Pb age, paleocurrent direction, Micang Mountain, Daba Mountain

detailed sedimentary description was conducted for the lower-middle Jurassic formations on Tieshan field profile, near Dazhou northeastern Sichuan Basin. Sedimentary environment, provenance property and their coupling relationship were studied. Sedimentary facies description, paleocurrent direction, heavy mineral composition and detrital zircon U-Pb ages were analyzed in this study. Results show that the Zhenzhuchong member is characterized by sufficient debris sources supply and is dominated by fluvial-delta environment. From the Dongyuemiao to lower Lianggaoshan formation the study area was dominated by lacustrine deposits. The detrital supply began to increase in the lower Lianggaoshan member and significantly increased from the middle Lianggaoshan member accompanied by paleocurrent direction change and lake shrinkage. Comprehensive analysis on provenance indicated that changes in provenances were related to environment changes. Both of them were controlled by orogenesis around the basin. Inferred from the characteristics of zircon age distribution the provenances change at the end of Ziliujing Formation, middle Lianggaoshan member and end of Lianggaoshan Formation is respectively resulted from uplifs of Micang Mountain, Daba Mountain and Qinling Mountain.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks
Presentation Preference: Oral Preferred

Sedimentary record of latest Ordovician to Silurian arc-continent collision processes in the South Qilian belt during the closure of the Proto-Tethyan Ocean

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Keywords: arc-continent collision, foreland basin, proveance, South Qilian belt, Proto-Tethyan Ocean

Arc-continent collisions are important tectonic processes that drive growth of continents and development of orogenic belts and associated sedimentary basins throughout geological time. They continue today along tectonically active plate boundaries such as those in the SW pacific and the Caribbean. The Qilian orogenic belt along the NE margin of the Tibetan Plateau is the northernmost orogen of the Tethyan domain in southern Eurasia, which preserves a record of long-lived subduction-accretion processes associated with the Proto-Tethyan Ocean and an arc-continent collision during early Paleozoic time. Results of our recent geological mapping demonstrate that Early Paleozoic volcano-sedimentary strata in the South Qilian belt are dominated by highly dismembered Cambrian-lower Ordovician intraoceanic subduction-accretion system, regarded as the basement of Middle Ordovician Andean-type intermediate to felsic arc. Their volcano-sedimentary successions are intruded by granitoids of Late Ordovician in age. As the collision between both arcs and Central Qilian block progressed from 450 to 420 Ma in response to closure of the Proto-Tethyan Ocean, a foreland basin system developed nonconformably across them. Sedimentary units in this basin are dominated by deep-marine to fluvial deposits to the upward, with a northward shallowing of the water-depth and a northward radial transport pattern, followed by a southwestward radial transport pattern up-section. Compositions and ages of these sediments within foreland basin demonstrate that the initial deposition was mainly originated from a mixed source of 530-480 Ma oceanic-crust and 490-450 Ma continental arc in the South Qilian belt and 910 Ma rocks of the Central Qilian block, while subsequently shifted to the 480-450 Ma arc-accretionary complex and Andean-type arc. These results indicate that the united Central and South Qilian belts in the NE Tibetan Plateau were uplifted and eroded during the latest Ordovician-Silurian in response to closure of the Paleo-Tethyan Ocean and arc-continent collision.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks
Presentation Preference: Oral Preferred

Neoproterozoic sedimentary records in South China: Implication for the supercontinent reconstruction

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Keywords: South China, Neoproterozoic, Detrital zircon

The South China Block, consisting of the Yangtze and the Cathaysia blocks, is one of the largest Precambrian blocks in eastern Asia. Neoproterozoic paleogeography of the South China is directly linked to the formation of Rodinia, its break-up, and the subsequent amalgamation of Gondwana (Cawood et al., 2018, 2020). In this paper, we compiled ~40000 published Precambrian detrital zircons from ~450 (meta)sedimentary samples in ~140 papers, in order to use the detrital zircon U–Pb age and Hf isotope datasets as an alternative approach to delineate the early history of the South China Block.

The lithotectonic associations of Neoproterozoic and older rocks units can be defined into five domains: Cathaysia, Jiangnan, Hainan, Western Yangtze and Northern Yangtze. Detrital zircon age spectra of the samples from the Hainan Block display age patterns distinct from the samples that accumulated on the other domains, with a major peak at ca. 1430 Ma, reflecting their spatial separation. Detrital zircons from clastic rocks within the Cathaysia, Jiangnan, Western Yangtze and Northern Yangtze all display a pronounced age peak at ca. 800 Ma, which consistent with derivation from local sources within the South China. However, Neoproterozoic sedimentary rocks from the Cathaysia Block and West Yangtze also contain abundant late Mesoproterozoic to early Neoproterozoic (ca.1200-800 Ma) detrital zircons. The timing and character of the ages of zircons, Hf isotope, and MDS plots match the records of North India (Lesser Himalaya, Greater Himalaya) and Indo-Antarctica, indicating that the Cathaysia Block and West Yangtze received detritus from North Gondwana. On the other hand, zircons from the western margin of Cathaysia Block and southeastern margin of the Yangtze Block provide evidence of bidirectional sources, suggesting the closure of paleo-South China Ocean before late-Neoproterozoic.

Overall, the Yangtze Block assembled with the Cathaysia Block along the northern margin of India during early Neoproterozoic, and together they were linked to North India from Tonian. The assembly of Gondwana in the early Paleozoic led to the collision of South China and India with the rest of Australo-Antarctica (Mulder et al., 2019), until opening of the Paleo-Tethys at ~400-385 Ma, after which South China drifted towards the assembling Asian continent (Xu et al., 2017).

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Petrology and gecochemistry of the Silurian sicliciclastic rocks: constrain on the provenance and tectonic setting of deposition in SE Yangtze block

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Keywords: Yangtze block, Sedimentary basin, Sedimentary facies, Provenance analysis

The Jiangnan Orogen is a suture zone between Yangtze block and Cathaysian fold belt, which is a huge tectonic melange belt in the south China and one of the most important tectonic-magmatic-metallogenic belts in China. Knowledge of the provenance and tectonic setting of the lower paleozoic in NW Zhejiang region closely adjacent to the Jiangnan Orogen eastern section is essential to understanding the mechanism and timing of the amalgamation between the Yangtze and Cathaysia blocks. In this paper sandstone detrital fragments, detrital heavy mineral assemblage, geochemistry of siltstone and sandstone, paleocurrent data are used to constrain the provenance and depositional setting of the Silurian clastic sedimentary rocks from SE Yangtze block.

Silurian deposits in the SE Yangtze block consist of sandstone, siltstone and shale. They were deposited in a shallow environment, showing water-depth deepening northwestward. Petrographic features show that the lithic sandstones and arkose lithic sandstones, which have low compositional maturity and textural maturity. In the sandstone samples, the average content of quartz clasts are 27%, feldspar clasts are 17%, rock debris are 56%, among them, quartz is mainly single crystal quartz, feldspar is mainly plagioclase, and a small amount of potassium feldspar. The composition of rock debris mainly includes rhyolite, slate, and a small amount of andesite, etc. In the discriminant diagram of the tectonic background of the source area of sandstone, the sandstone sample falls into the transitional island arc area, which indicates that the debris comes from the source area of the island arc background. Minor pyroxene, chromite, magnetite and garnet grains occur in the sandstone. Geochemical analysis shows that sandstone and siltstone have a wide variable content of Fe203T+MgO, Cs, V, Ni, and Ti. They also show a distinct negative Nb-Ta trough compared to the average upper continental crust (UCC) and have a light rare earth element (LREE) enrichment pattern with obvious Eu anomalies, similar to subduction-related rocks in an arc setting. Paleocurrent indicators pointto a southeastward origin. These results demonstrate that the Late Ordovician deposition took place in a northwestward-facing active continental margin along the southeast Yangtze block.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

The characteristic and provenance of the sandstone of the Neoproterozoic Changlongshan Formation in the Xingcheng area, Liaoning Province, China

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Keywords: basin history, Proterozoic, paleogeography, sandstone

The Neoproterozoic Changlongshan Formation in the Yanshan Rift Trough is a set of terrigenous clastic coastal clastic beach facies under the transgressive cycle. The sandstone in the lower part has high maturity, and the provenance characteristics in different locations of the basin are complex. The Changlongshan Formation from Shangchangmao section in Xingcheng area, Liaoning Province, is located at the southeast edge of Yanshan Rift Trough. Through profile observation, microscopic observation, and heavy mineral analysis, we found that the sedimentary environment and sequence of the Changlongshan Formation in the Xingcheng area is similar to that in the Liujiang area of Qinhuangdao and Huailai of Hebei Province. The overall grain size of strata is from coarse to fine, which is a set of transgressive sequences. Sandstone has high compositional maturity, small weathering coefficient, and developed authigenic pyrite. It should be a shallow sea environment with strong to weak hydrodynamic conditions, gradual deepening of the water body, and redox conditions of reducibility or weak oxidation conditions. The sandstone of Changlongshan Formation might have a simple origin, mainly composed of regenerated sedimentary rocks and basic igneous rocks. The provenance of the basic igneous rocks might be related to a large number of emplaced diabase dikes from late Paleoproterozoic to Mesoproterozoic in the Yanliao area. The transgression history of the Changlongshan Formation is one of the sedimentary responses of the breakup of the supercontinent Rodinia.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks
Presentation Preference: Oral Preferred

Evolution of the 1.60-1.35 Ga Northern Marginal BasinsNorth China Craton

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Keywords: North China Craton, the Yanliao Basin, Mesoproterozoic, Gaoyuzhuang Formation, Xiamaling Formation

The continental rifting processes in the northern margin of the North China Craton (NCC) during 1.7−1.3 Ga was considered related with the breakup of the Columbia supercontinent. Two rift basins, the Yanliao Basin and the Zha'ertai-Bayan Obo-Huade Basin in the northern NCC have similar stratigraphic sequences and ages. The ~1.32 Ga anorogenic magmatism wide-spread in these two basins indicated a final separation of the NCC from the Columbia supercontinent. Based on the precise chronological framework and stratigraphic constraints, we scrutinized the 1.60−1.32 Ga sedimentary successions in the Yanliao Basin, which suggested a relatively stable stage with limited chasmic activities during 1.60−1.40 Ga, and a reactivation stage with continued crustal extension during 1.42−1.32 Ga. Carbonate-dominated rocks and clastic-dominated rocks formed during the above two stages, respectively, should deposit in open system since a ~1.58 Ga large-scale transgression. So, the Yanliao Basin might have a good connectivity with the open ocean during the early Mesoproterozoic era, forming a unified continental margin rift system with the Zha'ertai-Bayan Obo-Huade Basin in the northern NCC, and belong to a huge gulf between NCC and the Columbia supercontinent.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Provenance and tectonic setting of the Lower Silurian clastic rocks in the southeast Upper Yangtze Block, South China: Implications for paleographic evolution of South China and initial formation time of Xuefeng mountain belt

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Keywords: Detrital zircon, Sedimentary provenance, Xiaoheba Formation, Xuefeng mountain belt

The Xuefeng mountain belt is located in the western part of the Jiangnan belt and generally considered to have formed in the early Paleozoic, which is significant to understanding the tectonic and paleogeographic evolution of South China. However, the initial formation time and nature of the Xuefeng mountain belt in the early Paleozoic are still controversial. In this work, petrology, whole-rock geochemical data, and detrital zircon U-Pb ages are applied to analyze the sources and tectonic settings of the Lower Silurian Xiaoheba Formation on the west flank of the Xuefeng mountain belt. Samples were collected from three sections dominated by fine-grained sandstones with two pelitic rocks. Major oxides and trace element signatures suggest the Xiaoheba Formation was deposited in a passive margin setting, with the detritus mainly derived from felsic igneous rocks and experienced sedimentary recycling. LA-ICP-MS detrital zircons U-Pb dating from four samples display a prominent age population of 1000–900 Ma and a subordinate population of 900–700 Ma, with minor populations of ca. 2500 Ma, ca. 1700 Ma, 1300–1200 Ma and 650–500 Ma. Combining detrital zircon ages with geochemical and paleocurrent data, we suggest the zircon grains represented by Grenville-aged grains and Pan-African aged grains were largely derived from north India and southeast Antarctica, with limited input from west Australia. Those zircon grains were first deposited in the late Neoproterozoic to early Paleozoic strata of the Cathaysia Block and subsequently transported to the study area due to intraplate orogenesis. The grains with an age of 900-700 Ma within the Xiaoheba Formation were probably inputted from the Neoproterozoic basement of the Jiangnan-Xuefeng Uplift. These results imply that early Silurian sediments deposited in a stable passive margin setting along the southeastern Yangtze block and the Xuefeng mountain belt was a basement uplift rather than a Paleozoic orogenic belt. In addition, we suggest that the Xuefeng mountain belt had formed during the deposition of the Xiaoheba Formation. However, the uplift appears to be discontinuous, rather than a continuous barrier that blocked the detritus derived from southeastward in this period. The two youngest zircon grains yielded a weighted average age of 436±7.4 Ma, indicating the maximum depositional age of the Xiaoheba Formation and further suggesting that the initial uplift time of the Xuefeng mountain belt was roughly in the early Telychian.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks
Presentation Preference: Oral Preferred

Geochoronolgical, petrological and geochemical evidence that Cryogenian proximal terrestrial detritus in the northwestern Tarim Craton derived from the Yili-Central Tianshan Block, and its tectonic significance

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Keywords: Tarim Craton, Yili-Central Tianshan Block, Neoproterozoic collision-fragmentation-drift, Debris provenance tracer, Assembly and breakup of the Rodinia supercontinent

Neoproterozoic tectonic setting and evolutionary affinity of the Tarim Craton and the Yili-Central Tianshan Block (YCTB) in the southern Central Asian Orogenic Belt are still controversial, which in turn hinders the understanding and reconstruction of the evolution of the Rodinia supercontinent. The Cryogenian System (Nanhua System) in the northwestern Tarim Craton mainly consists of a set of proximal and fast-filling terrigenous clastic deposits. Based on the systematic study of zircon U-Pb chronology, petrology, geochemistry and Sr-Nd-Pb isotope of these clastic sandstones and igneous gravels, this study proposes that these clasts are mainly derived from early Neoproterozoic (Tonian) igneous rocks and their equivalent debris, and provide key evidence for the tectonic assembly and breakup between the Tarim Craton and the YCTB during the Neoproterozoic.

Six granitoid and one rhyolitic tuff boulders were collected from the conglomerate unit of the Cryogenian strata and gave a range of crystallization age spectrum of ca. 930-850 Ma. These igneous boulders mostly exhibit calc-alkaline to high-K calc-alkaline affinities with high contents of SiO2 (66.7-78.3 wt%), total alkali oxides (Na2O + K2O = 6.0-8.6 wt%), and low contents of P2O5 (≤0.15 wt%) and ASI (0.4-1.1), and show relatively enriched LREE and LILEs with significant negative Eu anomalies (δEu = 0.02-0.8) and Nb-Ta-Ti trough, akin to those typical I-type granites. Nd and Hf isotope of these igneous boulders show slightly negative εNd(t) values from -5.11 to -0.52 and varying εHf(t) values from -17 to 12and yield model ages of 1.5-2.0 Ga and 1.2-2.3 Ga, respectively, distinct from those reworking magmas of ancient Archean- early Paleoproterozoic Tarim Craton basement (3.5-2.5 Ga). Besides, detrital zircon ages and Hf isotope of four sandstondes in this study and compiled data from the sandstones of Cryogenian sequence reveal a hybrid provenance from abundant felsic magmatic rocks with similar age range (960-850 Ma) of aforementioned igneous boulders and anonther Archean- and Paleoproterozoic- craton basement.

Our study shows that such previously existing huge magma belt aross the northern margin of the Tarim Craton continued to provide a large amount of sedimentary debris not only for the Aksu Group, but also for the subsequent Neoproterozoic Cryogenian and Ediacaran basins in the northwestern Tarim. It is worth noting that the existing Precambrian igneous rock chronology and geophysical data observations show that the northern margin of Tarim was a typical passive continental margin in the early Neoproterozoic, and there is no such a magma belt. Further analysis shows that this magmatic belt and the Tonian magmatic belt of the YCTB are not only consistent in age spectrum, but also share very similar petrological, geochemical and isotopic characteristics. Therefore, the results of this work support the Neoproterozoic collision-fragmentation-drift hypothesis for the Tarim Craton and the YCTB, which may represent the final assembly and subsequent complete breakup of the Rodinia supercontinent.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks
Presentation Preference: Oral Preferred

Sedimentary evidence for hitherto unrecognized synsedimentary tectonics affecting the Furongian Chaomidian Formation (Shandong Province, China)

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Keywords: breccias, Late Cambrian, Shandong, sliding, synsedimentary tectonics

Shandong Province (E China) is commonly considered to have been a tectonically quiet region during the Late Cambrian (Furongian). An epeiric sea extending at the time from China to Korea covered a large part of the North China Plate. During the Furongian, accumulation of sediments kept pace with the subsidence of the basin. The youngest fully Furongian formation in the study area, which is situated near the city of Laiwu, is the Chaomidian Formation, which consists mainly of limestone/shale alternations, limestone/marlstone alternations, thin-bedded lime mudstones, limestone conglomerates and breccias, gravelly grainstones, cross-bedded grainstones and microbialites. Some levels occur that are spectacular mixtures of breccia and conglomerate (the so-called bamboo-leaf breccia), which resulted from the formation of 'fountains' of pore-water/sediment mixtures (due to overpressurization) that escaped under high pressure and broke up overlying limestone layers. This resulted in breccia fragments of about a decimetre in diameter, many of which are oriented vertically.

One of these layers of bamboo-leaf breccia was broken up. The resulting blocks (up to several metres wide and several decimetres high) show characteristics that indicate that the blocks slid down a (probably very gentle) slope. They are now embedded in an oolite layer that started accumulation before the sliding of the blocks took place, and that continued after emplacement of the blocks.

Oolites originate in shallow water, most commonly at depths of not more than ~2 m (max. some 10 m). Since the blocks of bamboo-leaf breccia are embedded in an oolite that started forming before the sliding of the blocks, and continue without interruptions to after this event, all these processes occurred at very shallow depths. Considering the local geology, the blocks must have slid down over distances of some hundreds of meters. Their depositional site was still very shallow, and there are no signs of any special process that may have triggered the sliding. It must therefore be deduced that an inclination of the sedimentary surface must have exited that allowed the sliding. Such a slope was not present before, so that only tilting or a fault-induced slope can be held responsible. In both cases, some tectonic activity must have been involved, although such activity has never been noticed before.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks
Presentation Preference: Oral Preferred

Provenance Analysis of Early Neoproterozoic Metasedimentary Rocks in Western Central Tianshan Block and Paleogeographical Reconstruction

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Keywords: detrital zircon, multidimensional scaling plot, paleogeographical reconstruction, early Neoproterozoic, western Central Tianshan Block

The Central Tianshan Block (CTB) is one of the Precambrian microcontinents in Central Asian Orogenic Belt (CAOB). It can be divided into the western Central Tianshan Block (WCTB) and eastern Central Tianshan Block (ECTB). To investigate their relationship and paleogeographical location, we collected metasedimentary rocks of the Kekesu Group in WCTB. The results of detrital zircon LA–ICP–MS U-Pb dating, combining with previously magmatic ages, suggest that the Kekesu Group was deposited during the earliest Neoproterozoic. Detrital zircon populations of the Kekesu Group were dominated by ca. 2.0–0.9 Ga grains with age peaks at ca. 1480 and 920 Ma. The Archean to the end of Paleoproterozoic zircon grains had variable $\varepsilon_{Hf}(t)$ values from +12.5 to -8.7, and most (88%) of the Mesoproterozoic to early Neoproterozoic zircons had positive $\varepsilon_{Hf}(t)$ values (+13.9 to +0.6). The Kekesu Group has similar zircon age populations and $\varepsilon_{Hf}(t)$ values with the Kawabulake Group in ECTB. Combining with magmatism, we suggest that WCTB and ECTB have similar tectonic affinities and locations during the earliest Neoproterozoic. The zircon age probability density plots and multidimensional scaling (MDS) plot of kernel density estimates suggest that some microcontinents in southwest CAOB, including the Issyk-Kul, Kokchetav, Erementau-Niyaz and Ishkeol'mes terranes, might be located near the northern Laurentia and southeast Siberia in earliest Neoproterozoic. These terranes and Xingxingxia Group in ECTB have similar sources mainly derived from the northern Laurentia. Afterward, the sources have changed. The strata in Central Tianshan Block and Yili Block have similar sources mainly derived from Grenvillian and Sveconorwegian orogens, and these blocks were located between the East Greenland and southwestern North China Craton during Rodinia assembly.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks
Presentation Preference: Oral Preferred

Micro Slope break and its control on sequence, sedimentation and hydrocarbon accumulation of Pinghu Formation in K Area, Xihu Sag

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Keywords: Micro Slop break,hydrocarbon accumulation,pre-existing structures

Based on the analysis of the pre-existing structures and palaeogeomorphology, the typical and characteristic micro-slope break zones are identified in the study area, and their genetic type is flexural slope break. The NW-trending pre-existing structure formed during the Indo-Chinese Movement was reactivated during the Pinghu Movement, forming the structure 'down-fault and up-torsion ', which was a flexural slope break during the Pinghu Formation. The controlling effects of micro-slope break zone on sequence development pattern, sedimentary system distribution characteristics and dominant reservoir distribution are established. Based on the hydrocarbon source conditions, reservoir conditions, migration conditions, trap conditions and preservation conditions, the hydrocarbon accumulation model of ' hydrocarbon generation in low slope belt-separation trough controlling migration and accumulation-micro slope break controlling trap and reservoir ' is proposed, which effectivelyrdin guides the evaluation of the K Area. According to the comprehensive analysis of the control of micro-slope break on sequence, deposition and hydrocarbon accumulation of Pinghu Formation in the K area of Xihu Sag, the scale of slope break zone research is extended, and the slope break zone theory is enriched.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks
Presentation Preference: Oral Preferred

The Doushantuo formation, the onset of the Ediacaran rifts in South China

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Keywords: Doushantuo Formation, Ediacaran rift, South China, sequence stratigraphy

The Ediacaran Doushantuo Formation (ca. 635–551 Ma) in South China is one of the most intensively investigated units in the world, as it contains exceptionally well-preserved fossils of multicellular eukaryotes including early animals. The majority of the Doushantuo Formation was deposited on a rimmed carbonate shelf of the Yangtze platform, with a shelf margin shoal that restricted the shelf lagoon from the open ocean. However, the previous studied were mostly based on the outcrops without detailed analysis of the interior of the platform. We analysis the drilled data in the interior of the Yangtze platform, indicating that there existed two rifts, one is the Deyang-Anyue rift in the West and the EXi rift in the East. This study established a stratigraphic framework of the Doushantuo formation by litho-, chemo-, bio-, and sequence stratigraphy. Regional correlation across South China relies on two distinctive marker beds, the cap carbonate at the base and the organic-rich black shale at the top of the Doushantuo Formation. During Ediacaran and Lower Cambrian, the Doushantuo Formation, the Dengying Formation, and the Niutitang Formation represent different stages of the rifts at the Yangtze platform from bottom to up. Firstly, the Doushantuo Formation indicates the beginning of the rifts in South China. Secondly, carbonatite of the Dengying formation was controlled by syn-sedimentary faults, which forming the "graben-horst" structural model, with Deyang-Anyue and EXi rifts. Finally, a set of organic-rich shale filled up the rifts by Niutitang Formation during the Early Cambrian. The rifts provided the geological background of location for the conventional and unconventional nature gas exploration.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks
Presentation Preference: Oral Preferred

A late Paleozoic extension basin constrained by sedimentology and geochronology in central Inner Mongolia, eastern CAOB

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Keywords: late Paleozoic extension, Paleo-Asian Ocean, basin and uplift

According to sedimentary structure, petrology and sequence analysis from seven sections (S1–S7) across the West Ujimqin basin, the late Carboniferous to Permian sedimentary facies have been recognized and summarized as four sedimentary systems, i.e. the late Carboniferous-early Permian sedimentary system (SA) comprising the alluvial fan–delta–littoral facies, the late Carboniferous sedimentary system (SB) including the littoral facies–delta facies–platform margin facies, the early Permian sedimentary system (SC) characterized by delta front and prodelta facies, and the middle Permian sedimentary system (SD) with alternations of littoral and delta facies. According to the spatial and temporal distribution of the four sedimentary systems, the basin filling process can be divided into three stages. The first stage (324–290 Ma) is dominated by bidirectional terrigenous sediments containing the SA from alluvial fan to delta and littoral facies in the northwestern and the SB from littoral–delta to platform margin facies in the southern, respectively. The second stage (290–270 Ma) is characterized by delta front and prodelta facies of the SC marked by thick-bedded matrix-supported conglomerate, rapid accumulation of terrigenous sediments and volcanic debris, syn-sedimentary deformation and slump. The third stage (270–255 Ma) formed the SD with the alternations of littoral and delta facies, which is represented by complex terrigenous clasts and intra-basin carbonate. These shallow and proximal sedimentary systems from fan delta to littoral facies indicate that there was not oceanic sedimentary system in the eastern CAOB during the late Carboniferous to Permian except for some small red sea basins, which provides convictive evidence that the Paleo-Asian Ocean (PAO) had closed before the late Carboniferous. Detrital zircon dating reveals bidirectional provenances of the West Ujimqin basin, indicating that it was a limited basin between two uplifts, which implies presence of the late Paleozoic “basin and uplift” tectonic framework that developed on the eastern CAOB during the late Paleozoic.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks
Presentation Preference: Oral Preferred

Detrital zircon ages and Hf-isotope characteristics of the Neoproterozoic – Cambrian Marwar Supergroup sediments, NW India: implications on the East Gondwana assembly

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Keywords: Detrital zircon, U - Pb geochronology, Precambrian - Cambrian sediments, NW India, East Gondwana

The Precambrian – Lower Paleozoic sedimentary successions in northwest India have been investigated to evaluate the assumption that they record the collision between Western and Eastern Gondwana continental blocks and contain detritus derived from the East African Orogen. The detrital zircon U – Pb age distribution patterns and Hf-isotopic characteristics of Marwar Supergroup (Pc – C transition)sedimentary rocks, together with paleocurrent analysis, suggest a proximal provenance within the Eastern Gondwana. The time equivalent successions from the Qiangtang terrane and the northern margin of Neoproterozoic India display similarity in the provenance record, along with additional input of late Mesoproterozoic and Neoproterozoic detritus from East Antarctic-Eastern India and Western Australia. Detritus from the uplifted East African Orogen are abundant in the north African sedimentary deposits, which constitute part of the Western Gondwana, but are absent in the equivalent successions in the Indian Eastern Gondwana. The consistency in sedimentary provenance of the late Neoproterozoic to early Palaeozoic strata in NW India, combined with the lack of evidence for deformation/metamorphism since at least ca. 760 Ma, argues against collision between eastern and western segments of Gondwana in this northern domain of the supercontinent. These domains remained as passive continental margins, separated by a large-scale embayment of the proto-Tethys ocean, until the late Paleozoic fragmentation of the continental blocks.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-1: Sedimentary records and correlation of supercontinent crustal blocks
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Deep structural characteristics and formation and evolution of Dongying Depression

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Keywords: Dongying depression,Deep structure,Construction style,Differences,Formation and evolution

The deep structure of Dongying depression has always been the research focus of many scholars. This paper mainly studies the deep structure of the fourth member of Shahejie formation from Kongdian formation to Shahejie Formation in Dongying depression, including the section style and plane style of deep structure. It is found that the structural styles are mostly extensional structural styles and extensional strike slip structural styles, such as "Y" shaped structure, flower like structure, warped fault block, graben Horst structure, salt mud diapir structure and so on. In addition, the distribution of regional tectonic belts and their horizontal and vertical differences in Dongying sag are also a research scope of this paper. Dongying depression is located in Jiyang depression of Bohai Bay basin. It has experienced the influence of multi-stage tectonic movement and plate movement, forming a unique structural pattern and multi-stage faults. With the evolution of the profile, combined with the large tectonic movement at that time, the tectonic evolution history can be reasonably deduced, and the key "red bed" strata in this study have experienced basin rifting expansion stage, regional uplift stage, secondary rifting stage and so on.

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Session T2-2: Interactions between basement, volcanism, and sedimentary cover

ID: T2-20088

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Oral Preferred

The evolution of the Chaoshan Depression controlled by multistage subduction of the Paleo-Pacific plate

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Keywords: Paleo-Pacific plate subduction,Chaoshan Depression,fore-arc basins,migrating arc,tectono-sedimentary evolution

The South China Block is characterized by giant and multistage magmatic belt associated with the subduction of the Paleo-Pacific plate in the Mesozoic. In contrast to the extensive research on this magmatic belt, the associated fore-arc basins are still poorly known, in particular the tectono-sedimentary evolution of fore-arc basins in response to the Paleo-Pacific plate subduction. Chaoshan Depression (CSD), one of a Mesozoic basin in northern South China Sea, was a typical fore-arc basin associated with the subduction of the Paleo-Pacific plate from the Jurassic to the Early Cretaceous. Thick Mesozoic sediments with precise stratigraphic age frame that determined by micropaleontology and zircon U-Pb ages of volcanic interlayers have been revealed in CSD and thus provide a great opportunity to investigate the evolution of fore-arc basin in response to complex subduction processes. In this study, we complied a large number of zircon U-Pb ages of the arc-related magmatic rocks to trace the magmatic belt, combined with well and seismic reflection of CSD to explore the sedimentation changes. The exposure of early Jurassic magmatic belt was possibly very limited, which was insufficient to provide great detritus to the CSD and shallow marine environment was inferred for the CSD. From the middle Jurassic, quick subsidence occurred in CSD and followed by rapid increase in the sea water characterized by Radiolarian siliceous rock that continued to the late Jurassic. This scenario was possibly caused by landward migration of the arc resulted from the flat subduction of the Paleo-Pacific plate. Since the Cretaceous, there was a prominently tilted denudation with NW increasing in erosion thickness and followed by a dramatic change of sedimentary environment in the CSD. These changes were consistent with the seawards migration of the magmatic zone in response to the rollback of the subduction slab. The plenty detritus eroded from this magmatic belt facilitated large deltas in the CSD. Our study shows how the migrating arc resulting from the changing pattern of the subduction plate controlled the evolution of fore-arc basin and provide new insights into the evolution of the Paleo-Pacific plate subduction.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Structural evolution and mechanism of Panyu 4 Sag, Pearl River Mouth Basin, South China Sea

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Keywords: Structural evolution, Analogue modelling, Formation mechanism, Panyu 4 Sag, Pearl River Mouth Basin

The Panyu 4 Sag is a relatively independent hydrocarbon-rich sub-unit that is located on the western side of the southeastern margin of the Zhuyi Depression, Pearl River Mouth Basin, South China Sea. In order to further understand the evolution of the Panyu 4 Sag, we present the results of seismic interpretation and analogue modelling to discuss the origin of the Panyu 4 Sag in this paper. Firstly, we describe the geological settings of the studied area based on literature. Secondly, we study the distribution and evolution of fault and sedimentation according to seismic interpretation and structural-sedimentary features of different members of the Wenchang Formation. Thirdly, for understanding the evolution of internal sub-structural units, we carried out analogue modelling to illustrate the formation in different periods to better constrain the evolution of the Panyu 4 Sag. Finally, a model for the formation of the Panyu 4 Sag was proposed. The Panyu 4 Sag can be divided into five parts (Northern, Central, Southern, Western, and Northwestern Sub-sags). The faults of the Panyu 4 Sag can be broadly divided into three fault assemblages that are oriented NE, NEE, and NWW. The NE-trending faults were mainly active during the deposition of members 6 to 2 of the Wenchang Formation, these faults had a significant controlling effect during the early deposition of sag. The NEE-trending faults are accommodation faults related to the NE-trending faults; they are short in extension and did not control deposition. The NWW-trending faults are primarily late-stage faults that were mainly active during the deposition of member 1 of the Wenchang Formation to Enping Formation; they controlled the distribution of late deposition. The Panyu 4 Sag has undergone three cycles of structural evolution—an early rift period (Wenchang Formation), a late rift period (Enping Formation), and a thermal subsidence period (Zhuhai Formation to Quaternary). Seismic interpretation and sandbox modelling results show that Panyu 4 Sag suffer two phases extension resulting in the superposition of structures of different generations during the Cenozoic. Influenced by the evolution of regional geological stresses, the stress field mainly exhibited a shift from NW-SE-trending tension to S-N-trending tension; the shift occurs in the upper Wenchang Formation. A combination of the above and the pre-existing basement fault systems controlled the transformation and superposition of the sedimentary features of the Panyu 4 Sag, resulting in the complex tectonic geomorphology of the present sag.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Oral Preferred

Spatio-temporal evolution and dynamic mechanism of lower Cretaceous volcanic-sedimentary strata in Songliao Basin, Northeast China: implications for regional tectonic evolution

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Keywords: Lower Cretaceous, Volcanic-sedimentary strata, Tectonic evolution, Songliao Basin, Northeast China

The Early Cretaceous tectonic evolution in Northeast China may be affected by the Mongolia Okhotsk and the ancient Pacific tectonic domain, but the mode of action, scope of influence and transform time of the two tectonic region have been controversial. Early Cretaceous magmatic rocks are widely distributed in Northeast China. Their spatial and temporal distribution and geochemical characteristics do not clearly reflect the dynamic mechanism. The Xujiaweizi fault depressionSK-2 drilling area of the International Continental Scientific Drilling Program, located in the central part of Northeast China, is one of the large grabens in the Songliao Basin. It is mainly a set of thick volcanic-sedimentary strata formed in the Early Cretaceous (118-101 Ma). Its formation and evolution process may record the history of regional tectonic evolution in detail, and it is an important research area to solve the problem of regional tectonic evolution. In this study, the volcanic-sedimentary strata (114-101 Ma) of Yingcheng Formation of Lower Cretaceous in Xujiaweizi graben are divided and compared based on three-dimensional seismic profiles, boreholes and logging data. According to the geological and geophysical characteristics of lithology and interface, the volcanic-sedimentary strata are divided into three members, i.e. volcanic member I, sedimentary member II and volcanic member III, and the two volcanic members can be further divided into three volcanic eruption stages respectively. Combined with the characteristics of the main faults in the Xujiaweizi graben, the plane distribution maps of each stratigraphic sequencethree volcanic/sedimentary members and six volcanic eruption stagesare compiled. It is found from the plane maps that the volcanic-sedimentary strata of the Lower Cretaceous have the spatio-temporal evolution law of migration from southeast to northwest from early to late, accompanied by the NNW-SSE sinistral strike-slip deformation. According to the regional tectonic setting, the spatio-temporal evolution of the volcanic-sedimentary strata of the Lower Cretaceous should be related to the westward subduction of the paleo-Pacific. Therefore, during the period 114-101 Ma, the westward subduction of the paleo-Pacific plate had a significant influence on the tectonic evolution of Northeast China, and the scope of influence included at least the SB and its eastern region.

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Analysis on Volcanic Development Model and Main Controlling Factors of Favorable Reservoir in the 3rd Member of Shahejie Formation in Zaoyuan Oilfield

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Keywords: volcanic reservoir, eruption mode, volcanic stage, volcanic lithofacies, main controlling factors

The volcanic oil reservoir of the third member of the Shahejie Formation in the Zao35 fault block of Dagang Oilfield is located in the Cangdong Sag of the Huanghua Depression, Bohai Bay Basin. It is a fracture-porous dual medium oil reservoir. Based on well logging, and 3D seismic data, the characteristics of volcanic rock reservoirs, volcanic eruption patterns and volcanic eruption stages were studied, and the influence of different volcanic rock factors on reservoir distribution was explored, which provided the geological basis for subsequent development of volcanic rock reservoirs. The research results show that there are two development modes of volcanoes in this area, the fractured eruption with the Litianmu fault as the channel and the string beaded central eruption. The volcanic rocks are divided into 3 main eruption cycles based on the comprehensive seismic response characteristics. Combined with the stable mudstone intervals drilled by wells, the volcano can be further subdivided into 8 eruption stages. Affected by the two eruption modes and the distribution of fractures, the favorable reservoirs in the volcanic rock are distributed between the Litianmu fault and the central eruption channel. Lithology is also the main reason for controlling volcanic rock reservoirs in this area. Basalt is developed on a large scale in this area, so it is more likely to be communicated by fractures to form favorable reservoirs. In addition, due to the different eruption stages, there are 3 different basalt reservoir types in the overflow facies reservoirs in each stage, namely thick and tight basalt without pores, basalt with pores develop at the top and dense at the bottom, and basalts with pores developed at the top and tight in the middle, so the oil reserves are mostly distributed on the top and bottom of the thick basalt, among which the volcanic rock reservoirs of stage III4 and III5 have the greatest oil reserves and development potential.

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Session T2-2: Interactions between basement, volcanism, and sedimentary cover
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Structural styles and extension-strike slip fault system:A case from Nanpu sag, Bohai Bay Basin, NE China

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Keywords: Deformation genesis, Analogue modeling, Extension-strike slip fault system, Nanpu sag, Bohai bay basin

Nanpu sag is located in the northeast of Huanghua depression in the Bohai Bay Baisn (BBB), and the northern part is the first-order boundary fault of the depression: Baigezhuang fault (BGZ) and Xi'nanzhuang fault (XNZ) form the depression boundary together. It is a continental dustpan sag with the characteristics of north Fault and south superstructure. The research data show that the shallow reservoirs (Nm, Ng, Ed) in the Nanpu sag have the characteristics of shallow burial depth, good physical properties and high production capacity. In order to clarify the way in which the staged tectonic deformation affects the fracture spreading of hydrocarbons, this paper systematically summarizes the stress field transformation in the Nanpu sag region, the spatial spreading characteristics of the No.4 structure belt and the zonation characteristics of the main fracture of the shallow Cenozoic layer system through detailed interpretation of 3D seismic data, and clarifies the structure deformation mechanism of the No.4 belt. The established spatio-temporal evolution process combined with the paleotectonic geometry of the No.4 structure belt is then used to design physical analogue experiments to recover the deformation process and simulation results. Research shows that: (1) the Cenozoic No.4 structure belt and the surrounding areas mainly have the characteristics of superposition of anisotropic extensional deformation in phases, and there are several groups of NW and NE trending faults, which mainly form the style of strike-slip stacked fan and horst-ground combination in the plane, and the style of compound "y" combination, conjugate combination and negative flower combination in the section. (2) The Cenozoic No.4 structure belt has the deformation characteristics of planar zoning and sectional staging, forming a strong slip-weak extension zone at the southern section of the No.3-4 structure belt, and a conjugate strong extension-weak slip zone at the northwest end where the slip component gradually decreases. (3) The "strike-slip stacked fan structure" in the No. 4 structure belt is the result of the diagonal boundary extension due to the near north-south extension under the preexisting basement conditions, and there is no significant combination of pure strike-slip deformation, and specific boundary faults, basement inhomogeneity and preexisting fractures have a controlling effect on the tectonic pattern of the fault system. (4) The mudstone at the base of Ed3 is both the main hydrocarbon source rock and the controlling material factor in the formation of the extensional-slip transition zone in No.4 structure belt.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
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Influence of tectonism and volcanism on depositional system in south slope area of Lufeng Sag, Pearl River Mouth Basin, South China Sea

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Keywords: ancient gully, fault trough, volcanic eruption, braided river delta, Lufeng Sag

Lufeng Sag, located in the Pearl River Mouth Basin on the northern continental margin of the South China Sea, is one of the important sag with abundant oil and gas. The Paleogene Wenchang Formation was a continental sedimentary system with a large number of braided river deltas developed in the slope area. In this study, we adopted palaeogeomorphic map, seismic data, well data and the casting thin sections to clarify the impact of basement geomorphology, faulting and volcanism on sedimentary system in slope area.

Huilu low uplift in the south of Lufeng Sag was a continuous source in the Paleogene. Through the geomorphic highs and slope changes of the basement paleogeomorphic map, 13 ancient gullies supplying sources to the south of Lufeng sag were identified, including U-type, W-type and composite type. The U-type ancient gullies are formed in channel maturity, with strong sand transport capacity and long sediment transport distance. The seismic facies have a strong amplitude, a high frequency, a high continuity and a low angle progradation reflection, resulting in braided river delta deposits with large plane range, long extension and large vertical thickness. The W-type ancient gullies are formed in the late bifurcation of the channel, during which hydrodynamic force is weakened and sand transport capacity of the gully is weak. The seismic facies are medium amplitude, medium frequency and medium continuous forward reflection, forming the same type of the delta but with small plane range, short extension and small vertical thickness. The composite ancient gullies are formed by the superposition of U-type and W-type ancient gullies, with medium sand transport capacity. In addition, the Paleogene rifting was accompanied by numerous faults and local volcanic eruptions in the slope area. Volcanic eruption forms volcanic debris, crystal debris and volcanic ash, which do not affect the shape and size of the sand body, but alter the reservoir's physical properties of it, especially the tuffaceous filling will significantly reduce the reservoir permeability. Faults have an obvious influence on the size of the delta, some of which strike in the same direction as source injection, forming fault trough source channels. The fault trough controlled by a single fault has the characteristics of dustpan structure and wedge filling seismic phase in the vertical provenance direction seismic profile, whereas the fault trough controlled by two dip-faults has the characteristics of symmetrical structure and parallel-subparallel seismic phase in the vertical provenance direction seismic profile. When the fault activity is stronger, the sand transport capacity of the fault trough is stronger, and the scale of the delta is larger.

When the catchment area, width-depth ratio, and cross-sectional area of the ancient gully and fault trough are quantitatively analyzed and compared to the corresponding area of the delta, it can be seen that the catchment area and the multiplication of width depth ratio and cross-sectional area are both positively correlated with the area of the sedimentary sand body. These two parameters jointly determine the size of the sedimentary sand body.

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Session T2-2: Interactions between basement, volcanism, and sedimentary cover
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Cenozoic Intermediate and Mafic Igneous Rocks in the Eastern Sag of Liaohe DepressionLithologyLithofaciesand Controlling Factors of Reservoirs

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Keywords: Eastern sag, Cenozoic, volcanic, reservoirs

Abstract: On the basis of 110 wells with 1100 meters drilling cores and 500 wells with 107000 meters long sections of igneous rocks in the Eastern sag of Liaohe Depressionlithologic and lithofacies of the Cenozoic intermediate and mafic igneous rocks and controlling factors of reservoirs were studied by means of description and slice identification of cores, reservoirs physical property data and oil reservoirs analysis. Based on these data, 16 types of volcanic, intrusive rocks and volcanic sedimentary rocks are recognized, basaltic lava and basaltic volcanoclastic rocks have the greatest thickness and the most widely distributed91%. The volcanic lithofacies are mainly divied into 6 lithofacies and 16 subfaciesduring which Effusive lithofacies accounts for about 63%. The reservoirs space can be grouped into 4 types and 9 sub-types, secondary porosity and fracture are most developed in the study area. Trachytic lava and Trachytic volcanoclastic rocks, basaltic volcanoclastic rocks, extrusive dome facies, volcanic conduit faciesand explosive facies are the most favorable reservoirs. Three factors including Lithology, lithofacies and faults are thought related to the porosity and permeability of igneous rocks reservoirs. Lithology determines types and microscopic characteristics of reservoirs; lithofacies controls the development of primary pores and distribution of reservoirs; faults control the range of igneous rocks, position of vent lithofacies and proximal lithofacies, and effectiveness of reservoirs. The areas of favorable petroleum accumulation are near oil sources, structural highs adjacent to faults, and advantage of lithology and lithofacies.

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Session T2-2: Interactions between basement, volcanism, and sedimentary cover
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An important tectonothermal event occurred in the middle and late Late Paleozoic in the Qinling Orogenic Belt

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Keywords: North Qinling Orogenic Belt, tectonothermal geochronology, tectonic event, provenance analysis, U-Pb geochronology

The Permian in the Liuyehe Basin of the North Qinling, the Lintan area of the West Qinling, the Zhen'an Basin of the South Qinling in the Qinling Orogenic Belt (QOB) and the Permian in the southern Ordos Basin on the north side of the QOB contain a large amount of ca.350~260Ma detrital zircons. Although the studies believe that the ca.350~260Ma detrital zircons come from the QOB, there are a few public reports of the magmatic/metamorphic age records of this period in the QOB. Only a small amount of reliable magmatic/metamorphic zircon age records of ca. 350–260 Ma have been found in the Jiangligou and Zhongchuan granites in the Western Qinling and the metamorphic rocks of the Wuguan Group in Danfeng County in the eastern North Qinling. Based on the existing work, we put forward the scientific hypothesis for the first time that "there is an important tectonothermal event that has not been fully revealed and recognized in the QOB during ca.350~260Ma". Through the research on the Jiangligou and Zhongchuan granites, and the metamorphic rocks of the Wuguan Group in Danfeng County (front side) by means of petrology, petrography, rock geochemistry, zircon U-Pb isotope dating and in situ Lu-Hf isotope. Through the study on the provenance, genesis and source area attribute of the ca.350~260Ma detrital zircons in the Permian of the southern Ordos Basin, the Liuyehe basin, the Lintan area, the Zhen'an basin (reverse side) by means of paleocurrent direction, sandstone composition, debris composition and heavy mineral characteristics analysis, sedimentary geochemical analysis, zircon U-Pb isotope dating and Lu-Hf isotope tracing. We combined with direct demonstration and indirect inversion, fully demonstrate the hypothesis from both pros and cons, and discuss the nature, tectonic evolution characteristic and tectonic setting of this tectonothermal event in the QOB during ca.350~260Ma. The research results are of great significance to further reveal the Late Paleozoic tectonic evolution history and plate tectonic attributes of the QOB, clarify the Qinling orogenic process and its control over the filling history of peripheral basins, and broaden the exploration fields and ideas of various mineral resources in the QOB and surrounding sedimentary basins.

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Session T2-2: Interactions between basement, volcanism, and sedimentary cover
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The development characteristics, genesis and formation environment of igneous rocks in Nanpu Sag of Bohai Bay Basin

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Keywords: igneous rocks in Nanpu Sag , developmental characteristics , petrogenesis , forming environment

Nanpu Sag is located in the northern end of Bohai Bay Basin. There are two types of volcanic rocks, intrusive rocks and exhalative rocks. The intrusive rocks include diabase, diabase porphyrite, quartz diorite, etc. Ejected rocks can be divided into volcanic lava and volcanic clastic rocks. The former mainly includes basalt, andesite, rhyolite, and the latter includes volcanic breccia, tuff, tuffaceous sandstone, etc.

Nanpu depression volcanic formation period can be divided into Shahejie, Dongying and Guantao three periods. The distribution characteristics of volcanic rocks : 1.Distribution direction deflection. In the early Shahejie period, the volcanic rocks were distributed in NE direction, and in the middle Dongying period, they were NW-SE direction, and in the late Guantao period, they were NE-SW direction, indicating that the regional stress changed. 2. Spatial distribution. The early volcanic rocks were distributed in the southwest of the sag, and the middle and late volcanic rocks extended to the middle and north. 3. Increased intensity of activities. From the early stage to the late stage, it is generally the expansion depression, and the expansion intensity increases.

The weighted average age of zircon U-Pb dating is 34.1 ± 0.5 Ma, so it is determined to be formed in Shahejie period. On the primitive mantle normalized spider diagram of trace elements, the curve generally tilts to the right, showing a zigzag jumping decreasing distribution , Enriched Rb, Ba, Sr and LREE, depleted Zr, Th ; in the REE distribution pattern map of chondrite, the curve was right-leaning, enriched LREE and depleted HREE ; the mean value of δEu is 0.97, indicating weak negative Eu anomaly.

The (Th / Ta) PM and (La / Nb) PM of the sample data are less than 1, suggesting no obvious crustal contamination. In the Huck plot with MgO as the abscissa, Ni, CaO and Al2O3 were positively correlated with MgO, TiO2 and P2O5 were negatively correlated with MgO. Sm-Sm / Yb diagram shows that the mantle source is composed of garnet , spinel and lherzolite, and 3 % ~ 16 % partial melting is speculated. The sample data have high Ta / Yb and Th / Yb values. The Th / Yb-Ta / Yb diagram, εNd-87Sr / 86Sr diagram and 208Pb / 204Pb-206Pb / 204Pb diagram show that the magma originates from the mixed source area of EMI and depleted mantle. In the 2Nb-Zr/4-Y diagram, TiO2-MnO-P2O5 diagram and Th / Hf-Ta / Hf discrimination diagram, it is shown that the formation environment is active rift expansion in continental plate.

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Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Geochronology, Geochemisty, and Tectonic Significance of Carboniferous Andesites of Zhongguai Uplift in Northwestern Margin of Junggar Basin

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Keywords: northwestern margin of Junggar Basin, Zhongguai uplift, Carboniferous, andesite, chronology, geochemistry

In order to deepen the understanding of the Carboniferous tectonic background in the western part of the Central Asian orogenic belt, the core and samples of andesites in JinLong 10 well area of Zhongguai uplift in the northwest margin of Junggar basin have been studied in petrography, chronology and geochemistry. The results show that brown gray, grayish green and dark gray andesites are mostly developed in the study area andesites in the study and they are belong to low potassium to medium potassium calc alkaline rock series, and its REE diagram is slightly inclined to the right, with weak Eu negative anomaly. In the standardized spider diagram of the original mantle, The Pb and LILE(Rb, Ba)enrichments and HFSE (Nb, Ta, Zr) depletions resemble those of typical subduction-related arc volcanic rocks. The Th/La, Th/Ce and Lu/Yb ratios of andesites are below those of average continental crust, but similar to those of typical mantle-derived magmas. The andesites in the study area belong to the normal island arc volcanic rocks and atypical adakite, which are derived from the water rich mantle wedge and are formed by the partial melting of the fluid metasomatic mantle wedge produced by the dehydration of the subduction plate. The zircon U - Pb dating of andesites LA - ICP - MS shows that the crystallization age is 322.4 ± 1.1 Ma, which is in the Middle Carboniferous, in line with the time range of the first tectonic magmatic event of the extinction of the western Junggar residual ocean basin (329 ~ 320 Ma). Combined with regional geological background and comparison with magmatite in similar period, it is considered that the andesites in the study area was formed in the continental arc environment, and was the product of subduction of the residual oceanic basin in West Junggar, and the remnant ocean basin was not completely closed at 322.4 ± 1.1 Ma.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
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Eocene magmatic activity and its influence on the formation of lacustrine high-quality source rocks in the western Zhu I depression, Pearl River Mouth Basin

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Keywords: South China, Pearl River Mouth Basin, Wenchang Formation, magmatic activity, source rocks

Following the collapse of the Yanshanian orogenic belt, mantle magma uplift, crustal stretching and thinning, and multiperiod strong magmatic activities widely developed during the Eocene in South China, especially in the western Zhu I depression, Pearl River Mouth Basin (PRMB). Moreover, the Eocene lacustrine mudstone of the Wenchang Formation has high OM abundance (total organic carbon (TOC): maximum of 3.20 wt%) and is an important source rock in the PRMB and in South China. Thus, the sedimentary records of the Eocene Wenchang Formation in the western Zhu I depression provide an interesting perspective for understanding the influence of magmatic activity on the formation of lacustrine high-quality source rocks. Based on detailed analysis of new three-dimensional seismic and drilling data and recent research results, using geophysical, basin analysis and geochemical means, this paper systematically analyzes the magmatic activity of Paleogene in Zhu I depression and its influence on the reconstruction of basin structure and the development of source rocks.

The results suggested that extensive magmatic underplating (mainly distributed in the depression) in the sedimentary period of Wenchang Formation of Zhu I depression, and the multi-stage magmatic underplating may be controlled by the rift of Zhuqiong movement and the tectonic transformation of Huilu movement. Under the joint influence of pre-existing faults and magmatic emplacement, Zhu I depression presents the complexity and diversity of structure. The preexisting detachment system controls the extension of the basin and forms many elliptical depressions with small aspect ratio. The synsedimentary magmatism promotes the tilt and rotation of the hanging wall of the detachment fault, resulting in the weakening of axial provenance, and the enhancement of gentle slope provenance and the development of large delta deposits. Meanwhile, the subsidence area in the fault depression forms an uncompensated deep lake environment, which provides excellent conditions for the formation of high-quality source rocks.

In addition, the detailed geochemical analysis of source rocks in the study area reveal that multiple hydrothermal activities occurred during Wenchang deposition, which is considered to be related to magmatic underplating in the same sedimentary period. During the hydrothermal activity period, regional tectonic activity caused the hydrothermal fluid to jet upward along the tensile fractures in the lake basin basement, thereby inputting abundant nutrients (Fe, Cu, Ni, P, Zn, etc.) and the common prosperity of lake microalgae and terrestrial plants greatly improved lake primary productivity. High lake level led to a reducing bottom water environment, and abundant reducing gases (H_2S, SO_2, and CH_4) were released into the lake along the hydrothermal overflow channel, which further influenced the anaerobic conditions of the bottom water. Therefore, the eugenic environment formed by magmatic hydrothermal activity (high biological productivity and reduction conditions) further promoted the development of high-quality source rocks of Wenchang Formation. The influence of magmatism on the formation of lacustrine high-quality source rocks will further enrich the organic matter accumulation mechanism of continental faulted lake basin, and provides useful enlightenment for oil and gas exploration in the PRMB and similar basins.

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Discovery of the Late Jurassic-Early Cretaceous lamprophyres in western Songliao Basin of northeast China and their constraint on regional lithospheric evolution

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Keywords: Songliao Basin, Northeast Asia, Lamprophyre, Geochemistry, Lithospheric evolution, Jurassic and Cretaceous

Contradictory to common concept that the lithosphere in NE China was thinned from Late Jurassic through Early Cretaceous. We discovered, however, a thickening episode in the long-term thinning background. A series of lamprophyre dikes have been recently found in the Tuquan Basin of western Songliao Basin. They were subsequently dated at 156.0 ± 2.3 Ma, 132.9 ± 1.2 Ma, and 126.2 ± 2.5 Ma, respectively, using the zircon U–Pb technique. The lamprophyres are subdivided into Late Jurassic biotite orthoclase lamprophyre (BOL) and Early Cretaceous quartz magnetite lamprophyre (QML).The BOL and QMLs are shoshonite and calc-alkaline in series, characterized by high contents of FeOT, TiO2, MgO, and Mg# values, and are enriched in LREEs and LILEs but depleted in HREEs and HFSEs. They have high ratios of (La/Yb)N, La/Ta, La/Nb, Th/Y, Ba/Nb, Ba/Ta, and Ba/Th, and low ratios of Zr/Ba, La/Sm, and Nb/Zr. These features collectively point to the derivation of the dike magmas from the partial melting of enriched lithospheric mantle that had been previously metasomatized by subduction-related fluids. The BOL has high ratios of Rb/Sr (0.42) and K/Yb*1000 (28.3), and low ratios of Ba/Rb (13.5) and Dy/Yb (2.35), suggesting a magma derivation from high degree partial melting of phlogopite-bearing lherzolite mantle in the spinel–garnet transition zone at a depth about 60 km, the QMLs have low ratios of Rb/Sr (0.02–0.06) and K/Yb*1000 (8.13–19.73), and high ratios of Ba/Rb (17.6–42.6) and Dy/Yb (3.48–4.09), indicating that the magmas were derived by low degree partial melting of lherzolite mantle in the garnet zone at a depth of ca. 85 km, the younger QML (126.2 ± 2.5 Ma) has lower Dy/Yb ratio (3.48–3.92) than that of the older QML (132.9 ± 1.2 Ma) with Dy/Yb ratio of 4.09, implying that the younger magma was produced at a shallower mantle depth (85 km) than that of the older one. These indicate that in the period of 156–132 Ma, the lithosphere thickened by approximately 25 km at a rate of approximately 1.0 km/Myr. A new geodynamic evolution model of three stages was thus proposed.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Oral Preferred

Jurassic Volcanism and Sedimentation along the Derbugan and Erguna faults, western Hailar Basin

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Keywords: volcanic edifice, volcanic sedimentation, Jurassic, Derbugan fault, Hailar basin

Derbugan and Erguna faults are the two important structures in the northeastern Asia. Recent studies suggest that the two fault belts control Jurassic volcanic eruptions, basin subsidence and sedimentary filling. The western Hailar Basin lies between the Derbugan and Erguna faults. Based on 2D/3D seismic data and field observation, this study aimed to characterize volcanic edifices, identify the lithofacies distribution of volcano-sedimentary rocks, and reconstruct volcanic paleogeography in the western Hailaer Basin. The volcanic rock belt distributed along the NNE-trending Derbugan and Erguna faults is about 50 km wide and hundreds of kilometers long. The volcanic edifices show multi-center eruption patterns as the typical features of composite volcanos, and they predominantly distribute along the NE-trending faults that are the secondary faults of the Derbugan and Erguna faults. The spatial distribution of the volcanoes is controlled by typical fault patterns, for example, parallel-fault assemblage, antithetical-fault assemblage, fault-transition zone and echelon-fault assemblage. Sedimentation usually takes place between volcanic edifices and the boundary faults of basin, and the fault-related structures and volcanic paleogeomorphology jointly impact the distribution of sedimentary rocks. The dip angle of boundary faults controls the range of sediment accommodation. The volcanic eruptions occur almost simultaneously with basin rifting and occupy a considerable part of the accommodation space. The sedimentary facies are developed in the accommodation space limited by volcanic edifices and faults. A detailed anatomy suggests that the volcanics in Bayanhushu depression mainly belong to effusive facies and explosive facies composed of tuffs. The Chagannuor depression is predominated by shallow lacustrine sediments, and the explosive facies and volcano-sedimentary facies mainly distribute in the south. Fan deltas and offshore sedimentary fans are generally developed in the gentle slope zone away from volcanic disturbance. The Derbugan and Erguna faults serve as a pathway for magma migration and affect the emplacement of volcanic edifices and the distribution of volcano-sedimentary rocks.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Oral Preferred

Characteristics of Volcano Stratigraphic Elements in Faulted Depression Basin and its Geologic Significance: A Case Analysis of Full Coring Well of Lower Cretaceous Yingcheng Formation in Jiutai, Jilin Province

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Keywords: Volcano stratigraphy, Yingcheng Formation, Deposit unit, Greenhouse gas, Songliao basin

Volcano stratigraphy has special temporal and spatial attributes and geological record characteristics, but it has not attracted enough attention in the analysis of basin filling. In order to further clarify the geological attributes of volcano stratigraphy, the characteristics and geologic significance of volcano stratigraphic elements of Lower Cretaceous Yingcheng Formation in Songliao Basin were studied by taking the full coring shallow drilling wells (Y1D1 and Y3D1) as examples. The results are described as follows: 3 eruptive interval unconformity boundaries and 10 eruptive conformity / unconformity boundaries are identified in the volcano stratigraphy of the first member of Yingcheng Formation in well Y1D1. 2 eruptive interval unconformity boundaries and 8 eruptive conformity / unconformity boundaries are identified in the volcano stratigraphy of the third member of Yingcheng Formation in well Y3D1. According to the attributes of eruptive interval unconformity boundary, the volcano stratigraphy of well Y1D1 can be divided into 4 volcano edifices, and the volcano stratigraphy of well Y3D1 can be divided into 3 volcano edifices. Rare earth and trace elements have a good response to the volcano edifice. There are 6 types of deposit unit: simple lava flow, braided lava flow, dome, pyroclastic flow, base surge and lahar. The emission intensity of volcano gas during the eruption of lava units is weaker than that of pyroclastic units. Volcano stratigraphy has the time attributes of short construction time and long eruptive interruption time, and the construction rate of volcano stratigraphy cannot be calculated simply by using the stratigraphy thickness and the time difference between the top and bottom of the test.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Development of extensional decollement structure and its petroleum implication in the Wushi east subsag, Beibuwan Basin.

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Keywords: Beibuwan Basin, Wushi Sag, Extensional decollement structure, Structural evolution, Oil and gas structure

Wushi Sag is located in the central part of the Beibuwan Basin, northwestern continental margin of the South China Sea. From the early Paleocene to the end of the Oligocene, it experienced multiple phases of extension. Based on the new high-quality 3-D seismic data obtained in the process of petroleum exploration, this study conducted an in-depth analysis of the extensional decollement faults in the Wushi east subsag, established the growth and linkage model of decollement faults and discussed the meaning to oil and gas exploration. The results show that there are 7 extensional decollement faults (Fa-Fg) in the Wushi east subsag, which are distributed in the near E-W or NE-SW direction. These decollement faults together with north-dipping No.7 boundary fault, controlled sedimentation from the 1st Member of Liushagang Formation to the 1st Member of Weizhou Formation, which formed a huge rollover anticline. In terms of evolution, during the Early-Middle Eocene, the basin is a graben or half-graben controlled by the NE-SW No.7 boundary fault and other local small basement faults. The 3rd member of Liushagang Formation strata are discretely distributed and were overlaid by thick layer of the 2nd member of Liushagang Formation. From the late Eocene to the late Oligocene, the basin deposited 1st Member of Liushagang Formation to the1st Member of Weizhou Formation , controlled by the oppositely dipping extensional decollement faults and the No.7 boundary fault. From the early Miocene to the present, the basin changed into a sag basin. This study depicted the geometry of extensional decollement structure which formed during the second rifting rift phase of Wushi east subsag, analyzed the growth and linkage pattern of decollement faults, proposed the decollement faults upslope-ward migration model, which has a great significance for solving the problems of oil and gas migration, storage and preservation.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Oral Preferred

Quantitative analysis of Mesozoic pollen and spores for detecting the interaction between volcanism and environment

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Keywords: Botanical affinity, Palaeoenvironment, Palaeoclimate, Palaeoecology, Sporopollen database

The eco-group classification based on the growth-form of plants (Eco-Plant model) is widely used for extant, Cenozoic, Mesozoic, and Paleozoic palaeoenvironmental reconstructions. However, for most Mesozoic dispersed sporomorphs, the application of the Eco-Plant model is limited, because either their assignment to a specific eco-group remains uncertain or the botanical affinities to plant taxa are unclear. A new database Sporopollen (http://www.sporopollen.com) focused mainly on Mesozoic sporomorphs is created.

With the help of the database, 861 dispersed Mesozoic sporomorph genera of Bryophytes, Pteridophytes, and Gymnosperms are reviewed by comparing the unique outline and structure/sculpture of the sporomorph wall with that of modern plants and in situ fossil plants. The results show that 474 of them can be linked to their closest parent plants and Eco-Plant model at family or order level, but 387 of them cannot because of the lack of detailed ultrastructure descriptions. The use of a light microscope (LM) for determination is one of the main reasons that some dispersed sporomorphs cannot be linked precisely to their parent plants. The presented eco-groups for dispersed Mesozoic sporomorphs provide the possibility to identify detailed vegetation and palaeoenvironmental change in the Mesozoic, especially in the context of climate change.

A new interface (http://www.sporopollen.com/sporemesozoicsegs.php?opencode=paper1) was created based on the reviewed result to quickly link dispersed sporomorphs to past vegetation patterns and climatic changes. Users can upload their data to the database and in return get quick results. It can automatically link all of the Mesozoic and Cenozoic sporomorphs to their possible parent plants at phylum, order, or family level as well as all of the Triassic and Jurassic sporomorphs to the Eco-Plant model to assess the effects of humidity (EPH) and temperature (EPT).

As an example, samples from a lignite bed of the Upper Triassic Haojiagou Formation (Rhaetian) have been studied palynologically to reconstruct the palaeovegetation and palaeoenvironment of a peat-forming wetland near the Triassic-Jurassic boundary by using the Eco-Plant model. We analysed assemblages in terms of an Eco-Plant model, which assigns the parent plants of the palynomorphs into five groups based on humidity and four groups based on temperature and used multivariate statistical analyses to infer palaeoclimate and palaeoenvironmental conditions. Our results suggest that the palaeoclimate of the Rhaetian was generally wet and subtropical with short seasonal drought periods. The analysis shows that the Eco-Plant model is a useful tool to reveal past vegetation patterns and climate changes, applicable to other Mesozoic assemblages.

Volcanic activities usually disturb the environment and affect the palynological assemblages. Our database and the Eco-Plant model can be useful tools to detect the interaction between volcanism and environment.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Reservoir characteristics and differences of basement gas reservoirs in front of Altun Mountain, Qaidam Basin

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Keywords: basement gas reservoir, lithologic, Reservoir characteristics, fracture characteristics, difference, Qaidam Basin

As a kind of unconventional oil and gas reservoirs, the basement reservoirs are widely distributed in the world. In recent years, breakthroughs have been made in exploration of basement buried hill gas reservoirs in front of Altun Mountain in Qaidam Basin. Three basement gas reservoirs (Dongping, Pingxi and Jianbei) have been discovered successively. They accumulated proven reserves of more than 100 billion cubic meters and is one of the most promising exploration fields in Qaidam Basin. The exploration proves that the differences of basement lithology and reservoir characteristics are related to the enrichment of natural gas. Therefore, it is of great geological significance to clarify the reservoir characteristics and differences of basement gas reservoir. Based on core observation, laboratory thin section identification, X-ray diffraction, ECS logging and electric imaging logging data, we made a comprehensive analysis and research. The results show that : There are various types of basement rock in front of Altun Mountain, and the reservoir lithology are mainly granite, granitic gneiss, granodiorite, crystalline limestone and slate. The mineral composition of different lithologies is different and shows obvious differences. The logging responses of different lithologies are different. The combination of ECS and conventional logging can distinguish lithologies. Different types of basement reservoirs have different reservoir space characteristics and physical properties. The reservoir spaces of magmatic and ortho-metamorphite are mainly dissolved pores and fractures, and the porosity is mainly distributed in the range of 2% ~ 7%. The reservoir space of para-metamorphic rock is mainly fracture, with a few dissolved micropores, and the porosity is mainly distributed in the range of 1% ~ 4%; The fracture characteristics of different lithologies are obviously different. The exploration practice shows that there are obvious differences in natural gas production due to different basement lithology, reservoir space and fracture development characteristics. The research results provide a certain reference for the exploration of basement reservoirs and have a guiding significance for the exploration of basement reservoirs in other areas.

Reference

As a kind of unconventional oil and gas reservoir, the total oil and gas reserves of basement reservoir are almost equal to 15% of the world's known oil and gas reserves (Yang and Xu, 2011), so it has attracted more and more experts' attention. Exploration practice shows that basement reservoirs are widely distributed in the world. 2017; Chen zhigang, 2016), White Tiger Oil Field in Vietnam (Chen et al,2009;Nguyen N T B et al, 2009; Nguyen T T et al, 2009; Dang C T Q et al, 2011), the Jatibarang oil and gas field in Indonesia (Ma et al,2006;Syarif M N et al,2015;), the Cupen Mahuida gas field in Argentina's Ueuquen Basin (Zubiri M and Silvestro J,2007;Luo Y Y et al.,2010) and so on are oil and gas reservoirs with reserves of hundreds of millions of tons. In China, there are such as the Bohai Bay Basin of Liaohe (Wang Xin et al., 2015; Hu Zhiwei, 2017), Songliao Basin (Song Borong, 2011; Zhu Yixiu, 2018), Kelameili Gas Field in Xinjiang (Hou Lianhua et al., 2012), Yaerxia Oilfield in Jiuquan Basin (Xie Gongjian et al., 1981), etc.

In recent years, great breakthroughs have been made in the exploration of basement reservoirs in Qaidam Basin. High-yielding oil flows have been obtained from basement in areas such as Kunbei (Li Jianming, 2011; Liu Guizhen, 2015), Dongping (Zhang Shenqin, 2014; Li Jiangtao, 2014; Cao Zhenglin, 2013; Li Yanli, 2019) and Jiandingshan and so on. Among them, Dongping Gas Field is considered to be a rare basement buried hill gas reservoir at home and abroad in recent years (Li Jiangtao, 2014). In recent years, the exploration of unconventional reservoirs has attracted much attention. With the deepening of exploration work, basement reservoirs will play an increasingly important role in the exploration and development of oil and gas. Therefore, the study of reservoir characteristics and accumulation law of basement reservoirs is of great significance for guiding the exploration and development of basement reservoirs.

Basement reservoirs are widely distributed all over the world. Most of the reservoir types are oil reservoirs, but a small number are gas reservoirs. Granite is the largest reservoir lithology, accounting for 32%, followed by igneous, metamorphic rocks and

limestone (Yang and Xu, 2011). strong heterogeneity of lithology and physical properties, the daily production of single well in basement reservoirs varies greatly. There are basement oil and gas reservoirs in almost all petroliferous basins. Some are oil and gas fields with geological reservoirs of up to 100 million tons, and some are only oil and gas shows. In recent years, the author has been devoted to the study of basement gas reservoirs in Dongping, Pingxi and Jianbei areas in front of the Altun mountains. The results show that different from the basement reservoirs in other basins, the basement reservoirs in the front of Altun of Qaidam Basin are mainly gas reservoirs. The basement rock types are complex and diverse, and the reservoir space types and characteristics of different lithologies are significantly different, leading to great differences in production. This paper aims to take the basement gas reservoir in this area as an example, through the analysis and research of the relationship between complex basement lithology, reservoir and fracture development difference and production, in order to provide inspiration and reference for the exploration of basement oil and gas reservoirs in Qaidam Basin and other areas.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Oral Preferred

Deformation Features and Genesis Simulation of Strike-Slip Faults in Junggar Basin, Northwest China

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Keywords: Junggar Basin, strike-slip structure, genetic model, tectonic evolution, physics simulation

The Junggar Basin located in the northwestern part of China, which is the second largest petroliferous basin of Chinese mainland. It has the pre-Carboniferous metamorphic rock basement, mainly depositing Carboniferous system to Quaternary system. The strike-slip fault structures of different properties and scales developed in the periphery and middle part of the basin were the result of the superposition of multi-stage tectonic evolution. Since the Late Paleozoic, the tectonic evolution of the Junggar Basin can be divided into four key stages, namely the Carboniferous-Permian extensional fault depression stage, the Triassic-Jurassic compressional depression stage, the Cretaceous equilibrium subsidence stage, Paleogene-Neogene squeeze and depression stage. Meanwhile, the Triassic-Jurassic compressional depression stage is the main period for the development of strike-slip structures. The different strike patterns of basement faults, various types of pre-existing structures, and compressional stress states of diverse directions are the main factors for the differences in strike-slip faults structural styles. Base on the field geological work, statistical analysis of fault occurrences and joint elements, interpretation of 3D seismic profiles, as well as tectonic physical simulation experiments, the deformation features and genetic mechanism of strike-slip structures in different areas of the Junggar Basin are discussed: (1) The Cenozoic NE strike-slip structure in the southern margin of Junggar Basin is a tear fault system formed by differential thrust in the northern part of Tianshan Mountain, which is controlled by dual factors of differential thrust velocity and basement properties. And a tear fault structure model has been established. (2) The structure system in the western margin of Junggar Basin is segmented in space and superimposed in time. It has experienced four stages: dextral extensional-shear in early Permian, dextral compressional-shear in middle and late Permian, sinistral compressional-shear in Triassic- Jurassic and dextral extensional-shear during Cenozoic. (3) The strike-slip fault system in the central Junggar Basin mainly overwent two evolutionary stages: Yanshanian compressional-shear and Himalayan extensional-shaer, which were controlled by the dual factors of basement properties and different shear modes. The strike-slip structure in the Zhong 3 block formed under the widely distributed right-lateral strike-slip mechanism jointly controlled by the basement pre-existing faults and Jurassic coal seams, and transformed during the thrusting process of the southern margin of the Himalayan period. The strike-slip structure in the Zhong 4 block is a combination of simple shear on both sides and pure shear at the thrust front caused by the displacement of the pre-existing basement uplift under the action of near-EW compressive stress in the Jurassic period.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Study on the evolutionary relationship of basement structure and Mesoproterozoic cover in Ordos Basin

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Keywords: evolutionary relationship, early sedimentary cover, Basement structure, magnetic and seismic data, Ordos basin.

To understand the influence of the basement on the development and evolution of early sedimentary cover in Ordos Basin, using 1:200000 magnetic data, the latest drilling and seismic data, the characteristics including the basement structure and the Mesoproterozoic Changcheng-Jixian system tectonic-sedimentary formation are studied respectively, and the evolutionary relationship between basement structure and the early cover is discussed. The results show that the basement structure of the basin is controlled by four primary faults, which are divided into five secondary structural units, showing the characteristics of NE horizontal blocking. The early sedimentary cover mainly experienced the two stages of the Changcheng period NE trending intracontinental rift and Jixian period depression and was dominated by continental coastal-clastic rocks and marine carbonate rocks respectively. The primary faults that control the basement structure of the basin are revived differently in the form of main boundary faults in the Changcheng period, manifested in the structural style of graben and half-graben, and controlled the sedimentary framework of the Changcheng period in the form of three depressions and two uplifts. The Mesoproterozoic cover is controlled by basement structure, characterized by early strong and late weak, west strong and east weak.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Influence of multi-stages strata uplift and erosion on hydrocarbon charging time in Late Mesozoic of Hangjinqi area, northern Ordos Basin, China

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Keywords: Erosion thickness, K-Ar dating, Hydrocarbon charging time, Tectonic evolution, Accumulation period

Ordos Basin had been subjected to multi-stages strata uplift and erosion in the late Mesozoic. How did this process affect the charging time of hydrocarbon? We selected the Hangjinqi area of northern Ordos Basin as the study area to discuss the question. This paper took the basin analysis system and thermochronology as the theoretical guidance. In the first, the late Mesozoic strata erosion thickness was calculated by acoustic time difference method, and then balanced cross-section technique and numerical simulation was been used for restored the strata uplift evolution process. Finally, the core samples of 16 sandstone reservoirs of Lower Shihezi Formation in the study area were measured and dated to restore the reservoir geothermal history and estimate the inflation time, which was based on the homogenization temperature of aqueous inclusions, thermal and burial history simulation and K-Ar dating of authigenic illite. The research results showed that the late Mesozoic strata in the study area experienced three stages of stratum uplift and denudation. The first stage occurred in the Middle Jurassic, caused the stratum had been eroded about 850 ~ 200 m, and the denudation thickness of the generally decreases from northwest to Southeast, meanwhile, the marching temperature variation range of sandstone reservoir inclusions was 140 ℃ ~ 30 ℃; In the second stage, it was the late Jurassic, the stratum suffered from uplift and denudation strongly with denudation thickness of about 920 ~ 200 m and decreasing from west to east. The temperature variation range of sandstone reservoir inclusion at this stage was 75 ℃ ~ 165 ℃; The third stage occurred in the late Cretaceous. Affected by fault activation, there was a significant difference in the erosion thickness between the north and south of the study area. The erosion thickness increased from 380 m to 730 m, and the temperature was 82 ℃ ~ 134 ℃. The time of three charging events were between 176 ~ 172 Ma, 166 ~ 154 Ma and 128 ~ 115 Ma respectively by K-Ar dating prior to the three stages of strata uplift and erosion. Due to the different erosion thickness of the strata in the north and south in the study area, the maturity and thermal evolution of the source rocks were different. In addition, the existence of the stratigraphic unconformity provided a channel for oil and gas migration, and the Middle Jurassic strata were uplifted and tilted, which became the dynamic factor of the second inflation event.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

U-Pb dating of sandstone detrital zircons from Chert–Spilite and Sapulut Formation in Sabah, Malaysia and its geological significance

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Keywords: Sabah, Chert-Spilite Formation, Sapulut Formation, Detrital zircons, Tectonic evolution

The Sabah area has a complex tectonic setting. Many ophiolites are exposed in the Sabah area, and there are still some problems of previous studies[1-3]. Chert-spilite (Cs) and Sapulut (Sp) Formation as part of the Sabah ophiolite suites. These sediments may provide further evidence of the tectonic evolution of the Sabah.Through field samples test and analysis from the Cs and Sp Formation, the results are as follows. The minimum detrital zircons ages of three sandstone samples of the Cs Formation were 90 ± 2.0 Ma and 68 ± 2.0 Ma, the Sp Formation was 81 ± 2.0 Ma. The age spectrum of zircons of Cs Formation can be divided into four groups: 68~196 Ma (22%), 212~250 Ma (11%), 257~575 Ma (20%) and 618~3423 Ma (47%), respectively[4]. The discriminant diagrams of detrital zircon formation environment shows that most detrital zircons in Cs Formation were derived from continental crust rather than oceanic crust, indicating that zircons are not derived from Shaba basement. Dickinson diagram shows that Cs Formation sediments are mainly derived from the source area of cyclic orogenic belt. The Cs Formation zircon age spectrum of the sandstone samples is similar to those of sands in the drainage systems of South China and East Vietnam. This finding implies that the provenance of CS Formation and SP Formation was probably the South China block and/or the Sunda block. The Sp Formation sediment provenance was mainly derived from Schwaner Mountain in Southwest Borneo and Tin Belt in Malay Peninsula[5]. It indicates that the Sabah sediments source shifted from the northern to southern South China Sea during Late Cretaceous to Eocene. By comparing the tectonic evolution of Sabah and its adjacent areas, and combining with the analysis of detrital zircon age maps of sandstone in Cs and Sp Formation, it is inferred that Sabah was close to the northern South China Sea in Late Cretaceous.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
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Global typical basement boreholes comparation with the Songliao Basin

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Keywords: basin, basement,sedimentary cover, Songliao Basin

Based on the available data both internet literature and new data unpublished, the author performed a new research of global comparation of the typical basement borehole. The writer finally selected 14 globally typical basins that have borehole constraint basement-cover sections and clearly show the main phases of the overlying basin fills. The basins are: Tarim Basin, China; Junggar Basin, China; Ordos Basin, China; Erlian Basin, China; Hailar Basin, China; Songliao Basin, China; West Siberian Basin, Russia; Alberta Basin, Canada; Molasse Basin, Germany; Cankiri–Corum Basin, Turkey; Olduvai Basin, Tanzania; Pairs Basin, France; Rennes Basin, France; Campos Basin, Brazil. By comparing basement and overlying sedimentary cover of the 14 globally typical basins, we found that the Songliao Basin should be a world unique basin.

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Session T2-2: Interactions between basement, volcanism, and sedimentary cover
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Geological characteristics and controlling factors of bedrock gas reservoir in the eastern part of the Altun mountains in the Northwestern Qaidan Basin

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Keywords: Altun front, bedrock gas reservoir, weathering crust, geological features, controlling factors

The eastern section of the Altun Mountains starts from Crescent Mountain in the west and ends at Lenghu in the east, with an exploration area of nearly 8,000 km2. The whole has a structural pattern of alternating uplifts and sags, with a resource of 1.3 trillion cubic meters. Bedrock is the main exploration target layer. However, due to the complex factors controlling reservoirs and the strong differences in reservoir formation, it is necessary to carry out systematic comparative studies to identify favorable exploration targets for the next step.

The bedrock reservoirs are mainly developed into four categories: granite, granodiorite, granite gneiss and metamorphic rocks. The weathering leaching zone in the weathering crust of the bedrock is mainly composed of dissolved pores and fractures, with an average porosity of 4.3% and an average permeability of 0.66mD. The reservoir is the best. The average porosity is 2.4%, and the average permeability is 0.52mD, which is the same as the reservoir level.

The cracks in the piedmont developed in the late Caledonian, Indosinian, Yanshanian and Himalayan periods. Natural fractures were formed in the early stage, and high-angle and low-angle fractures developed; in the late Yanshanian-early Himalayan paleo-structural sites, weathering, leaching and denudation, the high-angle fractures provided infiltration channels for atmospheric water, and dissolved along dark minerals, forming a network of fractures-cavities system; the weathering leaching in the middle-late Himalayas was strengthened, and the weathering leaching zone formed a layered gas reservoir composed of a network of fracture-cavity systems, and the gas reservoir was relatively high-yield; the semi-weathered zone formed an isolated small-scale gas reservoir along high-angle fractures .

Through the analysis of the bedrock gas reservoirs, the accumulation law of "uplift-controlled accumulation, fault-cap controlled accumulation, and differential enrichment" is proposed, which clarifies the basis. The three main controlling factors of rock differential accumulation. Reservoir development characteristics are different. High-angle fractures and dissolution fractures along dark minerals are the main reservoir spaces of bedrock and control the physical properties of bedrock reservoirs. Differences in tectonic pattern. Controlled by faults from the piedmont to the basin, it can be divided into three tectonic steps: high fault step, middle slope, and sag middle uplift. Oil and gas first enter the second and third steps in the lower part, migrate upward along the fault, and continue to migrate to the higher part after being sealed by the caprock and charged with a certain amount. Differences in fault activity. The formation period of the piedmont faults controls the formation of bedrock structural traps, and the fault activity during the hydrocarbon accumulation period controls the migration and enrichment of natural gas. The low-fault steps and sag-middle uplifts located on the second and third steps are near-source and below-source accumulations, with superior reservoir-caprock assemblage and enriched lower assemblage. It is proposed that the bedrock structural traps in the Niuzhong slope belt are favorable practical breakthrough areas in the piedmont.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Characteristics and geological significance of calcarenaceous sandy conglomerate of Upper Cretaceous Quantou Formation based on the ICDP borehole SK3 in the Songliao Basin, NE China

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Keywords: Songliao Basin, SK3, Quantou Formation, calcareous concretions, calcarenaceous sandy conglomerate

Borehole SK3 is the last borehole of International Continental Scientific Drilling Program (ICDP) in the Songliao Basin consisting of "three wells and four holes". Together with well SK1(consists of north borehole and south borehole) and borehole SK2, borehole SK3 has realized the scientific goal of drilling through the Cretaceous strata of the Songliao Basin, which provides an important basis for the study of paleoenvironment, paleoclimate, paleogeography during Cretaceous and tectonic evolution of the Songliao basin. 1592.35m cores of Upper Cretaceous Quantou Formation and Lower Cretaceous Denglouku Formation has been collected by borehole SK3. Through the fine description of cores of borehole SK3, several calcarenaceous sandy conglomerate layers with calcareous concretions debris as the main clastic components (i.e. calcareous concretions debris more than 50%) was found at the depths of 1001.54m, 1002.29m and 1083.00m of the third member of Quantou Formation and 1344.80m of the second member of Quantou Formation, thickness of which ranging from 4cm to 1.3m.

Calcarenaceous sandy conglomerates develop massive structures and grain texture, with grain size ranging from 0.5mm to 5mm, roundness ranging from sub angular to sub circular and medium clastic separation. Gravels of calcarenaceous sandy conglomerates are mainly composed of calcarenaceous(calcareous concretions debris), with proportions of about 70% and small amounts of torn mud gravels. Gravels of calcarenaceous sandy conglomerates cemented by sand grains, amount which quartz fragments accounts for about 15%, feldspar fragments account for about 10% and lithic fragments account for about 5%. Through fine core description and sedimentary facies analysis, sedimentary model of calcarenaceous sandy conglomerates of Quantou Formation revealed by SK3 is preliminarily summarized. The flood plain and natural levee are exposed to the surface during the drought. A large number of calcareous concretions are precipitated because of strong evaporation. Calcareous concretions with large granularity are transported and broken in the subsequent flood period. Finally, a set of calcarenaceous sandy conglomerate is developed on the point bar and riverbed. The scale of calcarenaceous sandy conglomerate is affected by length of pre-diagenetic drought period, strength of weathering and denudation, strength of hydrodynamic force in flood period and duration.

The development of calcarenaceous sandy conglomerate in the second and the third member of Quantou Formation in SK3 suggests a new diagenetic model of terrigenous clastic rocks in the Songliao basin. The development of calcarenaceous sandy conglomerate indicates that the climate of the diagenetic stage of the parent rock is dry and hot, with strong evaporation, accompanied by weathering and denudation, which gradually weakens with the deepening of river water depth and the strengthening of hydrodynamic force. The reservoir space of calcarenaceous sandy conglomerate is dominated by intergranular pores, intragranular dissolved pores and fractures, and the measured porosity can reach up to 12.9%. If this kind of reservoirs with large thickness and scale were found in the basin, it would have the potential to form high-quality lithologic reservoirs.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Early Carboniferous volcanic-sedimentary filling pattern in the northeastern margin of Junggar Basin

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Keywords: Carboniferous, volcanic arc, interarc basin, backarc basin, volcanic-sedimentary filling pattern

Carboniferous strata in the northeast margin of Junggar basin are important targets for oil and gas exploration. The detailed volcanic-sedimentary filling pattern is key to the research of source and reservoir relationships and hydrocarbon exploration. Based on outcrops, drilling, seismic and non-seismic data, the Carboniferous basin filling pattern was characterized by lithologic association, sedimentary facies sequences, geochemical and tectonic settings, and proofs of gravity-magnetic-electric-seismic inversion, etc. The northeastern margin of Junggar Basin in the early Carboniferous was a multi-arc and basin system. A NW-SE volcanic island arc belt formed along Luliang-Kelamei area, and isolated aquatic volcanic arcs formed in Sangequan and Shiyingtan, respectively. Interarc basins developed in Shixi, Shibei, and Dishuiquan. Lapilli and lava were dominating in beaded volcanic edifices. Pyroclastic and fan-delta terrigenous coarse clasts were deposited in the proximal island arc region. Deep water fine grained argillaceous material precipitated in the distal island arc region. The configurations of source rocks with volcanic rocks are overlapping or inter-finger in vertical, and centered to volcanic rock as a ring in plane view. Wulungu area was a backarc basin where accepted sediments from northern Altay ancient land and southern Luliang-Kelamaili island arc. Influenced by the two side sedimentary provenances, the sedimentary filling within the Wulungu area is stripped from the north Zhaheba-Chakurt district, the center Well Wucan1 district, to the south Well Zhunbei 1- Quan 1 district. Fan delta coarse clastic deposits were developed in the north under the control of the northern terrigenous sedimentary provenance. Tuffaceous mudstone, mudstone, intercalated tuff and volcanic rock were developed in the center in the backarc deep-water environment under the co-influence of dual provenances. Volcanic rocks and tuffaceous sandstone mixed with tuffaceous mudstone deposits were developed in the south in the shallow backarc environment influenced obviously by volcanism. The deep water areas of interarc and backarc basins are favorable for source rock development. Volcanic lapilli and lava in the island arc area are favorable for reservoir development. Pyroclastic rocks and fan delta tuffaceous sandstone in the flank of the island arc area are favorable for tight reservoir development. Fine grained argillaceous rocks in the deep water area of backarc and inter-arc basins are favorable for shale oil and gas reservoir development. The source-reservoir (trap) configuration styles of overlap and lateral contact under the complex configuration of volcanic-sedimentary rocks in the multi-island arc basin system are attractive hydrocarbon exploration targets.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Oral Preferred

Practice And Enlightenment Of Efficient Development In Complex Oilfield Under The Influence Of Igneous Rock

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Keywords: Igneous rock, Evolution of igneous rock, Spatio-temporal coupling relationship, Lateral plugging mode, tap potential of oilfield

Bozhong 34-9 oilfield is located in the southern part of Bohai Sea and the regional structure is in the Huanghekou sag in the southeast of Bohai Bay Basin. This area is rich in oil and gas resources, relatively active oil and gas migration, which is a favorable zone in Bohai Bay Basin, more importantly, it's the first Cenozoic sandstone reservoir which is most affected by igneous rock discovered in Bohai Sea during these years. It is worth noting that this kind of oilfield is put into development for the first time in China, so the practical experience of oilfield exploration and development is quite important. The main oil-bearing strata (Paleogene) of the oilfield is affected by multi-period superimposed volcanic eruption, the spatial distribution of reservoir is quite complicated. At the same time, as the igneous rocks interpenetrate and cut reservoir, the understanding of the evolution law of igneous rocks and the spatial configuration relationship between igneous rocks and sandstone are still vague, they seriously restrict the implementation of development Wells. This paper makes full use of the core, the micro chip, drilling and logging information, also 3D seismic forward modeling data, detailed analysis the characteristics of basalt, diabase, andesite and tuff, summarise the identification templates of various igneous rocks in the aspects of pattern characteristics, drilling characteristics, lithologic assemblage and seismic response characteristics, discuss the temporal and spatial evolution law of igneous facies, at the same time, the lateral sealing mode of igneous rock, the matching relationship between igneous rock and sandstone and the oil and gas potential area are explored. Under the influence of volcanism, the longitudinal alternating superposition degree of igneous rocks in the formation of E3d1 and E3d2 is much greater than that in E3d3 and Shahejie Formation in Cenozoic, it mainly develops Volcanic channel facies, intrusive facies and overflow facies igneous rocks. Based on the identification of various igneous facies, combined with actual drilling data and well-seismic matching relationship, Bozhong 34-9 oilfield is dominated by igneous rock/sandstone matching relationship of volcanic channel lateral occlusion and intrusion lateral occlusion, also the spatial and temporal distribution relationships of three kinds such as multi-rock facies, namely, lateral plugging of rock wall, lateral plugging of layered igneous rock mass and lateral not plugging of layered igneous rock mass are clarified. On the basis of abundant data, volcanic channel facies or intrusive facies with quite well matching relationship with target layer can be regarded as better hydrocarbon potential areas. It can effectively guides the development plan of oilfield and provides sufficient geological basis for the implementation of development Wells and rolling tapping potential of the oilfield. During two years of development and adjustment, a total of 78 development Wells including evaluation Wells were drilled, alse 4 wells drilling more than 100 meters oil reservoir, which successfully avoiding the risk of igneous rock drilling and achieving good implementation effect, more importantly, it provides a good reference for the exploration and development of Bohai Sea or similar oil fields at home and abroad.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Research on Sedimentary, geochemical characteristics and isotope tracer study of Permian transitional shale in the Lower Yangtze region, China

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Keywords: marine-continental transitional facies, shale gas accumulation, Permian, Lower Yangtze region

ABSTRACT: Starting from the major needs of the investigation of shale gas resources in China, this paper studies the sedimentary of marine-continental transitional facies shale layers, the geochemical characteristics of reservoirs, the evolution of process and preservation conditions of shale gas in this area. In order to study the sedimentary characteristics and reservoir geochemical characteristics of shale gas in this area, this paper obtained the data of reservoir organic and petrographic characteristics, experimental test analysis and regional data comparison. Combined with the actual drilling data of wells JY1, WJD1 and WJD2, the geochemical tracer method, the comprehensive analysis of the formation and preservation conditions of shale gas in this area finally completed. The results show that marine-continental transitional facies shale in the Lower Yangtze region have higher in the southeast and thin in the northwest. The organic carbon content of shale is 0.37-2.90%, the kerogen is mainly type II and type III, and the shale organic matter maturity has entered the dry gas generation stage, and the degree of thermal evolution is in a higher mature stage, which was distributed in the range of 0.55~2.66%. Drilling revealed that the area has good shale gas accumulation, which shows the shale gas enrichment mode under syncline controlled reservoir, stable structure conditions is beneficial for the preservation of shale gas. Considering the shale of the Permian transitional facies in the Lower Yangtze region are often interlayered with coaltight sandstone and limestone, it is indicated that shale gascoalbed methane and tight sandstone gas could be developed in a collective manner, so as to become a favorable area for increasing shale gas reserves and production in China.

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Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Oral Preferred

Late Permian volcano-sedimentary succession description and basin filling characteristics in Sichuan Basin

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Keywords: Sichuan Basin,Late Permian,Mantle plume,Volcano-sedimentary succession description,Basin filling characteristics

As a product of mantle plume activity, Permian Emeishan Large igneous province is widely distributed in Sichuan Basin. Compared with the extensive research on volcanic rocks around the world, the research on volcanic rocks in Sichuan Basin is still in its infancy. Previous studies have shown that uplifting mantle plumes can usually cause large-scale crustal uplift and the formation of dome-like uplift features, and control regional paleogeographic pattern and sedimentary facies distribution. The surface uplift caused by mantle plume uplift, differential denudation of existing sediments, changes of sedimentary facies and lithofacies paleogeography must profoundly affect the paleogeomorphology and eruption mechanism of volcanic rocks in Permian Emeishan Large igneous province before eruption. This study constrains the temporal sequence of different regions and types of volcanic rocks in the Permian Emeishan Large Igneous Province, combines the spatial distribution patterns of different types of volcanic rocks, paleogeomorphology and eruption environment before eruption, reduction of volcanic eruption to build process, established above the cycle and lower cycle of 2 major eruption cycle of 4 stages of the volcano-sedimentary succession description, The filling characteristics of Permian basin in Sichuan Basin are also discussed.

The Permian volcanoes in Sichuan Basin underwent four stages and two major eruption cycles. From bottom to top, the mantle plume in stage 1 began to rise, and the tectonic pattern of uplift and depression was formed by the geofissure movement. The uplift area suffered weathering and denudation, and the deep-water area and depression area were covered by sea water. Stage 2 early intense volcanic eruption and overflow interaction, the formation of underwater pillow lava and pyroclastic rock interbedded or underwater pyroclastic rock. In the late stage of stage 2, massive quiet overflow was carried out to build a huge thickness of basalt. The early stage 3 was characterized by localized ephemeral submerged volcanic eruptions in Jianyang and other areas; Stage 3 late locally onshore neutral volcanic debris accumulation with minor basalt development. Stage 4 tuffs are widespread, continuously exposed to dissolution, forming weathering crusts and laying the material basis for the formation of volcanic reservoirs.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

The transition mechanism of continental rifting to seafloor spreading: Insights from the SW South China Sea

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Keywords: South-western South China Sea,Detachment fault,Continental rifting,Breakup,Seafloor spreading

The South China Sea (SCS) is the largest marginal sea in the western Pacific region that is surrounded by three major tectonic plates, namely the Pacific, Eurasian, and Indian-Australian plates. The margins of the SCS are wide and rifting affected a hot and weak post-orogenic crust during a relatively short syn-rift interval in comparison with the Atlantic-type margins. Based on detailed observations of high-quality reflection seismic and wells data, we describe and interpret the characteristic structures of the SW-South China Sea Ocean Continent Transition (OCT) and their relationship with overlying syn rifting to syn breakup phase sediments and magma. Using the seismic lines imaging the complete sedimentary and magmatic architecture of conjugate rifted margin, we: (1) provide a detailed description of the crustal architecture; (2) define extensional rifting margin domains; (3) determine the tectono-stratigraphic-magmatic evolution linked to rifting and breakup. We discuss the link between the kinematic evolution and the sedimentary and magmatic record and illustrate it in a Wheeler Diagram. Relying on the identification and characterization of distinct stratal patterns and crustal architectures, we show that the OCT displays a transition from fault dominated rifting to magma dominated seafloor spreading. On its continent-ward side, the OCT is made of hybrid crust where tectonic thinning of continental crust is compensated by syn-extensional magmatic thickening; oceanward, the hybrid crust evolves into a fully magmatic. This study differs from previous interpretations of correlative surfaces in the distinction between: (1) different types of top basement and (2) syn-and post-tectonic packages within the syn-rift record. This study propose new interpretations of the tectono-stratigraphic-magmatic evolution and kinematic restoration of the breakup phase of the SW South China Sea.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Oral Preferred

Permeability-porosity relationship and the impacts of heterogeneous pore-structures of volcanic rocks affecting fluid-flow

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Keywords: Permeability-porosity relationship, volcanic rocks, fluid-flow, pore-structures

In this paper, we investigate the relationship between permeability and porosity of 787 rock samples from the Yingcheng formation, aiming to understand factors controlling the migration and accumulation of hydrocarbons in volcanic rocks.

We use information from a range of techniques, including analysis of thin section and mercury injection capillary pressure (MIP) tests to characterize the pore structure of these volcanic rocks. Our research shows a counterintuitive result that under 2500 m depth in Songliao Basin, coherent volcanic rock, e.g., lava and welded pyroclastic rocks, present higher porosity and permeability than volcaniclastic rocks e.g. unwelded pyroclastic rocks, volcanic epiclastic rocks, volcanic breccia. For coherent volcanic rock, we find fractures are the key factors providing permeability, while porosity is mainly provided by complicated combination of primary (vesicles) and secondary (dissolution and devitrification) pores in coherent matrix.

The permeability porosity relation of coherent volcanic rock is mutually controlled by fractures and coherent matrix pore system. The entry pressure of coherent volcanic rock is mainly controlled by fractures. For volcaniclastic rocks, porosity and permeability is mainly provided by intergranular pore network. Permeability porosity relation is mainly controlled by grain size of volcaniclastic rocks. Large grain size (>2 mm) volcaniclastic rocks provide better reservoir quality than small grain size volcaniclastic rocks.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Oral Preferred

Analysis of spatial distribution of volcanic rocks in fault depression based on the characteristics of pathway and magma chamber: taking Cretaceous Yingcheng Formation of Changling fault depression in Songliao Basin as a case study

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Keywords: Volcanic rocks, spatial distribution, controlling factors, Cretaceous Yingchen Formation, Songliao Basin

Volcanic rock is an important part of the filling in faulted depression. Volcanic rocks provide important clues for studying the genesis, age and evolution of basins. It is also an important target for oil and gas exploration in the deep part of basin. There have been extensive studies about petrology, chronology, filling sequence and reservoir geology of the volcanic rocks in the basin. It is recognized that volcanic rocks are unevenly distributed in faulted basins. But the reason of the uneven distribution is not clear. The distribution of volcanic rocks in the fault depression is unevenly. In the study of the distribution of volcanic rocks in the basin, the deep structure has not attracted enough attention. To further understanding the spatial distribution of volcanic rocks in faulted depression, the relationships between volcanic rocks and faults, volcanic rocks and deep structure characteristics are analyzed by using drilling data, seismic data, and existing research results of electrical structure for magma chamber interpretation. The followings are the results. In totally, the volcanic rocks divisions are along north-south ward. Then they are divided into blocks along the north-south ward. The central belt of faulted depression accumulates the most volcanic rocks. Horizontal throw of fault is more sensitive for volcanic rock existing, and the vertical throw of fault is more sensitive for volcanic rock thickness. The fault is only a necessary condition for the volcanic rocks existing, not a sufficient one. The distribution of volcanic rocks is also constrained by the magma chamber that can be characterized by the electrical data. The uplift of asthenosphere is the necessary condition. So, the spatial distribution of volcanic rocks can be inferred by the uplift of asthenosphere and the thinning region of extension crust. The filling of volcanic rocks in faulted depression usually corresponds to the subsidence and sedimentary centers. It can form good source-reservoir association with fine-grained rocks when the volume of volcanic rocks is small, and it can also reduce the proportion of fine-grained sedimentary rocks when the volume of volcanic rocks is large. So, the volcanic rock in the faulted depression is a double-edged sword for the oil and gas reservoirs.

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Session T2-2: Interactions between basement, volcanism, and sedimentary cover
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Middle Permian seamount sequences within the central Yarlung Zangbo suture zone: Implications for the opening of the eastern Neo-Tethys Ocean

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Keywords: Neo-Tethys Ocean, Yarlung Zangbo suture zone, Middle Permian (Guadalupian) seamount, Early Permian (Cisuralian) opening of the Neo-Tethys Ocean

The opening of the Neo-Tethys Ocean is an important geological event in the paleoceanographic and paleotectonic evolution through the Phanerozoic. However, when the Neo-Tethys Ocean began to open has been dispute due to the scarcity of contemporary oceanic crust and sedimentary records. This work presents multiple sequences of basaltic rocks + sedimentary covers of the Middle Permian (Guadalupian) preserved in the central Yarlung Zangbo suture zone, to provide an insight for the initiation of the Neo-Tethys Ocean. We conducted field investigation, lithological observation, and geochronological and geochemical analyses for a bundle of basalt + carbonate assemblages in north of Lang Co (Buma of Ngamring county), southwestern Tibet, China. Mapping and stratigraphic sections show multiple sequences of basement rocks upwards to sedimentary covers. Petrography and lithofacies indicate basement rocks are chiefly eruptional basalts and sedimentary covers are dominantly thick carbonate rocks with a few siliceous and calcareous mudrocks that deposited in the pelagic environment. Geochemical data demonstrate that the basalts are tholeiite series, closely identified as the OIB-type, very similar to Hawaiian oceanic island basalt. We have recognized at least eight sets of seamount sequences and four types of seamounts, in which part of seamounts have experienced a stage of island caused by the sea level falling. According to the stratigraphic texture and OIB-type basalts, we propose that sequences of the basalt basement + carbonate cover are probably relicts of seamounts, indicating the Middle Permian oceanic crust record of the eastern Neo-Tethys Ocean and implying an incipient opening already took place in the Early Permian (Cisuralian).

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Oral Preferred

U-Pb isotope geochronology and geochemistry of granites in Songnan low uplift, Qiongdongnan BasinConstraints on Mesozoic tectonic evolution of the South China Sea

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Keywords: South China Sea, Songnan low uplift, Mesozoic, Zircon U-Pb ages, Geochemistry, Tectonic evolution

The South China SeaSCSwas located in the transitional zone between the Paleo-Tethys ocean and the Paleo-Pacific ocean during the Mesozoic. There is no convincing conclusion on the transformation process of its tectonic regime yet. In this study, we take granites from deep water area of the Songnan low uplift in Qiongdongnan Basin as objects, and reconstruct the Mesozoic tectonic evolution of the SCS based on chronological and geochemical data. The granites in Y8-1 district of Songnan low uplift are high-K calc-alkaline series, with A/CNK values ranging from 0.97 to 1.18. The rocks are featured by distinctive enrichment in the RbUKPb depletion in BaPTiNbfractionated REEs (LREE / HREE = 3.03~9.02) , and moderate to weak negative Eu anomalies (0.30~0.71). They are highly differentiated S-type granites related to syncollision. Taking into account the zircon U-Pb age of 239.7±3.1Ma, the granites are the products of the collision between the Indosinian and South China blocks during middle Triassic. The granites in Y8-3 district of Songnan low uplift are high-K calc-alkaline series, with A/CNK ranging from 1.06 to 1.40. The rocks show distinctive enrichment in the RbKPbdepletion in NbTiP fractionated REEs (LREE / HREE = 4.98~10.58), and moderate to weak negative Eu anomalies ((0.48~0.74). They belong to the highly differentiated granites with arc affinity. Taking into account the zircon U-Pb age of 220.2±2.0Ma, the granites are related to the westward subduction of the ancient Pacific Ocean in late Triassic. Combined with the works of predecessors around the SCS, we establish the Mesozoic tectonic evolution model of the SCS region : (a) Late Permian~Early Triassic (272-247.2Ma), the branch of the Paleo-Tethys ocean northward subducted to the South China block. (b) Middle Triassic (247.2-237Ma), the branch of the Paleo-Tethys ocean closed, and the Indosinian collided with the South China block. (c) Late Triassic~early Late Cretaceous (237Ma-90Ma), the Paleo-Pacific subducted westward beneath the Indosinian-south China blocks, and the Andean-type continental arc developed.

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Session T2-2: Interactions between basement, volcanism, and sedimentary cover
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Characteristics and Main Controlling Factors of Bedrock Buried Hill Natural Gas Reservoir in Central Paleouplift Belt in Northern Songliao Basin

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Keywords: northern Songliao Basin,central paleouplift zone,bedrock buried hill,dual porosity gas reservoir,weathering crust, transportation system

The bedrock buried hill in central paleouplift belt in Northern Songliao basin is an important target for deep natural gas exploration in Daqing Oilfield. Although gas reservoirs have been found in many bulges, the degree of exploration is low with unclear gas reservoir characteristics ,vague main controlling factors and uncertain exploration direction. Based on data related core, experiment, well logging, high-precision three-dimensional seismic and gas production test, the characteristics of bedrock buried hill gas reservoir and the main controlling factors of reservoir are studied. The results show that the type of bedrock buried hill gas reservoir in central paleouplift belt is pore fracture dual porous medium gas reservoir. Its formation is mainly controlled by the following factors:The paleotectonic background that has been developing during the reservoir formation period is a favorable target area for natural gas to accumulae; Wih the influence of tectonism, weathering,leaching and dominant lithology, the netted pore fracture weathering crust reservoir with good connectivity is formed on the top of the bedrock buried hill; The natural gas generated by high-quality source rocks during the fault depression period around the buried hillmigrated and accumulated along the “ternary” lateral transportation system composed of faults, fractures and unconformity;The stable regional mudstone caprock of Denglouku formation formed during the period transformed from fault depression to sag provides sealing conditions. On this basis, the favorable zones determined by comprehensive research guided the exploration discovery of bedrock buried hill in the central paleouplift belt in northern Songliao basin, which will provide theoretical guidance and exploration case reference for bedrock buried hill exploration.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Differential evolution process and dynamic mechanism of Cenozoic prototype basins in the southwest margin of South China Sea

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Keywords: Prototype basin, Differential evolution, Tectonic-stratigraphic framework, Tectonic event, South China Sea

The southwestern margin of the South China Sea (SCS) is located at the tectonic junction region of continental blocks collision and subduction leading edge zones. By using recently collected 2D seismic profiles, drilling wells and outcrop data from onland Borneo to offshore Zengmu and Beikang basins, we identify three tectonic key interfaces in the Cenozoic basins, namely the basement unconformity (T_{100}, ca. 65Ma), Sarawak Orogeny (T_{80}, ca. 38Ma) and Sabah Orogeny (T_{50}, ca. 16Ma). On this basis, the Cenozoic tectonic-stratigraphic framework and prototype basins are determined. The result shows that the West Baram line (WBL) is not only an important basement fault boundary separating Zengmu basin and Beikang basin, but also an important dynamic deformation boundary in Cenozoic. The Beikang basin in the northeast of WBL has developed two prototype basins of rifting basin (T_{100}-T_{50}) and depression (T_{50} to present), while the Zengmu basin in the southwest has experienced the superposition evolution from rifting basin (T_{100}-T_{80}), foreland basin (T_{80}-T_{50}) to passive margin basin (T_{50} to present). Consequently, the formation and evolution of Zengmu and Beikang basins show remarkable differences. We proposed the dynamic mechanism of differential evolution for the prototype basin in the southwestern margin of SCS, through the tectonic movement events of the surrounding plates/blocks, combing with the results of basin tectonic-stratigraphic interpretation, prototype basin analysis, subsidence history and depth-dependent lithosphere stretching modelling. During the Late Cretaceous to Early Cenozoic, slab roll-back of the subducted paleo-Pacific plate contributed to the developing of continental rifting in the early stage. While the Late Eocene Sarawak Orogeny led to the collision between the Zengmu continental block and Borneo, on which a peripheral foreland basin was formed. Afterwards, the subduction of the Proto-SCS oceanic crust migrated to the east of the WBL and triggered the sustaining extension rifting of Beikang basin until the Sabah Orogeny. Since the Middle Miocene, Zengmu basin and Beikang basin have entered the evolution stage of passive continental margin basin and peripheral foreland basin respectively.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Reservoir characteristics and controlling factors of deep sedimentary pyroclastic rocks in the basin——a case study of Yingtai fault depression, southern Songliao Basin

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Keywords: Deep basin, Volcaniclastic sedimentary rocks, Reservoir controlling factors, Anomalously high porosity and high permeability zone, Clastic composition,

The reservoir characteristics and controlling factors of deep sedimentary pyroclastic rocks in basins have always been the focus of petroleum exploration research. Based on core, thin section, SEM, logging and reservoir physical properties, the reservoir controlling factors of volcaniclastic sedimentary rocks in deep basin is carried out on the relationship between reservoir and characteristics, sedimentary microfacies and diagenesis, so as to analyze the contributing factor of anomalously high porosity and high permeability zone. The physical property of the volcaniclastic sedimentary rocks in deep basin is gradually decreased with the increase of the buried depth, and there are several anomalously high porosity and high permeability zones were developed. The lithology characteristics and diagenesis of the volcaniclastic sedimentary rocks are closely related to the formation of the reservoir. The reservoir's physical properties of volcaniclastic sedimentary rocks with large volcanic clastic particles is better than that with small clastic particles, and volcaniclastic sedimentary rocks with unstable clastic particles (feldspar, debris) are more easy to form the high quality reservoir than the rocks with high quartz content. The dissolution is the most important and direct reason for the formation of the anomalously high porosity and high permeability zone of the volcaniclastic sedimentary rocks in the deep basin. It is shows that the size and composition of the clastic particles in the volcaniclastic sedimentary rocks are the internal controlling factors of the effective reservoir, while the diagenetic fluid and the burial process are the external controlling factors for the formation of the effective reservoir.

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Session T2-2: Interactions between basement, volcanism, and sedimentary cover
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The Easternward migration of the Early Cretaceus volcanic-rifting system in Northeast China

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Keywords: Mesozoic, extension, subduction, lacustrine, basin

The convergence between the paleo-pacific plate (Izanagi and Kula plates) and the Eurasian continent caused the complicated subduction and strike-slip tectonics in Northeast China from the Middle Jurassic to the end of the Cretaceous. The tectonic convergences acted in multiple directions during the Jurassic in eastern Asian, and then broadly and intensely extension and rifting during the Early Cretaceous. This transition of the tectonic system that occurred around the Jurassic/Cretaceous boundary is also equivalent to the second orogenic episode (episode B) of the Yanshanian Movement. During the Early cretaceous, exactly from 137 Ma to 131 Ma, along the tectonic line of Nenjiang - Balihan Fault and Kalaqin Metamorphic Core Complex (NBF-KMCC), the area of western side relative decline, and a series of volcano-graben basins formed in northern Hebei, the Greater Khingan Mountains and Arguna to Chita of eastern Russia, with lacustrine strata yielding the early fossil assemblage of the Jehol biota; at the same time, the Western Liaoning - Songliao area is a relatively uplifted broad tectonic plateau, which is subjected to denudation. During the period from 130 Ma to 110 Ma, the volcanic-rifting system extended to most parts of northeast Asia, and the volcanic basins formed on the eastern side of NBF-KMCC, with the middle and late assemblages of the Jehol biota spread around. The basin history and biogeographic evolution indicated that the Early Cretaceus volcanic-rifting system had migrated easternward in Northeast China, and this should be induced by the subduction of the paleo-pacific plates.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
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Sedimentary characteristics of the Early Cretaceous volcanic intermittent period in the Songliao Basin, data from the Shahezi Formation of ICDP borehole SK2

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Keywords: Early Cretaceous, Songliao Basin, Sedimentary characteristics, Shahezi Formation, ICDP borehole SK2

The Shahezi Formation in the Songliao Basin is a sedimentary cycle between two volcanic cycles, Yingcheng Formation and Huoshiling Formation[1]. It is significant for research on initial basin history restoration, global continental–marine stratigraphic correlation, climate during the age of dinosaurs[2]. As the first set of sedimentary sequence in the basin[3], it has irreplaceable research significance.

In our research, 6 categories and 12 kinds of lithology were identified from the Shahezi Formation, mainly sedimentary rocks, in accordance with the thickness ratio from high to low are mudstone, grit stones, siltstone, conglomerate, fine sandstone, medium sandstone and lithology containing volcano material, including tuffaceous sandstone, sedimentary breccia tuff, tuffaceous siltstone,sedimentary tuff, tuff and tuffaceous mudstone.

In the Shahezi Formation period, sedimentary process is dominant, sedimentary rocks of fan delta facies are developed, with 3 subfacies: fan delta plain, fan delta front, profane delta, 6 microfacies: braided channel, subaqueous distributary channel, inter subaqueous distributary channel, subaqueous mouth bar, sand sheet, mudstone of still water, showing a fining-upwards sequence.

According to the lithology combination, the Shahezi Formation was divided into 6 cycles which all of them are fining-upwards sequence. However, according to the sediment granularity, the particle size of cycle I with conglomerate mainly developed is maximum, that of cycle III with pebbly grit stone widely developed is second, and that of cycle VI with mudstone and silty mudstone mainly developed is minimum.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
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Segmentation and Linkage of a Basin Boundary Fault System: Insights from the Early Paleocene Evolution of the Lishui Sag, East China Sea Shelf Basin

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Keywords: Fault segmentation and linkage, Syn-rift sedimentation, Lingfeng fault; Lishui Sag, East China Sea Shelf Basin

The Lishuui Sag located on the southwest margin of the East China Sea Shelf Basin, which is a typical back-arc rift basin, is considered to be a one of the most prospecting oil and gas exploration zones. Fault superposition and linkage exert a significant influence on basin evolutionary history. A detailed stratigraphic and structural analysis of the three-dimensional (3-D) seismic survey on the Lishui Sag with throw backstripping and time thickness maps has illustrated the segmentation and linkage of the boundary Lingfeng Fault. We report that the fault system consisted of at least 7 segments, which were ca. 20–40 km long, during the initial 4.5 My of early Paleocene rifting(E1y). Throw backstripping indicates that fault segments were hard-linked or soft-linked during the succeeding 3.3My of syn-rift stage(E1l), and finally formed a single 180 km long fault zone during the last 1.2My of post-rift stage(E1y). Fault linkage has resulted in an obvious redistribution of displacement, with the locus of faulting initially locating on the center of each paleo-segment during the E1y, then being shifted from the south segments to the north segments during the E1l, and finally reached to the center of the through going fault during the E1y. The most redistribution occurred during the E1l, the main fault activities transferred from the south fault segments to the north fault segments. The average growth rate of the south faults segments was 450ms/My which was approximately 1.5 times of that of the north faults segments during the lower E1l(60.5Ma-60Ma), however the average growth rate of the north faults segments was 320ms/My which was approximately 1.6 times of that of the south faults segments during the upper E1l(60Ma-57.2Ma). The incised valleys crossing faults provide additional information on the geomorphological responses to fault growth. Early isolated fault growth is proved by the occurrence of major valley incisions at the fault linkage zones outlining the extent of the individual fault segments during the initiation of rifting. And the deterioration of the scale and amount of incised valleys of the south sections of the Lishui seg illustrated the weakness of fault growth in the south fault segments and the strengthening of that in the north fault segments during the late stage of syn-rift (upper E1l). The results identified that fault linkage exerted considerable control on sedimentation and evolution of the basin. This study demonstrates the importance of integrating stratigraphic and structural observations to reconstruct the temporal and spatial evolution of normal fault zones in the Lishui sag, as well as rift basins development in eastern China and similar areas throughout the world.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Quantitative analysis of structural evolution difference between East and West in Wushi Sag

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Keywords: Wushi sag,Differential evolution, Tectonic-stratigraphic framework, Tectonic event

Taking the Wushi Sag in Beibu Gulf Basin as the research object, four representative sections controlling the formation of the sag are selected from west to East. Use 2D move software to restore the equilibrium profile of the four profiles, and calculate the extension amount, extension rate and extension rate of each profile in different stages; EBM is used to calculate the fault subsidence activities of the East and West depressions. On this basis, the structural evolution process of Wushi sag and its east-west regional differences are quantitatively studied from the horizontal and vertical directions. The research shows that there are differences in time and space and intensity in the structural evolution of East-West sag: in the early stage of t100-83 sag, the overall activity of the early stage of West Sag is weak, but there are also sections with strong local activity. The overall activity of east sag is strong, and its extensional activity and subsidence activity reach the peak period of activity. After T80, the activity of dongwa tends to weaken, and the activity of Xiwa begins to strengthen gradually. T80-60 stage is the main stage of Xiwa activity, and the extensional activity and subsidence activity reach their peak at this stage. It shows the characteristics of early in the West and late in the East. In terms of tectonic activity intensity, the extensional activity of the west depression is stronger than that of the East depression, but the early subsidence activity of the East depression is stronger than that of the west depression, and the subsidence rate decreases gradually after T80. After T80 enters the peak period of dongwa activity, the extension rate and settlement rate of dongwa are stronger than those of Xiwa.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Influence of Eocene Regional Tectonic Stress Field Change on Beibu Gulf Basin Structure

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Keywords: strike-slip fault,Tectonic-stratigraphic framework,South China Sea

Clarifying the basin structure is an important part of the basin tectonic research, and it is an important precondition for further detailed research on the basin as well. Before and after the formation of the T_{83} structural interface, the structural style and fault distribution of the Beibu Gulf Basin were significantly different, and the subsidence center also moved from the edge of the basin to the center. The main reason for this series of changes is the subduction of the Pacific plate to the Eurasian plate before and after 40.4Ma, resulting in a clockwise rotation of the stress field in the Beibu Gulf Basin. Under the influence of this regional tectonic movement, the stress in the Beibu Gulf Basin was The original single tensile stress was transformed into the superposition of two stresses, and a series of right strike-slip faults began to develop in the basin. At the same time, the activity of the sag-controlling faults weakened, then the subsidence center began to migrate to the center of the sag. During the same period, the lakes in the basin shrunk greatly. The change of the depositional environment and the change of the stress field resulted in the formation of the T_{83} interface. Above this interface, strike-slip structure was superimposed on the original simple half-graben structure. T_{83} interface marks the transition of the basin structure, and also marks the transition of the basin from the rift episode II to the rift episode III.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Volcano - Sedimentary Stratigraphic Sequence and Tectonic Significance of Laiyang Group in Taolin Area, Ri-Qing-Wei Basin

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Keywords: volcanic-sedimentary squence, basalt, siliceous rocks, volcanism, Ri-Qing-Wei basin, Laiyang Group

Ri-Qing-Wei basin is a late Mesozoic rift basin in the central Sulu orogenic belt, which developed at the junction of North China plate and Yangtze craton. Taolin area is located in the southwestern margin of the basin, and the filling sequence is developed from sedimentary strata (Laiyang Group) to volcanic strata (Qingshan Group). The strata of Laiyang Group is divided into three sections from bottom to top: the bottom of the lower section consists of glutenite, the sandstone with interbedded gray siltstone and black siliceous rock, showing the characteristics of deep-water turbidite channel microfacies. The middle section is thick grey-white,grey siltstone interbedded with black siliceous shale, and several layers of mudstone. The upper section transits from the turbiditic siltstone-mudstone interbeds to siltstone and sandstone, indicating a incised valley developed in this period. Moreover, a layer of basalt developed at the top of the stratum. The overlying layer is the white rhyolite of Qingshan Group. The sedimentary facies evolved from alluvial fan -fan delta facies-subaqueous fan facies-turbidite fan facies-fan delta facies-volcanic effusive facies. The basin filling sequence shows the characteristics of transgression-regression, indicating that the evolution of the basin in Laiyang period experienced a rift basin evolution process of rifting-subsidence-closure. The siliceous rocks widely developed in Laiyang Group have the characteristics of mixed deposition of hot water and terrigenous clastic rocks, indicate deep magmatic activity. The rapid deposition of the massive thick sandstone of the middle section may be the response in shallow lithosphere tothe lithosphere thinning event caused by the delamination. The basalt in the top section owes the geochemical features of low SiO_2 (46.86 % -48.11 %), high ALK content (4.50 % -4.94 %) and high Mg# (75-87), indicating that it is high calc-alkaline series basalt. The trace elements enriched inthe large ion lithophile elements (Ba , K , Pb) and light rare earth elements, while depleted inof the high field strength elements (Ta and Nb) and heavy rare earth elements. The ratio of Th/Yb(average value of 2.90) and the tectonic environment discrimination diagrams (Y-Zr , Th / Ta-La / Yb) show that the geochemical characteristics of this basalt is similar to the arc volcanic rocks, which are related to the subduction of the oceanic plate, indicating that Ri-Qing-Wei Basin evlolved from rift basin into volcanic arc basin in the late Laiyang period. Above all, the evolution process of Ri-Qing-Wei Basin was co-affected by the delamination of lithospheric root and the subduction of thePaleo-Pacific plate (Zhou et al., 2022). The influence of the magmatic activities on the sedimentary rocks in shallow lithosphere also changed from early indirect participation to late intrusive transformation.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Oral Preferred

Buried hill types and genetic mechanism in Baiyun Sag, Pearl River Mouth Basin, northern margin of the South China Sea

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Keywords: South China Sea, Pearl River Mouth Basin, Type of buried hill, detachment fault, Magmatism,Pre-existing fault

The Pearl River Mouth Basin (PRMB) in the northern continental margin of the South China Sea (SCS) is unique and different from the orderly rifted structure of the typical passive continental margin of the Atlantic type. In terms of lithospheric structure and basin structure, the northern SCS is a continental margin with dual properties of poor magma and rich magma. The PRMB was formed and evolved under the background of plate subduction. Affected by the late extension and detachment, magma underplating coupling and strike-slip transformation, the basin structure and buried hill types are diverse.

In this study, based on the interpretation of large-scale contiguous high-resolution 3D seismic reflection volume in the Baiyun Sag, the sag tectonic system and evolution stages are studied. Considering the genetic mechanism and evolution of buried hills, it is divided into three categories: primary type, intermittent transformation type and continuous transformation type, with a total of 15 sub-categories. It is found that detachment, basement pre-existing structure, multi-stage magmatism and late strike slip faults play an important role in controlling and transforming the buried hills.

The geometric and kinematic characteristics of the detachment fault in the eastern Baiyun Sag are revealed for the first time, and the strong amplitude continuous S-reflection structure of the detachment fault is displayed through 3D imaging. The imaging results show that surface has a corrugated structure, which is the sliding track of the overlying block, and the detachment can transform the buried hill reservoir. In addition, the fluctuation of the fault plane was observed along the fault strike, forming a special type of buried hill formed by the detachment of the fault ridge.

Pre-existing structures, especially Pre-Cenozoic faults, have a controlling effect on the formation of buried hills. The influence of preexisting fault activation on the formation and evolution of buried hills is mainly reflected in two aspects. One is the activation of preexisting faults to form low-angle normal faults, which control the types of relay high and clamping block on the detachment fault. The other is differential subsidence caused by multi-phase fault activation, forming horst-type buried hills. The multi-stage activity of fault reversal can form fractured reservoirs of granite on both sides of the fault zone.

Previous studies have found that there are 3 to 4 stages of magmatism in the Baiyun Sag, and multi-stage magmatism forms a new type of volcanic cone. It also has a transformation effect on early buried hills. In addition to causing the early buried hill to be arched again, it will also cause the fault block to rotate and denudate, and even metamorphic core complexes will appear. Multi-stage magmatism enriches the types and evolution of buried hills. For granite buried-hill reservoirs with insufficient exposure weathering and leaching, the extrusion deformation, heat transfer and hydrothermal action caused by magma arching have a transformative effect on buried-hill granite reservoirs.

This study enriches the types of buried hills in extensional fault-depression basins, and provides a basis for the prediction of favorable buried hill areas in deep-water exploration.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Lithology Identification of Volcanic Lava Based on K-means Clustering Algorithm Optimized by Simulated Annealing

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Keywords: Lithologic identification,Optimized K-Means,Simulated annealing algorithm, Volcanic lava,Songliao Basin

Lithologic identification is the basis of volcanic reservoir research, which is affected by diagenetic environment and heterogeneity, logging curve is crossed obviously, the distribution between data sets is uneven, so the commonly used methods of lithologic identification such as K-Means clustering are not precise. This paper proposes an improved method: optimize K-Means clustering by simulated annealing, in view of the fact that K-Means clustering depends on the initial clustering center to easily produce local optimal solutions and simulated annealing has the characteristics of global search. The method is used to train and study 430 groups of logging data (core and rock ore identification data are complete) in Songliao Basin, and the actual logging data of a well in the study area are compared with the traditional K-Means clustering. The results show that the traditional K-Means algorithm has a recognition rate of 70.00%, while the optimized K-Means algorithm has a high lithologic recognition rate of 93.94% and It is significantly higher than the traditional K-means algorithm. In this paper, this method is innovatively applied to the lithology identification of volcanic lava, and the recognition effect is good. It can be used as a new volcanic lithology discrimination method.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

The Mesozoic and Cenozoic Structural Characteristics and Genesis of the Gissar foreland thrust belt, in the Eastern Amu Darya Basin

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Keywords: Gissar thrust belt, structural characteristics, basal detachment, decollement deformation

The Jurassic subsalt carbonate assemblage in the Gissar thrust belt in the eastern Amu Darya Basin is an important hydrocarbon exploration target. The tectonic origin in this area is unclear and complex, which restricts the discovery of hydrocarbon.By comparing regional seismic profiles and analyzing the basement structure of the Gissar thrust belt, the tectonic evolution and genesis of this area are discussed in this paper, on the basis of the description of the Mesozoic and Cenozoic structure frameworks.

The research results show that Gissar thrust belt can be generally described as detachment of shallow basement from southeast to northwest, and decollement - deformation of gypsum-salt layers in Kimmeridgian-Tithonian. In addition, some deformation characteristics , such as basement detachment, subsalt uplifting, and suprasalt passive decollement and deformation are presented as well.Gissar Mountain to the northwest(west-Joramergen structure) structral belt can be divided into root belt→middle belt→frontal belt→hedging belt→recoil belt. Correspondingly the structural style from southeast to northwest can be divided into basement involvement anticline → basement detachment double faulted anticline → basement detachment imbricate anticline → hedging syncline → basement decollement recoil fault anticline.The area has experienced two main tectonic compression since the Late Jurassic. The first compressions, "Middle Gypsum Movement", occured in Kimmeridgian, Late Jurassic. In this tectonic movement, faults in basement and faults formed by Early-Middle Jurassic extension were reversed due to the early response of Late Cimmerian or Neo Cimmerian in western central Asia. The second compressions which constituted the main Gissar thrust belt occurred in Middle Miocene due to the crustal convergence, crustal thickening and lateral flow deformation in Pamir on the east. In this tectonic movement, Gissar thrust belt undergone 4 progressive deformation stages consisting of basal detachment, subsalt uplifting, suprasalt decollement and deformation and finally formed. The detachment between the deep-shallow basement and the slipping adjustment of gypsum-salt layer of the Kimmeridgian-Tithonian vertically, are the two essential controlling factors of the complex structural deformation and transformation of the Mesozoic and Cenozoic in the Gissar thrust belt.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Oral Preferred

Reservoir Characteristics and formation mechanisms of basement granite from the central uplift of Songliao basin

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Keywords: Buried-hill reservoir, Granite, Basin basement, Songliao Basin

The granite buried-hill hydrocarbon accumulation has been discovered worldwide as an unconventional accumulation in recent years. As one of the most important deep accumulation types, the granite buried-hill accumulation has been found in ocean margin basins and some continental basins, and has shown significant hydrocarbon potential in China.The granite is a major lithological component of the basement of Songliao basin. Understanding the reservoir characteristics and formation mechanism is critical for the basement granite to evaluate its potential as a new exploration field. In order to characterize the reservoir features in multi-scales, granite samples were collected from different well cores of the basement, analyzed by thin section, SEM, zircon U-Pb dating, HPMI, NMR, and Micro CT, etc.

The basement granite of the central uplift had crystalized in the Late Jurassic. The lithology is dominated by monzogranite with less plagiogranite. Affected by dynamic metamorphism, mylonitization and schistization are locally serious. Primary pores in granite are limited. The effective reservoir spaces are dominated by secondary pores, including micro-nano erosional pores in feldspar crystals and micro tectonic fractures. The reservoir potential of granite is closely related to the secondary alternation and the types of feldspar. Weathered crust reservoir is more common than internal massif reservoir of granite. The subtype of weathered crust reservoir is dependent on its tectonic position as well as the weathering processes. Due to severe surface erosion and down-slope migration of weathered loose materials, reservoirs on local tectonic highs are fracture dominating reservoirs. Reservoirs on local depressions are featured by fracture and pore dominating reservoir spaces. Fault activity plays an indispensable role in the formation of an internal massif reservoir. Granites close to faults are prone to generate fractures and secondary erosional pores, thus, improving their reservoir capability and enlarging their reservoir potential.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Oral Preferred

New views of basement and Early Cretaceous strata based on the Continental Scientific Drilling Project-SK2 borehole in Songliao Basin

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Keywords: Songliao Basin, SK2 borehole, Early Cretaceous, Triassicbasement, volcanic-sedimentary strata

The Songliao Basin (SB) is one of the largest non-marine petroliferous basin and contains nearly complete Cretaceous sedimentary records. The International Continental Scientific Drilling Project of the SB includes the SK1 boreholes (south borehole and north borehole) (Wang et al. 2016), SK2 borehole and SK3 borehole. The SK2 borehole is to obtain continuous terrestrial geological records for the study of greenhouse climate change and basin development. The target strata are the Lower Cretaceous Shahezi, Yingcheng formations, and the basement of the SB (Wang et al. 2017). The depth of the SK2 borehole is 7,018 m. The length of the drilling core is 4,134.8 m, with a core recovery rate of 96.61%.

The lithology of basement in SK2 borehole is mainly andesitic volcanic rocks interbedded with sandstone and conglomerate. The isotopic age of andesite is 242.6 ± 1.5Ma, and the youngest peak age of sandstone is 242.2Ma (Yin et al. 2019); Shahezi Formation is mainly composed of lacustrine clastic rocks intercalated with volcanic ash layer. The age of volcanic ash at the bottom is 118.2 ± 1.5Ma (Liu et al., 2021), and the upper is 113.9 ± 0.9Ma (Yu et al. 2020); The lithology of the lower part of Yingcheng Formation is rhyolite, and the upper part is sandy conglomerate. The age of rhyolite is 112.078 ± 0.067Ma (Wang et al., 2022).

Based on the lithostratigraphy and chronostratigraphy research results of SK2 borehole, there are two new views on the basement and overlying sedimentary rocks of SB. (1) Previous studies indicated the absence of Triassic to Lower and Middle Jurassic strata in northeastern China because of uplift and erosion events associated with the return of geo-synclinal folds and orogenic movement during the Late Permian–Early Jurassic. To date, geochronological studies of intrusive and metamorphic rocks in the basement of the SB have also confirmed Carboniferous and Permian ages for the basement in general (Gao et al., 2007; Pei et al., 2007; Wu et al., 2000). Radiometric dating has been carried out for the entire drilling core of the SK2 borehole. As a result, we have discovered Triassic volcanic-sedimentary strata in the basement. These Triassic strata provide new clues for studying the basin origin and development, and a new target for oil and gas exploration in the SB. (2) A large number of zircon U-Pb ages of volcanic rocks from Yingcheng Formation are distributed in two ranges, 102-108 Ma and 110-121 Ma (Chen et al., 2017). We also dated ages in the volcanic ash and rhyolite of Yingcheng Formation in Xushen 22 borehole. The results are 112.2 ± 1.3Ma and 113.9 ± 1.4Ma, which are equivalent to the ages at the bottom of Yingcheng Formation and the upper part of Shahezi Formation in SK2. It indicates that the Shahezi Formation partially overlaps with the Yingcheng Formation, which is a sedimentary rock stratum that did not receive volcanic material accumulation during the volcanic eruption. This new view is of important guiding significance for oil and gas exploration in the fault depression of SB.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Geochemical characteristics of marble in the Ailaoshan Group and its constrain to the nature of crystalline basement in the Ailaoshan metamorphic complex belt, SW China

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Keywords: Ailaoshan metamorphic complex belt, Yangtze Block, crystalline basement, marble, Paleo-Tethys Ocean

The Ailaoshan metamorphic complex belt, located in SW China, is sandwiched between the Amojiang fault and Red River fault on southwestern margin of the Yangtze Block. The nature of crystalline basement in the Ailaoshan metamorphic complex has been controversial for a long time[1-3]. The Ailaoshan Group in the metamorphic complex belt considered as Neoproterozoic in age contains biotite hornblende gneiss, amphibole plagiogneiss, granite gneiss, augen migmatite, granulite and marble, and it can be divided into four units, including the Xiaoyangjie Formation, Along Formation, Fenggang Formation and Wudukeng Formation from bottom to top. The study on geological and geotectonic property of marble can provide constraints on the nature of crystalline basement[3-5]. The major and trace elements and C-O isotope compositions of marble samples in the Wudukeng Formation were analyzed to constrain the genesis and tectonic significance of the Ailaoshan Group. The major elements show the protoliths of marble samples are dolomite and dolomitic limestone. The marble samples are obviously enriched in large ion lithophile elements, such as Sr and Ba elements, and they have weak depletion of high field strength elements, such as Nb, Ta, Zr, Hf and Th elements with negative Eu anomaly. The chondrite normalized REE diagram and the LREE/HREE ratios ranging from 5.31 to 9.48 suggest the fractionation of LREE and HREE. The δ^{13}CPDB and δ^{18}OSMOW of marbles range from 1.36‰ to -1.43‰ and 17.45‰ to 23.94‰, respectively, indicating that the marble samples are marine carbonate rocks instead of igneous carbonatites suggested by previous studies. The salinity formula $Z=2.048 \times (\delta^{13}CPDB + 50)+0.498 \times (\delta^{18}OPDB + 50)$ was widely used to determine the sedimentary facies, and the Z data in the study area ranges from 117.19 to 126.59, indicating that marine carbonate rocks experienced weathering, leaching and metamorphism. Previous studies showed that the main peak ages of detrital zircons from marbles from the Along Formation in the Gasa-Mosha area in the Ailaoshan metamorphic complex zone concentrate at 424-550 Ma and 700-876 Ma[3-5], which indicated that some of the sediments were sourced from the Paleo-Tethys Ocean in the Paleozoic. The identification of marine sedimentary strata suggests that the Ailaoshan Group not only witnessed the assembly and breakup of the Rodinia supercontinent in Neoproterozoic [1-2], but also was affected by the Paleo- Tethys Ocean in the Paleozoic. Therefore, the Ailaoshan Group, whose protoliths contain Neoproterozoic magmatic rocks and Paleozoic sedimentary rocks, has obvious pro-Yangtze tectonic properties, rather than be considered as Precambrian crystalline basement of the Yangtze Block.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Micropore characteristics of pyroclastic lava of Yingcheng Formation in the Yingshan Fault Depression in the Songliao Basin

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Keywords: pyroclastic lava,tight reservoir,microstructure,pore type, Yingcheng Formation, Yingshan Fault Depression

The Yingshan fault depression is one of the most proliferous depocenters of the Songliao Basin, which is the main supplementary area for deep natural gas exploration to Xujiaweizi fault depression. Industrial gas flow has been discovered in the volcanic reservoir of early Cretaceous Yingcheng Formation. The volcanic reservoirs are mostly tight reservoirs with low porosity and low permeability. The lag in the research on their pore structure and influencing factors has affected the effective exploration and development. In order to qualitatively and quantitatively characterize micropore characteristics, the pyroclastic lava samples which are tuff lava but physical properties are obviously different from Yingcheng Formatio have been analyzed based on core observation, thin section identification, FE-SEM, LTNA, constant-rate mercury intrusion, HPMI, NMR, and micro-nano CT. The pyroclastic lava is mainly welded tuff, which has the characteristics of ultra-low porosity and permeability and complex pore structure. The reservoir space types are mainly devitrification pore, feldspar dissolved pore, and illite intercrystalline pore. The devitrification pore provides about 66.8% total pore volume, its shape is mostly honeycomb, evenly distributed, and its pore diameter is 1 ~ 10 μ m. It shows good spatial connectivity in three-dimensional space. The feldspar dissolved pore has the potential as storage space for oil and gas, but it is too isolated to establish an effective communication network. The main performance of illite is filling pores to damage the physical properties of the reservoir. The complete filling of macropores or sudden shrinkage of pore size in the illite-enriched part leads to an "ink bottle " pore combination. The intercrystalline pores of illite provide an additional 13.5% total porosity as a specific compensation for pore filling. The devitrification is vital to improving the reservoir's physical properties of tuff lavas. The vitric-dominated acid tuff lavas is prone to devitrification due to the high content of SiO_2 and glassiness, thus, it has a better micropore structure. The entire micron-nano scale quantitative characterization of pore structure of tuff lava reservoir has been preliminarily realized, which will benefit the further research on pyroclastic hydrocarbon reservoir.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Stages of the sediment cover formation in the Canada Basin, Arctic Ocean

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Keywords: Arctic, Canada Basin, seismic velocity distribution, 3d geophysical modelling, tectonics

The data of 145 refraction soundings obtained in the course of the American-Canadian studies of the Canada Basin in 2007-2011 were analyzed. The data were published (Chian, Lebedeva-Ivanova) as a digital atlas in 2015.

The analysis of the sedimentary cover is based on the dependence of the P-wave velocity in clastic rocks on the depth and age (Faust, 1951). A database has been compiled, in which for each of 145 buoys the depth and thickness of sediments of the Miocene, Oligocene, Paleogene (Paleocene-Eocene), Cretaceous and Jurassic ages are determined. The calculated data show that the reference horizons of the sedimentary cover of the Canada Basin have an age of: R10 – about 12 Ma; R30 – 23-25 Ma; R40 – 56-65 Ma. Note that our estimation of the R30 horizon age differs significantly from the generally accepted age (41 Ma).

An analysis of the thickness and velocity distribution in the crystalline part of the Earth's crust and the subsequent joint analysis of seismic and gravity data made it possible to construct a 3D model of the earth's crust in the Canada Basin. With the exception of the southwestern part, the crust of the Canada Basin is represented by oceanic-type crust formed in several stages. The area characterized by magnetic anomalies of the northwest direction, apparently, is part of the Paleopacific Ocean (Izanagi Plate), cut off from the Pacific Ocean in the Early Cretaceous. Sediments attributable to the Jurassic age occur everywhere at the base of the sedimentary cover in this extensive area. And only in the southeastern part of the basin, which at the Jurassic/Cretaceous time boundary was located closer to the spreading axis between the Izanagi and Farallon plates, there are no Jurassic sediments at the base of the sediment sequences.

In the central part of the Canada Basin, a Cretaceous zone of rifting and limited spreading is determined. Its axial zone is marked by an extended along 140 W gravity minimum.

In the northern part of the Canada Basin, in a number of buoys sediments older than the Cenozoic are not identified in the sequences. The upper part of the crystalline crust has low P-wave velocities, and a thick crust-mantle layer is noted in the lower part. All this is characteristic of the oceanic crust whose age is not older than the Paleogene.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Oral Preferred

Sedimentary strata and the rift valley position along Gakkel Ridge's segments

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Keywords: Arctic, Gakkel Ridge, rift valley, bathymetry, seismic surveys

Many cross-sections of the Gakkel Ridge and its rift valley were made using a profiler and seismoacoustic profiling during 2019-2020 expeditions. New data, coupled with the results of seismic surveys in 2011-2015 made it possible to reveal the features of the morphology of various parts of the ridge and its rift valley.

The slope gradients and seismic data reflect the subdivision of the Gakkel Ridge and its rift valley into three segments. In the western part, west of 75° E, the width of the ridge is 180-210 km. The rift valley runs approximately in the middle of the Gakkel Ridge. The relief of the ridge looks strongly dissected. The small areas of the seabed, on which the presence of sedimentary strata with a thickness of more than 10 meters, were recorded.

East of 75° E the rift valley is shifted to the southwestern margin of the ridge. The area of ocean floor with gentle slopes increases, occupying more than half of the total area of this segment of the Gakkel Ridge, the width of which varies within 105-130 km. Sedimentary strata are recorded in extended sections of the section, and in some places their thickness reaches more than 1 km.

Finally, a sharp change in the nature of the rift valley occurs south of the giant caldera (Piskarev and Elkina, 2017) located on the continuation of the Gakkel Ridge near the point with coordinates 81° N, 120° E. The rift valley turns to a graben of several hundred meters depth verging towards the Laptev Sea shelf. Faults forming the graben's walls are traceable deep into the thick (up to 4-5 km) sedimentary sequence, and, according to the data, the Cretaceous sediments constitute the lower layers.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Structure of the sedimentary strata in transition zone Laptev Sea shelf – Eurasian Basin

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Keywords: Arctic, Laptev Sea, Eurasian Basin, 3d geophysical modelling, gravity anomalies, earth crust structure

Over the past decade, a number of expeditions have collected data, that greatly detailed our knowledge of magnetic and gravity anomalies, structure of the sedimentary cover and basement of the region located south of 81°N, where the rift valley is interrupted by such a specific formation as a giant (80x45 km) caldera.
A poor quality of aeromagnetic observations does not allow to reliably correlate magnetic anomalies in the region. At the same time, a two-dimensional Fourier analysis of magnetic anomalies in the Eurasian Basin termination area shows that, with the exception of a narrow zone along the line of the present-day axis of the rift graben, the predominant direction of magnetic anomalies is east-northeast, parallel to the shelf margin.
Analysis of the probable age of seismic horizons, correlation with sections of the sedimentary strata of the Laptev Sea and the Taimyr shelf, analysis of the distribution of velocities in sedimentary strata with depth shows that Cretaceous, and, probably, Late Jurassic sequences occur at the base of the sections of sedimentary strata in the termination areas of the Nansen and Amundsen Basins.
The most important features of the new 3D geophysical model are the extension of the West Laptev Basin to the northwest into the Nansen Basin, continuation of the East Laptev horst to the north to the junction with the Gakkel ridge and the presence of a basement uplift in the termination area of the Amundsen Basin, overlain by Neogene deposits. On the map of the thickness of the Earth's crust blocks with a typical continental crust with a thickness of more than 30 km are clearly distinguished. In the southeast, this is the Kotelny massif, where the total thickness of the Earth's crust of 32-33 km was established according to the analysis of converted earthquake waves. An increased thickness of the earth's crust is observed on the Taimyr shelf and on the southern margin of the Laptev Sea, near the northern boundary of the Siberian Platform. The entire shelf area within the West Laptev Basin, where the thickness of the sedimentary cover reaches 14 km, is characterized by an extended thinned continental crust up to 20–22 km thick.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Study on tectonic regime change and sedimentary environment of Late Paleozoic in Junggar Basin

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Keywords: tectonic regime change, sedimentary environment, Late Paleozoic, Junggar Basin

The late Paleozoic in Junggar Basin mainly experienced two periods of tectonic regime change, including compression-extension type at the end of Carboniferous and extension-compression type at the end of Early Permian. The basin entered the post collisional extensional tectonic environment in the Late Carboniferous, and the water body in the basin is relatively shallow, mainly composed of marine land transitional facies and shallow marine facies. The tectonic regime change at the end of Carboniferous made the basin complete the ocean continent transformation process and enter the intraplate tectonic environment. The regional tectonic unconformity (C / P) formed between the Carboniferous and the overlying Permian is the stratigraphic response of this tectonic regime change, and an obvious thrust structure was formed around the basin. The tectonic regime change at the end of the early Permian brought the basin into a compressive tectonic environment. From the perspective of stratigraphic filling characteristics, the lower part of the lower Permian is generally characterized by volcanic rock coarse clastic rock assemblage, and the upper part is dominated by dolomitic rock fine clastic rock assemblage. This change in sedimentary sequence reflects the transition of the basin from a strongly extended fault depression to a relatively stable fault depression; The middle and Upper Permian changed from fine clastic rock to coarse clastic rock in the upper part. This reverse cycle sedimentary sequence with grain size from fine to coarse from bottom to top represents the process of compression uplift in which the water body gradually becomes shallower.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Oral Preferred

Diachronous accretionary history of East Junggar arc: insights from petrographic and geochronological studies of the Permian-Lower Triassic sandstones from southern and northern Bogda Mountains, NW China

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Keywords: Central Asian Orogenic Belt, provenance, detrital zircon, petrography

North Tianshan Arc has been suggested to contribute sediments to the greater Turpan-Junggar basin since the late Paleozoic. However, the timing of the amalgamation of the Central Asian Orogenic Belt is constrained to late Carboniferous – middle Permian, implying that the other adjacent terranes have the potential to provide detritus. We conducted high-resolution petrographic and detrital zircon geochronological studies of Permian-Lower Triassic sandstones from measured sections in Zhaobishan (ZBS) and Dalongkou (DLK) in the south and north Bogda Mountains, respectively. Kungurian samples from ZBS have a main peak at 290-310 Ma of detrital zircon ages, suggesting North Tianshan (NTS) arc is the source. Guadalupian samples in both areas have the main peak from 310-330 Ma, indicating a common NTS provenance. Additionally, the ZBS sample has unique peaks at 390-500 Ma and 1.5-2.0 and 2.6-3.0 Ga that suggest the East Junggar arc to the east is a source, and age spectra of the Wuchiapingian-mid Olenekian samples are similar with that of Guadalupian sample. Age signature of the East Junggar arc is recorded in the DLK Wuchiapingian-mid Olenekian samples, suggesting the East Junggar source appeared in the late Permian in DLK. Besides, increasing volcanic lithics in DLK's late Permian-Lower Triassic sandstones suggest a magmatic arc signature for the source area, which is consistent with the detrital zircon results. This study confirms that the NTS has been a persistent source since Permian and proposes that the East Junggar accreted to the Junggar block diachronously by the northward closure of Kelameili Ocean. It provides constraints on the timing of amalgamation of the southern CAOB from a sedimentary perspective.

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Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Oral Preferred

Control of tectonic-paleogeomorphology on deposition in the South Lufeng area of the Pearl River Mouth Basin

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Keywords: Fault activity, paleogeomorphology, sedimentary system, Paleogene, Lufeng Sag, Pearl River Mouth Basin

The Paleocene in the Lufeng South area has a complex spatial distribution of depositional systems, influenced by pre-depositional paleogeomorphology and multi-period tectonic activities. To clarify the role of tectonic and palaeomorphic control on the sedimentary body and effectively guide the lower oil and gas exploration. The Paleogene paleogeomorphic pattern in the southern Lufeng area was restored by the impression method, and the temporal and spatial evolution laws of the main faults were clarified. The results show that the supply capacity of the source area and the accommodated space of the lake basin are coupled to control the deposition scale. The slope controlled by the combination of paleogeomorphic assemblage and the activity of the main fault determines the sedimentary type. Braided river deltas developed stably in the long-axis gentle slope belt of the lake basin, while the short-axis sedimentary system changed from fan delta to braided river delta in response to the change of dominant fault strength from strong to weak. The tectonic slope fold zone controls the spreading pattern of the sedimentary sands. The cliff type of the single-fault steep slope zone is controlled by the boundary fault, with large fault throw and steep section, and develops wedge-shaped sand bodies. The multi-level fault-step zone provides the driving force for the advancement of the sedimentary system, and the sand body extends for a long distance.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Upper Jurassic-Lower Cretaceous Clastic Dykes in southern Tibet: Characteristics and Paleogeographic Significance

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Keywords: Jurassic-Lower Cretaceous, Clastic dykes, Southern Tibet, Northern Indian margin, Earthquakes

A clastic dyke is a tabular body of clastic sediments that fills open fissures across strata, and may provide important information on regional depositional processes and tectonic activity. Clastic dyke swarms are widely exposed in the Jurassic-Lower Cretaceous sedmentary strata in the Gucuo, Wölong and Jixiog areas of the Tethyan Himalaya in southern Tibet.

The Jurassic clastic dykes are composed of medium to coarse-grained quartz sandstones, which are sub-vertical. The length and width range from 5 to 50 m and from 10 to 50 cm, respectively. The U-Pb age spectra of zircon grains are similar to those in Upper Jurassic sandstones (Menkadun Formation). Petrographic analyses show that the dykes are similar to the overlying strata and the quartz grains are more than 90%, indicating that the dykes were derived from overlying strata and formed by passive deposition of unconsolidated clastic material into pre-existing fissures from above. We conclude that the clastic dykes may be related to a large-scale contemporaneous fractures formed during the Jurassic.

The Lower Cretaceous clastic dykes are composed of fine to medium-grained volcaniclastic sandstone and distributed along a series of normal faults. The length and width of clastic dykes range from 5 to 50 m and from 20 to 150 cm, respectively. The U-Pb age spectra of zircon grains are similar to those in Lower Cretaceous sandstones (i.e., Wölong vocaniclastics) and display a youngest peak at 124.3±2 Ma. Petrographic analyses show that the dykes contain more volcanic lithic fragments and less feldspar grains than the overlying strata, indicating that the dykes were derived from underlying strata and injected upward along faults. Their formation may be explained by a fault-induced clastic-dyke model: normal faults provided conduits for clastic material injected from the underlying unlithified sandstones which were undergoing re-fluidization owing to over-pressure. We infer that the liquefaction of underlying strata was induced by earthquakes associated with the extensive magmatic activity and regional extension that affected the Indian passive margin of Neotethys during the Early Cretaceous.

We thus infer that the Tethyan Himalaya had been in the regional extension during the Jurassic-Early cretaceous. The Kerguelen plume was likely suitably placed to cause weakening of the basal Indian continental lithosphere since the Late Jurassic. In the Late Jurassic, the farther from the Kerguelen plume resulted in a lower intensity of plate extension, and only a large number of contemporaneous fractures in the surrounding rocks to form the neptunian dykes. Until the Early cretaceous (~120Ma), the Kerguelen plume activity reached its peak, and the plate extension was of high intensity, leading to a large number of volcanic and seismic activities, forming the injection dykes.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-2: Interactions between basement, volcanism, and sedimentary cover
Presentation Preference: Oral Preferred

Tectonic setting and evolution of granite basement in Qiongdongnan basin, northern margin of South China sea: evidence from geochronology, geochemistry and apatite fission track

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Keywords: granite basement, geochronology, geochemistry, tectonic setting, apatite fission track, Qiongdongnan basin

The lithofacies, zircon chronology, geochemical and tectonic environment of the Songnan low uplift granite in Qiongdongnan basin, northern South China Sea are analyzed. The results show that the buried hill lithology is mainly composed of granodiorite and monzonitic granite. The zircon U-Pb dating results of LA-ICP-MS are 228.6 and 243.7 Ma, which is the product of Triassic magmatic activity. The rock mass belongs to high-k calc alkaline series, with high content of SiO2(54.94%-79.71%), moderate alkali (3.53%-6.43%), Al2O3(9.82%-18.23%), CaO(1.24%-9.55%) and MgO(0.37%-2.28%). The A/CNK values range from 1.09 to 2.13, which are both aluminum and peraluminous granites. The rocks are generally rich in large ion lithophile elements such as K, Rb and Th, depleted in high field strength elements such as Ta, Nb, Ti, and show moderate to weak negative Eu anomalies (δ Eu= 0.50~0.85). Petrographic and geochemical characteristics show that the granodiorite is aluminum I-type granite, and the monzogranite is peraluminous S-type granite, which was formed by partial melting of sediments in the crust. On the other hand, comprehensive analysis indicates that the granite has the characteristics of post-collisional granite, formed in extensional tectonic environment. It is related to roll back or the reverse extension after collision between South China and Indosinian blocks. In order to further study the regional tectonic evolution, cryogenic thermochronology, especially apatite fission track is used to restore the thermal history of the granite basement. The subsidence history is simulated by the thermal history with the fission track data. The multiple annealing model of Ketcham et al. (2007) is used for simulation. The inversion results are realized by HeFTy software (version 1.9.1). The results show that there were three subsidence and three uplift under the background of regional extensional tectonics since the late Cretaceous. The three episodes of subsidence were late Cretaceous subsidence (100-80 Ma), late Eocene-Oligocene subsidence (55-45 Ma) and Late Oligocene-early Miocene subsidence (32-20 Ma). All the three episodes of subsidence were rapid ones. The three uplift periods were late Cretaceous to Eocene (85 ~ 55Ma), middle Oligocene (45 ~ 32Ma) and middle Miocene to present (20Ma-). The first two were rapid subsidence, the last one can be divided into two periods, (20-10Ma) is the slow uplift period, and the uplift speed has accelerated since 10Ma.

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Session T2-2: Interactions between basement, volcanism, and sedimentary cover
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Evolution of tectonic geomorphology and provenance-sedimentary response of Cretaceous Qingshuihe Formation in central Junggar Basin

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Keywords: Junggar Basin, Qingshuihe Formation, Che-Mo paleo-uplift, Tectono-geomorphology, Provenance, Depositional systems

Provenance-sedimentary filling varies in different sites of basins corresponding to the evolution of tectonic geomorphology. Taking the Lower Cretaceous Qingshuihe Formation (K_1q) in the Moxizhuang-Yongjin area of the Junggar Basin as an example, we analyzed the sequence stratigraphy, provenance, depositional system, and the geomorphic evolution via integrated 3-D seismic data, outcrop, well logging, core, thin section and heavy mineral analysis. The results show that K_1q develops a 3rd order sequence in which the 1st member of K1q (K_1q^1) develops lowstand system tract (LST) and lacustrine transgressive system tract (TST), and the 2nd member (K_1q^2) develops high-stand system tract (HST). In the late Jurassic, the Chepaizi-Mosuowan (Che-Mo) paleo-uplift, in the centre of the study area, was strongly eroded, resulting in local topographic highs that attribute sediments to Paleo-Hammock. The Yanshan II movement resulted in the rapid subsidence of the basin and the study area submerged under the water and started to receive sediments. During the LST period, influenced by the residual Che-Mo paleo-uplift, the sediments from the northeast and northwest were deposited in the topographic lows, developing shallow braided river deltas, with successive underwater distributary channels developed. The earlier stage of continuous sedimentation of braided river deltas gradually reduced the residual rough topography, resulting in a wide and gentle slope which tilting to the south. During the TST period, rapid lacustrine transgression occurred from the southeast to the north, resulting in the deposition of shallow lacustrine that mainly featured mudstone and locally developed beach-bar sandstone. During the HST period, the climate gradually changed from arid to humid and the study area mainly deposited shoal-water meandering river delta which featured limited subaqueous distributary channels in the inner front of the delta and successive sheet sand in the outer front of the delta. The evolution of tectono-geomorphology controlled the provenance changes and the sedimentary filling, which provide an excellent example for similar basins worldwide.

Session T2-3: Impacts of volcanism on sedimentary systems

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-3: Impacts of volcanism on sedimentary systems
Presentation Preference: Oral Preferred

Volcanic-sedimentary succession and reservoir-seal assemblage in Junggar Basin : A case study of Carboniferous volcanic reservoir in Zhongguai uplift

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Keywords: Junggar basin, Carboniferous, Volcanic sedimentary sequence, reservoir-seal assemblage

The Junggar basin, located in northern Xinjiang, is a large petroliferous basin and a major field of volcanic petroleum development. This paper reveals the characteristics of the volcanic sedimentary sequence and petroleum reservoir-seal assemblage in the north of the Zhongguai uplift and defines the petroleum potential in this area based on data from outcrop investigation, drilling and logging comparison, core observation, and seismic interpretation. The results show that the Carboniferous volcanic activity in this location was intense, with multi-stage eruptions forming the volcanic rocks. The lithology consists primarily of medium-basic volcanic lava and pyroclastic rocks that range in pH from basic to acidic, but are primarily medium-basic. Rock types mainly include volcanic breccia, tuffaceous sandy conglomerate, andesite, basaltic andesite, and dacite. In this area, typical volcanic sedimentary sequences have formed. The lower part of the sequence is volcanic rock, and the upper part is sedimentary rock, which is characterized by the interbedding of volcanic rock and sedimentary rock. The sand-mud interbedding (primarily mudstone)–glutenite–mudstone–medium basic volcanic rock succession is mostly developed. Volcanic reservoirs come in a variety of shapes and sizes, with the most common lithologic reservoirs being “pyroclastic rock, lava, and tuffaceous sandy conglomerate”. Dissolution pores, pores, and microfractures make up the reservoir pores, forming a fractured pore dual medium reservoir dominated by pores. The reservoir has low physical qualities, falling into the medium porosity and low permeability categories. Porosity and permeability range from 5.0% to 18.1% and 0.011mD to 477mD, respectively, with an average of 9.6% and 0.477 mD. The Triassic Karamay lower formation, the Permian upper Urhe formation, and the Jiamuhe Formation from west to east are the carboniferous overlaying layers in the north of the area in terms of caprock. Among them, a set of stable lacustrine mudstones has developed in the third member of the Permian Urhe formation, which is an important regional caprock in the area. Due to the obvious enormous mudstone thickness and thin sand layer in the sand mud interbedding of the second member of the Urhe formation and the Triassic Karamay formation, it can also be used as local caprock. As a result, several well-configured reservoir cap assemblages in the Carboniferous can be found in the northern part of the area, including andesite–volcanic breccia–tuff assemblages in the overflow facies area, mudstone–tuff glutenite–fused breccia assemblages in the volcanic sedimentary facies area, and mudstone–tuff glutenite–tuff assemblages in the volcanic sedimentary facies area. And the sand–mud interbedded (mainly mudstone)–dacite–tuff assemblage, among which the mudstone–volcanic breccia–tuff assemblage is the most favorable in the overflow facies development area.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-3: Impacts of volcanism on sedimentary systems
Presentation Preference: Oral Preferred

Study on the Geochemical Characteristics of Highly Differentiated Granites in the Xiaozhushan, Qingdao, Shandong Province

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Keywords: Xiaozhushan, Petrogeochemistry, Highly differentiated granite, Laoshan period

The Xiaozhushan is located in the northern Jiaonan Uplift of the Sulu orogenic belt`s eastern extension in eastern Shandong Province, adjoining the Wulian-Qingdao fault. The Late Yanshan Cretaceous Qingshan stage igneous rocks are widely exposed in this area, appearing in rock stock, laccolite and batholite. The Xiaozhushan rock are mainly composed of Laoshan granite, similar to the Laoshan potassium granite. The sample rocks are dense, solid and light in colour. The rock types are alkaline granite, syenogranite and granite porphyry with clear contact zone with the surrounding rock and mafic inclusion. Based on the previous study, researching granite in the Lingzhushan National Forest Park, typical samples were obtained for the whole rock major elements, trace elements and rare-earth elements, U-Pb zircon dating, X-ray diffraction analysis and X-ray fluorescence spectrum analysis. The results are as follows: feldspar veins were found on granite, and the minerals in rocks are plagioclase, potash feldspar, cordierite and aragonite. Automorphic quartz, muscovite, sericitization and chloritization are developed under the microscope. The alteration is obvious and speculating that it may be the late hydrothermal transformation. As for the geochemical characteristics, the samples are all high-silica granites (SiO2>75%), with high total alkali content (Na2O+k2O>8.5), belonging to the high-potassium calc-alkaline series. The negative Eu anomaly is obvious (δEu=0.4-0.5), and the aluminim saturation index (A/CNK>1.2) reflects the characteristics of high differentiation. According to the calculation of CIPW standard minerals, the differentiation index (DI) is above 90, and the saturation temperature of zircon is between 832 °C to 875 °C. Zircon trace elements show the ore-bearing property of highly differentiated rocks (Eu/Eu*=0.03-0.27; Ce/Ce*=1.1-149). Geochronology shows that the granite age is 117±3 Ma, which is a typical Early Cretaceous Laoshan granite. Different types of granites have different geochemical characteristics. Combined with the diagram of 10000Ga / Al-Zr, it can be indicated that the granites in this area are mixed granites of type I and type S. It provides a basis for studying geochemical characteristics of Late Yanshanian high differentiated granites in eastern Shandong province.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-3: Impacts of volcanism on sedimentary systems
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Existence of C-P volcanic islands and reefs in Junggar Basin and its significance for deep oil and gas exploration

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Keywords: Junggar basin, Deep oil and gas exploration, Carboniferous, volcanic islands and reefs

Carboniferous volcanic eruptive rocks, basalt, pyroclastic rocks, tuff and sedimentary tuff are widely distributed in the deep layer of Junggar basin. However, limestone lenses or limestone intercalations of different sizes often appear in the strata dominated by pyroclastic rocks of Upper Carboniferous, with a thickness of more than 10-100 meters and an area of 0.1-tens of km^2, which are discontinuous. Predecessors explained that they represent a kind of marine carbonate bioclastic beach deposition. These limestone bodies do contain a large number of shell biological fragments, coral fragments, various calcareous bioclasts, and complete brachiopod shells. The field observation is indeed similar to bioclastic beach facies, represented by Shiqiantan formation and Qijiagou formation.

In recent years, through continuous observation and reinterpretation of several similar stratigraphic groups and sections, we found that the construction of volcanic rocks with limestone with similar sedimentary characteristics has the sedimentary characteristics of volcanic islands and reefs: one of the most remarkable features is that collapsed volcanic breccia and blocks are found in reef limestone, the contact boundary between limestone and volcanic rock is very irregular, and limestone and volcanic rock are irregular and interbedded with unequal thickness, The spatial shape is complex, which is completely different from the characteristics of normal carbonate platform, platform margin beach or platform inner beach.

Combined with the structure characteristics of its seismic profile, it is identified that it may be volcanic islands and reefs in the rift valley on the continental margin of marine facies. Various volcanic rocks and pyroclastic rocks controlled by ancient volcanic cones are developed in the stage of intense volcanic activity. In the quiet period of volcanic activity, the volcanic islands are denuded, collapsed, submerged near the sea level, and coral reefs are developed on them. The growth and transformation of reefs are controlled by the rise and fall of sea level and waves, or collapsed, or spread out, The formation of bioclastic beach is more consistent with the model of volcanic islands and reefs. The macro reservoir physical properties are excellent. It is very similar to volcanic islands and reefs and volcanic atolls in modern tropical ocean, but the Junggar basin was unlikely to be a far ocean environment at that time. The biological reef limestone of Carboniferous-Permian system is of great significance for oil and gas exploration all over the world, and there are many examples of large and giant reef limestone oil fields. At present, several possible volcanic islands reef structures with good preservation conditions have been preliminarily identified.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-3: Impacts of volcanism on sedimentary systems
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Alteration products and diagenetic evolution characteristics of tuffaceous clastic rocks in Paleogene Wenchang Formation in Lufeng and Huizhou area

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Keywords: Lufeng and Huizhou area, Wenchang Formation, Tuffaceous clastic rock, Alteration products, Apatite

Different authigenic minerals precipitated during the alteration of tuffaceous components in clastic rocks can significantly improve or destroy the reservoir space.The authigenic mineral types, characteristics and diagenetic evolution process of tuffaceous alteration in clastic rock oil and gas reservoirs in different structural zones in the study area are deeply analyzed by comprehensively using the technical means of core analysis, microscopic observation (cast thin section, scanning electron microscope, cathodoluminescence,et al), lithogeochemical analysis and testing in Lufeng and Huizhou area.The results show that 1) the tuffaceous alteration products that have an important impact on the reservoir space of Wenchang Formation in the study area are mainly chlorite, laumontite, kaolinite, apatite and authigenic quartz, and the types of alteration products are closely related to the properties of synsedimentary volcanoes; 2) There are three types of tuffaceous in the study area: acidic, medium basic, P/Ca
-rich alkaline. The acidic tuffaceous is mainly in-situ alteration, which can produce authigenic kaolinite and authigenic quartz; Medium basic tuffaceous is prone to in-situ Laumontite, and the precipitation of authigenic chlorite and authigenic quartz may occur at the same time of dissolution and pore formation; For alkaline tuffaceous matter rich in P and Ca, on the one hand, it is eroded into plate columnar apatite in situ. In the process of further dissolution, apatite will also dissolve and precipitate to form plate strip or fibrous apatite; 3) The early chlorite rim structure can protect the primary pores, and the laumontite cement can destroy the primary pores in the early stage, but the dissolution pores generated by later dissolution can improve the physical properties of the reservoir. Apatite authigenic minerals retain a large number of intergranular pores, and secondary dissolution can occur to form a large number of intergranular dissolution pores, while authigenic kaolinite and quartz are mostly filled in feldspar and tuffaceous dissolution pores to destroy the reservoir pores.Studying the alteration products and diagenetic process of tuffaceous clastic rocks in Wenchang Formation in different structural zones in Lufeng and Huizhou area can clarify the quality difference mechanism of tuffaceous oil and gas reservoirs and provide a scientific basis for high-quality reservoir prediction.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-3: Impacts of volcanism on sedimentary systems
Presentation Preference: Oral Preferred

The Research on Control Factors of Sedimentary System by Metamorphic Core Complex Tectonism in Kaiping Sag of Pearl River Mouth Basin

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Keywords: Kaiping, metamorphic core complex,sedimentary systems,Paleogene

Kaiping sag, located in the Pearl River Mouth basin, is the emerging hot spot of exploration in recent years, which developed rich types of continental sedimentary system in Paleogene. It is difficult to accurately identify the morphology and distribution characteristics of favorable source rocks and reservoirs for deep Paleogene, due to multiple tectonic periods, rapid changes of sedimentary systems, multi-periods of volcanic rock development and low-exploration area. The analysis of regional seismic data and limited Paleogene drilling data, shows that the uplift of the middle (lower) crust caused by the metamorphic core complex, controls the evolution of the fault system in the Kaiping Sag. The Wenchang Formation can be divided into two stages: the tensile fracture stage and the detachment fracture stage. During the tensile stage, in response to the regional extension of NW-SE trending, the faults are mostly NE direction and cease to be active at a later stage; during the detachment stage, in response to the uplift of metamorphic core complex, the faults are mainly rootless near EW direction and most faults are continuously active in Enping stage. In the depositional period of Wenchang Formation, due to the uplift of metamorphic core complex, the terrain became gentle, the valley-slope break zone was developed visibly in the northern sag. A series of developed paleo-valleys, indicating that the provenance has entered the middle of the sag from the steep slope zone. In the south and southeast of the depression, the topographic relief becomes slow, the scale of basement gullies become smaller, and the southeast is mainly supplied by scattered small gullies. Influenced by detachment faults, large fan deltas were in the northern sag and braided river deltas formed in the south slope of Kaiping sag, which were favorable zones for reservoir rocks formation.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-3: Impacts of volcanism on sedimentary systems
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Evolution of Mesoproterozoic continental rift : Evidence from Volcanic-sedimentary cycles of the Xiong 'er Group in southern North China Plate

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Keywords: Mesoproterozoic, North China Craton, Continental Rift, Xiong'er Group, Volcanic-sedimentary cycles

The Mesoproterozoic rifting event is one of the hot topics in the study of Precambrian tectonics. As the first volcanic-sedimentary formation in the North China Craton, reconstruction of the tectonic-sedimentary evolution sequence of the Xiong'er Group is of vital significance for understanding the early Mesoproroterozoic rifting and even Columbia supercontinent breakup. Based on the geological survey, petrology, and geochemistry data of the Xiong'er Group in the Ruyang region, the sedimentary facies, filling sequence, and tectonic environment of the volcanic-sedimentary rocks of this Group were determined, and the early tectonic-sedimentary evolution processes were discussed. The results show that the Xiong'er Group was formed in a continental rift environment. From early to late, it included three volcanic activities of the Xushan Formation with a gap-type volcanic eruption, the Upper Jidanping Formation with a central volcanic eruption, and the Upper Majiahe Formation with a gap-type fissure-type volcanic eruption, and the intermittent subsidence of clastic rocks in fluvial or lacustrine facies of the Dagushi Formation, the Mid-Jidanping Formation, the Mid-Majiahe Formation, and the Gaoshanhe Group. The Xiong'er Group generally reflects three volcanic-sedimentary cycles, in which the volcanic activity shows a weak-strong-weak evolutionary trend and the sedimentary source shows the evolution process of terrigenous clastic river facies-volcanic clastic river facies-volcanic clastic lake facies. This characteristic of intermittent volcanic activity associated with regional continuous extension and subsidence reflects the type of early tectonic-sedimentary filling of typical intracontinental rifts and represents the onset of the early Mesoproterozoic extension-breakup event in the North China Craton.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-3: Impacts of volcanism on sedimentary systems
Presentation Preference: Oral Preferred

Longest-reutilization hydrothermal pathway above a buried volcano in the Great South Basin of New Zealand

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Keywords: Hydrothermal vent, fluid migration, gas chimney, pockmark, shallow gas, Great South Basin

Structures that facilitate sub-vertical fluid migration are common in sedimentary basins. In this study, we used high-resolution 3D seismic data document several hydrothermal vents located above the Tuatara Volcanic Field in the Great South Basin of New Zealand. Four hydrothermal vents have been identified and three of them are vertically stacked, indicating episodic re-use of the same vertical fluid migration pathway between ~75 Ma to ~58 Ma. A gas chimney and pockmark has been observed above the hydrothermal vents. The pockmark dated to ~49 Ma and was filled with free gas. A small amount of free gas above the pockmark is recognized as developing at the Horizon H2 which is indicated that the hydrothermal pathway still can focus fluid flow upward after 28 Myr. The spatial association of the vents, pockmark, and free gas may suggest continued re-use of a fluid migration pathway for over 54 Myr. Our results imply reutilization of fluid flow pathways may affect the distribution of fluids within basins, potentially impacting hydrocarbon/geothermal exploration and geohazard assessment. Therefore, reassessment of the hydrothermal pathway' role on fluid flow should be pained where the hydrothermal vent occurs.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-3: Impacts of volcanism on sedimentary systems
Presentation Preference: Oral Preferred

A millimeter-scale insight into formation mechanism of lacustrine black shale in tephra deposition background

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Keywords: Tephra, Black shale, Organic carbon, Formation mechanism

To reveal the role of tephra in the deposition of black shale during periods of volcanic activity, we performed lithostratigraphic and geochemical analyses on 14 horizontally sliced samples drilled from a 2-cm-thick black shale interval in the lower Ch7 Member of the Upper Triassic Yanchang Formation, southern Ordos Basin. Results indicate that fewer plankton are preserved during tephra deposition than during periods of volcanic quiescence. With the decrease of volcanic activities and tephra deposition, the abundance of redox-sensitive trace elements (RSTEs) and biolimiting elements increases, while terrigenous elements gradually decrease, resulting in the improvement of organic matter (OM) preservation. Paleoenvironmental proxies suggest that the climate during the Late Triassic was generally warm and humid with freshwater. However, subsequent intense volcanic eruptions may have caused climatic cooling that affected the water column, resulting in enhanced salinity, primary production, water stratification, and bottom water anoxia, leading to enhanced organic carbon production and preservation. Primary productivity and redox conditions controlled the accumulation of organic carbon. Although physical and chemical reactions relating to the deposition of tephra into water are short-lived, climate change induced by volcanic eruptions is the critical cause of black shale formation.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-3: Impacts of volcanism on sedimentary systems
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Origin and diagenesis in volcanic matrix-rich sandstones: A case example from the Shanxi and Shihezi formations (Permian), Southwest of the Ordos Basin, China

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Keywords: Volcanic matrix-rich sandstones, Provenance attribute, Hyperpycnal flow, Diagenetic processes, Ordos Basin.

Complex interrelationships may exist between topography, depositional systems and volcanic activity in the volcanically active regions[1]. Additionally, volcanic eruptions can provide large amounts of sedimentary materials[2] and expose fluvial valleys or lakes to catastrophic hyperpycnal flood events. The Permian ancient fluvio-deltaic system in the Longdong Region (southwest of the Ordos Basin), which reveals evidence for abundant synsedimentary volcanism linked to the tectonic evolution of orogenic belt around the basin, provides a “natural laboratory” for volcanism-related hyperpycnal flows.

In this study, volcanic matrix-rich sandstone samples have been analyzed for petrology, mineralogy and geochemistry in order to explain the volcanogenic material provenance attribute, depositional and diagenetic processes. Discussion on detrital zircon geochronology and geochemical characteristics indicates that volcanogenic materials were not derived from the Yinshan-Yanshan Orogenic Belt as previously thoughts, but favors the southwestern origin from the North Qinling Orogenic Belt. Combined with the mapped distribution characteristics of volcanogenic materials and the tectonic setting around the basin, the crater may be located in the west or south of Longdong Region. Volcanogenic materials retained in the provenance area during frequent volcanic eruptions were transported to the basin via fluvial system shortly after eruption. According to the color, sedimentary structure and grain size characteristics of volcanic matrix-rich sandstones, thirteen lithofacies were recognized through detailed core observations, and five principal facies association in the Shanxi and Shihezi formations were identified and delineated. These deposits have met the criterion for hyperpycnites according to conceptual schema proposed by Zavala et al., 2011.[3], which suggests the occurrence of hyperpycnal flows during the deposition of volcanic matrix-rich sandstones. During the subsequent burial stage, three types of volcanic matrix-rich sandstones divided by the volcanic matrix content have similar paragenetic sequences but different diagenetic intensities. The cementation strength of authigenic minerals, however, was closely related to pore structure characteristics and the migration trend of volcanic-matrix alteration materials.

Within this study, it is proposed the possible tectonothermal events in the North Qinling Orogenic Belt during the Permian, which has been previously unidentified, and validates and reinforces theoretical work of volcanism-related hyperpycnal flow. This contribution provides new insights to the understanding of the depositional and diagenetic processes of lacustrine basins with similar tectonic settings.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-3: Impacts of volcanism on sedimentary systems
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Mechanism of Rhyolitic ash Promoting organic matter enrichment in a shallow carbonate platform: A case study of the Maokou Formation in eastern Sichuan Basin

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Keywords: volcanic ash, organic matter, productivity, bio-precursor, hydrocarbon generation, Sichuan Baisn

Erupted volcanic ash improve the amount of nutritive elements in the lake and ocean (Uematsu et al., 2004; Duggen et al., 2010; Hoffmann et al., 2012; Liu et al., 2019), but it is not fully understood how volcanic ash influences the total organic matter content (TOC) and bio-precursor, and the scope of influence. A volcanic layer, measuring 5cm in thickness, was examined using electron microscopy scanning, TOC/TS, pyrolytic, and inorganic geochemical analyses. The study of TOC and inorganic elements shows that the TOC content in the overlying shales increases by 18 wt.% on average, and the vertical scope of influence on shales is twice as thick as the volcanic layer. Organic matter enrichment is attributed to the fact that the volcanic layer provides nutritive elements and meanwhile changes the oxidation-reduction condition. Large variations of hydrogen index (HI) and oxygen index (OI) in the lower and upper parts of the volcanic layer is related to terrestrial organic matter vanishing, due to volcanic eruption and subsequently more terrigenous organic matter migrating into the ocean. Little change of the source organisms in the overlying and underlying shales may be related to the fast restoration within the ocean and land ecosystems after a volcanic eruption. The decrease in terrigenous sediments indicated by Rb/Sr, Zr/Y, and ∑REE after a volcanic eruption indirectly reflects fast restoration of terrestrial vegetation boom. These results may offer fundamental data support in the study of volcanic ash influence on source rocks.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-3: Impacts of volcanism on sedimentary systems
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Study of late Carboniferous tuffaceous sandstone and related manganese deposits in the Maerkansu manganese belt, western Kunlun, Xinjiang Province, Northwest China.

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Keywords: Maerkansu manganese belt, late Carboniferous, tuffaceous sandstone,zircon U-Pb dating, Hf isotope

The Maerkansu ore-cluser district in western Kunlun Metallogenic Belt hosts extensive Mn deposits including Aoertokaneshen, Muhu, Maekantu, etc, mainly for rhodochrosite, and the average grade is about 30%. The deposits are mostly associated with the late Carboniferous pyroclastic-carbonate formation, which have received lots of study and exploration. However, the genesis of the manganese and metallogenic relationship between pyroclastic rocks and manganese deposits have not been well constrained. In this study, we report new zircon U-Pb ages, Hf isotopic and geochemical of tuffaceous sandstone, orebody and host rock in the Maerkansu regoin. Two LA-ICP-MS U-Pb ages of tuffaceous sandstone in the Muhu deposit are 309.9±3.7Ma and 309.5±3.5Ma. Hf isotopic ratios are ƐHft=15.29~19.76 and 15.53~20.26, and Hf crustal model ages are 0.98 to 1.26 Ga and 0.92 to 1.29 Ga (average=1.09 Ga). Their model ages are similar to the ancient crustal basement in the West Kunlun area. Thus, we suggest that the magma is mainly derived from the anatexis of the Proterozoic crustal material. Based on our analysis, tuffaceous sandstone and manganese ore share similar distribution modes of rare earth elements and trace elements. Combined with volcanic hydrothermal sources of manganese are revealed by the geochemical characteristics, the manganese metallogenic materials are mainly derived from submarine volcanic activity.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-3: Impacts of volcanism on sedimentary systems
Presentation Preference: Oral Preferred

A tail of orogenic cycle from syncollisional crust thinking to post collisional subaerial uplift for the Mesozoic Qinling Orogen

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Keywords: Qinling orogen,foreland basin,crustal thicking,denudation

Through the study of typical orogenic belts in the world (such as the Himalayas and the Andes), it is found that there is a decoupling relationship between crustal thickening, surface uplift and erosion (Mulch and Chamberlain, 2006; Garzione et al., 2008; Govin et al., 2018; Fang et al., 2020). The tectonic evolution history of the Qinling orogenic belt in the early Mesozoic has always been the focus of debate (Dong et al., 2016; Wu and Zheng, 2013). Based on the provenance analysis of the foreland basin on the periphery of the orogenic belt, it is inferred that the North China plate and the South China plate had initially collided at the beginning of the Middle Triassic (Ma et al., 2021). Deformation structure and thermochronology show that after the closure of the ocean in the Late Triassic ca. 50 m.y., the continental-continent fusion continued, resulting in a reduction of at least 400-500 km in the crust. (Shi et al., 2012; Dong et al., 2013). The relationship between the geochemical characteristics of magmatic rocks in the Qinling orogenic belt and the thickness of the earth shows that the Moho depth of the South Qinling increased rapidly in the early Late Triassic (~230 ~ 220 Ma), reaching a maximum of ~60km-70km at ~220 ~ 210 Ma. After about 10 Ma, the depth of the Moho surface decreased rapidly (Hu et al., 2020). Thermochronology shows that from the early Middle Triassic to the Jurassic, the South Qinling region experienced multiple stages of lifting and cooling histories (Li et al., 2013; Wang et al., 2014; Wang et al., 2019). Although multiple evidences show that the basement of the Qinling orogenic belt in the Late Triassic was uplifted to varying degrees and the crustal thickness increased significantly, but at the same time, the orogenic belt did not undergo surface uplift and denudation. In this paper, by studying the trace geochemical data of detrital zircon in the foreland basin of the southern margin of the Qinling orogenic belt, it is speculated that the orogenic belt experienced a syn-collisional orogenic process in the Middle Triassic, and the crust at the end of the Late Triassic (~210 Ma) The thickness reaches the thickest (~76 km), and finally experienced a rapid denudation process in the Early Jurassic.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-3: Impacts of volcanism on sedimentary systems
Presentation Preference: Oral Preferred

Characteristics of the volcanic lithofacies of Cretaceous Qingshan Group in Jiaodong uplift

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Keywords: volcanic lithofacies, Qingshan Group, Jiaodong uplift, pyroclastic current deposit

The voluminous intermediate-acid volcanic rocks developed in Jiaodong Area in Cretaceous. Much work carried out are mainly about their petrologic, geochemical and chronological features. However, there are few studies about their lithofacies, at least out of proportion to their size. Here, we systematically analyse the characteristics of the volcanic lithofacies of Bamudi and Shiqianzhuang Formations, Qingshan Group, in Jiaodong area via better outcrop sections, which contributes to understand the volcanism process, and their genetic mechanism.

The volcanic rocks' lithologies of Bamudi Formation are mainly basaltic andesite, andesite and trachyandesite, whereas those of Shiqianzhuang Formation being dacite and rhyolite. They all belong to calc-alkalic series. In term of the volcanic facies, in Jiaozhou area, being close to the southeastern margin of Jiaolai basin, the explosive and effusive facies coexist in Bamudi Formation as well as in Shiqianzhuangzu. However, as a whole, the proportion of explosive facies is much greater than that of effusive ones, though the proportion of the effusive facies in Banudi Formation is a little higher than that in Shiqianzhuangzu Formation. Field outcrop sections in this area show that there were many episodes' volcanic eruption in these two sets of strata. In Bamudi Formation, each eruptive cycle is mainly comprised of pyroclastic flow subfacies, which sometimes being overlain by thin lava flow and occasionally overlying on the pumice fall deposit. The fine ash deposit is hardly seen. The pyroclastic current deposits(ignimbrites) mainly consist of ash-rich lapilli tuff, being poorly sorted, matrix-supported and often reversely graded. Some lithic fragments usually existed in the lower part of pyroclastic deposit sequence. Under the influence of the emplacement temperature and the lithostatic load, the pyroclastic current deposits are usually shown as welded ignimbrite with fiamme and eutaxitic textures. Additionally, the block and ash flow deposit also developed in Bamudi Formation, which showed a chaotic jumble of lava blocks of various sizes in an ashy matrix, a large block being about twenty meters in diameter, whose distinctive prismatic joints proving the high temperature origin of the deposit. In Jiaozhou area, the overall characteristics of volcanic lithofacies of Shiqianzhuang Formation are similar to those of Bamudi Formation, except that the lava flow became more less developed, only being occasionally found on the top of some sections.

The volcanic rocks of the Shiqianzhuang Formation also extensively developed in the interior of Sulu orogen zone. Based on the outcrop section in Huangdao area, their volcanic lithofacies were apparently different from those in Jiaozhou area and mainly consisted of effusive facies, though the pyroclastic current subfacies also developed in some volcanic cycle sequence. Intriguingly, the base surge deposit can be seen in the bottom of a certain cycle, with poorly sorted and cross-laminated ash beds, possibly implying the hydrovolcanic eruption style. Additionally, spherulites and lithophysae texture developed well in the thick lava sequence, indicating the high-temperature devitrification of some initial glassy lava. The variable volcanic lithofacies of Shiqianzhuang Formation in the various areas possibly suggest that they have the different origin.

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Session T2-3: Impacts of volcanism on sedimentary systems
Presentation Preference: Oral Preferred

Impacts of Permian Ashfalls on Bioproductivity and Abundance of Organic Matter in the Zaysan Basin, Eastern Kazakhstan

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Keywords: Permian, ashfall, volcanism, anoxia, bentonite, Zaysan basin

Permian sedimentary deposits are well exposed in the Kenderlyk trough (Eastern Kazakhstan) which was structurally detached from the Zaysan basin in the Late Cenozoic. These deposits are underlain by thick Devonian-Carboniferous flow basalts and conformably overlain by Triassic clastic deposits. The formation of accommodation space and sedimentation during the Permian was largely controlled by the collision of Kazakhstan and Siberian plates. As a result of the associated dynamic interplay of thrusting, magmatism, and sedimentation, the Permian terrestrial and lacustrine clastic deposits are interbedded with numerous variably thick (centi- to multi-meter scale) volcanic ash deposits and scarce small lava creeks. Our field sedimentological studies coupled with pyrolysis [RockEval] results from black shale strata of Kenderlyk (C3-P1), Karaungur (P1), Tarancha (P1) and Maychat (P2) formations are characterized by thicknesses of up to 50 m and organic richness averaging 5-10% of total organic carbon (TOC). The correlation between volcanic ashfalls beds and organic richness suggests that ashfalls had both positive and negative effects on paleo-bioproductivity and organic matter preservation. The positive effect, evidenced by increased TOC above thin ashfall beds is in line with the concept that mineral nutrients introduced to seas and lakes by ashfalls may increase bioproductivity and cause algal blooms, which then deplete oxygen and form anoxia needed for the preservation of organic matter. The negative effect, evidenced by the absence of organic rich strata in the proximity of thick (2-5m) lacustrine bentonites, implies that water column anoxia caused by long-lasting volcanic activity significantly reduces and/or terminates bioproductivity.

The absence of macroscopically noticeable ash deposits in the bottom 30m of organic rich (10-12% TOC) Tarancha formation black shales may imply a long-lasting high bioproductivity and anoxia in a stratified lake water column that may have existed in the Zaysan basin without the interference of ashfalls. However, considering the tectonic setting, it is more likely that the ashfalls were present, but had a lower preservation potential in deeper parts of the basin. The above interpretations may serve as a proxy for identifying intervals of interest for source rock and/or unconventional resource characterization, and as a predictive and/or a risk assessment tool during basin analysis for exploration in frontier basins. The former is feasible because of an easy recognition of ashfalls in cores and logs, but the latter requires well-established paleo-volcanic age databases as well as the source of these ashes. A higher resolution sampling in cm scale intervals would shed more insights into the bioproductivity during and shortly after ashfalls. Future studies may focus on establishing the relationship between bioproductivity and compositionally different ashes as the amount of mineral nutrients and/or toxic elements may greatly vary depending on sources.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-3: Impacts of volcanism on sedimentary systems
Presentation Preference: Oral Preferred

Volcanic activities pacing gravity flows deposition process during the Late Carboniferous in the southern margin of Jungar Basin, China

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Keywords: Volcanic activities, Collapse, Gravity flows deposits, NTS volcanic island-arc, Upper Carboniferous Qianxia Formation

The North Tianshan (NTS) is an important tectonic unit of the Central Asian Orogenic Belt in Xinjiang, China. During the Late Carboniferous, a large number of volcanical-sedimentary rocks which were regarded as turbidites were deposited, which recorded the paleogeographic evolution of the Paleo-Asian Ocean. Understanding the space-time evolution of deep-water gravity flows, and how the deep-water gravity flows responds to the changes of sedimentary and tectonic setting, are a key research focus for gravity flow sedimentology. Based on field outcrop investigation, through the analysis methods of petrology, isotope chronology and geochemistry, the co-evolution of Late Carboniferous volcanic activity and deep-water gravity flow deposition in the southern margin of Junggar Basin is discussed. Research shows that volcanic activities not only lead to instability of slope sediments, triggers sediment collapse, and forms slump-type deep-water gravity flow deposition, but also provides important material sources for gravity flow deposition. The occurrence of volcanic beds in the slump deposits confirms that synchronous volcanic activity accelerates the sediments instability and triggers the gravity flow slump. The Upper Carboniferous Qianxia Formation's structural environment indicators of the volcanic rocks, such as Th / Yb, Ta / Yb, and Th / Ta; the U-Pb age of sandstone detrital zircons, the directional arrangement of pebbles and the paleocurrent direction indicated by the trough model all indicate that the volcanic island-arc of the NTS Mountains provides sources for the gravity flow deposition area. In addition, through the statistics of pyroclastics components in the gravity flow deposition process, the intensity index of volcanic activity is established. The index shows that the coupling relationship between volcanic activity and gravity flow deposition process is good, and volcanic activity controls the type and distribution of gravity flow deposition. From eruption period to intermittent period of volcanic activity, the sedimentary type of gravity flow transits from imported pebbly debris flow to slump-sandy debris flow. Based on the above research, the sedimentary evolution model of volcanic-triggered deep-water gravity flow is established, which provides reference for the prediction of Paleozoic deep-water gravity flow reservoirs in Junggar Basin.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-3: Impacts of volcanism on sedimentary systems
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Carboniferous structure, sedimentary environment and the filling evolution in Junggar Basin

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Keywords: Carboniferous structure, sedimentary environment, filling evolution

The Junggar Basin belongs to the paleo-Asian Ocean tectonic domain, which records the dynamic processes of the Central Asia accretionary Orogenic Belt from subduction-accretion-collision to later intracontinental reformation. Carboniferous is the key period from subduction to closure of the paleo-Asian Ocean. The complex ocean-continent evolution in this period created the hydrocarbon accumulation examples of Carboniferous in Junggar basin. However, the study of Carboniferous prototype basins is still relatively weak, which restrains the evaluation of Carboniferous source and reservoir conditions and favorable zones. Therefore, the study of Carboniferous tectonic framework and filling evolution in Junggar area can not only enrich the understanding of the structural evolution of the Central Asia accretive Orogenic Belt, but also play an important role in promoting the oil and gas exploration process of deep volcanic basins. In this paper, structural geology, geophysics, isotopic geochronology and geochemical methods are systematically applied to systematically analyze and study the Carboniferous chronostratigraphic framework, geological structure, geotectonic environment and sedimentary filling sequence in Junggar Basin and its adjacent areas by comprehensively using drilling, field outcrop, seismic and gravity and magnetism data. On this basis, the structural framework of Carboniferous in Junggar Basin and its adjacent areas, as well as the evolution characteristics of structural sedimentary environment under the background of multi-stage structure, are revealed.

The geochronological results of volcanic rocks drilled in the basin show that there are five stages of volcanic activity in Carboniferous in Junggar area. The regional unconformity boundary divides the Carboniferous system into two structural stratigraphic sequences: upper and lower Carboniferous. The lower Carboniferous is dominated by compressional structural deformation, with a large number of calc alkaline basalt, andesite, dacite and rhyolite developed. However, the upper Carboniferous is mainly controlled by extensional faults. The volcanic rocks are mainly middle basic volcanic rocks, and there are bimodal volcanic rock assemblages in some areas. Based on the analysis results of volcanic tectonic environment and the study of structural deformation, combined with the division scheme of Carboniferous structural belt in Junggar Basin and its adjacent areas, four Carboniferous arc basin belts are determined. There are many types of basins are also identified. Based on the establishment of the structural framework and the analysis of the sedimentary filling sequence of the Carboniferous basin, the evolution process of the Carboniferous structural sedimentary environment in Junggar Basin and its adjacent areas is divided into three stages, i.e. the compressional flexure stage related to the early Middle Carboniferous subduction, the extensional rifting stage related to the late Early Carboniferous Middle Carboniferous subduction and the intracontinental fault stage related to the Late Carboniferous Depression stage. The results not only reveal that the basement of young continental crust lies in the Junggar basin, but also indicate that the Junggar basin, its adjacent area and even the whole Central Asia accretive orogenic belt are formed in the process of multiple rows of South accretive arc basin systems colliding and splicing in turn to the north.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-3: Impacts of volcanism on sedimentary systems
Presentation Preference: Oral Preferred

Astronomical and volcanic forcing organic-carbon during Later Ordovician – Early Silurian in the Upper Yangtze area, South China

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Keywords: cyclostratigraphy,obliquity,δ13C,CIA,thermohaline circulation,volcanic ash

Astronomical and volcanic forcing organic-carbon during Later Ordovician – Early Silurian in the Upper Yangtze area, China was studied by cyclostratigraphic and geochemical methods. δ13C and CIA were used to filter the astronomical orbit parameters recorded in sediments. Orbital drving climate change controls the fluction of sea level changes at different scale. Obliquity forcing climate changes drives thermohaline circulation (THC) of the ocean, and THC-induced bottom current transports nutrient-laden water from high latitude regions to the surface water of low-latitude area. THC is the main dynamic mechanism of organic-carbon supply. In late Hirnantian (E4), the marine paleoproductivity from index of Ba/Al and Ni/Al indicates that volcanic activities have limited effect. However, volcanisms have great influences on organic carbon preservation efficiency. Paleo-environmental indicators(Th/U, V/Cr and V/ (V+Ni) show that there is a significant relationship between volcanisms and oxygen content in Paleo-ocean. Volcanisms control the organic carbon preservation efficiency by regulating oxygen content in Paleo-ocean. The difference of Volcanisms intensity in different areas is an important factor for the differential preservation. The organic carbon input of orbital driving and the preservation efficiency affected by volcanisms are coupled to control the enrichment of organic carbon in the middle-upper Yangtze region.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-3: Impacts of volcanism on sedimentary systems
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Response of gravity flow sediments to volcanic activity in the context of remnant ocean basin subductionA case of the margin of the Junggar Basin during the Carboniferous

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Keywords: Gravity flow, Carboniferous , Remnant ocean basin, West Junggar

We conducted a study of the types, spatial distribution, and evolution of Carboniferous deep-water sediment gravity flows and their associated deposits in the West Junggar region of northwestern China.Combining information obtained from outcrop sections and cores and seismic profiles, nine lithofacies associated with sediment gravity flows were identified and attributed to formation by slide-slump,turbidity currents, detrital flows, hyperpycnal flows. The characteristics of these gravity flow sediments are mainly controlled by the tectonic processes of the subduction of the West Junggar remnant ocean basin and volcanic activity.From the analysis of petrological and paleogeographical features, it is known that the early Carboniferous and Late Carboniferous gravity flow sediments have great differences in material sources and genetic mechanisms.We have identified 5 typical vertical lithofacies assemblages.Subduction-related tectonic activity and volcanism and earthquakes are the main triggering mechanisms for the development of sediment gravity flow. The influence of volcanism on gravity flow sediments is directly reflected in the content of pyroclastics in coarse-grained sediments and tuffaceous matter in fine-grained sediments.

In the Early Carboniferous, the West Junggar remnant ocean basin was in the early stage of subduction and demise. The basin had a relatively large accommodation space, and the gravity flow sediments had sufficient migration distance to complete the fluid transformation process of slump-detrital flow-turbidity current. During this period, there was relatively little terrigenous input, and the material sources of gravity flow sediments were mostly products of the unstable continental slopes. In the Late Carboniferous, with the shrinking and filling of the ocean basin, the accommodating space of the basin became smaller rapidly. At this time, debris flow sediments and slump sediments were the main types of gravity flow sediments. In addition, along with changes in paleoclimatic conditions, flood-related hyperpycnal flow deposits are extremely developed during the late Carboniferous.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-3: Impacts of volcanism on sedimentary systems
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Red and green volcanic paleosol within Late Cretaceous Deccan volcanics, India: their paleoenvironmental implication

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Keywords: Paleosol, Deccan volcanic province, Pedogenesis

The Late Cretaceous interbasaltic paleosols of Deccan volcanic province present a unique opportunity to understand the paleoenvironmental condition during the volcanism. The interbasaltic paleosols are named as bole beds [2,7,8,9]. This study presents a combined field, petrographical, mineralogical and spectroscopic characterization of different types of Deccan bole beds for reconstructing paleoenvironmental conditions during a lull in volcanism. These bole beds may vary in thickness from a few cm to a few meters. The bole may be either massive or bedded, and they exhibit variable geometry. The bole bed shows both sharp and gradational contacts with underlying lava flow . However, the upper contact of bole beds with overlying lava flow is always sharp [8,9]. Petrographic investigation of red boles shows gradation in texture and constituents from incipiently pedogenised red bole to moderately pedogenised red bole. The red bole with incipient pedogenesis contains volcanic lithic fragments (lathwork, microlitic and vitric), scoria, pyrogenic particles or monomineralic grains (plagioclase, pyroxene) as essential phase along with accessory iddingsite, zircon, quartz, opaque phases [8,9]. The vitric particles are variably altered to palagonite, clay and zeolite [4]. Moderately pedogenised red bole reveals the presence of highly altered basaltic clasts (100 µm to 5 mm), iron glaebules, alteromorph and oxidized fragments set in the groundmass of homogeneous red ferruginous, clayey material showing b-striations under cross nicol [8,9]. The presence of 2.21 µm, 2.24 µm and 2.29 µm absorption features in reflectance spectra of VNIR spectroscopy indicates a mixture of Al smectite (montmorillonite) and Fe-smectite as the clay mineral constituents in red bole [3,5,8,9]. X-ray diffraction confirms the presence of montmorillonite as the dominant clay in red bole [6]. Green boles, in contrast, are only incipiently pedogenised. They contain volcanic lithic fragments, plagioclase, pyroxene and green clay as an essential phase. Red clay, zeolite, apatite and opaques occur as an accessory phase. The green clay occurs as dissolution and alteration of plagioclase, volcanic glass, mafic minerals and pore-filling cement. Celadonite in green bole shows variation in composition with K_2O ranging from 7 to 9 wt%, Fe_2O_3 from 14 to 19 wt%, MgO from 4 to 6 wt% and Al_2O_3 from 9 to12 wt %. The random and oriented X-ray diffraction mounts of <2 µm clay confirm the presence of celadonite along with Fe-smectite as major clay in green bole [6,8,9]. Characteristic absorptions of equal strengths at ~2.30 µm ($Fe^{3+}Fe^{3+}$–OH combination) and 2.35 µm (Mg_3–OH combination) and a strong slope between 1.00 µm and ~2.10 µm under VNIR spectroscopy [3,5,8,9] and a sharp band at 3558–3560 cm^{-1} (Fe(III)OHMg or AlOHFe(II), 3581–3583 cm^{-1} (MgOHMg), 3604 cm^{-1} (AlOHMg), and a shoulder near 3539 cm^{-1} (Fe(III)OHFe(III) in FTIR spectra confirms the presence of celadonite [10]. Although both red and green boles form during the pedogenesis of basaltic detritus in subaerial conditions, the former represents oxic while the latter represents dysoxic depositional conditions [1,8,9] during the soil-forming process.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-3: Impacts of volcanism on sedimentary systems
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Volcanic-sedimentary stratigraphy and facies architecture of the early Cretaceous volcanism on Lingshan Island in eastern China and its implication on basin system

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Keywords: Volcanic-Sedimentary Stratigraphy, Volcanic facies architecture, Lingshan Island, Basin system

Understanding the volcanism in sedimentary basin is crucial for unraveling the evolution, sedimentary environment and tectonic setting of basin system. In this study, volcanic depotion on Lingshan Island are reported based on the newest Scientific Drilling (well LK-1) and typical field outcrops. The Lower Cretaceous stratigraphy sequence consists of two main groups: Laiyang Group and Qingshan Group. The former one represents a typical passive-rifting sequence which was divided in four units (stages) from the bottom to the top: fan delta (initial rifting), subaqueous fan (basin expansion), turbidite fan (deep rifting) and delta (uplifting) *(Yuan et al., 2019; Zhou et al., 2022)*. While the Qingshan Group represents a crustal doming stage in a volcanic arc environment *(Zhou et al., 2022)*. There isn't any volcanic deposits developed in the stages of initial rifting and basin expansion, while in the deep rifting stage, a suite of volcanic rocks were developed as the interlayers in deep-water sediments. Additionally, large amounts and various types of volcanic deposition developed in the Qingshan Group, including rhyolitic tuff, trachyandesitic lava and volcanic breccia, lamprophyre lava and sill. Based on the fieldwork description, different volcaniclastic lithofacies were identified: mLT, mLTf, mLBr, mscAg, sLT and fpoorT. The facies architectures of volcanic deposits in the whole strata were composed by the different combination between those lithofacies above. In Laiyang Group, the volcanic deposits are mainly single thin layer of mLT, which indicates they were the products of pyroclastic flow from nearby onshore volcanic eruption. While in Qingshan Group, lithofacies combinations varied a lot and changed frequently, which indicates that the sedimentary environment also changed frequently. Combining with the results of grain-size analysis, the volcanic deposits are products of pyroclastic flow, pyroclastic surge and fallout depositsand the explosive activities involve phreatomagmatic explosions and phreatic explosions. For distinguishing the participation of water in volcanic eruption, Laser-Raman analysis was used to ensure the type of feldspar of volcanic deposits in different volcanic phases. Sanidine were only found in the pyroclastic flow deposits in lower Qingshan Group which indicates that there was a short subsidence stage during the crustal doming period. This stage may be the subsidence stage of the passive-rifting in Laiyang period, suggesting a complete passive-rifting sequence was developed, which has not been proven before *(Zhou et al., 2022)*. It is very complex to distinguish the different geological event products during the tectonic transformation of the basin evolution because many processes are synchronous, while the volcanic facies analysis could be a very useful tool.

Note: The terminology used for the lithofacies follows *Branney and Kokelaar (2002)*.

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Session T2-3: Impacts of volcanism on sedimentary systems
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The effect of volcanic activity on carbonate deposition

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Keywords: Key words: volcanic activity, carbonate deposition, lithologic assemblage, diagenesis, biological succession

Abstract: Volcanism is the phenomenon in which lava (magma), pyroclasts, and volcanic gases are ejected to the Earth's surface through craters. Volcanic activity and volcanic substances have certain influences on the formation process of carbonate rocks and their depositional environment: (1) Lithologic assemblages. Due to the influence of pyroclastic materials, the composition, content and structure of carbonate rocks will change, and different lithofacies combinations and combinations (lenses, interlayers or interlayers) will be formed during the deposition process. (2) Diagenesis. Under the action of fluids rich in carbon dioxide and silica, siliceous metasomatism and cementation, dolomitization, and dissolution are prone to occur in carbonate rocks, resulting in the formation of authigenic minerals such as dolomite, calcite, and siderite, and "nodules", "clumps", "bands" and other geological phenomena. (3) Biological succession. The effects of volcanism on organisms and their growth conditions are divided into destructive and constructive effects. The volcanic eruption caused a large increase in carbon dioxide , which caused the ecosystem to be affected by acidification, resulting in the inability of some organisms to survive. In the early stage, some organisms died and were quickly buried. In the later stage, the pyroclastic sediments were redistributed, and the volcanic ash dissolved and released phosphate, silica, iron and manganese plasma to promote biological growth. (4) Sedimentary environment. Gases and volcanic ash erupted during volcanic eruptions can cause increased sunlight penetration, increased water temperature, water turbidity, changes in chemical properties (salinity, pH, etc.) and water eutrophication,which will ffect the deposition of carbonate rocks.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-3: Impacts of volcanism on sedimentary systems
Presentation Preference: Oral Preferred

The interactions of volcanism and clastic sedimentation in rift basins: insights from the Palaeogene-Neogene Shaleitian uplift and surrounding sub-basins, Bohai Bay Basin, China

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Keywords: rift basin, volcanism, depositional systems, sediment supply, landscape, Bohai Bay Basin

Although volcanism is an important process in the evolution of rift basins, current tectono-sedimentary models largely neglect its impact on sediment supply, transport pathways, and depositional systems. In this paper, we integrate core, well-logs, and 3D seismic data from the Palaeogene-Neogene Shaleitian (SLT) uplift and surrounding sub-basins, Bohai Bay Basin, China, to investigate the sedimentology and geomorphology of a volcanic rift basin. Results of this study show that the spatial distribution of extrusive centres was strongly controlled by basement-involved intra-basin normal faults. During the early part of the syn-rift stage, the SLT uplift supplied sediments to transverse fan deltas and braided-river deltas that fringed the adjacent syn-rift depocentres. Volcanic deposits mainly occurred as relatively thin lava-flow and pyroclastic facies that partially filled fault-controlled topographic lows, reducing topographic rugosity, and enhanced breaching of basement highs between syn-rift depocentres. Integration of drainage to the syn-rift depocentres and development of through-flowing axial depositional systems was enhanced. During the later part of syn-rift and in early post-rift stages, the SLT uplift was progressively inundated, reducing sediment supply to the fringing transverse depositional systems. In contrast, axial braided-river deltas became the main depositional systems, sourced by large hinterland drainage from the Yanshan fold-belt to the northwest. Volcanism in the late syn-rift and early post-rift occur as thick lava-flow and pyroclastic facies that infill rift topographic lows and locally blocked axial fluvial systems creating isolated lakes. Within hanging wall depocentres, volcanic topographic highs split and diverted axial fluvial and deltaic systems. Furthermore, volcanism supplied large volumes of volcanic sediment to the rift resulting in increased sedimentation rates, and the development of unstable subaerial and subaqueous slopes and deposits, increasing the occurrence of landslides. Based on the observations of this study we update tectono-sedimentary models for rift basins to include volcanism.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-3: Impacts of volcanism on sedimentary systems
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Impact of volcanism on the Lower Permian sedimentary System in the Northwest margin of Junggar Basin

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Keywords: Volcanism,Junggar Basin,The Lower Permian,Volcanic Rocks

Volcanism is a phenomenon in which lava, pyroclastics and volcanic gases are ejected through a vent to the surface of the earth. Volcanic eruptions may inject large amounts of pyroclastics and Volcanic gases into the atmosphere and into marine and terrestrial environmental systems.Volcanism has a huge impact on the sedimentary environment. In addition to provide source, affect the ecological environment and organic matter enrichment, change the local deposition (micro) environment, etc associated hydrothermal activity on the basin water salinity, pH, oxidation, and its subsequent effects need to be studied.Because the diagenesis of volcanic rocks is generally related to magmatic condensation, the burial depth reflects the performance of volcanic rock storage The sound is far smaller than the clastic rock reservoir.Volcanic rock reservoirs are often available in oil-containing basins where volcanic rocks are widely developed It has become an important target of deep oil and gas exploration and development, and often has the characteristics of thick yield, high yield and large reserves.

Junggar Basin Early Permian Jiamu River Formation-Fengcheng Formation evolved in the weakly extruded foreland basin.Carboniferous to the Early Permian, northern Xinjiang from ocean basin to continental basin conversion, that is, from Marine environment to continental environment .In the Early Permian, the complete closure of the Junggar residual ocean caused the land fissure and subsidence, accompanied by the eruption of a large number of volcanic rocks and the invasion of.The Junggar Basin Permian system is the result of the "overlap" of the lower extended basin and the upper extrusion basin, with the extended fault basin formed during the Early Permian period.The northwest edge of the basin, including Kebai and Wuxia reigion, is the western Junggar uplift belt, adjacent to Mahu depression, is Junggar plate and Kazakhstan plate collision suture, performance as the reverse cover fault zone in different directions, can be further divided into tip zone, broken step zone, leading edge belt and slope belt.

This study is to study the rock type, petrology and distribution characteristics of junggar Basin in the northwest margin of junggar Basin as an example, using the volcanic rocks of junggar Basin with earthquake, drilling and core analysis.During the deposition of the Jiamu River Formation on the northwest margin, its sedimentary boundary can extend northwestward to near the Darbute fault (the northwest boundary of the Late Carboniferous and Early Permian ancient Junggar basins, while its sedimentary center is located in front of the present-day Mount Zaire.The sedimentation phase diagram of the stroke city group indicates that the sedimentation boundary of the newer wind city group is greatly far away from the Darbute fault, with plane movement distances ranging from 10 to 20 k m.Overall, the migration distance of the sediment boundary (20~30km) is much greater than that in Hashan (about 10km).The study shows that the formation environment changes the eruption mode, the structure and structural characteristics of the eruption products, and the central plains of volcanic rocks The spatial type of raw reservoir set and its development degree and development law have great influence.

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Session T2-3: Impacts of volcanism on sedimentary systems
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Accumulation of a mixed clastic-lava apron: an example from El Hierro Island (Canary Islands)

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Keywords: clastic-lava apron, volcaniclastic, 3D model

Clastic aprons represent sedimentary architectures controlled by the accumulation of sediments at the toe of slopes or at the mouth of narrow valleys. The main mechanisms driving their progradation are represented by mass-wasting deposits, such as rock avalanches and debris flows. When apron progradation occurs on slopes of active volcanoes, lava flows could become fundamental in their construction and evolution. Despite the abundance of topographic empties created by volcanic lateral collapses, the literature lacks examples in this sense.

Therefore, this work explores stratigraphic, petrographic, and architectural features of a mixed clastic-lava apron developed on the SE flank of El Hierro Island (Canaries Island – Spain). Fieldwork, including mapping of main volcanic and sedimentary facies, measurement of 7 logs, 5 landscape-style photographs, and a digital elevation model has been assembled into a GIS database. Ten samples of clastic and lava beds have been collected for textural and minero-chemical analyses. Six of them have been cut into standard thin sections and analyzed under a polarized microscope for the identification of textural features

The result is a 3D architectural model of a clastic-lava apron developed onto a lateral collapse of multiple surfaces, where clastic sedimentation is constantly interrupted by the accumulation of thick basaltic lava flows that also drove the sedimentary geometries. Petrographic analyses highlight the presence, at the base, of a thick basaltic lava flow, where zeolites grew onto primary glassy groundmass. This basal level can be considered a sea paleo-level marker and could be further correlated across the entire Island.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-3: Impacts of volcanism on sedimentary systems
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Riphean extension characteristics of the hydrocarbon-bearing basins of the Siberian Craton margin

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Keywords: Siberia Craton,Riphean,sedimentary succession,magmatism,extension event

The Eastern Siberia Basin is one of the oldest petroliferous basins in the world. Riphean strata, as the main source of hydrocarbons for East Siberian oil and gas fields, is widely distributed in the craton marginal basin. Thus, the dynamic settings of the cratonic marginal depression basin plays a key role in controlling the distribution of oil and gas resources in this area. The sedimentary succession corresponding to the extensional basin and mafic dyke swarms can be used as key clues for the identifying of the Riphean Extension in Siberian margins. A common feature of the Riphean stratigraphy in the Siberian craton is their gradual thickening towards the cratonic boundaries, representing passive continental margin depositional features during the Rifting process, which indicating that the Siberian Craton margin probably faced an open ocean during the Meso- and Neoproterozoic. These passive continental margin depositional sequences developed along the eastern, southern, western, and even northern margins of the craton, forming several extensional basins such as the Pre-Patom Basin. The Riphean extensional magmatism of the Siberian Craton shows different characteristics in different periods. In the Early–Middle Riphean, the mafic dykes were mainly distributed in the northern part of the craton, probably associated with intraplate extension result from the mantle plume. The mafic magmatism in Late Riphean was widely developed in the southern part of the craton, associated with the Rodinia supercontinent rifting and opening of the Paleo Asian Ocean, which migrated from the southeast to the west. The Riphean evolution process of the Siberia Craton southern marginal basin: continental rift (~1 000 Ma), the opening of the ocean (~850 Ma), and the formation of the foreland basin (~ 650 Ma) were reconstructed.

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ID: T2-31735

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-3: Impacts of volcanism on sedimentary systems
Presentation Preference: Oral Preferred

Volcanic architecture and its related processes on sedimentary evolution in salt-walled mini-basin --Example from Cretaceous post-rift marine depositional system, offshore Brazil

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Keywords: Volcanic architecture, mini-basin, sedimentary fill history, magmatic processes

The preserved volcanic and sedimentary expression of mixed successions accumulated in salt-walled mini-basins records the complex subsidence of basin evolution, the style of sedimentary stratigraphy, and the pattern of igneous rock distribution in response to a range of magma processes throughout the evolution of such basin. This paper provides an example of the control of volcanism on the evolution of post-salt sedimentary strata in a salt-walled mini-basin, offshore Brazil.

In this paper, 3D seismic data was integrated with biostratigraphic, petrophysical, geochronological and petrographic information from several drilled boreholes of the offshore basin, southeast brasil. The interpretation of 3D seismic data adopts a multidisciplinary method to integrate the insights of structural geology, stratigraphy and volcanology into a unified model to explain the geological characteristics of the studied area.

Compared with the surrounding sedimentary strata, igneous rocks show high impedance properties on the seismic profile. Various volcano-related facies, such as laccoliths, dikes, and sills, are frequently observed in the volcanic system. Sub-volcanic zones can be associated to uplift and arching of pre-eruptive strata deformed by laccoliths, dikes, and sills. According to the temporal and spatial filling patterns and changes of sedimentary thickness, the spatial location of volcanic crater and the relationship between sedimentary rocks and intrusive rocks beneath volcanic cones, the history of sedimentary filling history and/or mini-basin subsidence and active period of magmatism can be constrained.

This paper demonstrates a range of sediment–magma interactions, which demonstrate the current understanding of sedimentary fill history response to magmatic processes in a salt-walled mini-basin evolution.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-3: Impacts of volcanism on sedimentary systems
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Sedimentary characteristics and the significance of volcanic ash in organic-rich shale of Shahejie Formation in Jiyang Depression, Bohai Bay Basin, China

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Keywords: Volcanic ash, organic-rich shale, Shahejie Formation, Jiyang Depression

Most of the organic-rich shales of the world's source rock are deposited with volcanic ash layers. For one reason, the volcanic ash is the provenance of the sedimentary basin; for another, the substances and energy of volcanism carried before and after its subsidence process can change the physical, chemical, and biological fields of the sedimentary water column, and thereby changing the primary productivity and the preservation environment of organic matter in sedimentary basins. Therefore, this paper takes the organic-rich shale of the upper submember of Member 4 (E_{s4s}) and the lower submember of Member 3 (E_{s3x}) of the Shahejie Formation in the Jiyang Depression as the research object, by comparing and analyzing the sedimentary characteristics of organic-rich shales, which deposited with volcanic ash layers, we discussed the impact of volcanism on the formation and preservation of organic-rich shale, obtained the following understandings:

(1)The tuff of the organic-rich shale layer in the E_{s4s} and the E_{s3x} is composed of variable-sized volcanic debris. The volcanic debris in the tuff layer is coarse to fine from the bottom to the top in the organic-rich shale layers. Furthermore, there are biological debris and glass fragments in the thin piece of tuff layers. The irregularly shaped glass fragments mean less roundness and closer handling distances. XRD shows that the content of crispy minerals in the tuff layer sample is 0.0-56.1% (11.7% on average), and the content of clay minerals is 0.0-49.8% (25.7% on average). The clay mineral is dominated by the mixed layers of illite and montmorillonite. Other components in the tuff layer sample are rhodochrosite, magnesite, pyrite, galena, barite, and common pyroxene.

(2)The TOC in the upper and lower sections of the volcanic ash is richer than that in the volcanic gray section, but generally not more than 6%. Furthermore, the content of the TOC is not more than 0.5%, which is generally low in the roller gray section or gray mud section. XRF shows that the main element components of the tuff layer sample of the E_{s4s} and the E_{s3x} are SiO_2 (28.22-69.43%), CaO (0.49-41.85%), and Al_2O_3 (2.54-16.71%), followed by Fe_2O_3, MgO, K_2O. ICP-MS shows the tuff layer samples have enriched light rare earth elements (LREEs) represented by $(La/Yb)_N$ (subscript N denotes the chondrite normalized) ratios of 15.04-87.22 (29.19 on average). They mainly show slightly negative Eu anomalies in the chondrite-normalized REE patterns $2(Eu)_N/(Sm+Gd)_N$=0.22-0.27, 0.27 on average).

(3)The comprehensive sedimentary and geochemical analysis shows that the nutrients (Fe, Cu et al) carried by volcanic ash have promoted the biological bloom during the deposition of the E_{s4s} and the E_{s3x} and therefore improved the primary productivity. Furthermore, biological bloom consumed an amount of oxygen and quickly formed the hypoxic environment that was conducive to the burial and preservation of the organic matter.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-3: Impacts of volcanism on sedimentary systems
Presentation Preference: Oral Preferred

Volcanic influence on stratigraphic evolution of terrestrial rift-platform environments, Olduvai Gorge, Tanzania

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Keywords: sedimentology, volcaniclastic, fluvial, lacustrine, geochronology, archeology

Volcaniclastic sediment delivery to a rift-basin setting influences the spatial distribution and temporal evolution of sedimentary environments and their paleoecology. Additionally, intercalated tephra can provide high-quality ages to quantify sedimentary processes and rates of environmental change. Olduvai Gorge, Tanzania is a world-renowned archeological site; it's steep valley walls expose a Pleistocene terrestrial-to-lacustrine succession with frequent volcaniclastic input. Here, we utilize 40Ar/39Ar dating and detailed sedimentary characterization to quantify temporal and spatial variations in depositional environments and sedimentation rates from ~2 to 1.7 Ma.

Western Olduvai Gorge exposes ~45 m of rift-platform basin stratigraphy. Previous studies have characterized the stratigraphy and identified key marker tuffs, however, a detailed evaluation of sedimentological relationships at a finer scale has yet to be undertaken. We present bed-scale sedimentological characteristics compiled from seven measured sections that document bedding, grain size, and sedimentary structures, aided by thin-section analysis to characterize texture and mineralogy. A digital outcrop model was constructed to aid with physical correlations and stratigraphic architecture analysis. Samples of tuffs and an ignimbrite were separated for k-feldspar phenocrysts (i.e. sanidine) and dated by 40Ar/39Ar geochronology; additional geochemical analyses further support marker tuff identification and correlation.

Our results demonstrate spatial and temporal variations in depositional environments under changing conditions of volcanic activity. The lower portion of the succession is dominated by volcaniclastic input. The basal Naabi Ignimbrite (2.038 +/- 0.002Ma) is overlain by a thick volcaniclastic fan succession, including mass flow diamictites, weakly developed paleosols, and small-scale fluvial channel deposits. As volcanic mass flow events diminish, a lacustrine-to-fluvial system develops from east to west and is characterized by waxy clay lacustrine sediments and coarse-grained fluvial channel deposits, capped by a fluvially-reworked tuff (IA; 2.019 +/- 0.002 Ma). Lacustrine shoreline mud-flat deposits with episodic tuffaceous input persist throughout the remainder of the succession and contain thick intercalated tuffs (IB 1.867 +/- 0.006 Ma; IC 1.852 +/- 0.027 Ma). During times of high volcaniclastic input, we document sedimentation rates of ~1 m/ka; as the lacustrine-fluvial system develops, rates decrease to 0.02 m/ka. This change may be attributed to a combination of diminished volcaniclastic sediment input and decreased basin subsidence during a period of rifting quiescence. The decrease in sediment input is further supported by the development of persistent lacustrine environments in an endorheic basin. Overall, our study demonstrates rapidly changing environmental conditions driven by sediment input sources and basin subsidence. These results are applicable to analogous terrestrial-lacustrine settings globally and refine the paleoenvironmental context for past and future archeological discoveries at Olduvai Gorge.

Session T2-5 Tethys tectonics and sedimentation

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-5 Tethys tectonics and sedimentation
Presentation Preference: Oral Preferred

Records of oceanic and climatic changes in sedimentary evolution of Cretaceous basins in NW Turkey (Central Pontides)

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Keywords: Black Sea Basin, Pontides, Paleoclimate, Cretaceous OAE, NW Turkey

Stable isotopes values (O, C) of the bulk samples are obtained from measured stratigraphic sections in Cretaceous successions (Hauterivian-Barremian, Aptian, Cenomanian-Turonian) around Central Pontides (NW Turkey), (Hu et al., 2012a,b; Yilmaz et al, 2004, 2010 and 2012).

Lower Aptian platform carbonates of Pontides are generally composed of alternation of alternation of sandy limestone and subtidal facies. Average paleotemperature data in Pontides is 31,210C. Lower Aptian pelagic equivalents in Pontides display 24,380C in average. This change is interpreted to be related to OAE1a in the basin (Yilmaz et al, 2004, Hu et al., 2012a,b).

Hauterivian –Barremian platform carbonates of Pontides display different sedimentary evolution and present a drowning of the carbonate platform in western part. Presence of black shales over the drowned platform is related to the Faroni Event in the basin (Yilmaz et al, 2012). However, the Barremian is represented by shallow water carbonates in the north. Hauterivian platform carbonates display 16,170C and pelagic Barremian presents 26,030C. However shallow water Barremian displays 35,100C in the north.

Average paleotemperature value obtained in pelagic Late Cenomanian in Pontides is 24.50C and average paleotemperature of Early Turonian is 22.80C. Record of OAE2 within these pelagics are correlated in the whole basin (Yilmaz et al, 2010).

Temperature values fit to Global Cretaceous ocean values in Mediterranean Tethys Ocean, and it has been seen that there is good correlation of Cretaceous Global Events in Pontides (NW Turkey) successions. Paleotemperatures of platform and equivalent pelagics displayed considerable difference and can be used in global and regional correlation.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-5 Tethys tectonics and sedimentation
Presentation Preference: Oral Preferred

Geochemical characteristics of the Kındıralık Dere formation: New insight into Late Cretaceous evolution of the Eastern Pontides, NE Turkey

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Keywords: Eastern Pontide, Geochemistry, Cretaceous, Sandstone

The Eastern Pontides, as eastern contination of the Alp-orogenic belt, has a complex Mesozoic geodynamic evolution that is highly controversial. The Upper Cretaceous sedimentary successions constitute important products of Mesozoic geodynamics evolution of Tehysan basin. One of the important units is Kındıralık Dere Fm., which commonly known as yellowish sandstone lithofacies. The sandstone unit preserve important implications for paleoenvironmental conditions and tectono-sedimentary evolution of Tethys Ocean.
The sandstones are mainly sublithic-calclithic arenites in lithology showing poor textural maturities. They are mostly represented by relatively low SiO2 values and high CaO values, high CIA and CIW (98,99-99,35), wide range of SiO2/Al2O3, Cr/Th, La/Co, La/Sc , Co/Th, Zr/Sc vs Th/Sc. Their geochemical features, where sediments were subjected to intermediate weathering conditions and rapid erosions, and were finally transported to the studied area. The petrographic and geochemical characteristics imply that the sediments may have experienced relatively intermediate weathering processes and slight reworking and recycling processes with a short transport distance before deposition in the basin. The geochemical results show that the terrigenous fragments were derived from the acidic and intermediate products of an arc magmatism. The studied samples can be considered as transgressive series were deposited on slopes or the deep shelf basin at a complex CIA setting under a well oxygenated condition, which are most likely a extensional tectonic setting.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-5 Tethys tectonics and sedimentation
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

The paleogeomorphic background and tectonic evolution of the Qaidam Jurassic Basin

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Keywords: Qaidam Basin,Jurassic Basin, paleogeomorphic background, Tethys Ocean,tectonic evolution

The development of the Qaidam Jurassic Basin is inseparable from the pre-Jurassic tectonic evolution in this area. Before the Jurassic, the area experienced three major tectonic evolution and transformation stages. (1) The Cambrian-Early Silurian was the formation and development of the Qinqikun ocean basin and the closed-collision orogenic stage of the Early-Middle Silurian. The Sinian-Ordovician sedimentary caprocks are formed, and two types of sedimentary assemblages are mainly developed: the first type is distributed in the Quanji-Oulongbuk Mountains in the northern margin of the Qaidam Basin, which is platform-type stable sediments, and consists of shallow metamorphic carbonate rocks, clastic rocks, etc. It is characterized by rock assemblages (excluding volcanic rocks); the other type is distributed in the periphery of the Qaidam block, represented by the Tanjianshan Group, which is an orogenic belt-type active deposition, with fine-grained clastic rocks and thin-bedded carbonate rocks as the Features (including volcanic rock assemblages). (2) The Late Devonian-Carboniferous period was the formation of the Southern Kunlun Ocean (Paleo-Tethys) and the development of the trench arc basin system, the closure of the Permian, and the stage of the South Qilian epicontinental sea. It is the upper Devonian-Permian sedimentary caprock. After the Middle Devonian, due to the formation of the Eurasian unified plate, a new stage of sedimentary basins began to develop in the Qaidam area and its periphery in the Late Devonian. A set of clastic rocks and carbonate rocks of the marine-terrestrial interaction facies were deposited in the margin and South Qilian area. (3) The Middle Permian-Middle Triassic was the formation of the Jinshajiang Ocean and the development of the island arc basin, the end-Triassic-early Jurassic collision and closure, and the strike-slip thrust orogeny stage in the northern margin of the Qaidam and the southern Qilian. The Jurassic-Cenozoic sedimentary caprocks are formed. The Jurassic and its overlying Mesozoic and Cenozoic are the most important sedimentary caprocks in the Qaidam Basin, as well as the main hydrocarbon-bearing layers in the Qaidam Basin.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-5 Tethys tectonics and sedimentation
Presentation Preference: Oral Preferred

Tectonic stress influence the reliability of paleomagnetic data from the Upper Cretaceous redbeds in the Lhasa Terrane

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Keywords: redbed, AIRM, CPO, India-Asia collision, Lhasa terrane

The paleomagnetic results from the Lhasa terrane are commonly used to constrain the shape and paleo-position of the southern margin of Asia before the India-Asia collision. However, the reliability of the paleomagnetic data from the Upper Cretaceous sedimentary rock in the Lhasa terrane has long been under debate. We use the anisotropy of magnetic susceptibility (AMS), the anisotropy of isothermal remanent magnetization (AIRM), and the crystal preferred orientation (CPO) to analyze the remanence-carrying ferromagnetic minerals in the redbeds of the Shexing Formation. We found that no matter what structure the AMS data show, the AIRM data of these redbeds indicate a deformational magnetic fabric, whose minimum axes are roughly corresponding with the c-axis of hematite. We suggest choosing AIRM as the substitution of AMS to estimate the reliability of the paleomagnetic data from sedimentary rock. We recommend the data from the Upper Cretaceous redbeds in the Lhasa terrane should not be used for paleogeographic reconstruction before careful correction of the remanent magnetization direction, which calls for a full understanding of the deformation process of the rock.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-5 Tethys tectonics and sedimentation
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Major, trace elements and Sr isotope characteristics of Guadalupian bedded chert in the north margin of Yangtze religion: Implications for chert source, depositional environment and palaeooceanographic

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Keywords: Permian Chert Event, Sr isotope, Conodont, geochemical, Guadalupian

Unusual chert accumulation depositions were well developed worldwide in the Permian with a time span of tens of millions years, and are known as Permian Chert Event (PCE). In the Upper Yangtze region, the Middle Permian cherts are widely distributed and occurrenced in the form of nodule and bedded. In the northern and eastern of the Sichuan Basin, bedded cherts is developed near the boundary between the Midlle Permian Maokou Formation and the Upper Permian Wujiaping Formation. Based on the identification of micro paleontological fossils of limestone interbedded with bedded cherts from the middle and upper part of Maokou Formation to the bottom of Wujiaping Formation in northern Sichuan, the results show that the bedded cherts belong to the Capitanian of the Guadalupian and are the same age as the Gufeng Formation in the middle and lower Yangtze region. Geochemical analysis indicates that the bedded cherts have high Al/(Al+Fe+Mn) values ranging from 0.6 to 0.7, which are non-hydrothermal chert, and the large number of siliceous radiolarians observed in microscopic thin sections suggests that the silica origin of the Guadalupian bedded cherts is mainly biological. The LaN/YbN value, δCe, LaN/CeN value and diagram of LaN/CeN-Al2O3/(Al2O3+ Fe2O3) indicate that the cherts formed in a pelagic basin far from land. The measured 87Sr/86Sr values of cherts (HNO3 plus HF dissolved) range from 0.706903 to 0.708298, and after correcting with the Sr and Rb values of samples, the initial 87Sr/86Sr values ranging from 0.706315 to 0.707568, which is consistent with the global 87Sr/86Sr values of the Guadalupian. The 87Sr/86Sr values of seawater decreased to the lowest in the Paleozoic during the Capitanian at the end of the Guadalupian, which is related to the eruption of basaltic rocks in Emeishan and the addition of mantle-derived strontium in seawater at that time. In addition, the agreement of 87Sr/86Sr values of bedded cherts with those of seawater during the same period further indicates that the genesis of cherts was dominated by seawater deposition, but indirectly influenced by the eruption of the Emei Mountain basalt.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-5 Tethys tectonics and sedimentation
Presentation Preference: Oral Preferred

Feature and origin of the Late Jurassic sandy neptunian dykes in the Tibetan Tethys Himalaya

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Keywords: Quartzose sandstone, neptunian dyke, syndeposition, Late Jurassic, Tethys Himalaya

Neptunian dykes/sills (nepdykes) are widely recognized through the Phanerozoic sequence. In general models, nepdykes are commonly formed in older rocks, few were formed in the syndepositional (unlithified) sediments, and nepdykes have been interpreted to form under two main tectonic circumstances. In compressional tectonic settings, nepdykes typically form due to liquefaction when over-pressurized conditions lead to the injection of sands into the overlying strata. This produces nepdykes that are composed mainly of sandstone. In extensional tectonism, nepdykes are typically considered to form when rocks are fractured and are infilled with much younger pelagic sediments, nearby-sourced talus, and precipitated carbonates. These nepdykes have been largely reported in the Jurassic-Cretaceous sequences in western Tethys, but are rare in eastern Tethys. In those examples, nepdykes are composed of non-sandstone and developed within lithified platform deposits and some in the pre-Triassic granites and gneiss.

During the investigation of the uppermost Jurassic strata in the Tibetan Tethys Himalaya, we discovered a great number of a new type of sandstone nepdyke which differ from previously reported styles. We characterized the nepdykes and their host rocks through a comprehensive field study, together with petrographic observations and detrital zircon U-Pb dating.

Field investigations show that the nepdykes are meters to hectometers long and centimeters to meters thick. The nepdykes taper downward at relatively high angles and crosscut country rocks. Microscopic observations show that the sandstones within the nepdykes and the sandstone host rocks consist of predominant quartzose grains set with muddy matrix and moderate-bad sorting and roundness, and share the same detrital zircon U-Pb age clusters (600−500 Ma and 1000−800 Ma). Using available biostratigraphy data, we propose that both the nepdyke and stratal sandstones are contemporaneous in deposition and share the same provenance, implying the quartz sands were transported in a mass/gravity current to infill existing tensile fractures. There is no evidence of ptygmatic folds, liquefaction, or shale fragments observed within the nepdykes, indicating the tensile factures were yielded in an extensional tectonic setting which are consistent with the rifting tectonic circumstance within the East Gondwana.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-5 Tethys tectonics and sedimentation
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Provenance of sandstones related to pre, syn and post-rifting of N Gondwana: evidence from detrital zircon geochronology (Antalya Complex, E Mediterranean)

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Keywords: Ordovician to Eocene, Sandstone provenance, Zircon geochronology, Antalya Complex, N Gondwana

Detrital zircon geochronology of the Antalya Complex (=Antalya Nappes) sheds light on the pre, syn- and post-rift sedimentary-tectonic development of N Gondwana, related to opening and closure of S Neotethys in the E Mediterranean region. Recent fieldwork indicates that the Antalya Complex in its easterly (Güzelsu) outcrop includes three main thrust sheets of Lower Paleozoic-Upper Cretaceous platformal sediments, underlain by structurally dismembered Middle Triassic-Upper Cretaceous deep-sea sediments, Triassic volcanics and sparse ophiolitic rocks (imbricated thrust sheets and melange). The allochthonous units are restored as a pre-rift platform, Triassic rift and later-Mesozoic passive margin that bordered S Neotethys. The Antalya allochthon was assembled during the latest Cretaceous and finally emplaced onto the adjacent Tauride carbonate platform during Paleocene-Eocene.

Detrital zircons were extracted from 7 representative sandstone samples, previously dated (paleontologically) as Ordovician to Eocene, and then analysed for U-Pb ratios by LA-ICP-MS, yielding 700 discrete ages. For the upper structural units (platformal), the Ordovician (n=1) sandstone yielded abundant 600-740 Ma ('Pan-African') and Tonian ages, together with less pronounced clusters at 2.0 Ga and 2.6 Ga. The Upper Permian sandstone (n=1) has similar Precambrian-dominated zircon populations, mainly clustering in the Ediacaran (610 Ma peak), Tonian (950 Ma peak) and Paleoproterozoic (2.0 Ga). For the lower structural unit, Middle-Upper Triassic sandstones (n=2) contain abundant Precambrian detrital zircons, with major age peaks at ca. 640 Ma, 960 Ma, 1.9 Ga and 2.5 Ga, together with Devonian-Carboniferous (3%) and Triassic (1%). One sample of uncertain age (Jurassic-Cretaceous) is dominated by Neoproterozoic detrital zircon clusters (630 Ma peak), together with rare Devonian (1%) zircons. Another sample also of uncertain age (U. Triassic or U. Cretaceous) is Cretaceous based on a similar zircon age spectrum including Carboniferous zircons (299-343 Ma; 18%) together with rare Cretaceous (91 Ma) zircons. The Upper Paleocene-Eocene sandstone of the regionally underlying, autochthonous platform is dominated by Precambrian zircons, with Ediacaran (ca. 635 Ma), Tonian (750 Ma and 930 Ma) and also minor Paleoproterozoic (1.9 Ga) and Archean (2.5 Ga) fractions. Late Carboniferous zircons (7%) peak at 310 Ma, whereas Permian is minimal (n=1). Th/U ratios suggest that all of the Ordovician-Late Cretaceous grains analysed from all 7 samples are likely to be of igneous origin.

The Ordovician zircon age spectrum is consistent with a NE-Gondwana provenance. The Triassic sandstones include Late Paleozoic zircons that probably resulted from exhumation/reworking of Upper Paleozoic Paleotethyan units farther north, together with a more local rift-related Triassic source. The Upper Cretaceous terrigenous sandstone is interpreted as belonging to a foredeep, related to initial emplacement of the Antalya Complex. The upper structural units have few Late Paleozoic zircons, whereas the lower structural units have minor to common Devonian-Carboniferous grains. The early Cenozoic detrital zircon age spectrum is consistent with field and petrographic evidence of derivation from the Antalya Complex during its final emplacement onto the Tauride carbonate platform. Overall, the dominant NE Gondwana provenance is similar to tectonically transported rift/passive margin units elsewhere in the E Mediterranean; e.g., Taurides elsewhere, Cyprus, Crete and the Peloponnese (Greece).

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-5 Tethys tectonics and sedimentation
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

The significance of Tethys domain tectonic evolution to the petroleum system: a case study of Central Sumatra

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Keywords: Central Sumatra, Tethys domain, Sediment provenance, hydrocarbon resources

The Tethyan tectonic domain is acknowledged as a worldwide petroleum enrichment area. Central Sumatra Basin is the most oil-rich basin in S-SE Asia, the study of its structure and sedimentary evolution can not only understand the law of oil and gas enrichment in this area and implement its oil and gas resource potential, however, it is also necessary to define the resource influence of the Tethyan tectonic domain 's evolutionary process. Affected by the subduction of Indian ocean crust to the continental margin of SE Asia, early-middle Eocene to early Oligocene, the environment of alluvial fans, rivers, and lakes in the basin contributes to the formation of major source rocks under the action of back-arc expansion. Early Miocene, regional thermal settlement stage, formed sandstone reservoir mainly composed of Sihapas Formation. From middle-middle Miocene to the late Miocene, the Indo-Australian plate was subducted obliquely and most tectonic units in the basin were active. A large number of traps composed of anticline and faults have been formed. Due to crustal thinning and subsidence, the maturity of source rocks in different zones of the basin also varies greatly. The average geothermal gradient value in the basin is 4.98 ℃/100m, and Pedada Oilfield reaches 13.66 ℃/100m. Structural events caused by the subduction of the ocean crust make high heat flow values an important factor for hydrocarbon enrichment in this area.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-5 Tethys tectonics and sedimentation
Presentation Preference: Oral Preferred

MESOZOIC SEDIMENTOLOGICAL EVIDENCE IN THE BAINGOIN BASIN: CONSTRAINTS ON THE TIMING OF THE LHASA-QIANGTANG BLOCK COLLISION

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Keywords: foreland basin, Lower Cretaceous Duoni Formation, Lhasa-Qiangtang block collision, sedimentological, provenance, Tibetan Plateau

The Mesozoic sedimentary record in the central segment of the Bangong-Nujiang Suture Zone provides crucial information to constrain the timing of the Lhasa-Qiangtang block collision in the Tibetan Plateau. In this study, we perform detailed facies analysis and provenance analysis on the Lower Cretaceous Duoni Formation in the Baingoin basin, central Tibet. The nonmarine Duoni Formation widespread and unconformably overlies the Jurassic ophiolite and accretionary complex initially deposited in the lacustrine and deltaic environments adjacent to the shoreline, then evolved into a continental highland-related fluvial and alluvial environment upwards. Palaeocurrent data suggest a northward source for the lower portion and a southward source for the upper portion of the Duoni Formation. Quartzite clasts of the Conglomerates increase upward, and the composition of sandstones changes from greywacke to subarkose to quartz arenite upward. Detrital modal of sandstones supports a mixed to a recycled orogenic source transition through time. Zircon U-Pb dating of multiple interbedded andesite layers in the Duoni Formation indicates a depositional age at ca. 113 Ma. Collectively, integrated sedimentological evidence suggests that the Lower Cretaceous Duoni Formation was deposited in a collisional foreland basin system related to the Lhasa-Qiangtang block collision.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-5 Tethys tectonics and sedimentation
Presentation Preference: Oral Preferred

Sedimentary pattern influence of regional tectonic uplift: A case study of the Late Triassic in the southeastern Sichuan Basin of China

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Keywords: Tectonic uplift,sedimentary patterns,Sichuan Basin,Luzhou Paleo-uplift,Late Triassic

Regional tectonic uplift has a significant impact on regional sedimentary patterns. The Luzhou Paleo-uplift, which developed in the Sichuan Basin of Southern China during the Indochina period, sprouted during the sedimentary period of the early Triassic and died out in the Late Triassic, which had a significant impact on the sedimentation and ecological environment in the southeastern Sichuan Basin and was recorded in sedimentary strata. In the Luzhou Paleo-uplift core area, the Xujiahe Formation is directly covered above the Jialingjiang Formation, and the stratigraphic sequence is generally missing the Leikoupo Formation, but whether there is a sedimentary record of the firstsecond member of the Xujiahe Formation is still controversial, and the extent to which the paleo-uplift influenced the sedimentary patterns of the early Xujiahe period in the southeastern Sichuan Basin is unclear.

The study shows that the influence of the Luzhou Paleo-uplift on the sedimentary pattern in the southeast of the Sichuan Basin is limited, and the early strata of the Xujiahe Formation are still normally deposited. There are two main pieces of evidence: (1) Cyclostratigraphy: through the analysis of cyclostratigraphy, the sedimentary time of the XujiaHe period in southeast Sichuan was calculated to be about 5.9 Ma, which was basically consistent with the relatively complete stratigraphic development of the Xujiahe period in the Xuanhan Qilixia area of eastern Sichuan; (2) Sporomorph EcoGroup model analysis: sedimentary environment and biological succession were analyzed by SEG curves, and similar abundance changes were compared with the section of Tanba and Qilixia.

In addition, this study also shows that the Luzhou paleo-uplift affects the sedimentary differences between the East and West regions of the early Xujiahe period by controlling the regional sedimentary pattern, the eastern paleo-uplift region is dominated by continental sedimentation, and the western paleo-uplift is dominated by marine sedimentation. There are three main pieces of evidence: (1) Geochemistry: the ratios of Sr/Ba, MgO/Al_2O_3 and CaO/(Fe+CaO) indicated that the southeastern part of the Sichuan Basin was a freshwater sedimentary environment, It was not until the late sedimentary period of the first member of Xujiahe Formation, that the southeastern part of the Sichuan Basin began to transform into a marine sedimentary environment consistent with the whole basin; (2) Distribution of paleontology: The strata of the first member of the Xujiahe Formation in the western part of the Sichuan Basin contain abundant marine Lamellibranchia, while the eastern part is a large number of terrestrial plant fossils due to the uplift to land; (3) Stratigraphic distribution: the stratigraphic thickness of the Xujiahe Formation in western Sichuan is gradually thinning towards the eastern part of the basin. And the Xujiahe Formation of the core area of the Luzhou Paleo-uplift has been obviously thinner from firstthird member compared with other regions.

The above understanding is not only of great significance for determining the sedimentary time of the Xujiahe Formation and the comparison scheme of stratigraphic division in the basin at this period, but also has certain enlightenment for understanding the impact of regional tectonic uplift on sedimentary patterns.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-5 Tethys tectonics and sedimentation
Presentation Preference: Oral Preferred

The Anisian-Ladinian (Buntsandstein-Muschelkalk) paleogeographic evolution in W Tethys: biostratigraphic data from Sardinia (Italy) and regional correlation.

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Keywords: Palaeogeography, Middle Triassic, Western Tethys, Biostratigraphy, Sardinia

The Sardinian Middle Triassic successions (SMTs) have been studied from the end of the 19th century. Their importance in understanding the paleogeographic evolution of the southern margin of Paleo-Europe is long debated for its crucial significance. The SMTs, found in Germanic facies (Buntsandstein, Muschelkalk and Keuper), are reduced in thickness and they have been deeply dislocated by the alpine tectonics. Despite of this, they contain biostratigraphic key-elements allowing more precise insights about the modalities of the Western Tethys transgression. This westward transgression proceeded in a complex paleogeographic framework through a network of marine corridors, outlined by tectonically elevated blocks and subsiding areas. The present work focuses on the stratigraphical, sedimentological, and paleontological data of the Middle Triassic (Anisian and Ladinian) and aims in better understanding the paleogeographic evolution of the area.

To this end, the continental-to-transitional successions of Sardinia in Buntsandstein facies contain rich microfloristic associations that have been found mainly in key areas of the island (Iglesiente and Sarcidano-Gerrei, southwestern and central parts of Sardinia respectively). An extensive review of palynological content of these successions allows precise dating of the marine transgressive process and provides fundamental indications about the steps of the paleogeographic evolution of the island. In fact, during the late Anisian-early Ladinian period, Sardinia together with Minorca and the eastern area of Castellón (Spain), constituted an elevated area and acted as a barrier between the Paleotethys (in the northeast) and the Neotethys (in the southeast) domains.

The Ladinian shallow marine successions in Muschelkalk facies contain different and equally important paleontological elements (ammonoids, bivalves, conodonts, foraminifera etc.) and were deposited due to the regional transgressive episode recorded throughout the W Mediterranean. These biostratigraphic data, especially recorded in the Nurra region (northeast of the island), show the progressive westward settling of carbonate platforms, and consequently the development of new migration and irradiation routes for (i) the Sephardi faunas from the southeast (Paleotethys) and (ii) Alpine faunas (Neotethys) from the northwest.

The accurate study and revision of these associations allowed us to compare them with those of the adjacent domains (Balearic Islands, Levantine area) and to refine their paleoecological distribution. Moreover, the whole Anisian-Ladinian biostratigraphic record allowed us to better frame Sardinia in the paleogeographic evolution of the Western Tethys.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-5 Tethys tectonics and sedimentation
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Analysis on the Characteristics and Tectonic Significances of Triassic Volcanic Rock in Northwest Margin of Simao Basin

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Keywords: Triassic Volcanic Rock , Extensional Tectonic Environment , Rift Volcanic Rock Formation , Simao Basin

Simao basin is located in the southeast of Qinghai-Tibet Plateau and belongs to the Sanjiang tectonic domain in the east of Tethys tectonic domain. A set of Triassic volcanic-sedimentary rock strata dominated by basic volcanic rocks are exposed in the Manghuai - Dachaoshan area of Yunxian County on the northwest edge of Simao basin. The strata are completely exposed and have obvious rhythmic cycle characteristics. It is an ideal material for understanding the tectonic evolution of Simao basin and the southeast edge of Qinghai-Tibet plateau.

The Triassic volcanic-sedimentary rock strata are distributed between Lancangjiang fault and Jiufang fault in nearly north-south direction. They are in unconformable contact with Pre-Triassic strata and integrated or unconformable contact with overlying Jurassic strata. From bottom to top, the Triassic strata are divided into Manghuai formation and Xiaodingxi formation, the lower Triassic strata are missing. Among them, the Manghuai formation is divided into upper and lower segments, the lower segment is a set of andesite, siltstone and mudstone mixed with pyroclastic rock, and the upper segment is a combination of high potassium rhyolite and pyroclastic rock mixed with a small amount of basalt. The volcanic rocks of the Manghuai formation are characterized by high silicon and high potassium, which are calc-alkaline volcanic rocks.

The Xiaodingxi formation is a set of alkaline-subalkaline basalt, andesitic basalt with rhyolite, pyroclastic rock and sedimentary tuff, which can be divided into five sets of rhythmic layers composed of lava-pyroclastic rock-sedimentary tuff. Volcanic effusion facies and eruption facies, strong eruption and weak eruption occur alternately.

The SiO2 content of volcanic rocks in Xiaodingxi formation is concentrated between 47.94% ~ 54.02% and 76.92% ~ 84.16%. The basic volcanic rock is rich in sodium and the acidic volcanic rock is rich in potassium. Both basic and acidic volcanic rocks are rich in large-ion lithophile elements (LILE) and relatively deficient in high field strength elements (HFSE). The REE distribution curves are right inclined with enrichment of light rare earth (LRE). The basic volcanic rocks have weak Eu negative anomalies and the acid volcanic rocks have strong Eu and Sr negative anomalies.

The Triassic volcanic rocks are the result of subduction and closure evolution of Lancangjiang Ocean in the ancient Tethys, which completely records the transformation process from collision compression environment to post collision extension environment in the area. The volcanic rock assemblage has the dual characteristics of arc volcanic rock and intraplate volcanic rock, and the volcanic activity is intermittent and multistage. From 248 Ma to early Jurassic, there were at least five active periods of volcanism, with an interval of 8 ~ 10 Ma. Coupling tectonic and volcanic activity, the western margin of Simao basin experienced the evolution stages of pre-rift uplift and rift basin. To the late Triassic Carnian period, a set of rift volcanic rock formation was formed in the western margin of the basin.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-5 Tethys tectonics and sedimentation
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Study on hydrocarbon accumulation model of Paleogene-Cretaceous in North Sandaoqiao area of Tarim Basin

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Keywords: Sandaqiao, Tarim Basin, ternary controlled reservoir, structural trap, fault characteristics

In order to clarify the exploration direction of the Paleogene-Cretaceous in the northern Sandaoqiao area, the structural characteristics, formation and reservoir development are studied by using the comprehensive analysis technology of oil and gas accumulation, seismic inversion technology and core drilling data, and the conditions of oil and gas accumulation are discussed, and the controlling effect is analyzed, and the accumulation model is established. The results show that, under the influence of hercynian, Indosinian, Yanshan and Himalayan multi-stage tectonic movement and unconformity, faults and strata match to form structural traps, and oil source in Kuqa Sag is transported to Cretaceous and Paleogene traps along the migration network formed by faults and unconformity. Faults control the spatial distribution characteristics of oil and gas reservoirs. The unconformity between Paleogene and Cretaceous is an important channel for long-distance migration, and the paleogene plaster salt and mudstone cap is an important guarantee for long-distance accumulation. Based on the reservoir forming conditions and controlling effects, a reservoir forming mode of "lateral migration, vertical adjustment, three-way reservoir control and structural enrichment control" is established. It is pointed out that fault-controlled trap is the next favorable exploration direction in Sandaoqiao area.

Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-5 Tethys tectonics and sedimentation
Presentation Preference: Oral Preferred

Tectonic Evolution and Sedimentary Response of Yinggehai Basin

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Keywords: Yinggehai Basin,the Red River Fault Zone,Left-lateral Strike-slip and Right-lateral Strike-slip,Tectonic Evolution Stages,Sedimentary Response

Yinggehai Basin is located in the intersection of Eurasian plate, Indian-Australian plate and Pacific plate, and is one of the Cenozoic sedimentary basins in the western part of the continental shelf in the northern South China Sea. Its tectonic evolution is controlled by the plate collision caused by the intersection and recombination of the two tectonic domains of Tethyan-Himalaya and the Pacific. It is mainly the relative compression between the Indo-China block and the South China block caused by the collision between the Indian plate and Eurasian plate. The tectonic development of Yinggehai Basin has experienced three stages: rifting, left-lateral strike-slip and right-lateral strike-slip. The tectonic pattern and sedimentary response of different evolution stages are obviously different. Rifting stage (56-32Ma): The Yinggehai Basin is controlled by NW-trending boundary faults. The Yingxi slope zone, the central depression zone and the Yingdong slope zone are left-middle-right. During this period, the faults have strong vertical activity and obvious sedimentation control. The lacustrine Lingtou Formation and the swamp coastal plain Yacheng Formation are deposited, and the sedimentary center is located in the descending plate of No. 1 fault.Left-lateral strike-slip stage (32-5.5Ma): Affected by the left-lateral strike-slip of the the Red River Fault Zone (RRFZ), the vertical activity of the basin fault is weakened, and only the basin boundary fault has the characteristics of continuous activity, mainly the Yingxi fault and the Yingdong fault and the No. 1 fault, which control the sand body deposition from the Kunsong uplift in the west of the basin and the Hainan uplift in the east of the basin, respectively. The sedimentary center range is expanded to two large sedimentary centers, which are distributed in the southern part of the Lingao uplift and the descending plate of the No. 1 fault. Until the left-lateral strike-slip movement of the RRFZ is gradually stopped, the subsidence-controlling fault activity of the Yinggehai basin is reduced, the sedimentary rate of the basin is reduced, and the two sedimentary centers are merged. A new sedimentary center with smaller range is formed in the middle of Yinggehai Sag. From bottom to top, fan delta facies-shallow sea facies Lingshui Formation, shallow platform facies Sanya Formation, coastal facies Meishan Formation and shallow-semi-deep sea facies Huangliu Formation are developed. Right-lateral strike-slip stage (since 5.5Ma): Controlled by the right-lateral strike-slip of the RRFZ, the sedimentary center transited to the eastern part of the basin. Under the control of the continental shelf – slope break zone in the basin, the sedimentary center continued to migrate to the southeast of the basin. During this period, the faults were almost inactive, the sand bodies rapidly subsided, and the deposition rate reached the maximum. The shallow-semi-deep marine strata of the Yinggehai Formation of the Pliocene and the Ledong Formation of the Quaternary were deposited.Clearing the spatial and temporal differences of tectonic pattern and sedimentary response in Yinggehai Basin is of great significance for revealing the distribution of oil and gas.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-5 Tethys tectonics and sedimentation
Presentation Preference: Oral Preferred

Tectonic sedimentary evolution and overlapping unit division in Sichuan Basin

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Keywords: superimposed basin, basin superposition unit, basin evolution, vertical stratigraphic framework, sichuan Basin

Sichuan basin is located in the northwest of South China plate, and is located in the intersection area of Eurasian plate, Indian-Australian plate and Pacific plate. Its tectonic evolution is controlled by the intersection and combination of the two tectonic domains of Tethyan-Himalayan and the Pacific. In the tectonic dynamic background of the subduction of the ancient and modern Pacific to East Asia, the collision of the Indian-Australian plate and the interaction between plates wedged by the Philippine plate, Sichuan basin has experienced multiple tectonic movements such as Jinning-Chengjiang movement, Tongwan movement, Caledonian movement, Dongwu movement, Indosinian movement, Yanshan movement and Himalayan movement. It can be divided into five evolution stages : basement formation (Anz), marine sedimentary (Z-S), marine sedimentary associated with volcanism (D-T_2), continental clastic sedimentary (T_3-K_1) and differential denudation of whole basin uplift (K_2-Q). It has the characteristics of intracontinental basin formation, peripheral compression, multi-stage uplift, late denudation, planar composite and vertical superposition. The tectonic sedimentary pattern of the basin varies obviously in different periods. According to the vertical superimposed relationship of prototype basins in each stage, three types of superimposed units can be divided in Sichuan Basin.Type I : It is distributed in the Leshan-Longnvsi paleo-uplift, and continuously accepts marine stratigraphic deposition from Sinian to Ordovician. During the Caledonian movement in the late Silurian, it was eroded with the uplift of Leshan-Longnvsi paleo-uplift, and lacked stratigraphic deposition of Silurian, Devonian and Carboniferous. The continental clastic rock strata developed from Triassic to Jurassic, and only the sedimentary strata of western Sichuan foreland basin in the Cretaceous. After the late Cretaceous, the superimposed unit was eroded with the uplift of the whole basin. Type II : It is distributed in the range of Luzhou paleouplift and Kaijiang paleouplift. The Paleozoic sedimentary sequence is complete. During the Indosinian movement, it was eroded with the uplift of paleouplift, and the Triassic strata were missing. The Jurassic strata were deposited on it, and continued to be eroded until the late Cretaceous. Type III : distributed in the basin area except Leshan-Longnvsi paleo-uplift and Luzhou-Kaijiang paleo-uplift. Since the Paleozoic, marine and continental strata have been continuously deposited, and the vertical framework of strata is continuous. The northern Sichuan foreland basin area in the front of Longmen Mountain and the Chishui-Yibin area in the southern basin continue to accept the Cretaceous deposition, and then the other areas of the composite unit are subjected to differential erosion together. Different types of superimposed units have experienced different subsidence histories and have different combinations of source, reservoir and cover. Therefore, the division of superimposed units has important guiding significance for oil and gas exploration practice in Sichuan Basin.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-5 Tethys tectonics and sedimentation
Presentation Preference: Oral Preferred

Late Cretaceous to late Eocene exhumation in the Nima area, central Tibet: Implications for development of low relief topography of the Tibetan Plateau

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Keywords: Low temperature thermochronology, exhumation, internal drainage, low relief topography, Tibet

Much of the interior of the Tibetan Plateau is characterized by internal drainage, low relief topography and high altitude. How and when this landscape formed is controversial. In this study, we use new zircon U-Pb data and low temperature thermochronological data (apatite and zircon (U-Th/He), apatite fission track (AFT)) from the Late Cretaceous to Cenozoic Nima basin sedimentary rocks and Xiabie granite in the adjacent Muggar Thrust hanging wall (part of the regional Shiquanhe-Gaize-Amdo thrust system), to determine the palaeodrainage and timing of exhumation in the region. Individual AHe and ZHe cooling ages range from 9 to 60 Ma and 58-118 Ma, and the AFT ages range from 30-90 Ma. The thermal history derived from the Northern Nima Basin sediments and Xiabie granite require a period of exhumation between 70 and 40 Ma in the thrust fault hanging wall, and 40 to 30 Ma in the Nima Basin. Across the region this event was followed by low rates of exhumation and the deposition of locally-sourced sediment, lacustrine and evaporitic deposits that are indicative of an internal drainage system. We suggest that the exhumation event is associated with development of thrust-elevated relief that may have disrupted the drainage network favouring the development of an endorheic system. This system, sediment accumulation and/or post-30 Ma tectonic quiescence led to the generation of low relief topography.

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Scientific Themes: Theme 2. Tectonics & Volcano-Sedimentology
Session T2-5 Tethys tectonics and sedimentation
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Tectonic evolution Controlling on hydrocarbon accumulation in the central and western of the Tethys

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Keywords: Tethys,Paleo-uplift,Hercynian

The central and western section of the Tethys is an important oil and gas resource enrichment area in the world. The evolution cycle of the Tethys Ocean controls the formation of a pattern of east-west division and north-south division. The east-west division is represented by the Paleozoic basin in the west, the superimposed Paleozoic and Mesozoic basins in the middle, and the Mesozoic and Cenozoic basin in the east. The north-south division is shown in the north The Mesozoic and Cenozoic strata near the Tethys Ocean are developed, and the Mesozoic and Cenozoic strata far from the Tethys are not developed. The pre-Cambrian NS-trending paleo-tectonic belt laid the foundation of the tectonic framework and influenced the later sedimentary-tectonic framework. The Hercynian structure controls the appearance of the Paleozoic basin, strengthens or transforms the earlier structure, develops two types of paleo-uplift evolution and development models, and controls the distribution of Silurian source rocks and Paleozoic reservoirs. The Mesozoic-Cenozoic Hercynian new-genetic Paleo-uplift in North Africa was reversed to form a basin on the edge of the Tethys Ocean, which controlled the development of Mesozoic basins, the sedimentary centers of Mesozoic basins are mostly located in the Hercynian paleo-uplift area. While the Mesozoic in the Middle East shows an early extensional and late compressional basin model, forming an oil and gas accumulation model jointly controlled by a near-north-south structure, Hercynian structure, and Tethys extension.

Theme3

Environmental & Hazard Sedimentology

Session T3-1: Anthropocene sedimentology: From science to practice

ID: T3-10533

Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-1: Anthropocene sedimentology: From science to practice
Presentation Preference: Oral Preferred

Winter and Summer Sedimentary Dynamic Process Observations in the sea area off Qinhuangdao in the Bohai Sea

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Keywords: Sedimentary dynamic process, Winter and summer observations, Residual currents, Suspended sediment flux decomposition, Sea area off Qinhuangdao, The Bohai Sea

Using seabed base observation platform measurements obtained in February 2017 and August 2019, this study examines the winter and summer hydrography and suspended sediment concentration (SSC) in the sea area off Qinhuangdao in the Bohai Sea. In summer, accompanied with high temperature and low salinity, the relatively weak residual currents flowed northeastward and showed little correlation with the wind field, especially in the middle layer of the water column. In winter, the residual currents were strengthened, flowing to the northeast during strong wind periods, and predominantly to the southwest during intermittent periods. Moreover, driven by the pressure gradient force associated with the wind-induced sea surface height variations, the winter current was closely related to the wind speed, with correlation coefficients ranging from 0.4 to 0.6 and a time lag of 10 hours. The summer SSC was lower and mainly controlled by the tidal current, whereas in winter, owing to the enhanced Reynolds stress and turbulent kinetic energy, strong wind bursts triggered significant sediment resuspension and led to a higher SSC. The frequent sediment resuspension in winter further reduced the consolidation degree of the seabed sediment. For the suspended sediment flux (SSF), the advection terms contributed more than 80% in the winter and summer, while the vertical circulation terms contributed 13% in winter, and approximately half that much in summer. Generally, the suspended sediment is transported back and forth, with a little net northward and northeastward motions in winter and summer, respectively. This may explain the low SSC sustaining in coastal Qinhuangdao all year round.

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Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-1: Anthropocene sedimentology: From science to practice
Presentation Preference: Oral Preferred

Morphodynamic evolution of the macro tidal Sittaung River Estuary, Myanmar: Tidal versus seasonal controls

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Keywords: tide-dominated estuary, bedload convergence, morphodynamics, tidal bore, river flood, anthropogenic activity

The inner part of a tide-dominated estuary is often typified by a tight meander bend, where bedload transport from both upstream by river flows and downstream by flood tidal currents merges to establish a bedload convergence (BLC) with the weakest energy condition in the estuary. Despite the potential significance in evaluating relative importance between tidal and river processes, the morphodynamics of the inner estuary remains relatively unexplored in terms of their response to governing processes. This study, based on satellite imagery and field observation, demonstrates that the inner part of the Sittaung River estuary in Myanmar has evolved via active morphodynamics over various temporal scales ranging from monthly to centennial cycles. Channels, including swatchways and flood barbs, migrate rapidly in response to mutually evasive tidal currents on monthly time scales, leading to an increase in the channel sinuosity. Annually, seasonal river floods accelerate channel migration, causing a tight meander bend. A chute cutoff of the point bar at the tight meander bend occurs during the river floods every 6 to 9 years, triggering substantial down-estuary changes in the position of the main channel, bars, tidal flats, and saltmarshes. Over centennial time scales, the main channel formed a large-scale, tight meander bend with a sinuosity exceeding 5, near the downstream end of the inner estuary, which corresponds to the BLC of the estuary. A chute cutoff of the large-scale tight meander bend during the high river flows resulted in the morphologic changes throughout the fluvial-marine transition zone of the Sittaung River estuary: widening of the main channel and the estuary via accelerated channel migration to accommodate an increase in river flows and tidal prism caused by an increase in the hydraulic gradient due to the shortening of the channel length. The tight meander bend has migrated seaward at centennial time scales, suggesting that the river influence has increased over the time, and the estuary is in the progradational phase to become a sediment- exporting delta. The recurrence of the bend tightening after the chute cutoff, however, indicates that flood-tidal currents drive the morphodynamic evolution of the estuary, and the gradual transition from an estuary to a delta is unlikely. Rapid channel migration with bar growth, frequent cutoff, and subsequent infilling of the abandoned channels over various temporal scales all typify the tide-dominated estuary is charged with high sediment loads imported from both rivers and offshore. Despite the construction of dams and reservoirs that reduced sediment supply into the estuary, other anthropogenic activities such as mining activities and deforestation appear to drive an increase in sediment loads, promoting the morphodynamics of the inner part of the Sittaung River estuary.

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Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-1: Anthropocene sedimentology: From science to practice
Presentation Preference: Oral Preferred

Estimation on Centennial relative sea level change along the Quaternary sedimentary coast using InSAR and satellite altimeter, Wenzhou Bay, China

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Keywords: relative sea level,Quaternary sedimentary coast,InSAR,satellite altimeter

Land subsidence prevailed on Quaternary sedimentary coasts due to sedimentary compaction, which exacerbated the threat of relative sea level rise. In the past research on relative sea level change trend, point observation data is usually used instead of regional data, and it is assumed that the trend of coastal land deformation is very stable, which is inconsistent with the situation in areas frequently affected by human activities. This study aims to estimate the relative sea level change in Wenzhou Bay area, a typical Quaternary sedimentary coast, with high resolution land deformation correction, and evaluate the potential risks of sea level changes to the coast. We firstly use satellite SAR data to extract the surface deformation of the coastal area of Wenzhou Bay. Accordingly, we adapt the method of spatiotemporal replacement to estimate the trend of surface deformation for the modern terrain correction. Based on this corrected modern terrain, the relative sea level in Year 2100 and scenarios of extreme sea level change are analyzed by applying the machine learning methods on InSAR and satellite altimeter data. Finally, the impacts of relative sea level change over scales on the coastline are analyzed. Three main findings are concluded: 1) The results show that sedimentary compaction is the main reason for the vertical displacement of the estuary and coastal areas, and the sedimentary compaction has been strongly impacted by the enhanced coastal construction activities ;2) The relative sea level in this area is unevenly distributed along the coastline due to the different land deformation rate along the coast; 3) Coastal areas with different land use types are under different levels of risks to sea level change, especially to extreme sea level changes. The results of this study are helpful to improve the spatial and temporal resolution of coastal hazard risk analysis in Quaternary sedimentary coasts.

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Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-1: Anthropocene sedimentology: From science to practice
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

River, tide and morphology interaction in a macro-tidal estuary with active morphological evolutions

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Keywords: Tidal dynamics, River discharge, Tidal amplification, Morphological evolution, Qiantang Estuary

Understanding tidal dynamics in estuaries is essential for tidal predictions and assessments of sediment transport and associated morphological changes. This study analyzes the multiple-timescale tidal dynamics in the Qiantang Estuary, a macro-tidal estuary with an extremely active morphological evolution. A large dataset including water levels at representative stations, river discharges and bathymetries has been collected. The results of the analysis show that within a spring-neap cycle, the tidal amplification in the upper estuary is stronger during spring tide than during neap tide. On the seasonal and interannual timescales, the low water levels in the upper estuary depend on the local bathymetrical conditions. Tidal ranges in the upper estuary are larger in the high flow season and years, than in the low flow season and years, due to the erosion at high flow, in contrast to estuaries with less active morphological changes. During low flow season and years, the bed is gradually recovered, the low waters are elevated, and the tidal ranges decrease accordingly. A good relationship exists between the tidal ranges and the depth of the upper estuary. In the lower estuary, the flood dominance increases continuously due to embankment. In the upper estuary, the flood dominance is increased during the high flow periods, explaining the fast sediment input and bed recovery in the post high flow periods.

Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-1: Anthropocene sedimentology: From science to practice
Presentation Preference: Oral Preferred

Response of beach landform to different coastal engineering practices

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Keywords: artificial island, revetment, underwater barriers, beach nourishment, beach landform

From 2010 to 2018, 12 offshore artificial islands were constructed along the coast of Hainan, China. In this research, beach profile surveys over 8 years at sandy beaches in the vicinity of offshore artificial islands are analyzed to study How has the land coast evolved under the influence of artificial islands in the past decade, and What measures have been taken to protect the land coast.

The artificial island of Nanhai resort is in the south of Gaolong Bay, and the nearest offshore distance is about 108 meters. Profile 31 is in the south of the artificial island of Nanhai resort, where the beach was constantly eroded. The beach slope became steeper and the coastline retreated by more than 30 m. After the construction of the artificial island, block stone revetment was built on the beach surface on both sides of the road and bridge into the island, which destroys the continuity of the beach profile. When the wave propagates to the land, the stone dike will block the diffusion and infiltration of the upwelling wave flow along the slope, but increase the strength of the backflow and its scouring and erosion to the beach. If things go on like this, the collapse of the stone dike may also occur.

During the survey, sand replenishment works were carried out on the beach where profile 38 on the north side of the artificial island of Tamen fishing port. From July to December 2015, the beach elevation increased significantly due to human activities. The backshore of profile 56 is located on the coastal unsurfaced road used for the construction of Riyue Bay artificial island. From December 2013 to December 2014, the road was gradually piled up and reinforced, and block stone revetment was built on the upper part of the beach. The artificial sand replenishment of the beach temporarily increased the elevation and width of the beach, due to the lack of supporting wave dissipation works, the beach surface continues to retreat after sand replenishment. Today, the beach width is less than that before sand replenishment, but the beach shape is not stable and erosion continues. The block stone revetment on the beach also caused the erosion retreat of the lower part of the beach in profile 56.

Factors in the site selection, design, and construction of artificial islands, such as the short distance between artificial islands and land coasts, the inbound embankment intercepting the alongshore current, and the inadequate or improper protection measures for beach erosion have aggravated the impact and destruction of artificial islands on adjacent natural beaches and landscapes. In 2017, we suggested that "soft engineering", e.g., artificial underwater barriers and artificial reefs, as well as a combination of various ecological management scheme, could be considered to restore the damaged natural coast. Since 2020, we are pleased to see that such a combined project has effectively protected the land coast. Of course, their long-term role needs our continuous attention.

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Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-1: Anthropocene sedimentology: From science to practice
Presentation Preference: Oral Preferred

Recent spatiotemporal variations of morphodynamic response to the natural and anthropogenic changes in the Changjiang (Yangtze) Delta

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Keywords: delta, morphodynamic change, estuarine engineering, regime shift, tide

Numerous river deltas have been extremely altered by anthropic activities, where a regime shift from net accretion into net erosion may have occurred. For a mega-river delta, morphodynamic changes are quite obvious over different spatial and temporal scales. We examine these variations in the Changjiang Delta using time series bathymetric and remote-sensing data, together with numerical modeling by FVCOM.

The results show that a regime shift from net accretion into net erosion in the subtidal channel over the entire estuary should have occurred in 2009. However, nine sub-morphological units varied significantly in their responses to external and internal stresses. A mean annual erosion rate of -5.59 cm/yr was calculated in the subtidal channel during the period 2007-2019, and peak erosion occurred both in the South Branch and the delta front with mean annual erosion rates of -12.64 cm/yr and -8.11 cm/yr, respectively. The erosion lessened toward the middle estuary where sandy shoals prevail, and a net accretion rate of 3.13 cm/yr was solely measured at the Chongming shoal. Intertidal flats are accretional until now due to flood tidal dominance in the Changjiang Estuary. Coarse sediment by the channel erosion from the lower reach favors the river mouth accretion. We predict the accretion on the shallow mouth bars and intertidal flats will continue into the near future because of sediment supply from the river channel erosion and the tidal pumping effect to transport sediment landward from the offshore erosion.

Different from other distributary units, the North Branch is a typically abandoned distributary having evolved into a tide-dominated estuary where flood tides take a predominant role over ebb tides in sediment transport. Channel siltation has been accelerated recently due to land reclamation regardless of sediment deficit after the implementation of TGD and other mega-dams in the upper reach. This could be explained by strengthened tidal amplification due to the artificially reduced channel volume in the middle and upper segments of the North Branch after the implementation of several large-scale land-reclamation projects in the first stage (1997-2007) according to the numerical simulation of FVCOM. While tidal amplification was relaxed by the channel narrowing project at the lower segment through the large-scale land reclamation and the waterway improvement project through channel dredging works at the middle and upper segments during the second stage (2007-2017). Spatiotemporal variation in channel accretion and erosion patterns in response to estuarine engineering projects was vividly mirrored by the change of simulated bed shear stress in that the areas with increased (decreased) bed shear stress underwent severe erosion (accretion). These findings highlight again the dynamic feature of tide-dominated estuaries and the importance of simulation tools to the estuarine management.

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Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-1: Anthropocene sedimentology: From science to practice
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Human-induced changes in sediment transport and sedimentary environment in a macro-tidal estuary

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Keywords: Yalu River Estuary, FVCOM, sediment transport, suspended sediment concentration, land reclamation

During the past decades, extensive coastal areas have been reclaimed along the coastline of China, and a massive land reclamation activity was completed in the early 1970s in the Yalu River Estuary (YRE), China. To investigate the impacts of such human intervention, a three-dimensional (3D) coastal model is established using the Finite Volume Coastal Ocean Model (FVCOM) to explore the changes in the hydrodynamics and sediment transport in the YRE. Model results show that the tidal system was flood dominant both before and after the land reclamation, but the degree of flood dominance decreased slightly after the reclamation. Tidal-choking effect was enhanced in the main branch after reclamation, with a decreased tidal range and resulted in stronger tidal currents. Both vertical and horizontal mixing processes were strengthened due to the enhanced tidal-choking. As a consequence, sediments in the estuary became more well-mixed and homogeneous. Suspended-sediment concentration (SSC) in the estuary increased after the reclamation, and the horizontal gradient of SSC between the estuary and neighbouring shallow waters also became larger. The landward sediment flux caused by tidal pumping decreased significantly after the reclamation while the seaward sediment flux increased. Furthermore, according to results from a newly improved Lagrangian 3D particle-tracking model, sediments in the main branch were likely from different sources before reclamation but were more homogeneous with a common composition of sediment sources afterwards: fluvial sediments and local resuspended sediments contributed more to sediments in the estuary and material from the Western Korean Bay were more restricted out of the estuary after reclamation. This study shows that anthropogenic influence can dramatically change the sedimentary environment in a medium-scale estuary over a short period and the estuary may turn into a sediment source instead of a sink if more land is reclaimed in the future. The conclusions of this study could be useful for marine management and show the utility of using a coastal model to resolve marine-geology problems.

Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-1: Anthropocene sedimentology: From science to practice
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Shoreline protection with geotextile sandbags: the application of a stability equation

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Keywords: Stability equation, geotextile sandbag, coastal protection

Storm-induced coastal erosion is one of main natural hazards in China, taking place over one-third of the Chinese coastline. Because of the effectiveness and cost reduction, geosystems could be an alternative approach to mitigate the erosion of the coast, comparing with conventional coastal structures. The design equation was established to evaluate the hydraulic stability of geotextile sandbags under wave loads in many studies in the laboratory environment, but the application of the design equation has not been extended at the field scale. Based on the in-situ experiments of various design schemes with different sandbag structure, the field study was carried out from October 2018 till present. The field site is located on eroded coast of Chudao Island, China. We found that the existing sandbag stability equation has its limitations, which overestimates the design size of sandbag. Therefore, it is required to re-analyze the field condition, when waves hit the sandbag revetment to establish a stability equation that could be widely applied. According to the field observation, the general stability equation of geotextile sandbag structure is derived to satisfy coastal protection schemes, and the reference values of parameters are given by physical model test data, which are from the literature. The proposed sandbag stability equation can improve the design method of shoreline protection with the utilization of sandbags structures. Furthermore, the response of characteristic curves for the sandbag structure and the dynamic beach profile were obtained, with the consideration of several different field geotextile sandbag structure protections experiments.

Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-1: Anthropocene sedimentology: From science to practice
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Laboratory Investigation of the Beach Initial Slope Influence on Beach Stability for Beach Nourishment

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Keywords: beach stability,beach nourishment,cross-shore sediment transport

Much of the world's population live within the coastal zone and are vulnerable to coastal disasters as the impacts of sea level rise and extreme storm. This result in extreme erosion problem of sandy beach and serious shoreline retreat. Beach nourishment has been increasing believed as a common coastal management strategy to handle the coastal erosion resulting from storms and longshore transport imbalances. However, most present equilibrium theory is always used for underwater topography, there still has some problem in subaerial beaches equilibrium prediction. As rugged environment, there remains a lack of suitably measurements for foreshore stability research. As an alternative to obtaining natural or prototype data, smaller-scale physical models often behave in qualitatively similar ways to prototype beaches and shorefaces, forming the same characteristic features at a wide range of scales. Novel series of experiments are presented on different initial slope beaches to study the physical processes of sandy beach stability in a laboratory wave flume of 30 m long, 1m wide and 0.8 m high. Five initially uniform plane beach slopes of tan =1/5, tan =1/7, tan =1/10, tan =1/12.5 and tan =1/15 were used to discuss the mechanism of beach stability. Novel techniques were applied to simultaneously collect lab data on surface elevation and beach elevation profile. This lab experiment has the following new features that distinguish from traditional ones.

Firstly, non-intrusive instrumentations, video cameras, were applied during the whole experiment to monitor the continuous beach profile evolution in a spatial resolution of 2 mm and a temporal resolution of 0.1s, respectively. Image distortion was compensated by the calibration of grids of known dimensions. Time series of beach profile evolution and synchronous surface elevation can be obtained precisely with this image technique to measure the beach response on different initial slope beach.

Secondly, the influence of beach initial slope on beach profile stability is detail analyzed. During beach nourishment or artificial beach building, the purpose of construction scheme is hoping to make beach efficiently approach to equilibrium profile. The rate of beach approaching to equilibrium on different initial slope is compared. As beach profile approaching to equilibrium profile, the beach slope of different initial slope beach tends to same slope by cross-shore sediment exchange, and foreshore slope is evidently steeper than that of underwater part.

All data collected in this study are being analyzed. As beach approaching to equilibrium profile, better beach stability is believed to have smaller morphology change and shorter time. It is found that the influence of initial beach slope on sediment transport and beach stability is more obvious. Compared to beach initial slope S>1:10, beach initial slope S≤1:10 present better beach stability. As wave run, beach morphology in constant adjust by cross-shore sediment transport, when the overall beach slope is around 0.1 (S=1:10) and the foreshore slope is among 0.2~0.4 (S=1:5~1:2.5), sandy beach has the best stability, the beach profile is more close to the equilibrium profile, and the process of beach evolution to equilibrium is more efficient.

Session T3-2: Sedimentology in carbon neutrality and related geological technology

Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-2: Sedimentology in carbon neutrality and related geological technology
Presentation Preference: Oral Preferred

Experimental study of supercritical CO2-H2O-coal interactions and the geochemical effect on pore structure of high-rank coal

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Keywords: scCO2-H2O-coal, pore structure, permeability, high-rank coal, geochemical effect

Transformation of pore and fracture structure of coal with supercritical CO_2 ($scCO_2$) -H_2O is a key to CO_2 injection and CH_4 production efficiencies during the CO_2 enhanced coalbed methane process. To investigate the effects of $scCO_2$ - H_2O on the pore structure in high-rank coal, coal samples from Qinshui Basin, China was exposed to $scCO_2$ and deionized water for 240 h under 45 °C, 10 MPa and 80 °C, 20 MPa. Field emission scanning electron microscope, nuclear magnetic resonance, high pressure mercury intrusion, X-ray CT scanning and permeability experiments were performed. The results show that the reaction on carbonate in coal is the strongest, forming corrosion pit, corrosion crystal cone, dissolution ditch and so on. The congruent dissolution mode leads the element Ca and Mg shows the highest mobility. The second is aluminum silicate which crystallinity and morphology of the reaction are changed. The incongruent dissolution mode of aluminosilicate minerals leads to the migration of more cations in the interlayer than in the octahedral lattice; and the mixed elements of the isomorphism are more likely to migrate than the intrinsic elements in the crystal lattice. The interaction of $scCO_2$-H_2O can increase or enlarge pores and fractures, leading to an increase in the porosity, pore volume, specific surface area, and permeability, which will augment along with the increase of experimental burial depth, under the interactions of mineral dissolution-precipitation, clay hydration and expansion, coal expansion, and pyrite oxidation-precipitation. The change of pore volume was mainly due to the erosion cones and dissolution trenches on the surface of remaining carbonate particles and dissolution pores of other minerals, as well as the intragranular pores of the expansion and exfoliation of clay minerals. However, the change in the specific surface area is mainly caused by the change in pore volume. Due to the effect of coal expansion, micro-fractures were added and enlarged, which could enhance the connectivity between seepage pores and fractures, so that the growth of permeability could be as high as 114.10 times.

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Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-2: Sedimentology in carbon neutrality and related geological technology
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Dynamic fluid interactions during CO2-enhanced coalbed methane and CO2 sequestration in coal seams

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Keywords: Coalbed methane (CBM), Nuclear magnetic resonance (NMR), Wettability, CO2 injection, CO2 sequestration

The injection of CO2 into coalbed methane (CBM) reservoirs to enhance methane recovery has a second desirable benefit in simultaneously sequestering CO2. However, the real-time dynamic evolution of native adsorbed and rejected non-adsorbed methane/water during the process of CO2-enhanced coalbed methane (CO2-ECBM) production remains poorly constrained as a result of the nonlinear and hysteretic response of both CO2−CH4 interactions and CO2−H2O wettability of the coal under recreated reservoir conditions. By introducing the nuclear magnetic resonance (NMR), a non-invasive method, we explore the mechanisms of 1) methane desorption and CO2 replacement during multiple cycles of CO2-ECBM flooding, 2) influencing factors (pressure, temperature, water-state) on CO2-H2O wettability during CO2-ECBM. Results show that the cumulative methane sweep efficiency increases monotonically with successive cycles of CO2 injection, albeit at a reducing incremental efficiency, identifying the utility of cyclic CO2-ECBM as an effective method in both CO2 sequestration and enhanced gas recovery. CO2 wettability also increases with a decrease in temperature suggesting that shallower reservoirs may be marginally improved in this trend. Additionally, the presence of non-adsorbed water in coals significantly reduces both the sensitivity of CO2 wettability to pressure and the absolute magnitude of wettability relative to the case where free-water is absent. Thus, draining free-water from the reservoir will serve the dual purposes of both increasing gas transport and the potential for desorption from the perspective of CO2-H2O wettability. The far-reaching results in this study are significant for evaluating CO2-ECBM improvement both in enhancing methane recovery and CO2 utilization in coals.

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Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-2: Sedimentology in carbon neutrality and related geological technology
Presentation Preference: Oral Preferred

Molecular Modeling of Interfacial Properties of Complex Multiphase Systems for CO2 Flooding and Sequestration

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Keywords: CO2 Flooding and Sequestration, Multiphase Systems, Interfacial Properties, Molecular Simulation, Density Gradient Theory

In the process of carbon dioxide miscible/immiscible flooding and geological storage, interfacial properties of complex multiphase systems determine the capillary force that stores carbon dioxide and releases oil/gas. Understanding the interfacial behaviors of multiphase systems is crucial for evaluating the carbon dioxide storage capability and stability, and the oil/gas recovery efficiency. The interfacial properties (e.g. interfacial tension, wettability, etc) of multiple multiphase systems containing gas, oil, water, and solid have been studied by molecular dynamics (MD) simulation and equation of state-based density gradient theory (DGT). Studies on several multiphase systems including gas/brine two-phase, gas+oil/water two-phase, gas+oil/water/solid three-phase, gas/oil/water three-phase systems will be presented. In general, MD and DGT can accurately predict the interfacial properties by comparing them to the available experimental data. Our results also showed that the interfacial properties are greatly affected by environmental factors including temperature, pressure, gas impurity, oil type, solid type, etc. Importantly, the behavior of the interfacial properties was analyzed based on the density distributions in the nano-scale interfacial region. The enrichment of components in the interface significantly affects the interfacial properties. Finally, we will present a novel molecular simulation protocol for evaluating the interfacial properties of gas/oil/water three-phase systems. These results could help optimize carbon dioxide flooding and geological storage techniques.

Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-2: Sedimentology in carbon neutrality and related geological technology
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Gas desorption and diffusion characteristics in coal under different pressure-drop conditions

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Keywords: Gas desorption, Gas diffusion, Pressure-drop condition, Water block effect, Pore structure

To compare gas desorption and diffusion characteristics under different pressure-drop conditions, coal samples with different ranks were collected for conducting desorption and diffusion experiments under the direct pressure-drop condition (DPDC) and progressive pressure-drop condition (PPDC). Moreover, the mercury injection capillary pressure analysis (MICP) was performed to determine pore structure characteristics. When the pressure-drop condition is changed from DPDC to PPDC, the initial desorption rate decreases, the desorption volume increases, and the diffusion coefficient increases. The maximum change of these three parameters occurs in the medium-volatile bituminous coal, which increases from 0.255 to 0.063 $cm^3/(g \cdot min)$, from 2.96 to 18.82 cm^3/g and from 0.4732×10-10 to 3.8239×10-10 cm^2/s, respectively. Micropore and transition pore are predominate in all coal samples. With increasing coal rank, the pore volumes show generally decrease trend, while the fractal dimensions show generally increase trend. The difference in diffusion coefficient between DPDC and PPDC is attributed to the various diffusion regimes at different pressure ranges. Specifically, DPDC causes the atmospheric pressure condition throughout the experiment, under which Knudsen diffusion and transitional diffusion play dominant roles in micropores and transition pores during the diffusion process, resulting in the lower diffusion coefficient. The difference in the desorption volume between DPDC and PPDC arises from the water block effect. In DPDC, a large bubble easily forms with a rapid desorption rate in the micro-/transition-pore throat and shows large deformation when passing through the pore throat, which increases capillary resistance and intensifies the water block effect. In contrast, in PPDC, the size of the gas bubble in the same pore throat is smaller than that in DPDC, which can weaken the water block effect and enhance desorption capacity. The results of this study can provide strategies for optimizing the pressure-drop rate during CBM production periods.

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Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-2: Sedimentology in carbon neutrality and related geological technology
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Modified assessment method of CO2 geologic storage capacity in coal and its application in the Zhengzhuang Block, Qinshui Basin

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Keywords: CO2 geological storage, Modified assessment method, Anthracite, Adsorption mechanism, Reservoir environment, Geological storage model

Global climate deterioration forces mankind to make breakthroughs in greenhouse gas control and carbon emission reduction. As an important part of CCUS (carbon capture, utilization and storage), CO_2 geological storage in deep coal is one of the effective pathways to reduce atmospheric CO_2 concentration and achieve carbon neutrality in the immediate future. This study, taking No. 3 coal in the Zhengzhuang Block as an example, was based on the CO_2 isothermal adsorption experiments at various temperatures. The modified assessment method of CO_2 geologic storage capacity was established, the curves of CO_2 storage capacity in coals at depth profile in the Zhengzhuang Block were analyzed, CO_2 adsorption mechanism at different depths was presented, and theoretical CO_2 storage capacity of No.3 coal in Zhengzhuang Block, Qinshui Basin was estimated. The results show that: (1) The supercritical DR model for CO_2 adsorption data of CZ and SH coals has a high fitting accuracy. Their adsorption capacities at different temperatures ranged from 1.58 to 2.47mmol/g and from 1.51 to 2.38mmol/g, respectively. (2) The curves of the modified calculated CO_2 storage capacity per 1 g coal (CO_2-SCC) combined adsorbed and free CO_2 of CZ and SH coal presented maximum values (2.71mmol/g and 2.80 mmol/g) near 250m in the Zhengzhuang Block. At the depth of 2000m, the CO_2-SCCs of CZ and SH coals still maintained 76% and 67% of their respective maximum values. (3) At depth profile, the CO_2 adsorption behaviors were composed of three states: a. surface coverage adsorption at low density, b. micropore filling adsorption at high density and c. surface coverage adsorption at high density. The modified assessment method of CO_2 geological storage capacity can more truly demonstrate the spatial variation of CO_2 adsorption at different depths and therefore has a higher accuracy. (4) The theoretical CO_2 storage capacity of No.3 coal seam in Zhengzhuang block is 536.3 Mt, and the storage capacity in gas and gas-like zone, and liquid-like zone are 385.51 Mt and 150.79 Mt respectively. Although there is no significant difference in CO_2 storage capacity under different depths, CO_2 injection projects should be preferentially implemented in areas with high gas content and high permeability.

Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-2: Sedimentology in carbon neutrality and related geological technology
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Effect of Pore Structure on Water Vapor Adsorption Behavior of Coal with Different Coal Ranks

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Keywords: coal rank, pore structure, water adsorption, molecular simulation

The existence of water in the coal seam will not only reduce the adsorption capacity of CH_4, but also restrict the gas migration with the evolution of coal pore structure. It is of great significance to study the effect of pore structure of different rank coals on its water adsorption behavior, which can be used to analyze the production process of coalbed methane. Therefore, we selected 9 coal samples with different coal ranks, firstly conducted water vapor adsorption isothermal experiments under 10 relative humidity. Revealed the microscopic adsorption mechanism of water adsorption behavior through molecular simulation methods and discussed the differences in water adsorption behavior of different coal rank coals. Finally, analyzed the influence of different rank coal pore structures on water adsorption behavior by low-pressure N_2 and CO_2 gas adsorption experiments. The research results show that the dominant adsorption sites of water molecules in coal pores decrease with the increase of coal rank, and the water adsorption capacity also decrease in single-layer adsorption stage, multi-layer adsorption stage, water cluster connection stage, and pore filling stage. The inflection point of water vapor adsorption isotherm disappear with the increase of coal rank, which completes the adsorption isotherm transition from type II to type III. The water absorption increase with the increase of macropore volume in the four stages, The macropore volume play the dominant role in the water molecule single-layer adsorption stage. The mesopore volume has a promoting effect on water adsorption. The micropore volume has a certain positive correlation with the water absorption in the single-layer adsorption and multi-layer adsorption stagesthe correlation with the water cluster connection stage is not obvious, but it has a significant negative correlation with the pore filling stage. Micropore volume perhaps limited the water adsorption behavior in the pore filling stage. The fractal dimensions D_1 and D_2 are negatively correlated with the water absorption in the four stages, and the roughness of the pore surface and the irregularity of the pore structure will limit the water adsorption behavior in coal. The research results have theoretical significance for understanding the influence of different rank coal pore structure on its water adsorption behavior.

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Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-2: Sedimentology in carbon neutrality and related geological technology
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Study on carbon dioxide geological storage potential and favorable structural units in the Pearl River Mouth Basin

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Keywords: zhujiang mouth basin, ccs, Zhuyi depression

The annual carbon dioxide emission of Guangdong Province is about 470 million tons, which puts great pressure on carbon dioxide emission reduction. Carbon dioxide geological storage technology is the key link of CCUS technology. It is also a carbon neutralization technology most in line with China's resource endowment and national conditions. According to the estimates of the Chinese Academy of Sciences and the IEA, the contribution rate of carbon neutralization of CCS technology will be about 5% ~ 15% by 2060. Carbon dioxide emission sources in Guangdong Province are mainly large point sources such as iron and steel plants, chemical plants and power plants in coastal areas. There is a lack of large sedimentary basins in the land area. Therefore, it is necessary to evaluate the carbon sequestration potential of the Pearl River Mouth Basin in the adjacent sea area of Guangdong Province, delineate the favorable area suitable for carbon sequestration.

The project has carried out research in four aspects: Firstly, based on the systematic investigation of the latest research results of carbon sequestration in sea areas at home and abroad, and combined with the regional geological survey data, the carbon sequestration data set of China's sea areas is established; Secondly, the basic geological conditions of carbon sequestration in the Pearl River Mouth Basin are analyzed from the aspects of stratum, structure, reservoir cap rock characteristics, temperature and pressure system. Thirdly, using the deep learning model, complete the evaluation of regional carbon sequestration potential and select the favorable target areas suitable for carbon sequestration; Then the three-dimensional geological model of the favorable target area is established, and the migration law and storage effect of carbon dioxide under formation conditions are simulated. Finally, the geological feasibility and development route of the pilot project of marine carbon sequestration in the Pearl River Mouth basin are discussed.

The results show that the carbon sequestration potential of Zhuyi depression is 128 billion tons that is the largest in the Pearl River Mouth Basin, and the carbon dioxide storage life can reach more than 1000 years, which is the most suitable for carbon dioxide storage. The pilot project of marine carbon sequestration is recommended to be carried out in the distribution area of depleted oil and gas reservoirs in Zhuyi depression.

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Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-2: Sedimentology in carbon neutrality and related geological technology
Presentation Preference: Oral Preferred

Effects of Supercritical CO2 on Adsorption capacity of Coals with different ranks

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Keywords: Pore volume, Specific surface area, Mesopores, Micropore, Adsorption capacity, Coal rank

CO2 geological storage-enhanced coalbed methane recovery (CO2-ECBM) can be used to enhance coalbed methane (CBM) development and reduce CO2 emissions by effectively displacing CH4 using CO2, and this approach is considered as an important technology of CCUS (Carbon capture, utilization, and storage). The effects of supercritical CO2 (ScCO2) on pores in coal play a critical role in determining the CO2 capacity of coalbeds. To investigate the effects of ScCO2 on adsorption capacity of coals with different ranks under coalbed temperature and pressure conditions, CO2 sequestration processes are replicated using a ScCO2 geochemical reactor. Six coal samples with different ranks are exposed to ScCO2 and water for 240 h at 62.5 °C and 15 MPa, and gravimetric isothermal adsorption test, CO2 adsorption tests, mercury intrusion porosimetry, and nitrogen adsorption tests are performed to determine the adsorption capacity and volume and pore size distribution of the coal samples before and after the ScCO2-H2O treatment. Results show that the changes of pore volumes and pore specific surface areas determine the coal adsorption capacity after scCO2-H2O treatment. Among them, macropores have a weak effect on coal adsorption capacity, which is related to the small volumes and specific surface areas of macropores in coals with different ranks. The changes of coal adsorption capacity mainly depend on the changes of pore volumes and specific surface areas of mesopores and micropores after scCO2-H2O treatment. Under scCO2-H2O treatment, the variation trend of pore volumes and specific surface areas of mesopores and micropores in coals with different ranks is not uniform. With the increase of coal ranks, the adsorption capacity of coal samples decreases first and then increases after scCO2-H2O treatment. That is, the adsorption capacity of sub-bituminous coal slightly increases after scCO2-H2O treatment, due to the increases of pore volumes and specific surface areas of micropores. While that of high- and medium- volatile bituminous coal slightly decreases, because of the decrease of pore volumes and specific surface areas of mesopores after scCO2-H2O treatment. Then, the adsorption capacity of low-volatile bituminous coal, semianthracite, and anthracite greatly increases, thanks to the great increase of pore volumes and specific surface areas of micropores, although pore volumes and specific surface areas of mesopores decrease.

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Session T3-2: Sedimentology in carbon neutrality and related geological technology
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Pore morphology changes of coals associated with CO2 geological storage

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Keywords: CO2 geological storage, pore morphology, coal rank, ECBM

The understanding of CO_2 effects on coal pore morphology is important during CO_2 geological storage (CGS). The CGS was simulated with four different samples from 32-80 ℃ and 9-20 MPa respectively. Mercury intrusion porosimetry (MIP) and low-pressure nitrogen adsorption (LP-N_2GA) were employed to study pore size distributions, pore shapes, roughness and compressibility. The results show that the pore size distributions of high-rank coals are mainly influenced in the micropore range while low-rank in the macropore range. The pores in ScCO_2 treated samples become more complicated due to two peaks showing at 7.2 nm and 13.7 nm in the MIP curves, while only one occurs in the untreated samples. The CGS process is able to open, reshape or enlarge existing pores, which improve pore connectivity and porosity. The fractal dimension shows that the surface and structure morphology becomes more complex after the treatment with the increasing temperatures and pressures, leading to the increments of specific surface areas and total pore volumes. These parameters of SH samples treated under 62.5 ℃ and 15 MPa increase from 1.3579 m^2/g to 3.048 m^2/g and 0.001076 cm^3/g to 0.001338 cm^3/g. The compressibility changes indicate that coal samples are easier compressed after the treatment, which might negatively affect CGS. Even though no clear tendencies exist among different coal ranks, the compressibility does change with the increasing temperatures and pressures. The results show that the CGS increase the gas adsorption volume, specific surface areas and pore connectivity, which improve the storage capacities and benefit the enhanced coalbed methane recovery.

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Evolution of pore structure and gas adsorption properties in coal and shale by supercritical CO2

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Keywords: coal, shale, supercritical CO2, pore structure, adsorption properties

CO_2 injection into coal and shale strata can not only enhance the recovery of coalbed methane or shale gas, but also achieve the goal of CO_2 geological sequestration, reducing greenhouse gas emissions(Chen et al,.2022). CO_2 is likely to be stored in the form of supercritical state, when the burial depth of rock strata exceeds 800 m. Understanding the pore structure and adsorption properties effects of supercritical CO_2 ($ScCO_2$) on coal and shale plays an essential role in carbon capture utilization and storage (CCUS)(Klewiah et al,.2020).The experimental results of different types of coal (low, medium and high-rank coals) and shale (terrestrial or marine shale) are selected to discuss the interaction mechanism between $ScCO_2$ and matrix in coal and shale, as well as the pore structure and gas adsorption under different treatment conditions. The CH_4 and CO_2 adsorption, X-ray diffraction, scanning electron microscope and low-pressure N_2 adsorption measurements were carried out on the shale samples before and after exposure. The major conclusions are summarized as follows:

1. The changes in pore structure caused by $ScCO_2$ may be related to the following two mechanisms: (i) The $ScCO_2$ fluid has a certain ability to dissolve some organic matter and minerals. Carbonic acid is generated by the reversible chemical reaction between CO_2 and free water in shale, which dissolves some clay minerals and carbonate minerals in shale, thus broadening the pore structure of shale. (ii) The strong adsorption capacity of shale for CO_2 induces irreversible adsorption expansion of the matrix, resulting in the shrinkage of the pore throat size of shale(Lan et al,.2019). The initial pore structure of the rock and its own properties (TOC, Ro, mineral composition) are significant factors in determining which mechanism dominates the energy.

2. By researching the correlation between the integrated heat of adsorption and the adsorption capacity of different coal samples, it is found that compared with untreated coals, the adsorption amount and integral adsorption heat for the coal treated with supercritical CO_2 are reduced, and the decrements are largely dependent on the coal rank(Kang et al.,2020). The integral adsorption heat relates linearly with the adsorption amount, and the ratio coefficients for medium rank coals decrease after supercritical CO_2 extraction, whereas an increasing trend is found for low-rank and high-rank coals. In addition, it is revealed that the volume of micropores is reduced by supercritical CO_2 treatment for low-rank and medium-rank coals, while no significant change is found for high-rank coals(Liu et al.,2019).

3. The pore structure of clay-rich continental shales was more affected by $ScCO_2$ treatment compared to quartz-rich marine shales(Lu et al.,2020). These findings suggested that the adsorption capacity of clay-rich shales could be reduced after the CO_2 treatment, while the uniformed pore size distribution profile displayed by quartz-rich shales could cause an increase in the adsorption capacity(Fatah et al.,2022).

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Study of Carbon Sequestration Effect of Different Sediment Types in the Taiwan Strait

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Keywords: Carbon Sequestration, Sediment, Mollusk shell, Benthos

As most of the organisms with calcium carbonate shells in the benthic animals are concentrated in mollusks, the calcium carbonate shells formed by mollusks play an important role in absorbing CO2 from the atmosphere and seawater. Through analysis of the data of 450 stations of carbonate content of surface sediment and 165 stations of benthos, there are 6 types of seabed sediment in the Taiwan Strait , which are gravel, sand, silty sand and sandy silt, mudy silt and mud, mollusks biomass in sandy silt type in the highest, accounted for 38.4%, followed by mud, accounted for 26%, the third for silty sand, accounted for 18.0%, the fourth is mudy silt, accounting for 12.2%. Which means that the three kinds of sediments with high content of silt (sandy silt, silty sand and argillaceous silt) account for about 68% of the total biomass of benthic organisms, and play an important role in the carbon sequestration of benthic organisms. At the same time, the standard deviation of mollusk biomass distribution in silt related sediments are also large, indicates that the distribution of mollusk in these types of sediments is not uniform. Analysis of carbonate content in surface sediments with different grain sizes shows that the carbonate content in sediment of grain size range (-1 ~ 7) has no significant difference, ranging from 4.58% to 17.30%, and presents an exponential distribution, which decreases with the decrease of grain size. In addition, the grain size increased slightly in the range of 2.5~3 and 3~3.5 . Statistics of the data indicate that :(1) The distribution characteristics of mollusk biomass in benthic organisms and carbonate content in surface sediments has a lot of difference, which may be related to the accumulation of shells in coarse-grained sediments under hydrodynamic condition; (2) Finding out the main distribution area of mollusk and its controlling factors, will be of great significance to play the role of fishery carbon sink by developing shellfish farms appropriately. (3) Conventional sediment carbonate analysis mainly studies the content of carbonate components in terrigenous clasts, and shells are usually taken out before sample processing, these data should be carefully used when studying the role of sediment carbon sequestration.

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Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-2: Sedimentology in carbon neutrality and related geological technology
Presentation Preference: Oral Preferred

Emerging and outlook of Carbon Neutrality Sedimentology

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Keywords: Carbon Neutrality Sedimentology, definition, rationale, research areas and application directions, challenges and outlooks

Sedimentology is closely related to carbon neutrality, and Carbon Neutrality Sedimentology came into being. Hereby the authors try to explore the new research field and new branch, so as to give full play to the role of sedimentology in the realization of carbon neutrality goal. This paper advances and explains the scientific concept, constructs the rationale, defines the major research areas and application directions, concisely puts forward the key challenges, and looks forward to the development prospect of Carbon Neutrality Sedimentology. It is regarded as follows: Carbon Neutrality Sedimentology is a new branch of sedimentology that studies the sedimentary records and generalized sedimentation related to carbon emission or carbon sink alteration caused by human factors and their carbon neutrality effect. The core of its rationale is the carbon sequestration mechanism of generalized sedimentation and the geological carbon sink potential of sediments and sedimentary rocks. Carbon sequestration by rock weathering, biological sedimentation, chemical sedimentation, epigenetic diagenesis, water-rock interaction and mineralization constitute the major connotation of the study on the carbon sequestration mechanism of sedimentation. The research on the carbon sequestration potential of sediment and sedimentary rock includes coastal sediment carbon sequestration, soil carbon sequestration, typical sedimentary environment sediment carbon sequestration likely in lakes and wetlands, CO2 geological utilization and geological sequestration, solid waste imitated mineralization carbon sequestration, biological carbon sequestration, etc.. Modeling and numerical simulation of sedimentary carbon sequestration is also an important research area of Carbon Neutrality Sedimentology. It can provide an important fundament applied to carbon neutrality geological technologies related to the above sedimentary carbon sequestration. The carbon sequestration mechanism, mode and model of sedimentation, the evaluation method of carbon sequestration potential of sediment and sedimentary rock, and commercial engineering application of the related carbon neutrality geological technologies are the key challenges faced by carbon neutrality sedimentology. In the future, it will cross integrate with relevant disciplines like geology, geography, ecology, atmospheric science etc. to form an interdisciplinary knowledge system, and rapidly develop and be widely used.

Reference
omitted.

Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-2: Sedimentology in carbon neutrality and related geological technology
Presentation Preference: Oral Preferred

An analysis on influence factors of permeability of coal seam with CO2 injection

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Keywords: CO2-ECBM, CO2 adsorption swelling, effective stress, anisotropic permeability, CO2 injectivity, deep coal seam

Injecting CO_2 into deep coal seams cannot only improve the recovery of coalbed methane but also achieve CO_2 geological sequestration, which possesses dual benefits of energy and environment and meet major needs of carbon neutralization and low-carbon energy exploitation. However, the attenuation of CO_2 injectivity is the key technology bottleneck restricting the application and development of CO_2-ECBM. To reveal the attenuation mechanism of CO_2 injectivity, the anisotropic permeability test and CO_2 injection simulation experiment were conducted, and the characterization model of permeability evolution with CO_2 injection was established. Results show that effective stress and CO_2 adsorption swelling are the two main factors to control the dynamic evolution of permeability during the CO_2 injection process. Increasing the CO_2 injecting pressure can decrease the effective stress and promote the permeability of coal, while the concomitant adsorption swelling strain can compress the fracture space and reduce the permeability of coal. The permeability during the CO_2 injection process exhibits obvious anisotropic characteristics, the permeability in parallel face cleat and bedding plane direction is the maximum, followed by the permeability in parallel butt cleat and bedding plane direction, the permeability in vertical bedding plane direction is the minimum. The face cleat and butt cleat are narrow and short, which are easily affected by the CO_2 adsorption swelling deformation and contribute to the decrease of permeability during the CO_2 injection process. Based on the three-dimensional distribution structure of the face cleat, butt cleat and bedding plane, the anisotropic permeability model considered the adsorption swelling, effective stress and swelling deformation directivity is built and verified by the experimental data. The CO_2 injection process under the in-situ stress condition is simulated, and the changes in CO_2 injectivity are forecasted by the anisotropic permeability model. This study can rich the theory of efficient CO_2 injection into deep coal seams and promote the process optimization of CO_2-ECBM.

Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-2: Sedimentology in carbon neutrality and related geological technology
Presentation Preference: Oral Preferred

Geological records in sandstone after CO2 emplacement and its implications for CCS: a case study from Pliocene reservoirs in Yinggehai Basin, South China Sea

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Keywords: carbon capture and storage, diagenesis, CO2 emplacement, authigenic carbonates, kaolinite enrichment

Anthropogenic greenhouse gas, such as CO_2, which is generated from industry activities into atmosphere has been a key issue for global warming. Thus, reducing the impact of CO_2 concentration increasing in atmosphere is one of current major tasks. At present, more and more scientists propose that injecting CO_2 into subsurface formations, such as unminable coal seams, brine formations or sandstone aquifers, and depleted oil/gas reservoirs, etc., could be potential options for carbon storage and capture (CCS). Sandstone aquifers with impermeable cap-rock system could be ideal CO_2 storage sites due to their not only adequate permeability but also wide distribution in sedimentary basins across the world. In Yinggehai (YGH) basin, South China Sea (SCS), a lot of CO_2- and hydrocarbon gas-rich reservoirs have been discovered during natural gas explorations in recent decades. It has been established that there are several natural gases injection and replacement periods occurred in the reservoirs. Among these reservoirs, CO_2 injection time is later than hydrocarbon gases. In addition, CO_2 emplacement also displaced hydrocarbon gases in some of reservoirs. These current CO_2 enriched reservoirs give us an excellent opportunity to study the petrographic and geochemical impacts in sandstone aquifers or reservoirs due to CO_2 emplacement. This can also provide a natural analog for CCS managements.

Here, we did a series of analyses such as petrographic observations, carbon and oxygen isotopes, and numerical modelling to constrain geological records after massive CO_2 emplacement. According to the petrographic observations, we could conclude the sandstone types are mainly Quartz arenite and Sublitharenite in the Pliocene reservoirs in YGH basin. The detrital minerals are dominated by quartz, albite, mud matrix, lithic debris and biological debris. Wherever authigenic minerals formed in sandstone pores are secondary quartz, pyrite, siderite, dolomite, dawsonite, ankerite and kaolinite. The secondary minerals precipitated after CO_2 injection are microcrystalline quartz, kaolinite, dawsonite, siderite and ankerite, respectively. The $\delta^{13}C$ and $\delta^{18}O$ results for ankerite and dawsonite confirmed that these two authigenic minerals are tightly related to CO_2 emplacement. In addition, compared to the hydrocarbon reservoirs which are not impacted by CO_2 injection, most of CO_2 enriched reservoirs are especially enriched kaolinite if dawsonite was absent in YGH basin. This phenomenon is supported by our numerical modelling results, which shows that kaolinite, quartz, ankerite, and siderite are the dominated minerals during the fluid-rock reactions after massive CO_2 injection. Thus, we conclude that in the reservoirs of YGH basin, siderite, ankerite, and dawsonite could be carbonate minerals to effectively storage CO_2. Kaolinite enrichment in sandstone, wherever, could be a potential indicator for CO_2 accumulation in subsurface reservoirs if dawsonite was absent.

Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-2: Sedimentology in carbon neutrality and related geological technology
Presentation Preference: Oral Preferred

Depositional Architecture and Reservoir Properties of Lower Cretaceous Bedload-Dominated Fluvial Deposts in a World-Class CO2 Storage Complex, Kemper County Energy Facility, Gulf of Mexico Basin, Mississippi, USA

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Keywords: Lower Cretaceous, Gulf of Mexico, Mississippi, CO2 storage, fluvial deposits

The Mesozoic-Cenozoic section at the Kemper County energy facility contains a 1.7-km thick succession of saline reservoir and sealing strata composing a CO_2 storage complex with exceptional reservoir properties and complex depositional architecture. As part of the U.S. Department of Energy National Energy Technology Laboratory CarbonSAFE program, six exploratory wells have been drilled to characterize strata at the 137 km^2 energy facility. The wells were logged and cored, and CT scans were made of the cores and oriented using interpreted FMI logs. The cores were analyzed using a variety of stratigraphic, sedimentologic, paleocurrent, petrologic, and routine core and pressure decay permeability analyses.

Prospective reservoirs are mainly medium-grained, subarkosic, cross-bedded sandstone in the Cretaceous-age Paluxy Formation and Washita-Fredericksburg interval. The lower parts of the sandstone bodies are dominated by planar and tangential cross-beds, and the upper parts fine upward and contain adhesive meniscate burrows and localized current ripple cross-strata. Paluxy cross strata dip northwest, parallel to depositional strike. Porosity of Paluxy and Washita-Fredericksburg sandstone averages 28.5%, and permeability has a geometric mean of 3.6 Darcies. Red mudstone units are abundant in the Lower Cretaceous section and have permeability ranging from 1 nD to 1 µD, with values of 10-30 nD being typical. The sandstone was apparently deposited in transverse and longitudinal bars constituting multi-storey sandy braided stream deposits. Mudstone units contain desiccation structures, ferriginous nodules, roots, and meniscate burrows. The mudstone has high water saturation and plasticity, and depositional features indicate an origin as spodic paleosols deposited in longitudinal bars and interfluves. The mudstone is smectitic and has variable thickness and lateral extent, constituting a system of baffles, barriers, and seals.

Paluxy and Washit-Fredericksburg were deposited during Albian time (100-112 Ma) as 3 major 3rd-order sequence sets. Geochronologic analysis indicates that the individual sequences composing the sets have a frequency of about 100 ky, suggesting climatic control of sedimentation in the Milankovitch short eccentricity band. Accordingly, the bases of individual sandstone storeys are interpreted as widespread erosional surfaces representing minor {~10 m) base level drops, and the most widespread mudstone units apparently accumulated as the culmination of the 100 ky aggradational episodes.

The total storage resource at the energy facility is estimated to be about 1.4 Gt, or 10.5 Mt/km^2, and reservoir properties favor high injectivity. Characterizing the depositional architecture of the Cretaceous section is essential for developing storage and monitoring strategies, such as injecting sequentially upward in section with the aid of multi-zone monitoring to characterize reservoir performance and verify hydraulic confinement. Sealing intervals within the Lower Cretaceous section and the major topseal atop the storage complex contribute to a high level of storage security.

Session T3-4: Understanding natural hazards in sedimentological records

Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-4: Understanding natural hazards in sedimentological records
Presentation Preference: Oral Preferred

The Cretaceous varves in NE China and their paleoclimatic implications

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Keywords: Cretaceous, paleoclimate, varve, interannual, NE China

In effort to project future warm climate scenarios, it is invaluable to investigate times in the geologic past. The Cretaceous period is an archetypal example of a greenhouse climate, and the high-resolution geologic records (e.g. lacustrine varve) in this time interval offer important insights into how the Earth system responds to warm climates. The 'varve' includes all annually deposited laminae in terrestrial and marine settings, and it's a high-resolution climatic archive with at least annual and sometimes even seasonal resolution. Despite a lot of varved sediments are found across the globe, deep-time (i.e. before the Quaternary) varves are less studied compared to the Quaternary. Luckily, the Cretaceous varves are sporadically reported, especially in Western and Northern Liaoning, Northeastern China (NE China), researchers have found various lacustrine varves in the Early Cretaceous Yixian Formation of the "Jehol Biota". For the Late Cretaceous, previous work also showed varved lake sediments of the Nenjiang Formation in the Songliao Basin, NE China. With increasing amount of varve research, a systematic summary is needed. In this paper, the Cretaceous varves in NE China was compiled, and their implications for paleoclimate are reviewed. The specific objectives of this paper are as follows: 1) to briefly introduce the processes of varve formation in different areas of the NE China; 2) to dig for information about the Cretaceous climate variability on interannual to centennial timescales; and 3) to discuss the mechanisms affecting the deposition and preservation of those lacustrine varves in NE China. The varved records obtained in this study will be compared with other regions of the world and used to provide an important reference for the Cretaceous high-resolution paleoclimate studies at a regional scale.

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Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-4: Understanding natural hazards in sedimentological records
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Lunar nodal tide cycle influences on the input of coarse detrital sediments during the last glaciation in the deep southern South China Sea

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Keywords: lunar nodal tide cycle, laminae, X-ray fluorescence core-scanned elements, last glaciation, across-slope transport, southern South China Sea

Across-slope transport of coarse detrital sediments is thought to be dominated by hyperpycnal flow or gravity flow processes triggered by events. However, whether long-term non-event hydrological processes can affect longitudinal transport is still unclear. Here, high-resolution (1 mm) X-ray fluorescence core-scanned elements combined with coarse-fraction observations in typical samples have been conducted on laminae of Core MD05-2892 in the deep southern South China Sea. The laminated section developed during the last glacial 14.5–20.7 cal ka BP based upon AMS ^{14}C dating and oxygen isotope stratigraphy. The laminae show interbedded millimeter-scale dark and light layers. Dark layers are characterized by coarse-grained deposits rich in Ca, Zr, and Si, while light layers are characterized by fine-grained deposits rich in K, Ti, and Fe. Zr/K and Si/K ratios are then used to indicate laminar occurrence, and the ratios are well correlated to grayness value. Spectral analyses of the ratios and the grayness value both present a persistent 18.6-yr period, which is interpreted as the lunar nodal tide cycle. This signal in laminae could be related to remobilization of coarse sediments by mean-high-water-line variations driven by the lunar nodal tide at the low sea-level stage. The coarse fractions were then likely transported from the shelf break by suspended-load-dominated hyperpycnal flow to the lower slope to form dark layers, while fine fractions were dispersed during other time of the last glaciation through hemipelagic transport to form light layers. Our study firstly highlights the lunar nodal tide can periodically trigger longitudinal transport of coarse sediments.

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Session T3-4: Understanding natural hazards in sedimentological records
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Search for crypto tephra in varve sediments using synchrotron micro-XRF

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Keywords: varve sediments, crypto tephra, synchrotron micro-XRF

Scanning micro-XRF with synchrotron radiation (SR) was used to search for traces of the Changbaishan volcano eruption (~ 960 AD) in the bottom sediment core of Lake Bele (Khakassia). A core with a length of 1240 mm was obtained by a gravity tube in 2014. After opening, solid samples for scanning synchrotron XRF and optical thin sections were prepared from a half of the core. The age model for the Bele-2014 core was made by the varve chronology method using optical thin sections. Solid samples were scanned by synchrotron XRF with a step of 1 mm. At a depth of 860 mm (varve age 945 AD ± 30), a layer 2 mm thick with a high content of zirconium was found. Detailed scanning with a 20 μm focused SR beam was carried out. A large number of microparticles with a high content of Zr, Y and Nb were found. The possibility of finding traces of the eruption of the Changbaishan volcano is discussed. The study was supported by the Russian Foundation for Basic Research, grant No. 19-05-50046 Mikromir.

Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-4: Understanding natural hazards in sedimentological records
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Strawberry pyrite as a mineral indicator for sedimentary environment

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Keywords: strawberry pyrite,paleo-redox environment, particle size, Microcrystalline morphology

Strawberry pyrite, as an important mineral, is sensitive to geochemical conditions. It has a special formation mechanism and widely exists in sedimentary rocks. Because of its special formation mechanism, the formation of strawberry pyrite is controlled by the paleo-redox environment, so it plays an important role in the reflection and reconstruction of the sedimentary paleo-environment and can be used as an environmental indicator. This paper reviewed the reaction of particle size, morphology and existing form of strawberry pyrite to sedimentary environment, discusses the indicative significance of strawberry pyrite for the paleo-redox environment and proposes that the formation of strawberry pyrite may be affected by the combination of Fe saturation, S content, redox conditions and deposition water the strawberry pyrite formed in the oxidation environment has a large particle size, (maximum particle size greater than 20 μm), wide distribution, and round crystallite shape, whereas the strawberry pyrite formed in the reducing environment has smaller particle size (maximum particle size less than 20 μm) and narrow distribution, whose microcrystalline morphology tends to be square. The number of crystal sides of strawberry pyrite increases with increasing the S Fe ratio (Tetrahedron octahedron sub sphere). Transition from strawberry pyrite to euhedral crystalline pyrite shows that the paleosedimentary physicochemical conditions are changing, the water saturation may be changing slowly, which needs to be further confirmed.

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Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-4: Understanding natural hazards in sedimentological records
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Hydroclimatic variability during the last 1500 years recorded in the varved sediments of Grand Lake, Labrador, Canada

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Keywords: Detritic varves, NAO, Thin-sections, MicroXRF, hydrological regime

Grand Lake, Labrador, is a 250-m deep fjord lake that contains thick and very well-preserved detritic varves that can be correlated over tens of kilometres within this sedimentary basin. The chronology of this varved sequence is based on counts made from high-resolution images of thin sections at the scanning electron microscope, and from 100 µm-resolution microXRF profiles. The varve chronology established from these counts was validated by ^{210}Pb, ^{137}Cs and ^{14}C dating. Their thickness and grain-size can be directly linked to the discharge of its two main tributaries. The statistically significant correlation between varve thickness and the main tributary discharge during the instrumental period allows to develop a robust hydroclimatic reconstruction of the region. The river discharge was higher during the Medieval Climate Anomaly (1050–1225 CE) and lower during the Little Ice Age (15th–19th centuries). Moreover, the 1500-year-long record reveals strong similarities with large-scale atmospheric and oceanic variability modes, such as the North Atlantic Oscillation (NAO) and the Atlantic Meridional Overturning Circulation (AMOC). Finally, we found four different hydrological regimes during last fifteen centuries, against two only during the instrumental period.

Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-4: Understanding natural hazards in sedimentological records
Presentation Preference: Oral Preferred

A 5000-yr high-resolution record of dust storms inferred from varve sediments in Lake Xiaolongwan, northeastern China

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Keywords: Asian dust storms, Varve sediments, Atlantic Multi-decadal Oscillation, Northeastern China

Abstract: Dust storm events have significant impacts on climate changes and human activities, and the patterns and forcing mechanism of long-term variations of dust storm are essential for predicting their future changes and impacts. However, high-resolution dust storm records are scarce, though large amounts of the records have been reconstructed. In the present study, the clastic materials in varve sediments from Lake Xiaolongwan, a maar lake in northeastern China, were demonstrated to be mainly eolian deposits using Sr-Nd isotopes and element ratios. Then, a 5000-yr dust storm record, with the average time resolution of ~5-yr, was reconstructed using proxies including lightness and element concentrations. The results show an increasing trend of dust storm events during the past 5000 years, with higher values during 3200-2500 a BP, 2100-1400 a BP, and after 1000 a BP. The record shows obvious ~116 yr, ~78 yr, ~49 yr, 30-39 yrs, and 22-26 yrs cycles, some of which are consistent with those in solar irradiance. The co-variances of the dust storm record with the total solar irradiance and the AMO (Atlantic Multi-decadal Oscillation) further suggest that changes in dust storms in East Asia might be modulated by the sun through internal factors in the earth system.

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Session T3-4: Understanding natural hazards in sedimentological records
Presentation Preference: Oral Preferred

Anthropogenic and climatic driven vegetation succession during the past 300 years in Sihailongwan Maar Lake, NE China

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Keywords: pollen,vegetation succession, human activities,climate change

Anthropogenic activities and climate change are the two critical drivers of vegetation succession, but the magnitude of their roles in vegetation succession has been highly debated. Here, we obtained a high-resolution 300-year pollen record from the Sihailongwan Maar Lake (SHML) in northeastern (NE) China. A precise chronology was established by the combination of varve counting, ^{210}Pb, ^{137}Cs, and AMS^{14}C dating of plant remains. The pollen assemblages indicate that the vegetation in the study area has been characterized by a shift from temperate coniferous forests to temperate deciduous broadleaved forests over the past 300 years. Before 1900 AD, the vegetation in the study area was mainly temperate coniferous forest dominated by *Pinus* showing relatively low intensity of human activities and natural succession of vegetation, which is consistent with historical documents. After 1900 AD, the proportion of temperate deciduous broadleaved forests dominated by *Betula* secondary forests increased at the expense of natural forests of *Pinus*, which was related to the intensification of human activities (e.g. Qing government's closure policy, selective felling of pine trees by wars, and the population explosion in northeastern China). Besides, *Artemisia* dominated the herbaceous vegetation and was sensitive to precipitation, identifying two relatively large droughts in the periods 1875-1910 and 1940-1960 AD. In addition, according to the results of principal component analysis (PCA), human activities and precipitation jointly drive vegetation changes in the study area over the past 300 years, with the former playing a more prominent role. We suggest that it is essential to formulate reasonable policies to enhance vegetation conservation in the context of the increasing intensity of human activities and global warming.

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Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-4: Understanding natural hazards in sedimentological records
Presentation Preference: Oral Preferred

Tsunami Hazard in the Tiran Straits (Red Sea)

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Keywords: Submarine landslide, Tsunami, Geohazard, Tiran Straits, Gulf of Aqaba

The Red Sea is a maritime rift. Tsunamigenic submarine landslides are common in these deep, steep-sided and seismically active basins. Because the Red Sea is narrow, tsunami formed on one margin dissipate little before impacting the opposite side. Red Sea slope failures are therefore especially hazardous. We examine the tsunamigenic potential of a recently discovered incipient landslide in the Tiran Straits that started, but then stopped after a short distance. Radiometric and biotic analyses fix the age of this landslide to within the last 500 years. Tsunami modelling of the incipient slide predicts ~10 m wave runup-heights on the Egyptian coastline. This event eluded the historical record as the afflicted coastline was virtually uninhabited at this time. Of present concern is that the slope will eventually slide to completion with even more hazardous results. Tsunami simulated for this future event are twice as large as that generated by the incipient slide, so the threat posed by a future slide is consequential. Sharm El Sheikh, an Egyptian resort town now lies in its path, as does Neom – a Saudi gigaproject. While exact prediction is impossible, this study warns of credible tsunami risk in the rapidly urbanizing Tiran Straits.

Reference
Purkis, S.J., Ward, S.N., Shernisky, H., Chimienti, G., Sharifi, A., Marchese, F., Benzoni, F., Rodrigue, M., Raymo, M.E. and Abdulla, A., 2022. Tsunamigenic Potential of an Incipient Submarine Landslide in the Tiran Straits. Geophysical Research Letters, p.e2021GL097493.

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Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-4: Understanding natural hazards in sedimentological records
Presentation Preference: Oral Preferred

The “two-step” yielding process of the natural mud under steady and oscillating shear stress

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Keywords: natural mud, rheological properties, exterior loads, yield stress, two-step yielding

The yielding process of the natural soft mud have a significant effect on the morphology evolution, wave attenuation, nautical depth estimation, etc. In this study, both steady and oscillating rheological tests were performed through a rheometer with four natural mud samples collected from Luxi Island and Zhoushan Island, China. And the shear stress sweep, the oscillating amplitude sweep tests were carried out to obtain corresponding yielding process and yield stress of the natural mud. Both steady and oscillating experimental results show the existence of the “two-step” yielding feature of the natural mud samples, meaning that the “two-step” yielding process is the instinctive feature of the natural soft mud, despite the imposed manner of the exterior loads. Two yield stress, namely static yield stress and fluidic yield stress correspondingly to the state transition from solid to solid-fluidic state and from solid-fluidic to fluidic state respectively, were compared with its counterpart for steady and oscillating tests. The results show that the static yield stress of natural mud in steady shear tests is higher than oscillating shear tests, and the fluidic yield stress of natural mud in oscillating shear tests is higher than steady shear tests, this difference can be explained by the theorical analyzes. Furthermore, the higher frequency means the higher yield stress when natural mud is subjected to oscillating loads. The “two-step” yield process closely correlates to the internal structure of the mud sample, which is influenced by the density and the particle size of the natural mud, the results show that both density and particle size have a significant influence on the yield stress of the natural mud.

Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-4: Understanding natural hazards in sedimentological records
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Significant liquefaction effect formed by 2009 M5.1 Hami earthquake, Xinjiang, Western China

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Keywords: liquefaction, M5.1 earquake, sandy dyke, Hami

A M5.1 shallow moderate earthquake, just only being 4km in depth, occurred in December 14, 2009, in the city Hami, Xinjiang, western China, struck about a 10000 km2 area and formed very large quantities of exquisite, polygonal network, wedge-shaped, inclined and well-sorted sandy dykes. Typically, they occur mainly in sandy gravelly sediments, not being susceptible to liquefaction, with no fined grain cap and but salted crust cap or salt-rich cap. They are generally slightly inclined, on average, 75.10°. Largely because of the widely distributed salted crust and the shallow rigid basement the maximum epicentral distance of liquefied sites may extend to more than 100 km. Through the detailed research, we conclude as follows:

(1) The M5.1 moderate earthquake, the December 14, 2009, Hami, Xinjiang, convincingly form widely distributed small-medium-scale polygonal, wedge-shape, inclined, well-sorted sandy dykes. The 3D geometric morphology of these upward injected sandy dykes has been documented herein clearly. This kind of sandy dykes may be a reliable criterion used to distinguish them from similar but non-seismically generated sandy dykes.

(2) The sandy gravel layer may be genetically undoubtedly liquefied and form numerous sandy dykes without fine grain cap. This process has two important requirements--the widely-distributed salted crust and shallow basement apart from other general liquefaction factors.

(3) Conceivably, although unlikely according to the classic theory, the maximum epicentral distance of liquefied sites of more than 100 km, formed by the moderate earthquake (M5.1) in Hami, is characteristic of the composite-effect of the wide salted crust and shallow rigid basement.

(4) Well-sorted feature of the sandy dykes is certainly attributed to the well liquefaction and fluidization of sandy gravel layer.

The well-exposed seismically-induced sandy dykes in Hami provides an important avenue for future research on primary seismically-induced sand dykes. It is a very rare case in the world.

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Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-4: Understanding natural hazards in sedimentological records
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Sedimentological record of the Fuji Sagami-River Lahar flowing down during LGM along the upper reaches of Sagami River, central Japan

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Keywords: lahar deposit, Fuji Sagamigawa Mud Flow, Fuji Volcano, Sagami River, central Japan

Lahar is a general term for a rapidly flowing mixture of rock debris and water from a volcano (Smith and Fritz, 1989). The Fuji Sagami-River Lahar (Fuji Sagamigawa Mud Flow) originated from the Fuji Volcano (Older Fuji) around 22 ka (Machida, 2009) flowed eastward along the Sagami River valley through the southwest Kanto District, central Japan. The lahar deposit is covered by younger lava flows at the foot of the Fuji Volcano, and it is exposed intermittently along the Sagami River from ca.20 km to ca. 90 km apart from the present Fuji Volcano summit. Although the lahar deposit was investigated intensively by Geographical and Geological Research Group in Sagamihara City (1990), detailed description of the upper reaches of Sagami River has not been performed yet.

Our minute investigation of the lahar deposit in the upper reaches of the Sagami River revealed that (1) the lahar deposit filled the Sagami River valley floor entirely with ca. 20 m thick at least the studied area, (2) the deposit is divided the lower unit composed by boulder–cobble sized basalt and the upper unit composed by pebble sized basalt and scoria, (3) the upper unit is divided 6 or more subunits intercalating scoria or fluvial deposits and (4) the lower unit is more than 10 m thick at ca. 30 km apart from the present summit. Although the lower unit is almost hidden below the valley floor, it would be distributed up to 40 km or more distal from the present summit.

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Machida (2009) Nature in History of Sagamihara City. Sagamihara City, 159-165

ID: T3-40890

Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-4: Understanding natural hazards in sedimentological records
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Infuence of biopolymers on the rheological properties of natural silt

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Keywords: biopolymers,rheological properties,solid-liquid state transformation,yield stress,EPS network

In order to explore the effect of adding biopolymers (EPS) on the rheological properties of silt, we used rotary rheometer to study the shear dynamic response of kaolinite-quartz suspension and silt from tidal flat of Zhairuoshan Island, Zhoushan. Rheological properties of kaolinite-quartz suspension with different proportions and natural silt with different bulk densities were compared with or without the addition of biopolymers (xanthan gum was used instead). The results show that the tidal flat silt of Zhairuoshan Island has the characteristics of dual-Bingham under shear load, and the relationship between shear stress and shear rate can be quantitatively described based on dual-Bingham rheological model. With the increase of shear loading rate, the silt shows complex solid-liquid state transformation, and its dynamic response process can be divided into three typical stages: quasi-solid state, solid-liquid state and liquid state. In addition, biopolymers (EPS) can affect rheological properties in natural systems. Our experiments demonstrated that the fow behavior of sediment suspensions or natural silt mixed with an analogue material of EPS (xanthan gum) can be described by a Herschel–Bulkley model. The addition of EPS can also enhance the yield stress of silt, by means of formation of an EPS network that binds silt particles.

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Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-4: Understanding natural hazards in sedimentological records
Presentation Preference: Oral Preferred

Repeated deposition of earthquake-induced turbidites along the landward slope of the northern Japan Trench: how large ground shaking is necessary for generation of surface-sediment remobilization along the slope?

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Keywords: turbidity current, surface-sediment remobilization, slope sediment response, earthquake ground shaking, Japan Trench

Deep-sea turbidites have been utilized to understand the history of past large earthquakes. From a paleoseismological point of view, it is important to understand the trigger conditions of earthquake-induced turbidity currents. Surface-sediment remobilization is considered to be a mechanism for the initiation of earthquake-induced turbidity currents, based on the studies of the event deposits formed by the recent great earthquakes, such as the 2011 Tohoku-oki earthquake, although submarine slope failure has been considered to be a major contributor. Small age differences (less than a few 100 years) in radiocarbon ages between turbidite and hemipelagic muds in a piston core collected from the mid-slope terrace (MST) along the northern Japan Trench at 40.13˚N suggest that initiation of turbidity currents caused by the earthquake-induced surface-sediment remobilization has occurred repeatedly during the last 2300 years. A profile of excess 210Pb activities of an undisturbed surface sediment core from the same location suggests that the uppermost three event beds are correlative to three historical earthquakes along the northern Japan Trench. Estimations of peak ground acceleration (PGA) for the historical earthquakes indicate that >0.6 G of PGA is necessary for deposition of each event bed at the slope near the coring site. This limit is slightly larger than that (~0.4–0.5 G) at slope of 39.25˚N, suggesting the spatial difference of response of slope sediments to the earthquake ground shaking. However, the frequency of the event beds at 40.13˚N is higher than those at 39.27˚N and 39.12˚N. Great earthquakes near junction of Japan/Kuril trenches are possible candidates to form additional event beds at the northern Japan Trench slope.

Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-4: Understanding natural hazards in sedimentological records
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Geological record of a mega-tsunami in the Miocene Tanabe Group, central Japan

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Keywords: tsunami deposit, Miocence, Tanabe Group, Japan, mega-tsunami

Tsunamis generated by fault displacements, volcanic eruptions, and landslides on the seafloor often occur, with time intervals of tens to hundreds of years in active plate margins. Several such tsunamis have occurred in recent years, and some have been recorded in written documents since the dawn of history. Since mega-tsunamis, which are much larger than recent tsunamis and are generated by bolide impacts, violent volcanic activities, and oceanic island flank collapse, for example, are less frequent, they may not have been experienced by humans, and even if they were, they may not have been documented. However, sedimentary rocks with significantly longer time scales may record tsunamis of a magnitude never experienced or documented by humans.

This presentation will report on a shallow marine tsunami deposit found in the Miocene Tanabe Group, Wakayama Prefecture, Japan. The deposit is intercalated in tide-dominated shallow marine deposits. The deposit consisting of medium- to coarse-grained sandstones, rip-up clasts, and subangular-subrounded pebbles, is estimated to have eroded the underlying strata up to 1.5-6 m or more. The maximum thickness of this deposit is 8.8 m. The bed can be traced approximately 1 km in some coastal outcrops, and is characterized by the following sedimentological features; (i) multiple sub-layers separated by internal erosional boundaries, (ii) HCS, (iii) flame structure at sub-layer boundaries, (iv) fluid escape structures, and (v) organic debris at some sub-layer boundaries and the top. Trace fossils and bioturbate textures are not observed throughout the succession.

The existence of multiple sub-layers is a feature that has been reported from submarine and onshore tsunami deposits, and each sub-layer is considered to have been formed through the tsunami uprush or backwash. HCS indicates that this deposit was formed under the influence of waves with longer periods. Fluid escape structures may reflect that a large amount of sediment was supplied and deposited instantaneously. The abundant organic debris suggests that the onshore areas were also eroded during this event. This deposit shares characteristics with previously reported tsunami deposits, but its thickness and degree of substrate erosion far exceed those of present-day shallow marine tsunami deposits. This implies that the tsunami deposits found in the Miocene Tanabe Group were exceptionally large even in the geological time scale

Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
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Soft-sediment deformation structures in a lacustrine depositional context: An example from the Eocene Dongying Depression in the Bohai Bay Basin, East China

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Keywords: Soft-sediment deformation structures, Deformation mechanisms, Seismites, the Dongying Depression

The study documents soft-sediment deformation structures (SSDSs) in the lacustrine Dongying Depression, a Paleogene synrift basin located in the southeastern corner of the Bohai Bay Basin, East China. The focus of this study is the lower part of the upper 4th member of the Eocene Shahejie Formation ($Es4^{U}$), characterized by littoral to sublittoral deposits in the southwestern Dongying Depression. Nine lithofacies are grouped into the upper shoreface facies associations (FA1-1), lower shoreface facies associations (FA1-2), and sublittoral facies associations (FA2). Fine-grained calcareous sandstone was mainly deposited in FA1-1, with thinly alternating calcareous mudstone and siltstone or sandstone in FA1-2, while deposition in FA2 was dominated by mudstone, containing sediment gravity flow deposits. The SSDSs widely encountered in the lower $Es4^{U}$ can be classified into seven categories: (1) load structures, (2) water-escape structures, (3) folds and convolute lamination, (4) sediment-injection structures, (5) microfaults, (6) autoclastic breccias, and (7) slumps. Detailed observations of SSDSs from cores indicate liquefaction and fluidization as the main deformation mechanisms in the sands and muds. Moreover, rupturing of cohesive deposits also contributes to the soft-sediment deformation. The types and morphologies of the SSDSs are closely related to the rheologies of the sediments (e.g., the sand content), influenced by the facies that determine the lithologies and stratigraphic stacking patterns. Except for some deformation structures related to subaqueous sediment gravity flows (e.g., muddy debrite flows and slumps), most SSDSs are ascribed to rift-related seismicity due to the activity of the adjacent synsedimentary faults when the Dongying Depression underwent quick subsidence during the Eocene.

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Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-4: Understanding natural hazards in sedimentological records
Presentation Preference: Oral Preferred

Sediment dynamics on a tidal flat in macro-tidal Hangzhou Bay during Typhoon Mitag

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Keywords: Sediment dynamics, Tidal flat, Typhoon, Hangzhou Bay

Field records of waves, currents, and suspended sediment concentration (SSC) in the southern tidal flat (Andong) of the macro-tidal turbid Hangzhou Bay, China, were collected during Typhoon Mitag. The record showed little variance in the magnitude of the tidal currents during the typhoon. The directions were disordered with the peak ebbing currents changing from the southeast to the east, presumably due to the winds and northerly currents from the tidal creeks during the precipitation period. The significant wave heights (Hs) and turbulence kinetic energy (TKE) significantly increased during Typhoon Mitag. The SSC obtained by the optical backscatter sensor (OBS) near the bottom level rose rapidly to 6–7 kg/m^3 during the initial stage of tidal cycles during calm conditions but decreased to 4–6 kg/m^3 during Typhoon Mitag, probably due of the enhanced upward sediment transport by turbulent mixing. During normal weather conditions, the bed shear stresses induced by currents (τ_c) were mostly larger than those induced by waves (τ_w), while the τ_w exceeded the τ_c during the storm. The instantaneous bed shear stresses induced by currents and waves were mostly lower than the critical shear stress. Extracting turbulence from waves effectively diminishes the overestimation of turbulence. In calm conditions, the small-scale features (>0.5 Hz) of the scalograms exhibited some degree of disorder owing to the random nature of turbulence. Small-scale characteristics were embedded in relatively large-scale motions during extreme conditions, and a small quantity of plume-like streaks appeared between the frequency bands of 1/16 and 1 Hz. The temporal distributions of the high wavelet power regions of $U'W'$ and $c'W'$ coincided with each other, indicating the critical role of intermittent turbulence in sediment dynamics. The results of this study shed light on the study of coastal morphology and marine disasters.

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Presentation Preference: Oral Preferred

Sedimentary Record of Coastal Hazards in Zhangjiang Estuary since the Late Holocene

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Keywords: Typhoon hazard, Storm deposit, Zhangjiang Estuary, Bulk organic carbon isotope, Late Holocene

Rising sea levels as a result of global warming pose a great threat of coastal hazards to coastal areas, with flooding and storm surges being one of the most prominent. Such fact highlights the necessity of improving the resilience of coastal areas to risks, which strongly relies on accurate future risk assessment, for which, an improved understanding on the reoccurrence interval of major typhoon-induced coastal hazards is crucial. Due to the limited accuracy or timeframe for historical and instrumental records, sedimentary records have found to be useful for archiving strong coastal overwash events, especially for capturing catastrophic events usually with a returning period longer than 100 yrs. in order to understand the sedimentary features of coastal hazard deposits and to explore the temporal and spatial characteristics and driving mechanism of coastal hazards, this study focuses on the Zhangjiang Estuary in Fujian Province, southern China, where a sediment core was collected in 2018. By employing a range of biogeochemical indicators, this study reconstructs the history of coastal paleo-hazard since about 4200 years ago in this region and comes into three main findings: 1) Under fair weather conditions, the sediments in the Zhangjiang Estuary area are mainly composed of silt, while during strong hydrodynamic conditions, sediments are usually poorly sorted and of complex sedimentary provenances as indicated by biogeochemical indicators. 2) The intensity of the typhoon hazard in the Zhangjiang Esturay area has been increasing since the Late Holocene. Specifically, there were three periods of frequent coastal hazards during 1400-700 cal a BP (3 times / 700a), the frequency of which was about twice that during the period of 3900-2500 cal a BP (3 times / 1400a). 3) The spectrum analysis has identified ca. 700-year and ca. 400600-year cycle in late-Holocene climate change history in Zhangjiang Estuary. The 600-year cycle may be the cycle of frequent strong typhoon period, which may be related to Holocene solar activity at different time scales.

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Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

The world's longest continuous sedimentary record of large earthquakes was recovered by using an innovative quantitative method

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Keywords: Seismite, Marine/Lacustrine Paleoseismology, In situ soft-sediment deformation, Computational fluid dynamics modeling, Kelvin-Helmholtz Instability

The Dead Sea Basin is the deepest and largest continental tectonic structure in the world. *In situ* folded layers and intraclast breccia layer in the ICDP Core 5017-1 that recovered from the Dead Sea depocenter are identified as earthquake indicators, based on their resemblance to the lake outcrop observations of seismites that are known to be earthquake-induced.

Analysis of the physics of formation and temporal distribution of 413 seismites in the 457-m-long Dead Sea ICDP Core 5017-1 yields a continuous earthquake record spanning 220 kyrs in and near the Dead Sea Basin. Based on the Kelvin-Helmholtz instability, we model the ground acceleration (seismic shaking intensity) needed to produce each seismite by using the physical properties of the Dead Sea deposits. We invert acceleration for earthquake magnitude by considering regional earthquake ground motion attenuation, fault geometry, and other constraints. Based on the magnitude constraints, we develop a 220 kyr-long record of M_w ≥7 earthquakes.

The unique location of the drill site makes the 220 kyr-long earthquake record the most complete on the central Dead Sea Fault. Our analysis shows that the recurrence time of large (M_w ≥7.0) earthquakes follows a power-law distribution, with a mean of ≤ 1400±160 years. This mean recurrence is significantly shorter than the previous estimate of 11,000 years for the past 40 kyrs. Our unique record confirms a clustered earthquake recurrence pattern and a group-fault temporal clustering model, and reveals an unexpectedly high seismicity rate on a slow-slipping plate boundary.

Our study highlights the potential of in situ deformed sediment layers in a subaqueous environment as a strong-motion paleo-seismometer to record long seismic sequences covering multiple recurrence intervals of large earthquakes. Long records are vital for accurate hazard assessment. Our quantitative method of seismic record reconstruction, with paleo-earthquake intensity (ground acceleration) and magnitude estimation, is also applicable to other subaqueous environments along faults.

Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
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Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Seismic and non-seismic triggers of soft-sediment deformation structures in a landslide-dammed lake at Diexi, eastern Tibetan Plateau

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Keywords: Soft-sediment deformation structure, Late Pleistocene, Triggering mechanism, Seismic shaking

A variety of triggers can form soft-sediment deformation (SSD) structures, such as gravity-induced loading and slumping, floods, mass movement and debris flows. Much existing research is focused on understanding seismically-induced SSD structures known as seismites. Palaeo-earthquake information obtained from SSD structures has been applied to a wide range of earthquake attributes, but most studies on palaeo-earthquake were identified from field sections, the relationship between SSD structures in cores and seismic events remains unclear, and distinguishing seismic from non-seismic triggers remains a major challenge.

Diexi Lake formed when seismically-induced landslides blocked the main valley, creating the largest landslide-dammed lake in the upper Minjiang River, eastern Tibetan Plateau. An excellent record of SSD structures is preserved in a ~166 m-long drill-core (DX-2A) retrieved from Diexi Lake in 2019. Here, we identify and describe 454 SSD structures in the core and consider their mechanism of formation. Based on their morphological characteristics, we classify the SSD structures into three main types: (1) liquefied flow structures, (2) load structures, and (3) thixotropic flow structures. In addition, we propose at least five mechanisms for the formation of SSDs that are not necessarily linked to seismicity: (i) overpressure caused by gravity; (ii) fluidization of sediments affected by river runoff velocity; (iii) floods, landslides, debris flows and other slope failures triggered by extreme precipitation events; (iv) lake surface waves generated by wind; and (v) sediment instability at the lake floor margins. According to previous studies on the relationship between SSD structures and earthquake, if the SSD structures in DX-2A are triggered by earthquakes, the magnitude (Ms) of palaeo-earthquakes may be 2-7.5, mostly are Ms≥5-5.5. These findings provide a useful basis for a quantitative analysis of palaeoseismicity on the eastern margin of the Tibetan Plateau.

Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-4: Understanding natural hazards in sedimentological records
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Sediments prone to liquefaction – implications from field studies: review

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Keywords: liquefaction, soft-sediment deformation structures, statistical analyse, grain-size analysis

Liquefaction-induced soft-sediment deformation structures (SSDS) can be triggered by wide spectrum of mechanisms, e.g. seismic activity, volcanic eruption, ice and sediment loading, storm waves and tsunamis. To better understand their origin Owen (2003) suggested dividing liquefaction-induced SSDS into two groups: synforms (e.g. load casts, pseudonodules) and antiforms (injection structures).

The aim of this study was detailed grain-size analysis of the sediments (170 samples) within synforms and antiforms recognised in eight study sites in the southern part of the Baltic Sea basin (Latvia, Lithuania, Germany). Mastersizer 2000 by Malvern particle size distribution of each sample were analyzed using laser diffraction. Then, using the GRADISTAT software, the sediments were determined according to the Friedman and Sanders (1978) classification. Furthermore, basic statistical parameters were calculated: mean diameter, skewness, standard deviation and kurtosis (Blott and Pye, 2001).

Preliminary results of the research have shown that antiform structures are mainly composed of silty sediments (coarse-grained silt, very coarse-grained silt, very fine-grained sand), while the synform structures - sandy sediments (fine-grained and medium-grained sand). The sediments within antiforms are characterized by very poor and poor sorting, and leptokurtic (up to extremely leptokurtic) distribution. Sediments within synforms are moderately good and good sorting, and their distribution is platykurtic or very platykurtic (only a few % of the samples charactrised mesokurtic distribution).

The obtained results are in contradiction with previous studies suggested that the antiforms are composed of well-sorted sediments (e.g., Obermeier, 1996; Owen, 2003; Maltman and Bolton, 2003; Owen and Moretti, 2011).

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Session T3-5: Storm records in a changing climate from centennial to millennial timescales

ID: T3-50429

Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-5: Storm records in a changing climate from centennial to millennial timescales
Presentation Preference: Oral Preferred

A PIONEER STUDY OF HURRICANE IDA'S STRATIGRAPHIC SIGNATURE AND SIGNIFICANT DAMAGE TO THE MISSISSIPPI DELTA SHORELINE

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Keywords: Hurricane Ida, Mississippi River Delta, Paleotempestology, Multi-proxy analysis, Remote sensing, mangrove

Hurricane Ida devastated the Mississippi River Delta at the end of August 2021. The multi-proxy dataset from Port Fourchon, Louisiana, the eye of Ida at landfall indicates that backbarrier lake is a more sensitive repository in receiving and preserving storm surge deposits, and backbarrier mangrove swamp shows promising effects on attenuating storm surge impacts. The remote sensing analysis shows that the sand volume of the ~2 km studied beachfront was reduced by 240,858 m3 after consecutive landfalls of Hurricane Zeta and Ida in 2020 and 2021, losing almost 40% of its volume in 2019, while the average dune crest height was reduced by over 1 m and the shoreline retreated ~60 m after the two hurricane strikes. Our spatial-temporal analytical dataset suggests that the human-engineered beach nourishment effort is not adequate to protect the shorelines at the Mississippi River Delta from intense hurricane landfalls.

ID: T3-50481

Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-5: Storm records in a changing climate from centennial to millennial timescales
Presentation Preference: Oral Preferred

Simulated reconstruction of the Super Typhoon events along the coast of Hangzhou Bay during the decline of Liangzhu Culture

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Keywords: Storm deposit,Dynamic process simulation,Liangzhu Culture

Liangzhu Culture symbolizes the peak of neolithic culture development in the Yangtze River Delta. Its archaeological ruins spread the coast of Hangzhou Bay and reflects an early regional civilized country. But the Liangzhu Culture suddenly declined around 4300 yr BP, which may be related to the rapid sea level rise and the frequent occurrence of extreme storm events in a warm climate. However, previous studies mostly focused on the identification of the single storm based on sedimentary storm records, but failed to reconstruct the intensity, path and impact on cultural succession of extreme events. Therefore, this study intends to analyse the time and space distribution of the sedimentary storm records at Liangzhu sites, to obtain the inundated area of extreme storm events at the end of Liangzhu Culture; based on the paleotopography at the end of Liangzhu culture, a hydrodynamic model is established to simulate the tides, waves and inundation by paleo-storms with different intensities and paths and a sediment model is established to simulate the erosion and depositional processes along the coast of Hangzhou Bay. By comparing the sedimentary records and numerical simulated results, we reconstruct the intensity and path of the Super Typhoon events at the end of Liangzhu Culture, reveal the formation mechanism of coarse-grained sediments above the cultural layer, and discuss the relationship between extreme storm events and the decline of Liangzhu Culture. Thus, this study can extend the typhoon record in eastern China and provide analogical cases for extreme weather disasters prevention in the future.

ID: T3-50666

Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-5: Storm records in a changing climate from centennial to millennial timescales
Presentation Preference: Oral Preferred

The Index of Grain Size, Sporopollen and Magnetic Susceptibility Reveal the Environmental Change and the Shijiahe Civilization in Jianghan Plain of The Middle Reaches of Yangtze River

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Keywords: Tanjialing site, Sporopollen, grain size, Magnetic Susceptibility, Holocene environmental change

Shijiahe culture is the most widely distributed and developed culture type in the middle reaches of the Yangtze River at the end of the Neolithic age. The dating results obtained from the Tanjialing section and the ZJ-3 borehole are in good agreement with the stratigraphic sequence, especially the dating results of the Shijiahe culture layer, which are 4942-4097 cal. a BP after the correction of IntCal20 curve, without inversion and consistent with the relative age of The Shijiahe culture. Therefore, it can be considered that the absolute age of The Shijiahe culture in Tanjialing area is 4900-4100 cal.a BP. According to the analysis of palynology, grain size and magnetic susceptibility, the region had a warm and wet Holocene megalwarm-period before 5600 a BP, the climate tended to become dry from 5600 a BP to 4900 A BP, the climate was a relatively turbulent period from 4900 to 4800 cal.a BP, and the climate gradually became cool and dry in the following 600 years. The ancient people experienced the most prosperous period under the background of the great climate, and then gradually due to the drought of the climate, rice farming declined, which led to the decline of culture.

ID: T3-50787

Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-5: Storm records in a changing climate from centennial to millennial timescales
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Seabed erosion and deposition related to the typhoon activity of the past millennium on the southeast coast of China

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Keywords: sedimentary hiatus, erosion, typhoon, tsunami, the northern South China Sea

Catastrophic events often interrupt long-term Earth' s surface processes. In coastal areas, although millennial-scale trends of climatic and sea-level changes determine the trajectory of sedimentary landform evolution, storm and/or tsunami activity can cause abrupt changes in depositional conditions that may alter the long-term sedimentary processes. Here, we report a sedimentary hiatus that is widely observed from the late Holocene sedimentary sequence at the seabed along the southeast China coast. This hiatus was discovered by close temporal sedimentary and radiocarbon dating analyses of a seabed sedimentary sequence in the mouth area of the Pearl River estuary. The results suggest that a couple of meters in the middle to late Holocene sediment at the seabed were eroded by a catastrophic event happening c. 1000-800 cal. years BP. In theory, a mega-tsunami generated from the Manila Trench could have caused such erosion at the seabed, but there is a lack of direct geological and historical evidences to support such a hypothesis. Much more likely, a super typhoon struck the coast and caused the erosion. This hypothesis is strongly supported by the region’s historical and geological records which suggest a period characteristic of intense typhoons ranging from the Medieval Warm Period to the climate transition phase (c. 1000-600 cal. years BP). During the subsequent Little Ice Age, deposition of sandy sediment continued, suggesting frequent but weaker typhoon activity. Over the past two centuries, the deposition of sandy sediment and gravels began, implying the beginning of a phase of intensifying typhoon conditions, possibly a result of the recent warming climate.

ID: T3-50882

Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-5: Storm records in a changing climate from centennial to millennial timescales
Presentation Preference: Oral Preferred

Mid-Holocene drought and hurricane events in Central America recorded by Puerto Rico stalagmites

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Keywords: Speleothems, Hurricanes, Mid-Holocene, Central America

In recent years, the coastal areas near the Gulf of Mexico and the Caribbean have been repeatedly hit by hurricanes, which have brought serious harm to the local social and economic development. Therefore, predicting future hurricane activity is essential, and the reconstruction of past hurricane changes provides a possibility for future hurricane prediction. Speleothems are a kind of high-quality terrestrial paleoclimate archives that are widely developed. Speleothems have accurate dating and high resolution and were commonly used in paleoclimate research. Much research has also confirmed that stalagmite has the potential to reconstruct the history of hurricanes(Vieten et al., 2018 , Lases-Hernández et al., 2020, Frappier et al., 2007 , Nott et al., 2007).

With the Atlantic Ocean to the north and the Caribbean Sea to the south, Puerto Rico is highly vulnerable to hurricanes and is an excellent location for studying the history of hurricane activity. In this study, we reconstructed the Mid-Holocene hurricane and hydrological history of Puerto Rico based on multiple geochemical indicators of stalagmite IM-94. The results suggest that the frequency of hurricane activity varied on centennial to decadal scales during the study period, which may be regulated by atmospheric dynamics related to el Nino/Southern Oscillation. At the same time, rainfall in this area is mainly affected by solar radiation on a centennial scale. When solar radiation decreases, the North Atlantic becomes cooler, the subtropical high in the North Atlantic weakens, the tropical convergence zone moves southward, and regional rainfall decreases.

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ID: T3-51087

Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-5: Storm records in a changing climate from centennial to millennial timescales
Presentation Preference: Oral Preferred

Millennial Sedimentary Archives of Tropical Cyclones in South Pacific

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Keywords: South Pacific, tropical cyclone, sedimentary archive, reconstruction

Tropical cyclones (TCs, i.e., storms) have been causing significant damages and loss of human lives and resources in heavily populated coastal regions, and have gained extensive attention. As a result, it is critical to reveal the millennial variability of TCs for coastal risk management, while our centennial instrumental records in hand cannot meet this requirement. Fortunately, the high-energy dynamic conditions associated with TC landfalls could leave event layers in sedimentary archives from low-energy coastal environments, such as lagoons and blue holes, which allows us to recover millennial TC variability characteristics. Numerous paleo-storm reconstructions have been carried out based on sedimentary records from coastal areas prone to storm in the past several decades. For now, such reconstructing studies are relatively mature in the North Atlantic and the Northwest Pacific in terms of quality, quantity, spatial coverage and time scale, while there is a paucity of such work in the South Pacific, which is as well vulnerable to TC attacks. This status quo has restrained us to depict a full picture of TC activity characteristics from a global perspective.

In this study, three sets of sediment cores were recovered from tropical islands of Melanesia in the South Pacific (namely the Salt Lake, Fiji, a blue hole in the Bay of Islands, Fiji, and Marou Lagoon in Emao Island, Vanuatu). On basis of these sediment cores, three decadal resolution and millennial-scale time series of paleo-TCs were established by integrating sedimentological methods, statistical methods and age-depth model, and corresponding paleo-TC frequencies were calculated. The three TC time series present similar centennial variability shift; then they were combined with several previous studies in the South Pacific, and were compared with the ENSO proxy variability of the past 3000 years. It is suggested that TCs in Melanesia Archipelago and the northwest coast of Australia are active during El Niño events, and are more quiescent during La Niña events; however, in Polynesia, the TC activity patterns are in phase with the El Niño index before 1000 CE but they present reverse phase after that.

Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-5: Storm records in a changing climate from centennial to millennial timescales
Presentation Preference: Oral Preferred

Along-slope versus downslope sedimentation patterns on the high-latitude eastern Canadian continental margin during the last glacial period

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Keywords: Sediment dynamics, last glaciation,Holocene, nepheloid-flow deposits, mud-turbidites, Labrador Sea

Late Pleistocene Labrador Sea depositional systems developed in front of ice streams and glacier outlets from the Laurentide Ice Sheet (LIS) are documented by Huntec and 3.5 kHz seismic profiles and piston cores. Due to efficient grinding by the LIS, massive amounts of fine-grained sediments and meltwater in addition to the icebergs tied to the Heinrich events (H-events) of the last glaciation were delivered to the neighboring Labrador Sea. The position of the Hudson Strait ice stream during the periodic expansion and contraction on the Labrador margin allowed fine-grained sediments and meltwater direct delivery on the lower shelf and upper slope. These discharges were then transported southward by the Labrador Current and western boundary current. In contrast to the lower shelf and upper slope, sediment delivered on the mid to lower Labrador slope were transported by the Northwest Atlantic Mid-Ocean Channel to distal sites. Nepheloid-flow layer at or near the sea bottom or at mid-water depths develop from meltwater loaded with an excessive charge of fine-grained sediments. Contrastingly, non-discriminatory ice rafting process delivered detritus of all sizes, but its total contribution to the sediment column is only minor, notwithstanding its paleoclimatic significance during H-events.

Heinrich H1, H2, and H4 layers were identified by their characteristic nepheloid-flow layer deposits, i.e., alternating coarse silt and clay-sized laminae with thin ice-rafted debris interspersed by coarse to fine-grained dropstone. Further, the progressive thinning and eventual disappearance of the fine-laminae (i.e., coarse and fine silt/clay) in H-layers at the distal sites suggests the exhaustion and raining out of fines due to long-distance transport. However, the H3 layer was identified by a combination of nepheloid-flow layer deposits (upper slope) and finely-laminated mud turbidites (lower slope and deep basin) at proximal sites. In the lower Labrador Slope and Basin, the H3 stratigraphic equivalent layer was identified by exorbitantly thick finely-laminated carbonate-rich mud turbidites. The divergent sedimentation style (i.e., reflected by the sediment facies) and the thickness of the H3 layer compared to other H-events suggests that the Hudson Strait ice-stream position was different compared to other H-events. Therefore, our data imply that the divergence in the H3 layer between the eastern and western North Atlantic might lie with the position of the Hudson Strait ice stream on the Labrador continental margin.

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Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-5: Storm records in a changing climate from centennial to millennial timescales
Presentation Preference: Oral Preferred

Northwestern Pacific tropical cyclone activity enhanced by increased Asian dust emissions during the Little Ice Age

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Keywords: Tropical cyclone activity, Grain size, Sea surface temperature, Asian dust emissions, Little Ice Age

Instrumental records reveal that intense tropical cyclone (TC) activity varies with tropical sea surface temperature (SST) on annual-decadal scales. Drivers of intense TC activity at the centennial-millennial scale are less clear, due to the sparseness of pre-observational reconstructions. Here, we present a new 2 kyr continuous activity record of intense TCs from offshore eastern China. Our reconstruction indicates that this site witnessed enhanced TC activity during relatively warm periods, with a widespread increase in TC activity during the later part of the Little Ice Age. This latter observation reveals that enhanced TC activity was synchronized with increased Asian dust emissions during the Little Ice Age. TC activity was also lower in the late Roman Warm Period, when SST was higher but Asian dust emissions were lower than in the early phase. Such patterns suggest a centennial-millennial link between TC climatology and a combination of SST changes and Asian dust levels.

ID: T3-51207

Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-5: Storm records in a changing climate from centennial to millennial timescales
Presentation Preference: Oral Preferred

Event beds of the Changjiang River over the past 2000 years: Floods VS storms

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Keywords: flood deposits, storm deposits, multi-proxy method, Changjiang river delta

Storms and floods have exerted significant influences on the sedimentation of the river delta. However, how to distinguish the storm deposits from flood deposits in the large river deltas has not been well understood. In this study, a multiproxy analysis method (e.g. sedimentological, geochemical analysis) was established to distinguish the storm deposits from flood deposits, by using a 4.8-m-long sediment core retrieved from the subaqueous delta of the Changjiang River. This multi-proxy analysis indicates that the sedimentological signatures of palaeoflood deposits are characterized by a high EM5 content and high Zr/Fe ratios in the subaqueous delta sedimentary sequence, while storm deposits are characterized by a high EM5 content, with anomalies in Ca and Sr peaks.

Base on this multi-proxy method, we establish a flood history for the Changjiang River during the late Holocene, and14 continuous paleoflood regimes were identified during 19–66 BCE, 25–80, 255–350, 415–475, 550–710, 740–835, 970–990, 1080–1130, 1170–1235, 1275–1390, 1440–1500, 1560–1730, 1810–1830, and 1950–2011 CE respectively. These flood units match well with the observed large floods, documentary records of floods, and sedimentary flood deposits, confirming that the coarse units in the sequence are flood-derived and are regionally representative.

Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-5: Storm records in a changing climate from centennial to millennial timescales
Presentation Preference: Oral Preferred

Disentangling the drivers of tropical cyclone frequency variability across the North Atlantic throughout the late Holocene

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Keywords: Paleoclimate, Paleoceanography, Coastal, Reconstruction, Atlantic, Storms

The year 2020 Common Era (CE) observed the most "named" tropical cyclones since the instrumental record began in 1850 CE. Most downscaled models indicate that Anthropogenic climate change will increase the frequency and destructive potential Atlantic tropical cyclones. Problematically, it is difficult to ascertain if recent high-activity is unprecedented over longer-time scales due to the short instrumental record. Coastal and marine sedimentary archives may preserve a longer record of past tropical cyclones in the form of coarse-grained beds deposited by storm waves and surge, and therefore can be used to develop high-resolution reconstructions of local-scale variability tropical cyclones. We present an updated summary of six near-annually resolved tropical cyclone activity reconstructions developed from offshore sinkholes across The Bahamas. Each reconstruction documents decadal-to-centennial-scale periods of significantly enhanced local storm frequency, however substantial inter-island heterogeneity signals that single-site reconstructions may not reflect broader regional trends. A 1500-year statistical compilation of these individual records documents significantly higher storm activity in the subtropical North Atlantic during the Little Ice Age (LIA; 1300-1850 CE), which is coincident with an intensified West African Monsoon that could have promoted cyclogenesis in the Atlantic Main Development Region. This suggests that ocean/climate conditions in the subtropical North Atlantic remained favorable for storm development despite a globally cooler climate during the LIA. Problematically, many spatiotemporal gaps remain in record coverage, particularly in the high-mid latitude Canadian Maritime Provinces. To address this, we also present preliminary findings from new high-resolution sedimentary reconstructions being developed from coastal sites in north and south Newfoundland, Canada. By reconstructing the last ~7,000 years of high-mid latitude storminess, we aim to assess how regional ocean-climate conditions (e.g., vertical wind shear, Labrador Current intensity/sea surface temperature) modulate storm activity in the high-mid latitudes beyond broader changes in overall tropical cyclone frequency reflected by the lower latitude (i.e., Bahamian) reconstructions.

Scientific Themes: Theme 3. Environmental & Hazard Sedimentology
Session T3-5: Storm records in a changing climate from centennial to millennial timescales
Presentation Preference: Oral Preferred

Stormier mid-Holocene southwest Indian Ocean due to poleward trending tropical cyclones

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Keywords: Tempestites, continental shelf, tropical cyclones, SW Indian Ocean

Various geological proxies have been used to document pre-instrumental storminess and associated climate variability. Here we present the first such evidence for the SW Indian Ocean derived from shoreface tempestites and interpret it in the context of past and present coupled ocean-atmosphere climatic change driven by the Indian Ocean Dipole (IOD). Using a combined ultra-high resolution seismic, multibeam bathymetric, downcore-geochemical and modelling approach, we examine a series of high-energy sedimentary deposits preserved in the shoreface off Durban, South Africa. High-energy events are recorded as hummocky seismic units, the sediments of which have clear marine geochemical signatures and comprise discrete fining upward cycles characteristic of periodic high-energy storm-wave deposits (tempestites). The shoreface tempestites occur in an age range between 6480 cal yr BP to 4595 cal yr BP, a period when sea level was between 0 and + 3 m above present. Modelled wave-induced orbital velocities and bed shear stress required to entrain gravel-sized material on the shoreface for the largest historical event and the 100-year return-period storm, reveal that contemporary storms can potentially mobilise the lower shoreface seabed. The tempestite deposits in the cores were not reworked by such storm-waves and thus indicate deposition by paleo-storm waves much larger than those in the modern 100–year storm range. The time period during which the shoreface tempestites formed coincides with periods of strongly positive IOD anomalies, linked to warmer sea surface temperatures and points to much increased storm magnitudes associated with a poleward track and more intense tropical cyclones in the SW Indian Ocean. As global warming continues, stronger positive anomalies in the IOD are projected and, despite uncertainties, further intensification and poleward migration of tropical cyclones is expected. We suggest that intense tropical cyclones, likely responsible for the mid-Holocene tempestites, will impact the SE African coastline, requiring a major revaluation of coastal development and planning, especially in large coastal metropolis such as Maputo and Durban.

Theme4

Biological Process in Sedimentation

Session T4-1: Deep Biosphere: roles of subsurface life in elemental cycles and life-environment co-evolution

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-1: Deep Biosphere: roles of subsurface life in elemental cycles and life-environment co-evolution
Presentation Preference: Oral Preferred

Viruses, Membrane Vesicles, and Gene Transfer Agents: The Transductome of a 2.5km-Deep Subseafloor Community

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Keywords: horizontal gene transfer, virus, evolution, subsurface, transduction, microbiology

Horizontal gene transfer is an important driver of adaptation and evolution in microorganisms. Transducing biological nanoparticles such as viral particles are believed to be key facilitators of horizontal gene transfer.
In deep subseafloor sediments, energy and nutrients are highly limiting, supporting only extremely slow metabolisms with doubling times estimated to be as long as decades to centuries. In such low-energy, isolated environments where communities may subsist for millions of years, the mechanisms of subsurface microbial adaptation and evolution remain a mystery. Viruses have been found everywhere that life has been found, including deep subsurface environments. Recent findings show that viruses are even more abundant in subseafloor sediment than previously expected. While there is a good understanding that microorganisms are abundant and active in the Earth's subsurface, the role of viruses in shaping and influencing these slow-growing communities is only recently starting to be explored. Here, we analyzed sediments collected from a coalbed layer 2km below the seafloor offshore Shimokita, Japan in which a resident microbial community had been buried for 20 million years (IODP Expedition 337). We harvested biological nanoparticles (<0.2um) and cells (>0.2um) from a bioreactor enrichment seeded by the 20 million year old coalbed sediment. We sequenced DNA from the cells and nanoparticles and subsequently analyzed the metagenomes. Within the nanoparticle metagenome, numerous complete novel virus genomes were reconstructed. Comparison of the virus genomes to the prokaryotic MAGs (metagenome assembled genomes) revealed that many of the virus genomes were integrated prophage within bacterial genomes, suggesting the potential for virus-host interactions to occur in the subseafloor. Additionally, lysogeny may be an important survival mechanism for viruses in deeply buried, low-energy environments. Host genes were found to be packaged by viral particles, demonstrating the potential for specialized and general transduction by viruses. Not only viral particles, but there was also evidence that membrane vesicles and gene transfer agents may participate in transduction in this deep subsurface community. Horizontal gene transfer mediated by biological nanoparticles may be an important mechanism of adaptation for deep subsurface microbial communities and may provide insight into possible evolutionary processes shaping microbial communities in the deep subsurface. These results may also shed some light onto the nature of viral infection in the subsurface, potentially revealing insights about the long-term persistence of life under the extreme conditions of nutrient and energy limitation and how viruses may survive over geological timescales.

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-1: Deep Biosphere: roles of subsurface life in elemental cycles and life-environment co-evolution
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Microbial interactions in hydrothermal systems

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Keywords: biogeochemical cycle, hydrothermal ecosystem, deep sea microbes

Hydrothermal vent is a unique habitat in the deep sea. It is reported that there are more than 721 known hydrothermal regions in the world, which are widely distributed in mid ocean ridges, back arc basins and volcanic arcs. Deep sea hydrothermal vents are usually in a high-temperature and anoxic environment and rich in reducing compounds. The hydrothermal fluid is mixed with low-temperature oxygenated seawater, resulting in the imbalance of chemical reaction between reducing hydrothermal fluid and oxidized seawater. Hydrothermal autotrophic microorganisms can use the energy generated by reduced substances such as sulfur, hydrogen, methane, sulfide and iron to fix carbon, thus supporting the whole hydrothermal ecosystem. The different forms and degrees of mixing of hydrothermal and seawater shape the highly heterogeneous hydrothermal habitat. For example, symbionts formed by microorganisms and fauna, chimneys, mats, plumes, sediments and other unique microbial communities. Although some studies have made important contributions to revealing some characteristics of hydrothermal vent microbial community, these studies pay more attention to local areas, and the understanding of global hydrothermal microbial diversity, geochemical element cycle drivers and interactions is not clear. This study selected hydrothermal data from the global deep-sea microbiome to explore how the metabolic network formed by hydrothermal microbial interaction mediates the biogeochemical cycle. The purpose is to gradually sort out and form the domain knowledge base of deep-sea habitat through the research strategy from local to overall, and explore and try to reveal the mechanism of carbon, nitrogen and sulfur cycle driven by deep-sea microbial community.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-1: Deep Biosphere: roles of subsurface life in elemental cycles and life-environment co-evolution
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Methane flux shapes the methanotrophic microbiome at cold seeps of South China Sea

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Keywords: Cold seeps, Methane flux, Marine sediments, Community ecology, Methanotrophic microbiome, Deterministic processes

Marine cold seeps are chemosynthetic habitats fueled by deeply sourced hydrocarbon-rich fluids that are discharged at the seafloor. Despite the central role of the cold seep microbiome in mediating methane oxidization and other biochemical reactions, the assembly processes of seep communities remain poorly understood. Here we analyzed microbial communities and their assembling processes at two spatially distant cold seeps that cover a range of methane fluxes, habitat types, and sediment depths. We show that methane flux had a much stronger impact on the seep microbiome than geographical location, biological coverage and sediment depth. Phylogenetic-groups-based null model analyses further reveal the greater role of homogeneous selection than dispersal and drift on shaping community assembly under high methane flux. Within the community of anaerobic methanotrophic archaea (ANME), the ANME-1 clade accounted for >60% while ANME-2 and -3 accounted for >90% relative sequence abundance in sediments with high- and low-methane fluxes, respectively. Similarly, sulfate-reducing bacteria (SRB) SEEP-SRB1 and -SRB2 were abundant in the high-flux sediments, while an unclassified Desulfobulbaceae lineage enriched in the low-flux sediments. High methane fluxes also affected microbial co-occurrence patterns by supporting highly connected networks of ANME and SRB. Taken together, our results demonstrate that methane flux is a strong selective pressure that shapes the microbial community assemblages in cold seep sediments more profoundly than the seep-associated fauna and other tested habitat properties.

ID: T4-10422

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-1: Deep Biosphere: roles of subsurface life in elemental cycles and life-environment co-evolution
Presentation Preference: Oral Preferred

A map carbon and energy flow through deep sea sediments

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Keywords: archaea, metagenomics, carbon, bacteria, deep-sea

Marine sediments contain one of the largest pools of organic carbon on the planet but our understanding of how this organic carbon is processed by seafloor microbial communities is largely unexplored. We analyzed ~5 TB of assembled metagenomic sequence data from several locations, and depths, in Guaymas Basin (~2,000 m water depth in the Gulf of California) hydrothermally-impacted sediments. We recovered 6,756 uncultivated virus genomes (UViGs) and 510 archaeal and 2,487 bacterial metagenome assembled genomes, comprising 129 phyla, 21 of which are previously undescribed. We characterized their functional capacities to create a comprehensive genome-resolved map of organic matter degradation and remineralization in the deep sea. This analysis revealed that the diversity and abundance of low molecular weight organics (alcohols, acids, methylated amines, and methylated sulfur) are key drivers of microbial diversity. This high-resolution framework of carbon and energy will enhance our ability to model biogeochemistry in seafloor environments.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-1: Deep Biosphere: roles of subsurface life in elemental cycles and life-environment co-evolution
Presentation Preference: Oral Preferred

Supermountains controlled the biological evolution on Earth

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Keywords: supermountains, detrital zircons, biological evolution

Erosion of the continental crust provides the critical nutrients (P, Fe, etc.) that are essential for life in the oceans and the fastest erosion occurs on the steepest mountain slopes. We use the distribution of low-Lu zircons, derived from the roots of mountains, to identify periods of extensive high mountain (supermountain) formation, produced by continent-continent collisions. By applying this technique to 6,911 detrital zircons, from fifty-two of the world's major rivers, we show that there were two periods of supermountain formation. The first at 1.95-1.85 Ga, formed during the assembly of Nuna, likely Earth's first supercontinent. It coincided with the emergence of the first macroscopic fossils at ca. 1.9 Ga. The second, at 650-500 Ma, is associated with the amalgamation of Gondwana. It correlates with the emergence of the first large complex multicellular organisms of the Ediacara Biota at 575 Ma and the radiation of animals in the Cambrian Explosion. We argue that the rapid erosion of the Nuna and Gondwana supermountains may have caused a massive increase in the supply of bio-limiting nutrients to the oceans, increasing primary productivity and the energy flow through marine ecosystems. This increase in primary production, together with rapid burial of the resulting organic carbon, is also expected to have produced increases in atmospheric oxygen. The increases in the supply of bio-limiting nutrients and O_2 in surface oceans, both associated with supermountain erosion, might have driven organisms towards larger size and complexity.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-1: Deep Biosphere: roles of subsurface life in elemental cycles and life-environment co-evolution
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Authigenic carbonates in the deglacial Arctic Ocean revealing Fe/Mn-AOM and ice sheet retreat

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Keywords: western Arctic Ocean, biomineralogy, carbon cycle; anaerobic oxidation of methane; organic geochemistry, paleoceanography

Anaerobic oxidation of methane (AOM) is an important biogeochemical process which reducing the release of methane and consuming up to ~90% methane generated in anoxic marine sediments. In sulfate-depleted fresh water or melting water environments, Fe(III) and Mn(IV) is the possible electron acceptor and coupled to anaerobic oxidation of methane.

In the western Arctic Ocean sediments, **authigenic carbonates are first found in last deglaciation (18-11 ka) and MIS 4/3 deglaciation (~60 ka), and regarded as a new carbon sink in the global warming periods.** Mineralogical and geochemical evidences represented the depletion of δ13C both in authigenic carbonates and bulk sediments, which corresponded with deglacial methane emission in East Siberian Shelf. Furthermore, spatial distribution of authigenic carbonates indicated they only formed within the coverage of East Siberian Ice Sheet(ESIS), **we speculate that the authigenic carbonates were formed during the deglaciation when ice sheet melt and methane emission occurred synchronously.**

Thus, the preliminary conclusion of this study is: (1)The authigenic carbonates in MIS 4/3 boundary were formed because of Fe/Mn-AOM, as a sink of methane. (2)Existence of authigenic carbonates are likely to indicate the boundary and melting of ice sheets.

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-1: Deep Biosphere: roles of subsurface life in elemental cycles and life-environment co-evolution
Presentation Preference: Oral Preferred

Microbial Community in Sichuan Terrestrial Deep Subsurface

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Keywords: Deep Subsurface, Microbial Community, 16S rRNA, Nitrososphaeria, Acinetobacter

The terrestrial deep subsurface has been known to harbor extremophilic microbial life. Owing to the difficulties in accessing samples, there is still a knowledge gap in our understanding of the microbial community composition and functions in the deep subsurface biosphere. We extracted DNA from two rock cores (located at 1000 m, 47.5°C and 1200 m, 52.5°C) which were obtained from west Sichuan Province following standard protocol for contamination control.

The lithologies of 1000m and 1200m cores are tourmaline-bearing granite pegmatite and tourmaline-bearing two-mica pegmatite, respectively. Both rocks possess a white color and have a pegmatitic texture and massive structure. The main mineral composition in the 1000m sample is 50%-60% feldspar (albite predominantly, greyish-white anhedral columnar or plate-like), 30%-40% quartz (smoky grey or colorless transparent, euhedral crystal), 2%-5% micas, with a small amount of (1%-2%) euhedral and anhedral black tourmaline. The 1200m sample is composed mainly of 50%-60% feldspar (greyish-white euhedral columnar or plate-like), 30%-40% quartz (smoky grey or colorless transparent, anhedral crystal), 2%-5% micas, produced in flaky aggregates, with a small amount of (1%-2%) teardrop tourmaline. The major elements of these two samples mainly consist of SiO_2 (73.26%-78.47%), K_2O (6.83%-3.21%) and Na_2O (3.57%-4.03%). They both have trace elements of high Rb (477-186 ppm), Li (188-94.3 ppm), B (37.0-70.3 ppm), Mn (64.7-22.3 ppm) and Pb (69.1-43.2 ppm).

After conducting 16S rRNA V4 PCR and Illumina Novaseq DNA sequencing, we used QIIME2 feature-classifier classify-sklearn for the taxonomic annotation of the OTUs against the SILVA 138 database. The results consist of 233,278 OTUs belonging to bacteria and 8,226 OTUs belonging to archaea, including 174,429 OTUs belong to bacteria and 7,054 to archaea in the 1000m depth sample, and 58,849 OTUs belong to bacteria and 1,772 to archaea in the 1200m depth sample. The fraction of un-classified OTUs is almost negligible. The number of sequences assigned to archaea across both of the samples covered 3 classes from 2 phyla. Based on average abundance at class level, three archaeal phyla Nitrososphaeria, Methanobacteria and Bathyarchaeia account for 93.75%, 5.47% and 0.78%, respectively. Nitrososphaeria predominates both samples, including many genera of ammonia-oxidizing archaea (AOA), which is a significant contributor to ammonia oxidation in the marine nitrogen cycle and has less been studied in continental subsurface. In addition to Archaea, we also found some genera or families of bacteria associated with deep subsurface or extreme environment such as deep-sea sediments, hydrothermal vent, and permafrost. Based on average abundance at phylum level, Firmicutes (2.86%-7.12%), Bacteroidota (7.79%-5.71%), Acidobacteriota (10.71%-1.86%), Planctomycetota (13.89%-2.64%), Proteobacteria (18.56%-58.06%) and Actinobacteriota (21.2%-13.46%) constitute 75%-89% of the communities in the 1000-m and 1200-m sample, respectively. Additionally, based on genus-level, the genus *Acinetobacter* (27.17%) has the highest abundance in the 1200 m sample, while it was not found in the top 10 most abundant genera in the 1000 m depth sample. These

findings suggest that there are previously undiscovered microorganisms (such as AOA) in continental subsurface.

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-1: Deep Biosphere: roles of subsurface life in elemental cycles and life-environment co-evolution
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

New insights into the roles of Asgard archaea in the origin of eukaryotes and ecological functions

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Keywords: Asgard archaea, eukaryotic origin, metagenome

The hypothesis that eukaryotes originated from within the domain Archaea has been strongly supported by recent phylogenomic analyses placing Heimdallarchaeota-Wukongarchaeota branch from the Asgard superphylum as the closest knownarchaeal sister-group to eukaryotes. However, our understanding is still limited in terms of the relationship between eukaryotes and archaea, as well as the evolution and ecological functions of the Asgard archaea. Here, we describe three previously unknown phylum-level Asgard archaeal lineages, tentatively named Sigyn-, Freyr- and Njordarchaeota. Comprehensive phylogenomic analyses further supported the origin of eukaryotes within Asgard archaea and a new lineage Njordarchaeota was supposed as the known closest branch with the eukaryotic nuclear host lineage. Metabolic reconstruction suggests that Njordarchaeota may have a heterotrophic lifestyle with the capability of peptides and amino acids utilization, while Sigynarchaeota and Freyrarchaeota also have the potentials to fix inorganic carbon via the Wood-Ljungdahl pathway and degrade organic matters. Additionally, the Ack/Pta pathway for homoacetogenesis was found in Freyrarchaeota. Some previously unidentified eukaryotic signature proteins for intracellular membrane trafficking system, and the homologue of mu/sigma subunit of adaptor protein complex, were identified in Freyrarchaeota. This study expands the Asgard superphylum, sheds new light on the evolution of eukaryotes and improves our understanding of ecological functions of the Asgard archaea.

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-1: Deep Biosphere: roles of subsurface life in elemental cycles and life-environment co-evolution
Presentation Preference: Oral Preferred

Genome-informed understandings of nitrogen loss in marine sediments

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Keywords: Genome, nitrogen cycle, marine sediment, nitrite, anammox

About two-thirds of nitrogen loss in the marine realm occurs in the sediments. Microbes with the capacity to denitrify or perform anaerobic ammonium oxidation (anammox) are considered responsible for this process. In the nitrogen cycle, nitrite is a critical inorganic nitrogen compound required by both denitrifiers and anammox bacteria and whose availability exerts profound control on the magnitude of nitrogen loss. Nitrite rarely accumulates in sediment porewater and has been largely overlooked, yet many details about nitrogen loss in marine sediments remain unknown. Because most microbes in deep sea sediments (including denitrifiers and anammox bacteria) are yet uncultured in laboratory, de novo genome reconstruction via metagenome sequencing is a powerful approach to disentangle nitrite transformation processes in these regions. Here we present a new understanding of nitrogen loss in marine sediments obtained by genome reconstruction combining with high-resolution geochemical measurements and microbial community characterization. We will 1) introduce an overlooked but ancient family of anammox bacteria prevailing in marine sediment, 2) showcase how the niche partitioning of two anammox bacteria families (accomplished in a duration of up to 55 000 years) resulted in a partial collapse of the anammox population and concomitant nitrite accumulation, and 3) elucidate new lineages of nitrite-oxidizing bacteria thriving in anoxic sediments, which enable a cryptic nitrogen loss together with other nitrogen-cycling groups. Implications of these new organisms on marine nitrogen biogeochemistry will also be discussed.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-1: Deep Biosphere: roles of subsurface life in elemental cycles and life-environment co-evolution
Presentation Preference: Oral Preferred

The microbial nitrogen cycle in the deepest part of the ocean

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Keywords: hadal trench, deep biosphere, metagenomics, nitrogen cycle

The Mariana Trench is known as the deepest region of oceans on Earth. Previous studies have described the microbiome of hadal seawater and surface sediments in Mariana Trench, but the microbial life in hadal deep biosphere is poorly explored. Here, we applied comparative metagenomics to study three hadal habitats in Mariana Trench slope, including hadal seawater (9600-10500 mbsl), surface sediment (0-46 cmbsf at water depths between 7143 and 8638 mbsl), and deep biosphere (200-306 cmbsf at water depth of 8300 mbsl). Through analyzing the relative abundance and species diversity of the metagenome-assembled genomes (MAGs) in nitrogen metabolisms, our study showed that each of the three hadal habitats was characterized by unique nitrogen cycling processes. In deep biosphere, N_2 might be produced by anaerobic ammonium oxidation (anammox) bacteria. The relative abundances of ammonia-oxidizing archaea (AOA) and nitrite-oxidizing bacteria (NOB) in the surface sediments were significantly higher than those of the deep biosphere, suggesting that chemoautotrophy is an important process in this environment. In the hadal seawater, an abundant MAG designated to *Ketobacter* (relative abundance of 4.0%) had the ability to couple n-alkane degradation and N_2 fixation. In total, this study expands our knowledge of the microbial nitrogen cycle in hadal deep biosphere.

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-1: Deep Biosphere: roles of subsurface life in elemental cycles and life-environment co-evolution
Presentation Preference: Oral Preferred

Iron (oxyhydr)oxides shift the methanogenic community in deep sea methanic sediment - Insights from long-term high-pressure incubations

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Keywords: Marine sediment, Iron oxides, Methanogenesis

Intermittent increases of dissolved ferrous iron concentrations observed in deep marine methanic sediments challenge the traditional diagenetic electron acceptor cascade, where iron reduction precedes methanogenesis. Here we aimed to gain insight into the mechanism of iron reduction and the associated microbial processes in deep sea methanic sediment by setting up long-term high-pressure incubation experiments supplemented with ferrihydrite and methane. Continuous iron reduction was observed during the entire incubation period. The enriched samples were then amended with 13C-labeled methane and different iron (oxyhydr)oxides in batch slurries. Intensive iron reduction was observed, the highest rates with ferrihydrite, followed by hematite and then magnetite, however, no anaerobic oxidation of methane (AOM) was observed in any treatment. Further tests on the enriched slurry showed that the addition of molybdate decreased iron reduction significantly, suggesting a link between iron reduction with sulfur cycling in the slurry. Intriguingly, ferrihydrite addition shifted the archaeal community from the dominance of hydrogenotrophic methanogens (Methanogenium) to methylotrophic methanogens (Methanococcoides). This was accompanied by the enrichment of microbes capable of dissimilatory sulfate reduction and thiosulfate oxidation, which supports the presence of a cryptic sulfur cycle in the incubation system stimulated by the addition of iron (oxyhydr)oxides. Our work suggests that under low sulfate conditions, the presence of iron (oxyhydr)oxides would trigger a cascade of microbial reactions, and iron reduction would link with the microbial sulfur cycle, changing the kinetics of the methanogenesis process in methanic sediment.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-1: Deep Biosphere: roles of subsurface life in elemental cycles and life-environment co-evolution
Presentation Preference: Oral Preferred

Membrane lipid composition of Thermococcs eurythermalis A501 and its response to environmental stresses

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Keywords: Hyperthermophilic archaea, Lipids, Environmental stresses

Thermococcales is a representative group of hyperthermophilic archaea that widely exists in marine hydrothermal systems and belongs to the dominant group in hydrothermal chimney walls, plumes, and hydrothermal sediments. The broad growth span of Thermococcales poses challenges to the structure and function of its cell membrane. Here, the composition characteristics of the core membrane lipids and intact polar membrane lipids of the type strain Thermococcs eurythermalis A501 were simultaneously analyzed, and the response characteristics of A501 to different growth stages, pH, salinity, pressure, and temperature were comprehensively explored for the first time. The results showed that A501 composed three core membrane lipids, glycerol dialkyl glycerol tetraether (GDGT-0), archaeol (AR), and 2OH-GDGT-0, and seven kinds of IPLs with different polar headgroups. 2OH-GDGT-0 was identified for the first time in hyperthermophilic archaea. It was found to be tripled at low temperature, suggesting that hydroxylation modifications expand the local cell membrane area to increase penetration and broaden low-temperature boundary of A501. The monolayer membrane formed by tetraether has low fluidity and permeability, which was found that its proportion is sensitive to temperature and pressure but insensitive to salinity and pH. The ratio AR/GDGT-0 was significantly positively correlated with pressure and had the potential as a biomarker of pressure in environments with less temperature change. The content and proportion of total IPL increased under most environmental pressures, suggesting its importance under different ecological pressures. However, further research on the changes of varying IPLs under various environmental pressures found that no specific IPLs could reflect specific environmental stresses. This study completely expounds on the characteristics of the lipidome of Thermococcales under different environmental pressures and provides biological mechanisms of potential membrane lipid-based proxies in biogeochemical or ecological studies.

Scientific Themes: Theme 4. Biological Process in Sedimentation
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Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Response of microbial communities to different geochemical and thermal gradients in hydrothermal sediments of the Guaymas Basin

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Keywords: Guaymas Basin, hydrothermal surface sediments, geochemical and thermal gradients, Bathyarchaeia, microbial coexistence

The Guaymas Basin in the Gulf of California is characterized by active hydrothermal activity and massive organic-rich sediments. Newly formed, and hot basalt sills convert organic matters of sediments into diverse chemical compounds including CO_2, H_2, low-molecular-weight organic acids, ammonia, and a series of hydrocarbons. These compounds migrate to the sediment surface with rising vent fluids, where they fuel various microbial communities. Although there are many studies that examined microbial communities of the Guaymas Basin sediments, most of them have focused mainly on hot hydrothermal sediments and microbial mats where temperatures reach or exceed 80°C, warm sediments with temperatures near or below 30°C are seldomly determined. To deepen our understanding of microbial communities and relevant environmental controls in different types of hydrothermally influenced sediments, we examined different Guaymas Basin sediments with various degrees of hydrothermal activity supported by week-long temperature logging, from temperate sediments with constant conditions at the Aceto Balsamico site, to moderately hot or extremely hot sediments characterized by increasingly dynamic hydrothermal fluctuations at the Cathedral Hill site. Their geochemical characteristics showed obvious differences of diverse sites profiles. To identify patterns and potential controls on bacterial and archaeal community composition, we analyzed the Non-metric Multidimensional Scaling Analysis (NMDS) of bacterial and archaeal sequence dataset, which were both separated by sampling sites and temperature, indicating that bacterial and archaeal communities followed similar structuring patterns independently. Bacterial and archaeal 16S rRNA gene sequences showed distinct differences in microbial community composition between warm and hot sediments of different depths. In the temperate Aceto Balsamico core, the most frequently detected archaea are Methanosarcinia, Bathyarchaeia and Thermoplamata in all samples, whereas the bacterial spectrum shifted from a diversified community of Planctomycetes, Gammaproteobacteria, Bacteroidetes, Deltaproteobacteria (Desulfobulbia and Desulfobacteria), Chloroflexi (Anaerolineae) and Atribacteria (JS1) in the surficial samples to a JS1-dominated spectrum of bacterial sequences in the deeper samples. In hydrothermal core of Cathedral Hill, the bacterial community changed to thermophilic heterotrophic lineages (Thermotogae, Armatimonadetes, Calditrichia) and thermophilic sulfate reducers (Desulfofervidales, Thermodesulfobacteria) are added. Within the archaeal sequence dataset, the thermophilic archaea Thermoprotei, Thermococci and ANME-1 became more frequency. While these microbial communities changed continuously in composition along the thermal spectrum of Guaymas Basin sediment cores, they consistently maintained these functions, and the functional redundancy across different lineages could tolerant more environmental fluctuations, which was well verified by co-occurrence network analysis. Through the further study of Bathyarcaheia and JS1 with the most frequency archaea and bacteria, it was found that diverse Bathyarchaeia subgroups could well illustrate the environmental and temperature preference, while JS1 could not withstand the high temperature and the subgroups had no obviously environmental implications. In conclusion, we found that in addition to temperature influencing microbial community distribution, the integrated impact of the geochemical regime within the entire sediment core a composite of electron acceptors and donors, nutrients, and carbon sources shaped the community composition at the sediment surface.

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-1: Deep Biosphere: roles of subsurface life in elemental cycles and life-environment co-evolution
Presentation Preference: Oral Preferred

Effects of sulfurization on the microbial breakdown of organic matter in lake sediments

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Keywords: Lake sediment, organic matter, sulfurization, carbon burial, microbial community

Lake sediments are globally important organic carbon sinks. Yet the factors controlling the cycling and storage of organic carbon in these sediments remain poorly understood. During a process called 'sulfurization', organic matter (OM) often become recalcitrant by reacting abiotically with dissolved (poly)sulfide. Although past research has revealed the potential significance of sulfurization in controlling organic carbon cycling in lake sediments, the extent to which sulfurization affects the degradation rates of different organic compounds and the microorganisms that are involved in these processes are not understood. In this study, we test the effect of sulfurization on sedimentary carbon cycling, by adding OM with divergent reactivity (lignin, chitin, cellulose, starch) in their sulfurized and nonsulfurized forms to sediments from different depths (10, 30, 70, 500, 1300 cm) of a eutrophic lake (Rotsee, Switzerland). Preliminary results show that the effect of sulfurization on OM reactivity is inversely correlated to its original reactivity. Thereby sulfurization has nearly no impact on the degradation of the more recalcitrant lignin, while it significantly lowers the reactivity of the more labile starch to a level that is similar to lignin. The negative effect of sulfurization on OM degradation appears to increase with sediment depth, indicating an increasing contribution of sulfurized OM to long-term organic carbon preservation in deeper sediments. On-going analyses on the compositions of organic molecules and microbial communities will further reveal the largely unstudied role of microorganisms in utilizing labile and refractory pools of organosulfur in lake sediments.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-1: Deep Biosphere: roles of subsurface life in elemental cycles and life-environment co-evolution
Presentation Preference: Oral Preferred

Depositional dynamics determine the microbial community succession in marine subsurface sediments

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Keywords: Microbial community, succession, subsurface, deep biosphere, deposition

High-resolution vertical changes of marine benthic microbial diversity and association with local depositional processes are poorly described. Here, we perform microbial and geochemical analyses on sediment cores collected from different marine sediments of contrasting depositional environments including the Changjiang Estuary (CE), South China Sea (SCS) and Challenger Deep (CD). Community variation shaped by redox zonation is common in the different locations. Palaeoenvironmental factors represented by terrestrial input of dormant cells and spores are the other determinants in the SCS composed of mainly river-borne sediments. Selection induced loss of rare species leads to high species replacement effect between deeper and surface sediment layers. The subsurface communities in the CD vary to a lesser extent from the surface layer compared to SCS, which is likely contributed by massive burial of organic matter due to the high and noncontinuous sedimentary deposition. Meanwhile, microbial abundance and activities fluctuate along the vertical profile, likely as a reflection of in situ growth, a pattern different from previously characterized subsurface biosphere dominated by survival and persistence. CE represents another classical depositional system featured by intensified mobile mud. Mud mobility alters redox condition of the local sedimentary environment by increase of oxygen penetration depth. We observe an increased relative abundance of aerobes in sediments affected by mobile mud, which contributes to a higher rate of organic matter degradation. Sulfur-oxidizing bacteria is enriched and active at the oxic-anoxic interface in the deep sediment layers, likely providing a source for sulfate-reducing bacteria. Overall, our results demonstrate that the subsurface microbial community is significantly controlled by depositional and hydrodynamic processes.

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-1: Deep Biosphere: roles of subsurface life in elemental cycles and life-environment co-evolution
Presentation Preference: Oral Preferred

Methane conversion into organic carbon regulated by pressure in cold seep ecosystems

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Keywords: carbon cycling, cold seep, high pressure

In the ocean, almost all of the emission and consumption of deeply burried methane occurs in cold seeps; therefore, understanding the methane cycling in cold seeps is crucial to estimating the oceanic methane budget. Cold seeps are often found in deep ocean where the methane is saturated under high pressure. Moreover, the cold seeps are not always stable, while their eruptions lead to the dramatic destruction of microbial ecosystems that drive methane cycling. However, because of technical challenges, the direct monitoring of the methane conversion as well as the microbial communities'shifts in such unsteady high pressure ecosystem has never been achieved. In this study, we took an alternative approachby simulating cold seep using specially designed DOES (deep ocean experimental simulator) system. DOES is to construct an environment in laboratory that is similar to the deep ocean, in terms of gas pressure, hydrostatic pressure, temperature, flow rate, pH, nutrient availability, et. al. DOES also allows us to monitor the microbial activity by sampling without depressurization. Here we used an enrichment originated from Captain Aryutinov Mud Volcano (35° 39.700' N, 07° 20.012'W, water depth ~1200m) with high AOM (anaerobic oxidation of methane) activity. We performed a series incubations under different methane pressures (8, 12 MPa) and hydrostatic pressures (8, 15, 30 MPa) for 12 months, supplied with methane and sulfate as the only energy source, simulating the cold seep undergoing periodical eruptions. Every 2 days we took samples for activity analysis and every 2 months we took biomass samples for metagenomic analysis. We found that the methane conversion pathways were highly dependent on pressure. Spontaneously happened with the classical AOM process (methane is converted into carbon dioxide), approximal up to 25% of the total consumed methane was anaerobically converted into organic carbon under elevated methane pressures, e.g. acetate under 8 MPa and methyl- compounds under 12 MPa. Both genomic and enzymatic evidence supported that ANME (anaerobic methanotrophic archaea) was capable to oxidize methane into acetate via acetyl-CoA. According to the genomic analysis, Methylobacter played an important role in incomplete methane oxidation into methyl-compounds that was catalyzed by pmoABC under anaerobic condition. Therefore, we propose a modified model of carbon cycling in cold seeps: during AOM process, methane can be converted into organic carbon, which further fuels the heterotrophic community in the ecosystem. These results suggest that a more sophisticated calculation of the methane budget in cold seeps that considers the in situ pressures is needed.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-1: Deep Biosphere: roles of subsurface life in elemental cycles and life-environment co-evolution
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Potential metabolic and genetic interaction among viruses, methanogen and methanotrophic archaea, and their syntrophic partners

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Keywords: Methanogens and Methane-oxidizing Archaea, Virus, Environmental Adaptation

The metabolism of methane in anoxic ecosystems is mainly mediated by methanogens and methane-oxidizing archaea (MMA), key players in global carbon cycling. Viruses are vital in regulating their host fate and ecological function. However, our knowledge about the distribution and diversity of MMA viruses and their interactions with hosts is rather limited. Here, by searching metagenomes containing *mcrA* (the gene coding for the α-subunit of methyl-coenzyme M reductase) from a wide variety of environments, 141 viral operational taxonomic units (vOTUs) that potentially infect methanogens or methane-oxidizing archaea were retrieved. Four MMA vOTUs (three infecting the order Methanobacteriales and one infecting the order Methanococcales) were predicted to cross-domain infect sulfate-reducing bacteria. By facilitating assimilatory sulfur reduction, MMA viruses may increase the fitness of their hosts in sulfate-depleted anoxic ecosystems and benefit from synthesis of the sulfur-containing amino acid cysteine. Moreover, cell-cell aggregation promoted by MMA viruses may be beneficial for both the viruses and their hosts by improving infectivity and environmental stress resistance, respectively. Our results suggest a potential role of viruses in the ecological and environmental adaptation of methanogens and methane-oxidizing archaea.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-1: Deep Biosphere: roles of subsurface life in elemental cycles and life-environment co-evolution
Presentation Preference: Oral Preferred

Phylogenetically novel and catabolically diverse diazotrophs reside in deep-sea cold seep sediments

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Keywords: cold seep, nitrogen fixation, diazotrophs

Microbially mediated nitrogen cycling in carbon-dominated cold seep environments remains poorly understood. So far anaerobic methanotrophic archaea (ANME-2) and their sulfate-reducing bacterial partners (SEEP-SRB1 clade) have been identified as diazotrophs in deep sea cold seep sediments. However, it is unclear whether other microbial groups can perform nitrogen fixation in such ecosystems. To fill this gap, we analyzed 61 metagenomes, 1428 metagenome-assembled genomes, and four metatranscriptomes derived from 13 globally distributed cold seeps. Nitrogen isotope ratio ($\delta^{15}N$) data compiled from different locations suggest microbial nitrogen fixation occurs at various types of cold seeps. These sediments contain phylogenetically diverse nitrogenase genes, spanning conventional and novel groups, corresponding to an expanded diversity of diazotrophic lineages. Diverse catabolic pathways were predicted to provide ATP for nitrogen fixation, suggesting diazotrophy in cold seeps is not necessarily associated with sulfate-dependent anaerobic oxidation of methane. Nitrogen fixation genes among various diazotrophic groups in cold seeps were inferred to be genetically mobile and subject to purifying selection. Our findings extend the capacity for diazotrophy to five candidate phyla (Altarchaeia, Omnitrophota, FCPU426, Caldatribacteriota and UBA6262), and suggest that cold seep diazotrophs might contribute substantially to the global nitrogen balance.

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-1: Deep Biosphere: roles of subsurface life in elemental cycles and life-environment co-evolution
Presentation Preference: Oral Preferred

Geo-electrochemistry in water/rock interacted environment

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Keywords: Geo-electrochemistry, Mineral catalysis, Astrobiology, Origins of life, Carbon fixation, Ammonia generation

Geo-electrochemical processes have been proposed to occur in various water-rock interacted environments, including submarine hydrothermal vents and early Mars. These environments harbor steep gradients of pH, redox, and temperature. The electrically conductive minerals (e.g., sulfides, oxides) form the electron conduit while ionic species in the fluid serve the ionic transfer function. The chemical gradients can thermodynamically drive abiotic carbon fixation or ammonia formation through mineral-catalyzed electrochemical processes. These abiotic organic syntheses could have contributed significantly to the mineral-supported origins of life scenario.

In addition, the availability of transition metals is intimately associated with the evolution of prebiotic catalytic systems. Since sulfur ligands participate actively in various types of redox-active metalloenzymes, transition metal sulfides have been proposed as protoenzymes for catalyzing carbon and nitrogen-related redox conversions (bio-inspired, enzyme-mimetic catalysis). In this presentation, I will introduce the progress in this field and some of the results obtained in the related projects.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-1: Deep Biosphere: roles of subsurface life in elemental cycles and life-environment co-evolution
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Differential transformation and bioavailability of recalcitrant DOM in marginal and deep-sea sediments during microbial early diagenetic processes

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Keywords: pore waters, fluorescent dissolved organic matter, PARAFAC, coastal, deep sea

Sedimentary dissolved organic matter (DOM) is an important pool of intermediates produced and consumed during microbial early diagenesis of organic matter in anoxic sediments. The accumulation of humic-like DOM has long been observed in coastal sediments and the recalcitrant pore water DOM is regarded to play an important role in the global oceanic DOM cycle and sedimentary DOM preservation. However, the bioavailability of humic-like DOM in pore waters is still under debate. Here, the geochemistry of pore waters, including concentrations of ferrous iron, sulfate and fluorescent dissolved organic matter (FDOM) components, were determined in 5 sediment cores from Pearl River Estuary to the South China Sea. The net reaction rates of sulfate and FDOM were further constrained by geochemical reaction modeling. Contrasting behavior of humic-like FDOM was found in the five cores. In marginal sediments, humic-like components are increasingly accumulated during sulfate reduction, which might be the byproducts of microorganisms degrading labile organic substrates. While in deep-sea sediments, humic-like components are consumed during sulfate reduction, especially in the deep, which indicates that recalcitrant DOM may serve as substrates for microbial early diagenetic processes in the energy-limiting sub-seafloor sediments. The microorganisms responsible for the degradation of humic-like components remain to be further studied.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-1: Deep Biosphere: roles of subsurface life in elemental cycles and life-environment co-evolution
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Characterization of a novel extracellular contractile injection system in the deep-sea bactrium Shewanella psychrophila WP2

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Keywords: Extracellular contractile injection systems, Shewanella psychrophila WP2, deep-sea sediment, Killing activity, hydrogen peroxide

Extracellular contractile injection systems (eCISs) are widely distributed in bacteria and archaea. They are related to contractile bacteriophage tails and mediate interactions between bacteria and eukaryotes. Besides, recent studies indicated that they eCISs can inhibit the growth of bacteria. Although several eCISs have been characterized in insect pathogens, their presence and ecological function in deep-sea sediment are still unknown. Here, we identified a novel eCIS named SpsCIS from a deep-sea bacterium *Shewanella psychrophila* WP2, which was isolated from deep-sea sediment at a water depth of 1914 m. Interestingly, the production of SpsCIS was significantly induced by hydrogen peroxide, while not by mitomycin C. Moreover, transcriptomic data showed that SpsCIS was produced spontaneously during the whole growth period of S. psychrophila WP2 at low temperature (4 °C), with the highest production at early exponential phase. Both of the non-contractile and contractile sheath structure of SpsCIS were observed by transmission electron microscopy. Moreover, Spot assays indicated that SpsCIS has bactericidal activity on 3 *Shewanella* species. Taken together, we propose that SpsCIS probably play an important role in biogeochemical cycling in the deep-sea sediment.

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-1: Deep Biosphere: roles of subsurface life in elemental cycles and life-environment co-evolution
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

The high hydrostatic pressure affects microbial nitrogen transformation in hadal trench sediments

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Keywords: hadal trench, high hydrostatic pressure, nitrogen cycling, denitrification, DNRA

Hadal trenches, most typically characterized by high hydrostatic pressure (HHP), are one of the most extreme environments on our planet[1-3]. The HHP as a key environmental factor influences redox reactions usually mediated by microorganisms to a greater extent[4-7]. Previously, a fully functional benthic nitrogen cycling has been found in hadal trench sediments[8-13]. However, how the HHP further drives the microbial nitrogen metabolism largely remains unknown. Therefore, the study of hadal microbial nitrogen metabolism in the context of HHP is necessary and important for evaluating element cycling in the deep biospheres and deeply understanding life processes in extreme environments. Here, we investigate the microbial nitrogen transformation and rate in a continuous high-pressure bioreactor maintained under different hydrostatic pressures (0.1, 40, 70, 90 and 115 MPa), combining the metagenomic and metatranscriptomic analyses. Compared with initial microbial communities, the dominant groups changed significantly, from *Pseudomonadaceae* and *Rhodobacteraceae* to *Halomonadaceae*, *Thalassospiraceae* and *Shewanellaceae* after continuous high-pressure incubation. Compared with 0.1 MPa, for the first step of nitrate reduction, nitrite accumulated, meanwhile Nar and Nap genes also highly expressed at 70, 90 and 115 MPa; for nitrite further reduction to ammonium, NirB gene expression was highest at 115 MPa and NirD gene expressed highly at 70 and 115 MPa, NrfA gene expressed highly at 90 and 115 MPa, simultaneously ammonium was detected at 70, 90 and 115 MPa; for nitrite further reduction to NO, N_2O and finally to N_2, the expression of NirS and NosZ genes increased with increasing HHP (highest expression at 115 MPa) and Nor gene highly expressed at 70, 90 and 115 MPa, meanwhile the gas products N_2 reached the highest at 115 MPa and N_2O concentration increased significantly 70, 90 and 115 MPa; which indicates that HHP is likely to promote the denitrification and DNRA pathways, while further tests are required to validate metabolic rates from continuous high-pressure incubations. The key genes involved in anammox pathway were not identified and expressed suggests that anammox is not a major player in the nitrogen cycling in the trench sediment. Our findings reveal differences in the distribution of nitrogen metabolism pathways at different high hydrostatic pressures and deepen our understanding of microbial elemental cycling in hadal trench sediments.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-1: Deep Biosphere: roles of subsurface life in elemental cycles and life-environment co-evolution
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Anaerobic microbial processes largely contribute to organic matter mineralization in the Mariana Trench

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Keywords: Mariana trench, Anaerobic microbial metabolism, Organic matter mineralization, Element cycling

The Mariana Trench underneath the oligotrophic west Pacific open ocean has recently been shown as a hotspot for organic matter early diagenesis, supporting active microbial communities in the trench sediments. Quantitative estimation of microbial activities is required in the Mariana Trench to evaluate their contributions to deep-sea organic carbon mineralization and element cycling. Previous microbial diversity surveys on the surface sediment layers (< 50 cm) have suggested that aerobic microbes play significant roles in organic matter mineralization in the deep trench sediments. The oxygen consumption rate is also generally applied to indicate hadal microbial processes. However, it remains elusive if and to what extent anaerobic microbes, whose metabolic potentials are closely associated with the cycle of C, N, and S, take part in OM mineralization under this high hydrostatic pressure extreme sedimentary environment. Here, we carried out geochemical measurements, early diagenesis modeling, and 16S rRNA gene amplicon sequencing for gravity cores, comparing the trench sites, including the deepest bottom (~10,500 m) and southern slope (~8,300 m) of the Mariana Trench and the reference abyssal site (~4,500 m). A clear zonation of microbial communities between the trench and reference sediment cores was observed. Compared to the reference abyssal plain, the organic matter mineralization rate was estimated to be ~20 times higher in the slope and ~50 times higher in the bottom sediments, and 1/3 of the organic matter mineralization was contributed by the anaerobic microbial lineages as calculated by geochemical modeling. The microbial nitrogen cycling processes differ primarily in the two trench sites. The bottom sediments enriched in both denitrification and dissimilatory nitrite reduction to ammonium (DNRA) groups. In contrast, the slope sediment showed a close coupling of aerobic nitrification and anaerobic denitrification processes. Nevertheless, denitrification almost exclusively drives the fixed nitrogen loss in both sites, distinguishing the Mariana Trench from other trenches wherein anaerobic ammonium oxidation (anammox) is the predominant nitrogen sink from the benthic ecosystem. These results combined geochemical and microbial profiles to shed light on the essential role of anaerobic microbial processes, contributing to the enhanced organic matter early diagenesis and the C, N, and S cycling in the Mariana Trench.

Session T4-2: The coupling of geological and microbial processes in the deep-sea hydrothermal system

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-2: The coupling of geological and microbial processes in the deep-sea hydrothermal system
Presentation Preference: Oral Preferred

The geochemical indicators of hydrothermal alteration of MORBs and its implication for potential polymetallic sulfide mineralization

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Keywords: MORB, hydrothermal alteration, sulfide deposit, major and trace element, Carlsberg Ridge

Hydrothermal alteration of submarine mid-ocean ridge basalts (MORBs) is a normal phenomenon that can be evidenced by sampled rocks. The byproducts of this process may be the sulfide mineralization. The polymetallic sulfide can be a source of metals that related to people's everyday life. However, locating these sulfide deposits underneath the water is quite difficult. Is there any chance that we can investigate the composition of altered basalt samples and give a judgement about the potential of nearby sulfide mineralization?

By systematic study of the altered basaltic samples close to existing known hydrothermal vents (HV), we may find any traces of sulfide deposit. Take the samples from Carlsberg Ridge Tianxiu HV for example, the samples can be classified into three types: the normal MORBs, the slightly altered basalts, the intensely altered basalts. The systematic comparisons of mineral composition, major and trace elements between them implies the mobility and variations of specific elements. The loss on ignition (LOI) is positively correlated with the intensity of hydrothermal alteration. With the increasing extent of alteration, elements K, U, Zn, Cu, and Co become more enriched, whereas the Ca, Mn, Ba, Sr, Th and Y gradually decreased. A lot more elements varied differently at different alteration stages, e.g., MgO, Al_2O_3, Na_2O, Li, and Fe. While plotting all the data from Tianxiu HV, some indicators can be suggested as the distinguish basis for potential intense hydrothermal alteration as well as the sulfide mineralization, i.e., $Zn+Cu+Co>500CaO+MnO*100<15Rb+U>2Sr+Th*1000<250$. These simple approximations may give a quick review of the potential sulfide deposits located close to the highly altered basalts, which would be more easily sampled than the sulfide itself. This would greatly improve our efficiency while we explore the vast seafloor for sulfide ore deposits.

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Effects of Mineral on Taxonomic and Functional Structures Microbial Community in Tengchong Hot springs

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Keywords: mineral particles, microbial communities, diversity, functional groups, stochastically adhere

Terrestrial hot spring ecosystems, as a representative extreme environment for the co-evolution of minerals and microbes, exhibit a variety of habitat differentiation in sedimental microbial communities. Although diverse mineralogical compositions occur in hot spring sediments, the impact of the single mineral on the diversity and structure of microbial communities remains poorly elucidated. In this study, different mineral particles with various chemistries (i.e., hematite, biotite, K-feldspar, quartz, muscovite, aragonite, serpentine, olivine, barite, apatite, and pyrite) were incubated in two Tengchong hot springs to determine the impacts of minerals on the microbial communities taxonomic and functional diversities. Two hot springs included one alkaline (pH~8.34) with a high temperature (~82.8 ^{o}C) and one acidic (pH~3.63) with a relatively low temperature (~43.3 ^{o}C). After 10-day incubation, the minerals and the surrounding bulk sediment were collected. The 16S rRNA gene high-throughput sequencing approach demonstrated that the mineral-associated bacterial taxa differed from those of the bulk sediment samples in the two hot springs. The relative abundance of Proteobacteria, Euryarchaeota, and Acidobacteria increased in all minerals, suggesting that these microorganisms are apt to colonize on solid surfaces, other than live freely. Generally, the α-diversity indices of the microbial communities on the mineral surfaces were higher than those from the bulk sediment samples (P<0.05), which may be caused by stochastically adhering process on the mineral surfaces during 10-day incubation, unlike that the microbial community in sediment has experienced long-term environmental and ecological screening. The microbial ecological functional groups involving in energy sources, C, N, and S metabolism were predicted using the FAPROTAX database. Chemoheterotrophy increased with minerals incubation, which was dominant in most cultured minerals (the relative contents were 5%~20%). Most notably, the sulfate respiration bacteria (mainly related to Desulfobacterales and Syntrophobacterales) associated with aragonite in the acidic hot spring significantly differed from other minerals, possibly due to the pH buffering effect of aragonite providing more favorable conditions for their survival and proliferation. By comparison, aragonite cultured in the alkaline hot spring highly enriched denitrifying bacteria and promoted the nitrogen cycle within the system. Collectively, we speculated that diverse microbes stochastically adhered on the surface of minerals in the water flows and the physical and chemical properties of minerals drove the enrichment of certain microbial communities and functional groups during the short-term incubation. Taken together, these findings thereby provide novel insights into mechanisms of community assembly and element cycling in the terrestrial hydrothermal system associated with hot springs.

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Metagenomic Insights into Carbon Fixation pathways and Energy Sources of Thermophilic Chemoautotrophic Microorganisms

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Keywords: Thermophilic Microorganism, chemoautotrophy, carbon fixation pathway, high-throughput sequencing

Volcanoes and geothermal hot springs are hydrological conduits that connect the subsurface, the surface, and the atmosphere, where fluids and gases, mainly the greenhouse gas CO_2, are released from the deep crust and even the mantle while experience a number of geological processes during upward migration. Hydrothermal fluids contain H_2S, H_2, Fe^{2+}, and other reducing components, which may be oxidized by chemoautotrophic microorganisms as they reach the surfaces, and some inorganic carbon may be fixed into biomass and other organic carbon by microorganisms meanwhile. Previous research shows that chemosynthesis plays an important role in carbon cycling in deep-sea and terrestrial hot springs, but terrestrial hot springs often have geochemical complexity because of uneven land surface topography, gradients of temperature and spring water chemistry. Thus, terrestrial hot springs provide an excellent place to more easily study the carbon budget in aquatic systems. In this study, seven hot springs with different and irregular physical and chemical parameters were selected in Tengchong Volcano Geothermal National Geopark, Yunnan Province, to explore the carbon fixation capacity and community structure of chemoautotrophic microorganisms in hot springs, and discuss the energy sources and influencing factors of carbon fixation through in-situ cultivation with $NaH^{13}CO_3$ and metagenomic sequencing technology. The results showed that the rates of carbon fixation by chemoautotrophy were far lower than those by photosynthesis, and chemoautotrophy was inhibited by light potentially caused by that the ultraviolet radiation in the sun light has a negative impact on carbon-fixing metabolism. Among high-temperature hot springs (79.3-88.7 ^{o}C), *Aquificae* is the dominant phylum; reductive citrate cycle and reductive acetyl-CoA pathways were the dominant carbon-fixation pathways; and the hydrogen oxidation was a major energy source. In the mid-high temperature springs (54.3-72.5 ^{o}C), the microbial diversity was higher; and there were six carbon fixation pathways among which the reductive citrate cycle is the main carbon-fixation pathway. Hydrogenation, iron oxidation, sulfide oxidation, sulfur oxidation, and thiosulfate oxidation were the potential energy sources. In acid springs (42.8 ^{o}C, pH=4.5), *Proteobacteria* accounted for 80%, 3-Hydroxypropionate bi-cycle was the main chemoautotrophic carbon fixation pathway, and the oxidation of sulfite might the major energy source. The above results revealed the response relationship between the carbon fixation capacity of hot spring microorganisms and environmental factors, which is helpful to deeply understand the carbon cycle process of the hot spring system, and comprehensively understand the carbon budget of hot spring ecosystem in global volcanic regions

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Temporal and spatial evolution of bacterial communities in Wocan hydrothermal-plume influenced zone, Carlsberg Ridge, Northwest Indian Ocean

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Keywords: hydrothermal-plume, microbial diversity, tempora-spatial evolution, high-throughput sequencing, Indian Ocean

Hydrothermal-plume influenced zone includes the areas within and underneath the hydrothermal plume. The structure of microbial communities in the hydrothermal-plume influenced zone evolves temporally and spatially. However, due to the difficulties in observation and sampling, the diversity of microbes and how they evolve with the time and space is less investigated. During Chines DY49-5 cruise in 2018, a sediment trap mooring system was deployed approximately 300 m southeast of the Wocan-1 hydrothermal vent field (6°22N, 60°31'E), Carlsberg ridge, Northwest Indian Ocean. Eighteen months later, a total of 42 hydrothermal plume samples were retrieved from the 40 m and 300 m above the seafloor, respectively. In this paper, we used Illumina Miseq high-throughput sequencing technology combined with in-situ turbidity anomaly data to study the diversity of bacterial communities within and beneath the neutral buoyancy plume, respectively, and how they evolved with the time, with the aim to understand the factors causing the spatial and temporal heterogeneity of the microbial communities. Our results showed that the bacterial communities in the samples were dominated by γ-Proteobacteria, Camplylobacteria, α-Proteobacteria, Bacteroidia, Clostridia and Desulfobulbia. The relative abundance of Camplylobacteria increased when the hydrothermal venting was more active as suggested by the high turbidity anomaly, while the relative abundance of γ-proteobacteria and α-proteobacteria were on the contrary. Spatially, γ-proteobacteria was more abundant within the hydrothermal plume, while Camplylobacteria was more abundant beneath the hydrothermal plume. We conclude that the studied area has been affected by the dynamics of hydrothermal plume from Wocan-1 hydrothermal field. When the hydrothermal influence was stronger, the relative abundance of Camplylobacteria was higher. The samples collected beneath the neutral buoyancy plume contained more Camplylobacteria than those collected within the neutral buoyancy plume, suggesting that the abundance of sulfide particles is likely the main factor causing the spatial and temporal heterogeneity of bacterial communities in the hydrothermal-plume influenced zone.

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Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Biodiversity, biomineralization and metabolic potentials of the neutrophilic, microaerophilic iron-oxidizing Zetaproteobacteria in seafloor hydrothermal environments

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Keywords: hydrothermal vent, Fe-oxidizing bacteria, Zetaproteobacteria, ultrastructures.

Iron is one of the main components of deep-sea hydrothermal activity products and an important driving element for the chemoautotrophic microbial ecosystem at hydrothermal vents. The neutrophilic microaerophilic iron-oxidizing bacteria, represented by Zetaproteobacteria, is the main drivers of biomediated Fe^{2+} oxidation in hydrothermal vents and their surroundings. Fe-oxidizing bacteria acquires the energy necessary to maintain their metabolism through Fe^{2+} oxidation, while secrete organic matter to precipitate the oxidized insoluble iron (oxides or hydroxides) outside the cell, forming microstructures with twisted stalks, hollow sheaths, branching hollow tubes and other special morphological features. They accumulate into iron-rich oxides/hydroxides which are widely distributed on the seafloor. More and more studies have shown that the *cyc2* gene encoding cytochrome-porin is the key gene of Fe^{2+} oxidation by Zetaproteobacteria, while *c*-type cytochrome or other periplasmic cytochromes are the main electron transport carriers in Fe^{2+} oxidation. Metagenome-based studies revealed that Zetaproteobacteria also generally possesses multiple functional genes and metabolic pathways closely related to nitrogen, sulfur, hydrogen and arsenic cycling, suggesting its potential role in these elements cycling process. In this presentation, we systematically summarize the diversity and physiological characteristics of neutrophilic microaerophilic iron-oxidizing bacteria found in hydrothermal environments, as well as the microstructure records of their biomineralization, key genes and electron transport pathways that mediate Fe^{2+} oxidation. It is helpful to comprehensively and systematically understand the role and contribution of these microorganisms in the migration and enrichment of key ore-forming elements, the maintenance of vent ecology and the mineralization of microorganisms in submarine hydrothermal vents.

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Session T4-2: The coupling of geological and microbial processes in the deep-sea hydrothermal system
Presentation Preference: Oral Preferred

Designation of a mathematical modeling framework for microbial-mediated dissolution, migration and precipitation of metallic elements in hydrothermal systems

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Keywords: numerical modelling, hydrothermal foam, metallic elemation, migration

While the dissolution, migration and precipitation of metallic elements in hydrothermal systems are strongly mediated by microorganisms, there has been rare mathematical modelling work that appropriately consider this process. Potential reason may include the limited quantitative understanding on the microbial-mediated process, and the potential knowledge gaps between what can be used in a numerical model and the main outputs from experimental and field works on the micro-mediated process. Here a modeling framework for microbial-mediated dissolution, migration and precipitation of metallic elements is designed, based on which the potential knowledge gaps are discussed. Moreover, the Hydrothermal Foam, which was originally developed by Guo et al. (2020, Geoscientific Model Development), is further extended to consider migration of metallic elements. Using this extended open-source code, physical factors that may affect the migration rate of metallic elements are numerically investigated using an idealized single-pass hydrothermal system. These factors include the regions for the rock-seawater chemical interactions, the permeability distribution of the domain, as well as the temperature of the magmatic chamber.

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Virus-associated iron metabolism in deep-sea hydrothermal systems

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Keywords: Iron metabolism, Zetaproteobacteria, Virus

Deep-sea hydrothermal field is considered as one of the most productive ecosystems on Earth. Chemolithotrophic primary production supported by sulfur-oxidizing has been well documented, yet iron-oxidizing process were usually overlooked in spite of the fact that iron is the most abundant source of energy for chemolithotrophy. Zetaproteobacteria, the typical marine neutrophilic iron-oxidizing bacteria, is still under-researched partly because of the difficulties of culturing this clade. In addition, very limited information is available for the viruses of Zetaproteobacteria. In this study, we firstly resolved the genomic compositions of four complete Zetaproteobacteria prophages from reference genome database. By expanding to Zetaproteobacteria inhabiting metagenomes in global scale, we identified 649 potential Zetaproteobacteria viruses. The virus-host infection network revealed a distinct interaction pattern between Zetaproteobacteria and their viruses. The viruses of Zetaproteobacteria showed high host specificity. The discovery of viral encoded iron-oxidizing marker gene (*cyc2*) indicates that viruses may boost the growth of their hosts by promoting iron oxidation. Moreover, ferric uptake regulatory protein (*Fur*) was found widespread in viral genomes identified from Fe (II)-rich hydrothermal deposits. This study sheds light on the relationships between viral infections and deep-sea iron metabolism.

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Mineralization of Alvinella tubes at hydrothermal vents on the East Pacific Rise

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Keywords: tubeworm, mineralogy, multilayered tubes, sulfide mineralization, weathering oxidation

This paper presents a comparative study of the mineralized *Alvinella* worm-tubes at seafloor hydrothermal vents along the East Pacific Rise. Our study found that worm-tubes mineralization begins in the outer layer of the tubes and is characterized by single or multi-layered concentric colloform pyrite bands as mineralized walls. There are structural differences in the tube-worm mineralization, influenced by the rate of mineral precipitation. For example, tube mineralization is accelerated, its wall thickens, and the number of concentric layers decreases and the spacing becomes smaller. In addition, a small amount framboidal pyrite polycrystalline polymers occur in the colloform pyrite bands, indicating a potential intermediate pathway for the conversion of nano-micron crystalline sulfide minerals to colloform pyrite during the mineralization stratification phase. This process is mainly controlled by the difference in fluid metal ion concentration gradient confined by the organic worm-tubes. On the contrary, the worm-tubes with relatively slow mineralization rates are mostly characterized by a high number of concentric layers, and have a tendency of gradually increasing oxidation and gradually thinning colloform pyrite from the inside to the outside. This feature is related to the oxidation of Fe-Si-rich hydrothermal fluids and the weathering oxidation of low-temperature seawater, respectively. Additionally, we found that sphalerite band developed in the middle layer of the tubes has the effect of isolating seawater oxidation, which can effectively limit the development of seawater oxidation to the inner wall. These findings provide a new perspective for understanding the biological-mineral interactions and their weathering processes in seafloor hydrothermal vent sites.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
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Presentation Preference: Oral Preferred

Iron sulfide minerals formation by thermophilic iron-reducing bacteria Anoxybacter fenmentans DY22613 via sulfur-mediated electron shuttling

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Keywords: Iron sulfide minerals, Iron reducer, Thermophilic, Deep-sea hydrothermal vents

Iron sulfide minerals are common in the natural environment and play a key role in maintaining the oxygenation of Earth's atmosphere over geological timescale. Sulfate reducing microorganisms have been recognized as an important player for sedimentary iron sulfide mineral formation reactions in low-temperature environments. Yet, the role of biotic processes in the formation of iron sulfide minerals is poorly understood, especially in hydrothermal vents. A novel piezophilic, thermophilic, anaerobic, fermentative iron-reducing bacteria of class *Clostridia*, named *Anoxybacter fermentans* DY22613^T, was isolated from East Pacific Rise hydrothermal sulfides. It can enzymatically reduce elemental sulfur and degrade cysteine to hydrogen sulfide with final concentration 3.6 and 2.5 mM, which accordly enhanced the growth and impacted iron reducing process. Scanning electron microscopy and X-ray diffraction revealed that iron sulfide minerals produced in the presence of strain DY22613 exhibit unique morphology and aggregate differently than abiotic minerals formed in media without cells. The transformation of iron oxides including goethite and akaganeite to Mackinawite (FeS) and Marcasite (FeS_2) occurred two days of incubation with live cells to two months with dead cells. Minerals precipitates containing Fe and S are visible at the surface of cells and extracellularly. These results implied that the potential role of *A. fermentans* DY22613^T in situ in deep-sea hydrothermal sulfids is coupling iron and sulfur cycles, contributing iron sulfide mineral formation.

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The Characteristics of Metal Elements in Mussel from Wocan-1 Hydrothermal Vent of Northwest Indian Ocean

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Keywords: Mussel,Distribution of metal elements,Rare earth elements,Rare earth elements pattern,Wocan-1 hydrothermal field

The deep-sea mussel, *Bathymodiolus marisindicus*, collected from the Wocan-1 hydrothermal vent of the Northwest Indian Ocean were choose to study the characteristics of metal trace elements during their lifetime in vent system. The content of trace and rare earth elements (REEs) in the mussel shell and tissue were determined using LA-ICP-MS and ICP-MS respectively. Furthermore, the distribution and relationship of metal elements of mussel shell, tissue and sediment, as well as the ecological and chemical characteristics of REEs were explored. The results show that Fe (284.2μg/g), Mn (4.2μg/g) and Zn (12.0μg/g), and Fe (717.6μg/g), Cd (15.0μg/g), Cu (361.9μg/g), Mn (13.0μg/g), Pb (19.4μg/g) and Zn (230.2μg/g) are mainly enriched in the mussel shell and tissue of Wocan-1 hydrothermal vent, respectively. The trace elements are more enriched in mussel tissue than shell. The trace and REEs contents of the mussel of Wocan-1 hydrothermal vent are correlated with the elements contents of the sediment of the hydrothermal field. The total rare earth elements (ΣREE) of mussel shell and tissue are 0.45μg/g and 0.33μg/g, respectively. Both light and heavy rare earth elements (L/HREE) show the fractionation, and LREE (La~Eu) contents are higher than those of HREE (Gd~Lu), which are 0.27μg/g and 0.26μg/g, 0.18μg/g and 0.07μg/g, respectively. Therefore, the LREE is significantly enriched in the mussel shell and tissue, and the mussel shell is more enriched with HREE than the tissue. The REEs distribution pattern shows positive anomalies for La and Eu, negative Ce anomalies in mussel tissue, and positive anomalies for Gd, Eu, Pr and Ho, negative anomalies for Sm and Dy in mussel shell, which further indicate the REEs are selectively enriched for the mussel shell and tissue. The δEu and δCe of the sediment of the Wocan-1 hydrothermal field were 0~3.00 and 0~1.00 (excluding 1)(Qiu et al.,2021), and the δEu and δCe of the mussel shell and tissue of the hydrothermal vent are 3.95 and 4.52, 0.94 and 0.33, respectively. The δEu and δCe values of mussel shell, tissue and sediment are all greater than 1, while the δCe values are all less than 1, indicating that the REEs in the mussel of hydrothermal vent are homologous with those in the sediment of the hydrothermal field, and the REEs in mussel are affected by the seawater and hydrothermal fluid. The distribution and enrichment characteristics of trace and rare earth elements in the mussel of hydrothermal vent are investigated in this paper, which will provide a technical and theoretical basis for further study of hydrothermal geochemical characteristics recorded by organisms of hydrothermal fields.

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Seafloor microbial weatheringResults from in-situ incubation of sulfide minerals in the hydrothermal field

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Keywords: seafloor sulfides, in situ incubation, microbial weathering

Seafloor microbial weatheringResults from in-situ incubation of sulfide minerals in the hydrothermal field

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The seafloor hydrothermal sulfides could serve as energy source for the metabolic growth of chemolithoautotrophs. The activities of the microbes could mobilize and transform the elements in the sulfide minerals and as the consequences that sulfide minerals got weathered and new minerals formed. In order to understand the characteristics and processes of the seafloor microbial weathering, we deployed various types of hydrothermal sulfide samples near the Wocan-1 hydrothermal field to conduct an in-situ incubation experiment for a period of 18 months. In this study, we observed and analyzed the samples before and after the experiments using SEM and Fourier infrared spectroscopy (FT-IR). Our results show that brownish, yellowish and greenish secondary minerals formed on the surface and fissures of the sulfide slabs. Abundant microbial structures in the size from 0.5 μm to 50 μm and dissolution pores in the size of individual cells were observed. The polysaccharides and amide functional groups increased significantly in the samples dominated by chalcopyrite and sphalerite after the experiment, indicating that the activity of microorganisms produced rich extracellular polymer (EPS) on the surface of sulfide samples. While carboxylic acid (-COOH) group and phosphate group (P=O) increased in Cpy-rich samples after the experiment, suggesting that the specific adsorption of carboxylic acid groups(-COOH) to Cu ions (and phosphate groups (P=O) to Zn ions. The findings provide strong evidence for the role of microbes on the oxidation of seafloor sulfides.

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Microbial iron metabolic feature in Longqi hydrothermal vent chimneys, Southwest Indian Ridge

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Keywords: Southwest Indian Ridge, hydrothermal vent, iron oxidation, siderophore, metagenome.

Deep sea hydrothermal vents are responsible for discharging at least one third of iron into oceans[1], which significantly influence primary production in water columns and sulfide deposition in subseafloor. The ultra-slow spreading Southwest Indian Ridge (SWIR) is hot zone for future polymetallic sulfide exploration[2] as deep subsurface detachment and hydrothermal circulation system formed large deposition of sulfide minerals[3]. Meanwhile, it is also known as important component in global deep-sea ecosystems with unique and prospering macrofauna[4]. Thus, research in iron biogeochemistry is significant for both understanding chemosynthetic ecosystems in hydrothermal regions and providing guidelines for future environmental conservation.

To study microbial iron functional feature in SWIR, metagenomic sequencing and binning were utilized to revealed the microbial composition and metabolic potential in two active hydrothermal vent chimneys. In addition to autotrophic iron-oxidizing Zetaproteobacteria, 22 MAGs from 12 uncultured bacterial phyla such as KSB1, SAR324, Gemmtimonadota, Eisenbacteria and Calditrichota were detected with iron-oxidizing enzyme Cyc2, which suggested potential chemoheterotrophic iron-oxidizing microorganisms inhabiting in hydrothermal vent chimneys. As for iron transport and storage, 66% of MAGs contained siderophore transport potential while 59% of MAGs encoded Fe(II) ion transporter *feoABC* or *futABCD*. Ferritin-related genes responsible for cellular iron storage and iron mineral transformation were carried by 66% of MAGs from 30 bacterial phyla and 6 archaeal phyla. To sum up, our study revealed strong microbial metabolic potential involved with iron oxidoreduction, transportation and storage in active chimneys, which indicated intensive flow of iron between hydrothermal vent environment and microbial communities and might be responsible for mineral biotic oxidation.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-2: The coupling of geological and microbial processes in the deep-sea hydrothermal system
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Possible contribution of microbial activity to the active black smokers on the mid-oceanic ridge: Constraints from the micro-texture and in-situ sulfur isotope of pyrite in EPR 1-2°S hydrothermal field

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Keywords: Sulfur isotopes, Pyrite, Microbial activity, Sulfide chimney, East Pacific Rise

Deep-sea hydrothermal vent systems have wide-ranging gradients of organic matter contents, redox potential, pressure, and temperature, which provide habitats for a large number of extreme microorganisms. Seafloor hydrothermal deposits are usually interpreted to precipitate abiogenically in the sediment-covered back-arc setting, but rarely occur in the hydrothermal systems on the sediment-starved mid-oceanic ridge. Thus, the role of microbial activity on the sulfide precipitation in the sediment-starved mid-oceanic ridge remains poorly understood. We study the micro-textural and in-situ sulfur isotope analysis of the pyrite varieties across the active black smokers at the EPR 1-2°S hydrothermal field using SEM, EPMA, and NanoSIMS. The petrographic observations show that the anhedral/colloform pyrite with a rounded or semicircular shape under an optical microscope can be identified as likely relics of sulfidized fauna on the surface zone of the black smoker. Their sulfur isotopes results are characterized by the near and negative $\delta^{34}S$ (−0.51 ~ 1.08‰, mean: 0.08‰, n = 4), which is in contrast to the other chimneys with elevated $\delta^{34}S$ values in the outer wall associated with the thermochemical sulfate reduction (TSR) of ambient seawater sulfate (Bluth and Ohmoto, 1988; Meng et al., 2019). The outermost sulfide surface formed by the rapid quenching of H_2S-rich fluids during fluid-seawater mixing in a low-temperature environment is suitable for biological survival. The pyrite would be oxidized by seawater and then produce chemosynthetic energy to support bacterial survival as well as bacterial reduction (Mccollom and Shock, 1997). We hypothesize that the low $\delta^{34}S$ values of anhedral pyrite (low to −0.51‰) are most likely related to the incorporation of 8 ~ 24% of bacterially reduced sulfur. This study let us reconsider the possible contribution of bacterial activity to the growth of mature chimneys on the mid-oceanic ridge.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-2: The coupling of geological and microbial processes in the deep-sea hydrothermal system
Presentation Preference: Oral Preferred

Calcium and copper isotope signatures in hydrothermal sediments as proxies for hydrothermal actives in mid-ocean ridges

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Keywords: Calcium isotopes, Cooper isotopes, Hydrothermal activity

Hydrothermal sediments, which inherit or record the characteristic of sources and geochemical signals of hydrothermal activities, are one of the essential sinks of hydrothermal output (German and Seyfried, 2014; Stein and Stein, 1992). Hence, hydrothermal sediments can be exploited to detect and locate new hydrothermal fields and calculate material fluxes from any particular vent field by mineralogical and geochemical characteristics (Cave et al., 2002; German et al., 1999; Huang et al., 2017; Liao et al., 2019). As sensitive indexes, unconventional stable metal isotopes have been widely used as mineralization tracers in seafloor hydrothermal circulation and new proxies for the marine material circle (Little et al., 2014; 2017; Schmitt et al., 2003; Zhu and Macdougall, 1998). In this study, we explore the mineralogy, geochemistry, $\delta^{44/40}$Ca and δ^{65}Cu variation characteristics of a near-vent sediments core in the Tianxiu hydrothermal field, identify material sources, quantify the contribution of hydrothermal plume calcium (Ca) and copper (Cu), and then assess the activity intensity's evolution trend of the hydrothermal field. The primary material sources of Ca in the Tianxiu sediment core are hydrothermal calcite and bioclastic. The $\delta^{44/40}$Ca of bio-calcite is significantly correlated with its precipitation temperature. According to the $\Delta^{44/40}$CaBio-Seawater = 1000ln(α) that the $\delta^{44/40}$Ca (0.57 ± 0.065‰, 95% confidence interval) of marine biogenic calcite is controlled by the surrounding seawater's temperature (2 ℃ to 7 ℃). Additionally, during hydrothermal circulation, the $\Delta^{44/40}$CaCal-HydFluid of hydrothermal endmember calcite in the altered basement follows a $1/T^2$ (T: temperature in Kelvin) relationship. On the other hand, hydrothermal Cu is derived from hydrothermal plume Cu precipitation and Cu-enriched hydrothermal minerals in the altered basement detrital. During early high-temperature hydrothermal processes, preferentially formed ^{65}Cu-enriched sulfides, causing the subsequent derived hydrothermal plume significantly enrich ^{63}Cu. The δ^{65}Cu of hydrothermal sediments is significantly correlated with its hydrothermal products. In this paper, the estimated δ^{65}Cu of the hydrothermal plume endmember is -0.51 ± 0.20 ‰ (95% confidence interval), and its formed significant ^{65}Cu-depleted hydrothermal precipitation (oxide/hydroxide). Hence hydrothermal plume may provide a critical source of light Cu isotopes entering seawater and metalliferous sediments. In general, the $\delta^{44/40}$Ca value of hydrothermal calcite records the hydrothermal reaction field precipitation temperature, which may be closely related to the intensity of hydrothermal activity and has to be constrained in future studies. While Cu isotopic composition is affected by sources and redox, thus it is more complex to use δ^{65}Cu as an exploration proxy to investigate hydrothermal activity intensity.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-2: The coupling of geological and microbial processes in the deep-sea hydrothermal system
Presentation Preference: Oral Preferred

Particle Transport and Deposition Released by Horizontal Buoyant Jets in Stratified Fluids

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Keywords: Sediment transport, Sedimentation, Stratified Fluids, Buoyant Jet

Particle-laden buoyant jets are ubiquitous in coastal and ocean environments. Here, we reveal the propagation and mechanism of particles with different sizes, densities, and concentrations horizontally transported by buoyant jets in the stratified fluid, using a computational fluid dynamic model fully coupled with a discrete element method. Particles with a large settling velocity deposit quickly after moving forward in a short distance horizontally and associate with a narrow particle accumulation band on the bed. The lateral probability distribution of deposited particles in this pattern is Gaussian-like. The proportion of particles settled near the source is positively related to their density. Particles with a medium settling velocity are driven up by the buoyant flow and then settle. The lateral probability distribution of deposited particles in this pattern deviates from the Gaussian distribution because particles at the head of the deposition area are not subject to the constraint of the jet boundary layer during settling and form dispersed depositional fan on the bed. The length of the deposition area is independent of the volume fraction of particles, while the maximum rise height of particles will decrease with the increase of the volume fraction. Particles with a small settling velocity can remain suspended until the jet rebounds. In this pattern, particles diffuse from the inside of the jet near the neutral buoyancy layer. During the diffusion process, partial particles are recaptured due to the inward flow field caused by the entrainment of the jet.

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-2: The coupling of geological and microbial processes in the deep-sea hydrothermal system
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Microbial-mediated weathering of hydrothermal sulfide in the presence of iron-oxidizer Alcanivorax sp. MM125-6

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Keywords: hydrothermal sulfide weathering, Alcanivorax, autotrophic Fe(II)-oxidation, element exchange, deep-sea hydrothermal field

Seafloor weathering of hydrothermal sulfides is a common phenomenon. Yet the role of microorganisms during the process of seafloor weathering is not well studied. In this study, we carried out an experimental study on the interaction between the microbes and hydrothermal sulfides, simulating the water chemistry of bottom seawater of Wocan hydrothermal field, Carlsberg Ridge, in the presence of hydrothermal sulfide particles and Alcanivorax sp. MM125_6 at 28 ℃ for 3 months. Strain Alcanivorax sp. MM125_6 was isolated from Wocan hydrothermal field which has potential of autotrophy and Fe(II)-oxidization. Our results show that after experiment, the water chemistry and pH value changed significantly in the presence of microbes, but insignificant in the absence of microbes. For example, compared to abiotic experiment, the concentrations of Fe, Zn, Cu and Pb in the medium in the presence of microbes increased 6.7-35.2, 1.2-1.5, 2.3-4.3 and 15.3-53.7 fold, respectively. The surfaces of the hydrothermal sulfide grains were colonized by abundant cells as revealed by Fluorescence microscopy images. Scanning Electron Microscopy analysis revealed the presence of extracellular polymeric substances and microbes with the shape of short rods. Besides, particulate iron-oxides, and irregular polygon pits on the surface of sulfide grains were also observed in the biotic experiment, but not in the abiotic experiment. Our findings suggest that Alcanivorax played an important role on the weathering/oxidation of hydrothermal sulfides, and the metabolism of Alcanivorax could accelerate the process of seafloor weathering.

Session T4-3: Using bioturbational structures to understand sedimentological and geochemicalprocesses in modern and ancientmarine environments

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-3: Using bioturbational structures to understand sedimentological and geochemical processes in modern and ancient marine environments
Presentation Preference: Oral Preferred

Bioturbation enhanced petrophysical properties in the Ordovician carbonate reservoir of the Tahe oilfield, Tarim Basin, China

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Keywords: Bioturbation, Carbonate reservoir, Diagenesis, Ordovician, Tahe oilfield, Tarim Basin

Bioturbation plays an important role in enhancing the reservoir capacity of tight reservoirs. This study aims to understand the alteration mechanism and effects of bioturbation on oil and gas reservoirs, to clarify the key control factors and constraints influencing the production of bioturbation. The petrophysical characteristics of bioturbation and host sediments in carbonate rocks, such as mineral composition, pore spaces, porosity and permeability, were studied based on the detailed observation and description of the Ordovician cores from the Tahe oilfield. The effect of bioturbation on petrophysical properties of carbonate rocks were carefully analyzed. The results show: (1) Two types of bioturbation, *Thalassinoides*-like burrows and *Planolites*-like burrows, mainly occur in the Ordovician cores of the Tahe oilfield, ranging from the Lower–Middle Ordovician Yingshan Formation to the Middle Ordovician Yijianfang Formation. The burrow-fills are mainly composed of dolomite with subhedral and euhedral crystals. The host sediments mainly consist of micrite. (2) The pores in the host sediments are poorly developed and are incapable of forming effective reservoir spaces. However, well-developed intercrystalline pores among dolomites and microfractures in bioturbated sediments with better connectivity can form effective pore spaces. The results of porosity and permeability show that the host sediments without bioturbation are characterized by poor porosity and permeability. However, with the increase of bioturbation intensity, the porosity of the bioturbated sediments firstly increases and then decreases, whereas the permeability increases all the time. (3) Multiple burrows overprinted in the Ordovician carbonate rocks, forming a large-scale bioturbated carbonate rocks with lateral continuity and vertical connectivity, due to the suitable sedimentary setting, ecological conditions, favorable spatiotemporal sediment matching, and abundant organism-substrate interaction. Subsequently, diagenesis (particularly dolomitization and dissolution) has played a positive role in altering the rock fabric and improving the petrophysical properties of bioturbated carbonates.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-3: Using bioturbational structures to understand sedimentological and geochemical processes in modern and ancient marine environments
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Thalassinoides ichnofabrics of Lower Cambrian Longwangmiao Formation (Stage 4, Toyonian) on the Yangtze Platform, South China: Improving paleoenvironmental interpretations

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Keywords: Cambrian, Thalassinoides, Carbonate platform, Paleoenvironment

The analysis of Thalassinoides ichnofabrics in the Cambrian Stage 4 Longwangmiao Formation in the Middle and Upper Yangtze Block of South China is conducted to promote the understanding of the paleoenvironment of this period. Thalassinoides ichnofabrics are divided into three types (banded, mottled and grid) according to their morphology, bioturbation index, abundance and related parameters.

The completeness of ichnofabrics gradually increases from banded to grid, the scale of burrows expands, and the structure transitions from two-dimensional to three-dimensional. Malacostracans, phyllocarids and enteropneusts are the most likely burrowers. The findings reveal that frequent changes in paleoenvironmental conditions are the dominant factors for generating the various Thalassinoides ichnofabrics. The changes in depositional rate, substrate properties and nutrient levels affect the behavior and building pattern of the burrowers, thus leading to the diversity of Thalassinoides ichnofabrics. In the early Longwangmiao period, many incomplete Thalassinoides burrow systems were built in the substrates with terrigenous detrital minerals, revealing the significant environmental pressure on the burrowers. In the following period, the Thalassinoides burrows went into complete three-dimensional boxworks. At the end of the period, bioturbation almost disappeared, which indicates that burrowers were difficult to survive in the harsh environment.

Scientific Themes: Theme 4. Biological Process in Sedimentation
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Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Behavioural imprint of the Ordovician Radiation: evidence from Middle–Upper Ordovician deep-sea trace fossils in western Inner Mongolia, North China

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Keywords: bioturbation, deep-marine environment, ichnodisparity, Great Ordovician Biodiversification Event, Late Ordovician, North China Craton

Trace fossils are unique evidence of the body plan and behavioural complexity of animals. Major radiation periods in the Phanerozoic were associated with not only changes in biodiversity, biomass, and ecosystems but also transformations in the relatively implicit, behavioural world. Here we report on a diverse ichnoassemblage from the Middle–Upper Ordovician deep-marine deposits of Inner Mongolia, North China, totalling 24 ichnogenera (including two undetermined forms). They include *Alcyonidiopsis*, *Bifasciculus*, *Bifungites*, *Chondrites*, *Circulichnis*, ?*Cochlichnus*, *Dendrorhaphe*, *Diplocraterion*, *Halopoa*, *Gyrophyllites*, *Monofungites*, *Multina*, *Nereites*, *Paleodictyon*, *Phymatoderma*, *Ptychoplasma*, *Rhizocorallium*, *Sinusichnus*, *Taenidium*, *Thalassinoides*, *Trichichnus*, *Zoophycos*, bag-like trace, and closed ring trace. They are attributed to 21 architectural designs, encompassing 13 subhorizontal structures, 3 subvertical structures, and 5 complex structures. Highly regular and complex burrow systems have been discovered, i.e., the branched circular pattern of *Circulichnis sinensis*, elaborate radial graphoglyptid tunnel system *Dendrorhaphe racemosa*, sinusoid mazework *Sinusichnus sinuosus*, and the boxwork bag-like trace consisting of highly symmetric horizontal galleries and numerous semi-equidistant vertical shafts. The occurrence of these complex trace fossils suggests distinct behavioural complication and novelty in deep-sea communities during the Middle–Late Ordovician. We speculate that along with the onshore–offshore displacement of ichnofauna and significant expansion of deposit-feeding structures possibly driven by accelerated competition in the shallow-marine niches and aided by ameliorated deep-sea benthic food level, there was underlying behavioural evolution towards more delicate, geometric, and efficient feeding patterns. The Late Ordovician may represent the early peak not only in ichnodiversity but also in ichnodisparity and behavioural complexity of deep-sea ichnofauna, which probably reflect the complex interplay of biodiversity, biomass, and ecological changes during the Ordovician Radiation.

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-3: Using bioturbational structures to understand sedimentological and geochemical processes in modern and ancient marine environments
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

A large crustacean burrow system from the Lower Devonian of the northwestern Yangtze Platform, South China

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Keywords: Trace fossil, engineering, crustacean burrow, Early Devonian, paleoecology

By means of digging and turning over the substrate, bioturbation may have both direct and indirect effects on bottom sediment characteristics. These activities, also known as engineering, promote the remobilization of sediment grains and nutrient cycling, changing the physical and chemical features of the local even global environment. Burrows also provide potential living space for co-habitants and thus largely increases the complexity of benthic community. Crustacean burrows especially have a chance to produce these effects for their higher complexity in burrow architectures, larger sizes and nature as deep-tiered systems. However, records of crustacean burrows during the earlier periods of Paleozoic are scarce. Here we report an unusually large (segments up to 58 mm across), three-dimensional burrow system from the Lower Devonian Pingyipu Formation on the northwestern Yangtze Platform, South China. The burrow system is characterized by horizontally-developed networks, with vertical shafts connecting to the sediment-water interface. The burrow surfaces are characterized by scratches including ridges and bundles of ear-shaped striae, allowing an assignation to *Spongeliomorpha* aff. *S. chevronensis* Muñiz and Mayoral, 2001. Analysis of their morphological features, especially the scratches reveals that the trace maker could be a colony of large, unknown crustacean with thoracic appendages decorated with acute seta or denticulations. The burrows represent both the earliest known and some of the largest *Spongeliomorpha* in geological history that may be comparable to their modern analogues in both morphological and functional aspects. The well-documented presence of large trace fossils produced by infaunal crustaceans shows that, the factor causing more dramatic impacts in substrate properties as observed later may has already present during the Early Devonian.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-3: Using bioturbational structures to understand sedimentological and geochemical processes in modern and ancient marine environments
Presentation Preference: Oral Preferred

Early Triassic trace fossils from South China marginal-marine settings: Implications for biotic recovery following the end-Permian mass extinction

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Keywords: Ichnology, Ichnodisparity, Ichnodiversity, Biotic recovery, Longmendong section

The Longmendong section is one of the few Early Triassic sections containing fluvial to marine deposits in South China. No trace fossils have been recorded in the fluvial deposits, but a total of 26 ichnospecies are reported from the Lower Triassic Dongchuan, Feixianguan and Jialingjiang formations in this section. This ichnofauna represents brackish-water conditions during the late Dienerian to Smithian, and fully shallow-marine settings in the Spathian. Several ichnologic metrics, such as ichnodiversity, ichnodisparity, ichnoabundance, bioturbation intensity, burrow size, and depth of bioturbation, have been analyzed in order to evaluate the role of environmental and evolutionary factors. Although the upward increases in ichnodiversity, ichnodisparity, burrow size and bioturbation intensity may be linked to the biotic recovery after the end-Permian mass extinction, environmental controls also play an important role in this case. Transgressive-estuarine successions typically show a vertical decrease in the salinity stress, showing the passage of brackish-water ichnofaunas to more diverse associations showing more marine affinities. However, the vertical increase in depth of bioturbation cannot be explained by environmental controls alone, instead most likely reflecting the phase of biotic recovery. Overall, ichnologic data suggest that the brackish-water ecosystem was less impacted by the end-Permian mass extinction than the fully marine realm. The shallow, fully marine benthos completely recovered in the Spathian as is the case for other areas in South China. This study underscores the importance of a careful evaluation of sedimentary facies and environmental conditions as a pre-requisite for interpreting evolutionary mechanisms of biotic recovery.

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-3: Using bioturbational structures to understand sedimentological and geochemical processes in modern and ancient marine environments
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

3D BURROWS OF THE POLYCHAETE ON A TIDAL FLAT OF THE YELLOW RIVER DELTA IN CHINA: IMPLICATIONS FOR THE ICHNOFOSSILS POLYKLADICHNUS AND ARCHAEONASSA

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Keywords: 3D, Perinereis, analogous fossil, Polykladichnus,Archaeonassa

Abundant biogenic sedimentary structures produced by Perinereis aibuhitensis (formerly Nereis) occur in tidal flats of the Yellow River Delta in China. The burrows of Perinereis are visible as vertical tubes and irregular strings in slabbed cores. The cores were studied by X-ray radiography, computed tomography and VGStudio MAX to obtain three-dimensional images of the burrows and their inner structure. The burrows are vertical to steeply oblique, Y-shaped tubes with multiple branches. They are considered as analogues of the trace fossil Polykladichnus. Some gutter-like surface traces are similar to the trace fossil Archaeonassa. Perinereis burrows and trails occur mainly in the mixed flat, less frequently in the mud flat or sand flats. Potentially abundant occurrences of some analogous fossil burrows and trails (Polykladichnus, Archaeonassa) could mark position of the intertidal zone

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-3: Using bioturbational structures to understand sedimentological and geochemical processes in modern and ancient marine environments
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Response of the macrobenthic trace maker community to palaeoenvironmental conditions during Termination V and MIS 11 at the western Mediterranean Sea: surface conditions affecting deep-sea settings

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Keywords: Ichnology, Mediterranean Sea, Surface production, Benthic conditions, Pleistocene

The Marine Isotope Stage (MIS) 11 is an interesting climatic period as it is considered a long and extremely warm interglacial on the Pleistocene. Additionally, its late part records suborbital-scale instabilities associated with Heinrich-type (Ht) events at Iberian latitudes. These climate changes have been registered and analyzed from coccolithophore records at the OPD Site 977 at the western Mediterranean Sea, showing intense variations on surface primary production that could affect deep-sea conditions. Here, we propose the study of the ichnological content and sediment color to analyse the trace maker response and palaeoenvironmental conditions along this period. Then, we integrate the obtained information with previously studied high-resolution coccolithophore data to check if there is a relation between surface and deep-sea conditions. The trace fossil assemblage is characterized by *Chondrites*, *Planolites*, *Scolicia*, *Thalassinoides* and *Zoophycos*, showing notable differences in abundance and diversity along the cores. Ichnological content was integrated with sediment color data and high-resolution coccolithophore records, showing that trace maker communities were mainly affected by oxygen levels and surface organic productivity. First, during Termination V (i.e., right before MIS 11), an intense upwelling caused high surface organic productivity, which increased the deep organic matter accumulation. This, together with the poorly deep-water removal, generated an Organic Rich Layer and a low degree of bioturbation. However, during MIS 11 the surface organic productivity was stable and moderate, causing a lower organic matter content in the deep-sea setting and better oxygen conditions for the macrobenthic trace maker community. This is recorded by a higher degree of bioturbation and lighter sediments. Ht events 3 and 2 are also registered and characterized by a higher ichnodiversity and abundance. These periods are dominated by low surface organic productivity, but intense deep-water circulation, which increase the deep-water removal and oxygen level. The study of palaeoenvironmental conditions from ichnological content, and the integration with additional proxies, show a clear example of the transference of surface conditions to deep-sea settings.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-3: Using bioturbational structures to understand sedimentological and geochemical processes in modern and ancient marine environments
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Ichnological analysis of the Rambla de Tabernas section (Tabernas Basin, SE Spain), a preliminary approach to improve characterization of a turbiditic system

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Keywords: Turbidites, Trace fossils, Paleoenvironment, Ichnofacies

Tabernas Basin is a Neogene basin of the Betic Cordillera (SE Spain), with an exceptional exposure of continental and marine sediments (Serravallian – Messinian), and a remarkable presence of well-developed turbiditic deposits. These deposits have been mainly studied focusing on sedimentological and tectonic aspects, but other features, as the ichnological content, especially relevant in this facies, has not been studied in detail. Here we present a preliminary study of one of the most representative turbiditic sections from the Tabernas Basin, the *Rambla de Tabernas* section, allowing interpretation of palaeoenvironmental conditions and differentiation of sub-environments in the turbiditic system. The *Rambla de Tabernas* section is a 50 meters long section mainly composed of brownish and olive grey compacted mudstone interbedded with fine- to medium-grained sandstone moderately to poorly sorted. Lithological information, together with sedimentary structures (e.g., parallel and cross laminations) allows differentiating some Bouma turbiditic sequences. Regarding ichnological content, a trace fossil assemblage composed of 14 ichnotaxa is observed, with a pre-depositional traces represented by ?*Circulichnis*, *Cosmorhaphe*, *Desmograpton*, *Helminthorhaphe*, *Megagrapton*, *Paleodictyon*, and *Urohelminthoida*, and a post-depositional association with *Chondrites*, *Ophiomorpha*, ?*Palaeophycus*, *Phycodes*, *Planolites*, *Scolicia*, and *Thalassinoides*. This assemblage can be assigned to *Nereites* ichnofacies, commonly associated to turbiditic deposits. On this general ichnofacies context, variations in trace fossils distribution and Bioturbation Index along the section, allow to differentiate between the *Paleodictyon* ichnosubfacies and *Ophiomorpha rudis* ichnosubfacies, associated to different sub-environments of the turbiditic system. Intervals dominated by *Cosmorhaphe*, *Helminthorhaphe*, *Paleodictyon* and *Urohelminthoida*, assigned to the *Paleodictyon* ichnosubfacies, can be related to the distal part of the turbidite lobe deposit (fan fringe). Those characterized by a major presence of *Ophiomorpha*, *Scolicia*, *Thalassinoides* and *Chondrites*, and a higher abundance, assigned to the *Ophiomorpha rudis* ichnosubfacies, represent a more proximal area within the turbiditic system. This preliminary study supports the usefulness of the ichnological analysis to improve the interpretation of these turbiditic deposits, providing additional information of scientific relevance about depositional sub-environment into the turbiditic system, but also of economic importance considering the interest of these deposits as potential analogues to reservoir facies.

Reference

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-3: Using bioturbational structures to understand sedimentological and geochemical processes in modern and ancient marine environments
Presentation Preference: Oral Preferred

Ichnological and geological evolution of the Lower-Middle Paleocene successions in the Lishui-jiaojiang Sag of the East China Sea Shelf Basin

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Keywords: lacustrine, marine, delta, trace fossil, Paleocene, Lishui-jiaojiang Sag

In this study, integrated ichnological, sedimentological, geochemical, and seismic analyses of the Lower-Middle Paleocene succession (Yueguifeng and Lingfeng formations) were undertaken to provide insights into the reservoir and source rock predictions in the Lishui-jiaojiang Sag of the East China Sea Shelf Basin. Our studies have revealed that the Lower Paleocene Yueguifeng Formation, the chief source rock in the Lishui-jiaojiang Sag, is actually characterized by a package of mixed coarse-grained and fine-grained deposits in a lacustrine setting. During the accumulation of the Yueguifeng Formation, there existed a predominant clastic influx from the west via the gentle-slope delta system while the local clastic supply from the steep-slope fan system in the east cannot be overlooked. Despite a lack of core samples of the Yueguifeng Formation, the geochemical and paleontological evidences suggest its depositional transition from independently segmented freshwater lakes to a partially closed bay condition. Thereby, the distribution of good-quality lacustrine source rock of the Yueguifeng Formation exhibits significant heterogeneity.

The ichnofossil assemblages and sedimentary structures revealed by core samples have shedded lights on the paleoenvironments and stratigraphic evolutions of the Middle Paleocene Lingfeng Formation. Two facies associations (delta front and prodelta), recorded by an overall transgressive transition from *Skolithos* to *Cruziana* ichnofacies, are interpreted from the cores. The delta front deposits, characterized by intensely bioturbated sandstones with thinly interbedded mudstones, exhibit a low-diversity trace fossil suite of *Ophiomorpha* and *Thalassinoides*. The prodelta deposits, in contrast, document a high abundance and diversity of marine trace fossil assemblage of *Asterosoma*, *Chondrites*, *Ophiomorpha*, *Planolites*, *Phycosiphon*, and *Thalassnoides*. In addition, the presence of high-frequency interbedded sandstone and mudstone features attests to the influence of storm-generated currents during depositions.

Scientific Themes: Theme 4. Biological Process in Sedimentation
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Presentation Preference: Oral Preferred

Paleopedologic, ichnologic, and sequence-stratigraphic characterization of the early Miocene Khari Nadi Formation, Kutch basin, Gujarat state of India

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Keywords: Paleosol, Khari Nadi Formation, mollisol, Termitichnus ichnofacies, micromorphology, Kutch basin

The presence of multiple well-developed paleosol horizons and their associated continental ichnofacies in the Aquitanian Khari Nadi Formation (KNF) testify a number of subaerial-exposure episodes having significant duration to produce them. This observation apparently contradicts the previous understanding in the literature of an overall deepening of the basin during the Aquitanian Age. Mesoscopic field observation reveals that the intervals toward the base as well as toward the top of the formation demonstrate the most prolific development of paleopedogenetic features, e.g., soil horizonation, formation of peds, mottling, presence of fossilized plant-root traces (i.e., grey rhizotubule and surrounding yellow-brown rhizocretion). The diagnostic redoxiomorphic features with well-developed mottling indicate substantial water logging and characterize the paleosol horizons to be “gleyed” (Mollisol) with a skewed prominence of the B-horizons. The mesoscopic observation has also been substantiated by the micromorphological studies providing evidences of the presence of micro-structures (peds), various types of voids (planes, channels, chambers), characteristic coarse-fine distribution (c/f ratio), and b-fabric with a copious number of intrusive pedofeatures (e.g., coating, hypo-coating, quasi-coating, Fe-Mn nodule) and matrix pedofeatures (e.g., degree of impregnation and development of redoxiomorphic feature).

Extensive termite activity, superimposed on the softground shallow- and marginal-marine ichnofacies associations, has been documented. Its ichnodiversity is restricted and includes ichnogenera Vondrichnus and Termitichnus – both showing several of their ichnospecific preservations. High bioturbation intensity and low ichnodiversity of the isopteric trace fossils along with the association of root traces characterize the Termitichnus ichnofacies that supports the paleopedological features of mollisol development, elucidates a warm and humid Aquitanian paleoclimate and a very shallow paleo-water table, and concur with the earlier paleobotanical studies suggesting a closed tropical evergreen forest. Organism-paleosol interaction has also been found in micromorphological study indicative of trace producers. Delineation of burrow wall and grainsize alignment along it (i.e., fine-grained coating and long-axial alignment of coarse grains parallel to the wall) are the two criteria to distinguish burrows from the surrounding matrix.

This novel integration of the paleopedology and ichnology strongly evidences multiple low-order Aquitanian regressions in the Kutch basin culminating at least twice toward the lower and the upper ends of the interval. Such sharp high-frequency baselevel fluctuations must have been superposed on a previously suggested 3rd-order early Miocene transgression.

Scientific Themes: Theme 4. Biological Process in Sedimentation
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Presentation Preference: Oral Preferred

Endobenthic colonization of Cambrian fan delta deposits associated to basement uplifted blocks in southwestern Saskatchewan, Canada

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Keywords: Cambrian, fan delta, Basal Sandstone Unit, Earlie Formation, trace fossils, Canada

In southwestern Saskatchewan, middle Cambrian strata of the Basal Sandstone Unit (BSU) and the Earlie Formation are found in subsurface resting on the Precambrian basement. In the studied area, these units record deposition from fan delta wedges to embayment settings accumulated within the context of an epeiric sea, formed during a transgressive event that covered the western margin of Laurentia during the Paleozoic (Slind *et al.*, 1994). In recent years, the economic interest in Saskatchewan's Cambro-Ordovician rocks has increased after the discovery of large amounts of helium in the southwestern regions of the province (Yurkowski, 2016). This led to the development of different exploration and production projects. Core material — recovered by North American Helium (NAH) from eight wells drilled at the flanks of tectonically uplifted Precambrian blocks in southwestern Saskatchewan — from helium-bearing rocks comprised in the BSU and the Earlie Formation was logged in detail. Sedimentologic and ichnologic analyses reveal that environmental stressors, such as coarse grain-size, rapid deposition, and very high hydrodynamic energy, have direct impact on bioturbation intensities and trace fossil distribution in fan deltas. Basal and proximal subaerial fan delta deposits are dominated by very coarse-grained sandstone and boulder conglomerate that are devoid of bioturbation. Subsequent transgression led to landward migration of the fan-delta system and the accumulation of subaqueous mid- to distal-fan sandstone deposits on top of proximal facies. Mid-fan and fan toe deposits reveal subaqueous conditions, and they are characterized by coarse- to medium-grained sandstone and mudstone facies displaying rapid bioturbation events in between sedimentation episodes, when environmental stressors were ameliorated. Transgressive embayment deposits accumulated after the abandonment of the fan delta system once it was completely flooded during Earlie Formation times. Proximal to distal bay deposits consist of various glauconite-rich, coarse- to very fine-grained sandstone and mudstone facies with interbedded carbonate rocks. These embayment deposits display high levels of bioturbation intensity, reflecting stable environmental conditions that favored endobenthic colonization. The presence of bioturbation in both subaqueous fan delta and transgressive deposits provides further support to the view that Cambrian levels of biogenic mixing were high in the absence of extreme environmental stressors. Our study underscore the importance of evaluating sedimentary facies changes to assess the impact of environmental factors prior to making evolutionary inferences.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-3: Using bioturbational structures to understand sedimentological and geochemical processes in modern and ancient marine environments
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Ichnofossils from the Late Permian to the earlist Triassic at Meishan, South China and their environmental implications

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Keywords: end-Permian, mass extinction, ichnofossil, Meishan, redox evolution

The end-Permian mass extinction (EPME) was one of the most devastating biotic crises in the Phanerozoic (Erwin, 2006). Over 80% of marine species were annihilated in this catastrophe (Stanley, 2016). Previous studies of this mass extinction have mainly concentrated on geochemistry and body fossil records. Meishan section is the Global Stratotype and Point for the Permian–Triassic boundary in South China, yeild abundant ichnofossils. A High-resolution investigation of ichnofossils from the Meishan section reveals the presence of *Arenicolites* isp., *Chondrites* isp., *Diplocraterion* isp., *Palaeophycus* isp., *Planolites* isp., *Skolithos* isp., *Thalassinoides* isp., *Zoophycos* isp.. Ichnofabric index and ichnofossil assemblages in the Meishan section provide an opportunity to detect the palaeoceanic redox evolution in the Permian–Triassic transition. Before the EPME (Beds 1 to 24d), the sediments are strongly bioturbated (ii=5–6), representing a high oxygen level. During the EPME interval (Beds 24e to 27), both high inchnofabric index (ii=4) and low ichnofabric index (ii=1–2) occurr in this interval, indicating a fluctuation of oxygen level. During the post-EPME interval (Beds 28 to 30), the ichnofabric index distinctly dropped, no bioturbation can be observed. The ichnological data suggest that the bottom waters were not permanently anoxic, but interrupted by aerobic periods during the Permian–Triassic transition.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
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Presentation Preference: Oral Preferred

Substrate lithification in early Cambrian carbonates triggered by intense bioturbation

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Keywords: bioturbation, burrow halo, substrate lithification, firmground, hardground

Burrowing organisms in the early Cambrian are often known for disturbing the microbial mat dominated seafloor, promoting the cycling of nutrients and oxygen and creating a mixed, loose layer in the substrate. Here we provide new insights on the influence that bioturbation had in modifying substrates in the Cambrian. Dense, morphologically complex burrows with thick diagenetic halos are manifest at several horizons in the Houjiashan Formation (Cambrian Stage 4) of North China. Fragmented burrow parts with their diagenetic halo indicate early and preferential lithification starting from the burrow margins and affecting the surrounding matrix. With increasing amount of bioturbation and the development of diagenetic halos, as well as depleted d13C values within the micrite halos suggest that these originally open conduits (i.e., burrows) facilitated the gradual consolidation and lithification of the soft substrate and transformed it into a firmground and, locally, incipient hardground. The possibility that bioturbation drives and expedites substrate lithification during the Cambrian may be a plausible explanation for the widespread occurrence of consolidated carbonate substrates and their subsequent erosion and reworking during this geological period.

Scientific Themes: Theme 4. Biological Process in Sedimentation
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Presentation Preference: Oral Preferred

Resilience of infaunal ecosystems during the Early Triassic greenhouse Earth

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Keywords: soft-bodied animals, trace fossils, ecosystem engineering, ichnodiversity, trophic-group amensalism

The Permian-Triassic mass extinction severely depleted biodiversity, primarily observed in the body fossil of well-skeletonized animals. Understanding how whole ecosystems were affected and rebuilt following the crisis requires evidence from both skeletonized and soft-bodied animals; the best comprehensive information on soft-bodied animals comes from ichnofossils. We analyzed abundant trace fossils from 26 sections across the Permian-Triassic boundary in China, and report key metrics of ichnodiversity, ichnodisparity, ecospace utilization, and ecosystem engineering. We find that soft-bodied animals recovered first in deeper marine habitats, and infaunal ecologic structure was well established in the early Smithian. Decoupling in diversity between deposit feeders and suspension feeders in carbonate ramp-platform settings implies that an effect of trophic group amensalism could have delayed the recovery of non-motile, suspension-feeding epifauna in the Early Triassic. This differential reaction of infaunal ecosystems to variable environmental controls thus played a significant but heretofore little appreciated evolutionary and ecologic role in the overall recovery in the Early Triassic hot ocean.

Scientific Themes: Theme 4. Biological Process in Sedimentation
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Presentation Preference: Oral Preferred

Softground and firmground opportunistic Thalassinoides (-Gyrolithes) ichnofabric and paleosol ichnofabric of the early Miocene Chhasra Formation, Kutch basin, Gujarat state of India

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Keywords: Paleosol, Chhasra formation, Kutch basin, Mixed siliciclastic-carbonate, Thalassinoides ichnofabric, Termitichnus

The Burdigalian Chhasra Formation (CF) of Kutch basin exemplifies a mixed-siliciclastic-carbonate depositional setting manifested by recurring alternations of carbonate and siliciclastic facies. The CF consists of the lower Claystone and the upper Siltstone members. The Claystone Member (an obvious misnomer) is characterized by the intercalated deposition of thick bioclastic carbonate, siltstones, claystones, and sandstones. These siliciclastic horizons contain predominantly pedogenized sandy-siltstone intervals, in which often the occurrence of complete paleosol horizonation can be observed (e.g., ~ 4 m thick amalgamated paleosol along the Berwali river).

The paleosol interval has been investigated with the establishment of paleo-pedogenic features (ped structure, mottling, texture, boundaries, presence of nodules, and fossil root traces). Both top and bottom contacts of the interval are sharp. The paleosol layer overlies a swaley-cross-stratified sandstone bed (thickness ~ 90 cm). A molluscan bioclastic packstone bed overlies the paleosol horizon. The section records both shallow-marine and continental ichnocoenoces overprinting each other.

The underlying sandstone shows a monospecific localized and sparce (BI 1) softground *Thalassinoides* ichnofabric. The overlying packstone demonstrates a monospecific softground *Thalassinoides* ichnofabric though with high to complete (BI 4-6) bioturbation obfuscating identification of any/all other softground trace fossils if were present. Both the units do not show any sign of pedogenesis. At and below the contact between the underlying paleosol and the overlying packstone, *Thalassinoides* transforms into firmground *Gyrolithes* forming a compound ichnotaxa into the paleosol.

The paleosol ichnofabric consists of *Vondrichnus*, *Termitichnus*, and other yet unclassified insect traces with the bioturbation intensity varying conspicuously at different subintervals of the amalgamated horizon and also laterally (BI 3-5). The amalgamated horizon is partitioned by the reactivation surfaces, along which lenses of fully-bioturbated (BI 6) siltstones with monospecific firmground *Thalassinoides* ichnofabric can be observed. From the reactivation surfaces downward, this firmground *Thalassinoides* ichnofabric suite is overprinted on the amalgamated paleosol fabric, hence also locally crosscutting its *Termitichnus* suite.

The early Miocene megasequence of Kutch basin, as a whole, and the Claystone Member, in particular, have earlier been reported to be deposited under a sustained 3rd-order (~7 Ma) transgressive systems tract (TST) (Kumar et al., 2009, 2016). The aforementioned facies association can be observed throughout the Claystone Member making its sequence-stratigraphic context further complex with recurring deposition of the upper-shoreface sandy tempestites, the subaerial exposure intervened by brackish incursions, and deposition of bioclastic packstone event-concentration (sensu Kidwell, 1991) beds. Such facies variations could be both autogenic or high-frequency lower-order allogenic. Both ways impart and maintain a set of ecological stresses on the shallow- and marginal-marine infauna making both the softground and firmground ichnofabrics solely dominated by the opportunistic generalist crustacean trace makers with their domichnial, deposit-feeding, and agrichnial ethology and suppressing all other forms.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-3: Using bioturbational structures to understand sedimentological and geochemical processes in modern and ancient marine environments
Presentation Preference: Oral Preferred

Ichnological and Sedimentological characteristics of the Oligocene Maniyara Fort Formation, Kutch basin, Gujarat, India

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Keywords: high-energy open-shelf, tropical bioclastic carbonate, ichnofabric, Oligocene, Kutch basin.

Along the banks of mostly N-S or NE-SW flowing streams, outcrops of varying thickness (ca. 30-35 m) of the Oligocene Maniyara Fort Formation (MFF) of the Kutch basin is exposed parallel to the present semi-circular coastline of the Gujarat state of India. Earlier works suggest that the formation was deposited during a marine transgressive environment varying from lagoonal to a high-energy open-shelf environment. Biswas (1992) subdivided MFF into four members, viz., the Basal, Lumpy Clay, Coral Limestone, and Bermoti members. The present study intends to construct a novel, comprehensive, and integrated ichno-sedimentological-stratigraphic model for the Oligocene of Kutch. The facies at the three studied sections, i.e., along the Berwali, Kharai, and Waior rivers, unequivocally consist of the alternations of moderate to completely bioturbated horizons of nummulitic grainstone, glauconitiferous shale, calcareous claystone, and thick cemented fossiliferous packstone-wackestone intervals. Numerous distinctive ichnofabric models can be defined based on the ichnotaxonomy, ichno-diversities, individual abundances of trace fossils, overall bioturbation indices, and tiering and inter-ichnotaxa interactions.

The primary sedimentary structure in nummulitic grainstone facies comprises of planar and trough cross-stratification which is disrupted by intense bioturbation of long networks and mazes of Thalassinoides horizontalis and T. suevicus having 6-8 cm diameter. It is the most common type of bioturbation present in the Oligocene of Kutch. Reburrowing by Thalassinoides, making a composite Thalassinoides ichnofabric, can also be observed that indicates multiple episodes of colonization along with changing sea-bottom conditions. The basal glauconitic shale of MFF unconformably overlies the middle Eocene Fulra Limestone, indicating a sharp transgression during the Oligocene. The green shale facies, which host abundant glauconite pellets, is finely laminated and sparsely bioturbated (BI 1) with Thalassinoides. The Coral Limestone Member characterized by Lepidocyclina packstone facies comprises of calcareous claystone in the lower part and hard nodular fossiliferous limestone with abundant coral bioherms in the upper part. The packstone facies exhibit swaley cross-stratification and laminae at places with localized pinnacle corallite bafflestones and trace-fossil assemblage of Thalassinoides, Ophiomorpha, Paleophycus, Psilonichnus, and Chondrites with moderate to intense bioturbation (BI 3-5). A high-energy open shelf environment is suggested for this member. The uppermost Bermoti Member is characterized by the Spiroclypeus packstone facies, which is laterally extensive throughout the onland exposures and is highly fossiliferous. This facies is characterized by a trace-fossil assemblage of Thalassinoides, Skolithos Rhizocorallium and Taenidium with relatively intense bioturbation (BI 5-6). Ichnofabric analysis conducted by correlating the studied sections over the area demonstrates the overprinting of hardground bioerosion belonging to Trypanites ichnofacies (Entobia and Gastrochaenolites) on the former burrows and body fossils (bivalves, echinoids, and gastropods) at specific intervals corresponding to the periods of stagnancy and/or low-net sediment accumulation. Ethologically, they all represent domichnia and fodinichnia groups and indicate shallow-marine conditions which align with previous studies on lithofacies and depositional settings of the area.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
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Presentation Preference: Oral Preferred

Nummipera saraswatii, a new armored ichnospecies, and the Nummipera-Cylindrichnus ichnofabric in a parautochthonous biofabric: A transgressive bank setting from the early Eocene Naredi Formation, Kutch basin, India

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Keywords: Armored burrow, Nummipera saraswatii, Nummipera-Cylindrichnus ichnofabric (NCi), Naredi Formation, Early Eocene Climatic Optimum (EECO), Kutch basin

The ichnogenus *Nummipera* Hölder 1989 is one of the significant ichnogenera amongst ten rare armored burrows, which reflect the ability of marine infaunal producers to assemble and manipulate available clasts defining the burrow architecture. *Nummipera eocenica* has earlier been designated as the sole type species of the ichnogenus *Nummipera* with the ichnotaxobases: vertical to oblique orientation, reinforced wall ornamented with the tests of larger benthic foraminifera (LBF), no branching, lumen containing the host material, and no spreiten. In the *Assilina* packstone facies of the early Eocene (Ypresian) Naredi Formation from the Kutch basin in western India, a distinctively different ichnospecies, *Nummipera saraswatii*, as we propose here, has been documented. The description of *N. saraswatii* along with the ichnotaxobases are as follows: (1) Horizontal to gently inclined (< 25º), tubular, intermittently vertically flattened (circular to elliptical cross-section), straight to feebly curved, and with two different diameter classes, i.e., 1-1.3 cm (narrower) and 2-3 cm (wider); (2) Well-compacted lining with mostly unbroken megalospheric (A-form) tests of *Assilina* sp. that are aligned at 0º to 30º to the burrow axis both towards and away from the lumen. The wall contains either a single armored lining of tests or a complex structure with multiple concentric layers; (3) Lumen both actively and/or passively filled with either (A) passively filled homogeneous host material or (B) alternate coarse- and fine-grained ferruginous-cemented sandy active backfill showing pinch-and-swell (annulated) variation of diameter; and (4-5) No branching or spreiten. It envisages both crustacean and polychaete producers with distinctive burrow morphology and ethology. The wider burrows are interpreted to be produced as domichnia for sheltering or hiding by crustaceans shown by the irregular inner wall reinforced by their appendages with poorly sorted *Assilina* tests and active backfill. Towards upper bedding surface, the wider burrows rarely transform into *Thalassinoides* isp., thereby, forming a compound ichnotaxa and affirming the crustacean-producer interpretation. The inferred polychaete-made narrower traces are passively filled with smooth inner wall lined with well-sorted *Assilina* tests and were possibly used as domichnia for protection, seclusion, and prevention from collapse.

The shallow-tiered *N. saraswatii* occurs in association with the deep-tiered *Cylindrichnus concentricus* in the trough-cross-stratified 30 cm-thick bed of packstone that overlies a 40-80 cm-thick wackestone. Both lithounits consist primarily of *Assilina* although some *Nummulites,* various other benthic foramaminifera, and ostracodes components are present in the wackestone. The low ichnodiversity and intense (BI 5) *Nummipera-Cylindrichnus* ichnofabric (NCi) of the packstone depict a depauperated Cruziana ichnofacies deposited in a parautochthonos biofabric of the shelfal bank setting. The unbioturbated wackestone formed in a back-bank restricted lagoonal setting. The non-repetitive NCi is featured in the *Assilina* packstone bed of Naredi Formation and corresponds to the‘maximum flooding zone'. In the Kutch basin, this demarcates an overall deepening and opening of the restricted eutrophic marine condition transitioning to the oligotrophic shelfal bank during the Early Eocene Climatic Optimum (EECO).

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-3: Using bioturbational structures to understand sedimentological and geochemical processes in modern and ancient marine environments
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Ichnofossils and paleosol from the early Eocene Naredi Formation (Kutch, India): Proxies for construction of an integrated paleo-depositional and high-resolution sequence-stratigraphic model

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Keywords: Camborygma, lungfish aestivation burrow, Skolithos, Macanopsis, paleosol, Eocene Kutch basin

Trace fossils and paleosol are the best proxies for integrating a high-resolution sequence-stratigraphic model along with the regional paleo-depositional and paleo-climatic reconstruction. The present study aims to construct the same for the topmost paleosol (continental) interval of early Eocene (Ypresian) Naredi Formation from the Cenozoic Kutch Basin. The investigated lithology is characterized by a thickening up intercalation of laterite and paleosol (silty shale) horizons, developed by cyclic episodes of erosion, subaerial exposure, and deposition.

The topmost laterite soil profile is of detrital (allogenic) origin due to the absence of conventional laterite horizons (parent rock). Petrographic study has led to the identification of hard laterite, soft laterite or mottled clay zones, and saprolite layers as identified from the micromorphological features (*viz*., plinthite, channel voids, monosteriated b-fabric, undifferentiated micromass, along with coatings, hypocoating, and nodules). This secondary laterite occurs at the paleo-interfluves, consisting of highly weathered trapwash deposits from the Deccan Traps. The silty-shale beds show pedogenic features such as fine-grained subangular-blocky ped development, few medium sized indistinct faint mottles, silty loam to silty clay loam texture, common occurrence of medium to coarse root traces, nodules, very weakly to non-calcareous, and prominent bioturbation – all bearing convincing evidence of subaerial exposure and weakly developed paleosol. The boundaries between the silty shale and laterite layers show gradual transition in a wavy to irregular pattern.

The topmost laterite bed is intensely bioturbated (BI 5), in decreasing abundance with root traces, *Camborygma* isp., and a composite ichnotaxa of vertebrate aestivation burrows and *Skolithos* isp./*Macanopsis* isp., respectively produced by crayfish, lungfish, and arachnids. The silty shale beds represent moderate to high bioturbation (BI 3-4) with the paucispecific assemblage of *Camborygma* burrow systems and root traces. Two different ichnospecies of *Camborygma*, *viz*., *C. symplokonomos* and *C. araioklados*, have been identified at two distinguishing colonization surfaces. Ichnotaxonomy and ichnofabric analyses assisted in better understanding of the ethology of the terrestrial crustacean producers, the alluvial stacking patterns, and the depositional environment. The variation of morphological complexity and ichno-abundance of *Camborygma* burrows serve as a crucial tool for the demarcation of sequence-stratigraphic horizons and fluctuation of the paleo-water table due to the low-order allocyclicity.

The investigated interval has been designated as a pedogenized variety of Scoyenia ichnofacies – a characteristic firmground ichnofacies evolving under alternating subaqueous and subaerial conditions. The paleo-pedological and ichnological investigation leads to interpretation of the paleoclimate to be fluctuating between hot humid to arid condition, with seasonal rainfall and intermittent inundation. The depositional setting has been inferred to be a very shallow lacustrine to lagoonal environment. The shallowing-up and drying-up laterite-paleosol horizon was deposited due to the high-resolution or low-order (*i.e*., higher than 5th order) climatically influenced fluctuations in the sequence-stratigraphic context. The top of the aforementioned sequence demarcates the sequence boundary (the Lutetian forced regression), which is a subaerial unconformity separating it from the overlying fully marine Bartonian late lowstand-early transgressive Harudi Formation.

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Presentation Preference: Oral Preferred

Bioherms produced by gregarious coven of armored-burrow producers from the early Eocene Naredi Formation of the Kutch basin, Gujarat, India

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Keywords: Bioherm, carbonate mound, Nummipera saraswatii, Early Eocene Climatic Optimum (EECO), larger benthic foraminifera (LBF), Naredi Formation

The early Eocene (Ypresian) succession of Naredi Formation (NF) belonging to the Cenozoic Kutch basin of western India attributes to an ideal case study of mixed siliciclastic-carbonate depositional system developed in a pericratonic, partly-restricted, marginal-/shallow-marine setting. The lower succession of NF is dominated by argillites, whereas the mid-upper interval consists of the mixed-carbonate-argillite units.

The mixed-carbonate-argillite member belonging to the shallow-benthic zone (SBZ) 11 of NF consists of, from bottom to top, (A) wackestone bed; (B) *Assilina* packstones with *Nummipera-Cylindrichnus* ichnofabric; (C-E) brown, red shale, and greenish-grey shales; (F) semi-consolidated carbonate mudstone-wackestone hosting *Nummipera* bioherms; (G) calcareous brown shale; (H) *Assilina* packstones with monospecific *Thalassinoides* ichnofabric. Beds (A, C-E, and G) are unbioturbated.

The present study focuses on the semilithified carbonate mudstone-wackestone bed (about 1.75 m thick) hosting a discontinuous biohermal interval of intensely bioturbated, sparsely bioeroded, and lithified grainstone mounds (diameter 15-30 cm for each) characterized by nesting of larger-benthic-foraminifera (LBF) tests unlike the host lithology. The bioherm is unique for its accumulation and growth induced by armored burrows. The armored burrows (*Nummipera saraswatii*) have been identified by their characteristic resistant and discrete walls reinforced with bioclasts. An individual *N. saraswatii* is a horizontal to sub-horizontal tube (diameter 1-1.3 cm) with straight to gentle curvature and circular to elliptical cross-section. The burrow wall shows well-compacted smooth inner lining with imbricated, well-sorted and rarely broken A-form tests of *Assilina* sp., aligned parallel to the burrow axis or gently inclined towards and away from it. In each mound, the wall-ornamenting tests define a complex wall structure with multiple concentric layers. The lumen, devoid of any bioclast, is passively filled with micritic cement. Branching or spreiten are absent. N. saraswatii defining the bioherms are interpreted to be produced by the facultative vermiform infauna (e.g., polychaetes) as the gregarious dwelling traces for nesting, protection, reproduction, and possibly agricultural purpose.

The diagenesis of the bioherm initiates concentrically around the *N. saraswatii* burrows at eogenetic stage where the processes are essentially fabric selective along with porosity reduction due to precipitation of carbonate mineral. The cementation progresses from being the Mn-bearing calcite-rich core (marking anaerobic metabolism) abruptly changing into the ferroan calcite-rich rim (aerobic metabolism). Simultaneous compaction and diametric expansion take place consequent to burial and outward cementation, thereby, opening up the tensile septarian gashes oriented perpendicular to the long-horizontal axes of each bioherm. From circumference inward of bioherm, secondary open burrows are observed to recolonize the primary *N. saraswatii* burrows. Sponge borings (*Entobia* isp.) can be observed only at the side circumference of the bioherm outer rim and are absent at their top and interior. The bioherm facies only occurs once in the non-repetitive carbonate mudstone-wackestone facies corresponding to the highstand systems tract (HST) in the oligotrophic open shelf during the Early Eocene Climatic Optimum (EECO). They are interpreted to be formed as the gregarious coven of facultative vermiform armored-burrow producers, where they entrap and accumulate LBFs using mucus, and feed on the suspended and precipitated nutrients through a complex assortment of trophic strategies.

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Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Seismically induced soft-sediment-deformation structures (sand volcanoes) and the ichnological responses from the early Miocene Khari Nadi Formation of Kutch basin, western India

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Keywords: Sand volcano, ichnoseismite, ichnofacies, Khari Nadi Formation, Kutch basin, Miocene

Distinctive sedimentary structures called the soft-sediment-deformation structures (SSDS) are developed by post-burial deformation of unconsolidated sediments. The sand volcanoes can truly typify the SSDS, which indicates particularly paleo-earthquake activities, defining the concept of “seismite”. The Kutch basin has been tectonically active due to the Indian-Eurasian plate convergence since the onset of eastern Gondwana rifting to the later tectonic inversion during the Cenozoic. A series of sand volcanos from the Aquitanian (early Miocene) Khari Nadi Formation are exposed along the Khari River trail near Aida village. The process-sedimentary characteristics are manifested by the sand volcanoes exposed along the transitional stratum separating the shallow-marine deposits below and the non-marine deposits above.

The section consists of four layers, from bottom to top: viz., fine-grained sand (layer I), shale (layer II), medium-grained sand (layer III), and fine-grained sand (layer IV). Preservation of marine trace-fossil assemblages defined by *Psilonichnus* isp., *Thalassinoides* isp., *Ophiomorpha annulata*, and *Planolites* isp. belonging to the Psilonichnus and Skolithos ichnofacies can be documented in the layers I and II with overprinting of deep-tier continental trace fossil *Vondrichnus* isp. coming from the layer IV. The swaley-cross-stratified layer III is a sand bed bioturbated with *Ophiomorpha nodosa* and, the sand volcanoes can be observed in this layer. The base of overlying layer IV is conformable and sharp. The layer III preserves both the marine (*O. nodosa*) and overprinted continental (*Vondrichnus* isp.) ichnofossils along with small-scale synsedimentary faults surrounding the central/axial feeders of the sand volcanoes, resembling caldera-like structures. The fabric produced by the crosscutting relationship of the *O. nodosa* burrows and the faults definitely indicate their syndepositional origin and the coeval occurrence of both liquefaction (the sand volcano extrusion and undulated layers III-IV contact) and brittle deformation (synsedimentary faults). The first generation of *O. nodosa* is disrupted by the faults therefore predates the latter. The second generation of *O. nodosa* burrows cut the faults across, because they were produced after the faulting and liquefaction event. The layer IV contains an intricate three-dimensional network of termite nests (*Vondrichnus* isp., *Termitichnus* isp.) and root traces within the channel-fill fine-grained sand and is devoid of any marine trace fossil. The deep-tier *Vondrichnus* isp. burrows are found to penetrate all the way to layer I and cut across the SSDS and *O. nodosa* in layer III.

Hence, it is proposed that a seismic event resulting in a tectonic upliftment and the consequent shallowing of the basin can be attributed from the development of sand volcanoes, since the horizon (layer III) containing them marks the transition from the marine to continental sedimentary regime – pointing towards a tectonically-influenced allogenic change for the basin. The observed evidences appear to contradict previous works that suggested a continuous rise of base level throughout the Aquitanian and Burdigalian time. We suggest that these two different phenomena belong to two different sequence-stratigraphic hierarchy with the tectonic uplift being a lower-order (higher-resolution) phenomenon within the Khari Nadi Formation sequence.

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Presentation Preference: Oral Preferred

An opportunistic trophic generalist strategy for survival in a hyperstressed benthic niche in an ultra-restricted marginal-marine embayment setting

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Keywords: Siphonichnidae, Rosselichnidae, deposit-feeders, trace fossils, bioturbation, ethology

From two opencast lignite mines from the restricted Kutch basin located at Matanomadh and Umarsar in the state of Gujarat, a monospecific and sparse (BI 0-1) preservation of the complex burrows has been studied and is reported herein from the intercalated organic-rich shale intervals between the middle Eocene amber-bearing lignite seams. The ichnotaxon bears the morphological and, thereby, behavioral affinity to both the ichnofamilies Siphonichnidae and Rosselichnidae.

The burrow has a vertical to oblique orientation and circular to elliptical horizontal section. It is characterized by a series of stacked concave-upward laminae and a concentrically lined axial cylindrical shaft, which penetrates through the conical components. Each individual conical laminae represents the trace of the feeding funnel that is radially fine-striated, as it appears, by a tentacular detritus-feeding organism. Bulbous undulations, particularly along the funnel perimeter, can be observed, which might have been produced due to the localized liquefaction by the moving tentacles. The trace-maker might be capable of sequestrating nutrients and waste along the margin of the shaft, as evidenced in the form of alternate concentric muddy and detrital organic linings. At places, the muddy lining can be either bright green glauconitic or bearing mud from the host lithology or dark brown Fe-oxide rich. The innermost lining can frequently be found bearing authigenic mm- to sub-mm-scale pyrite crystals – both equant and framboidal. Elemental maps derived from the X-ray-fluorescence-spectroscopic analysis also show enrichment of Fe-sulfides along the wall of the central shaft. This is indicative of metabolically induced early diagenetic decomposition of organic matter and the subsequent precipitation of authigenic Fe-minerals along the burrow walls. The lumen appear to be either empty or passively filled.

We postulate that the trace maker is a sessile, trophic generalist, and opportunist bivalve that can resort to combining the surface-detritus feeding, agrichnial chemosymbiosis, and possibly also suspension feeding strategies for its survival exploiting an oxygen-depleted and low pH ambient conditions with possible salinity fluctuation. The niche was unfavorable for colonization by any other common dysoxic trace producers, even the deep endobenthos. The empty shaft suggests that the producer occasionally obtained seclusion by sealing the entrance from the extreme events of ambient chemical changes (e.g., drop in pH or salinity) at the sediment-water interface.

The lithofacies association and succession in the mines are contrastingly different from elsewhere in the Kutch basin. Previously, paleontological and geochemical studies assigned the interval to be deposited under the restricted marginal-marine lagoonal and/or embayment condition. The ichnological evidence suggests a hyperstressed ultra-restricted condition prevailing inside the deep paleogeographical interior of the topographic furrows provided by the Deccan lava flows that offered a nascent and highly rugged basement for the newly forming Paleogene sea. The stress factors are primarily due to the extreme chemical variations at the basin floor and fluid-mud activity.

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Presentation Preference: Oral Preferred

Ichnology and sedimentology of the tide-influenced marginal-marine setting within a restricted paleo-embayment during Eocene in the Kutch basin of Gujarat, India

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Keywords: Trace fossils, ethology, tidal processes, brackish-water ichnofauna, bay-head delta, Kutch

Embayments having a limited connection to the open ocean are among the most stressful marine environments due to a complex and dynamic interaction of various physicochemical factors. These factors include the periodic fluctuations in hydrodynamic energy resulting in the varying salinity, fluid-mud activity, sedimentation-erosion rates, water turbidity, and dissolved oxygen content. The embayments, especially in their furrow-shaped interiors, receive enhanced tidal-energy dissipation; and, in combination with receiving the terrestrial influx, they offer further accentuation of such factors. Such extreme paleoenvironmental conditions, which vary both spatially and temporally within the embayment, drastically limit the benthic colonization of these regions.

Sedimentological and ichnological data from the outcrops exposed between Saran Nani and Jhulrai villages in the western Kutch basin represents a shallow tidal channel-interfluve-bayhead delta complex. The tidal channel deposits are characterized by bi-directional, mud-draped, trough-cross-stratified sandstones that are dominated by *Ophiomorpha-Paleophycus* ichnofabric. The interfluve deposits are characterized by thinly laminated, organic-rich mudstones having a monospecific *Camborygma* ichnofabric.

Facies in the Jhulrai section are arranged in a parasequence recording an overall progradation from prodelta to deltafront deposits separated by an amber-rich transgressive lag deposit that demarcates a flooding surface. The distal prodelta deposits are characterized by thick organic-rich mudstones containing *Chondrites* isp. (BI 0-1). Relatively small scale (2.8 m height; 36 m length), heterolithic-dominated coarsening-upward clinoform foreset with tidal bundles and rhythmites (lenticular to wavy laminae), and low-intensity bioturbation (BI 0-2) and sporadic lateral distribution of trace fossils (e.g., *Paleophycus* isp and *Asterosoma* isp.) characterize the deltafront. The proximal prodelta deposit of the second upper sequence above the flooding surface consists of heterolithic fine-grained-sand and mud intercalation having sparse bioturbation by *Thalassinoides* isp. and *Cylindrichnus* isp. (BI 0-2).

Ichnofauna across these sub-environments display (1) conspicuously reduced ichnodiversity, (2) dominance of infaunal structures, (3) stunted trace fossils, (4) simple structures produced by trophic generalists that point towards highly stressful conditions controlling benthic colonization accentuated by the basin's paleotopograhical constraints in the studied sections as offered by the Deccan Traps basement. The recognition of the above tide-influenced facies association as aided by ichnological analysis helps in refining the transgressive shoreline trajectories developed in an Eocene, tropical, yet, low sediment-supply environment.

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Trace fossils from organic-rich, contourite drift deposits: the Upper Jurassic-Lower Cretaceous Vaca Muerta Formation from Argentina

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Keywords: Fine-grained depositional systems, oxygen, traction structures, bioturbation, Neuquén Basin

In the last decades, new advancements on mud sedimentology triggered a renewed interest on fine-grained depositional systems. Of these, organic-rich systems are of special importance for unconventional reservoir exploration and development. The Upper Jurassic-Lower Cretaceous Vaca Muerta Formation from Argentina represents one of the most important unconventional reservoirs in the world, showing a high organic carbon content. This formation constitutes bottomset and foreset locations of a mixed carbonate-siliciclastic, shelf-margin, subaqueous clinoform system, typically displaying basin and slope environments. However, m-scale successions consisting of laminated, rippled and bioturbated, mixed to calcareous, crinoidal mudstone and fine to coarse mudstone are interbedded in this clinoform succession. These deposits were interpreted as produced by semi-permanent, low-concentration contour currents in drift environments. These drift deposits were recorded in cores from five wells (660.5 m total) located in areas that are currently explored and developed by oil and gas companies. An ichnofabric analysis was carried on these drift deposits in order to understand paleoenvironmental controls on trace fossils.

The contourite drifts record *Crininicaminus* isp., *Lockeia siliquaria*, ?*Lockeia* isp., *Nereites* isp., *Palaeophycus* isp., *Palaeophycus heberti*, *Phycosiphon incertum*, *Planolites* isp., ?*Skolithos* isp., and escape and equilibrium trace fossils. Four different ichnofabrics were observed: the *Palaeophycus heberti*, *Nereites* isp., *Phycosiphon incertum* and Equilibrichnia-Fugichnia ichnofabrics. Locally, m-thick successions showing an upward decrease and then increase in bioturbation index are comparable to bi-gradational successions of contourites. Benthic activity was shown to be controlled by food distribution, oxygenation, hydrodynamic energy and water turbidity. Suspension feeding strategies in trace fossils (Equilibrichnia-Fugichnia ichnofabric) were associated with food being delivered in suspension by higher energy currents, whereas deposit-feeding behavior (*Nereites* and *Phycosiphon incertum* ichnofabrics) was dominant during times of lower energy currents bringing food to the surface sediments. Hydrodynamic energy controlled the preservation of sedimentary structures, precluding bioturbation during high-energy events. Contour currents increased background oxygen levels of bottom and interstitial waters, although these levels may have remained within the upper dysoxia (as suggested by relatively small burrow diameters). Suspension feeding strategies suggest overall low water turbidity. This example supports the fact that intense bioturbation is characteristic of contourites and provides an example of fine-grained, organic-rich contourites showing a high degree of preservation of sedimentary structures due to oxygen deficiency associated with high organic carbon content.

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UNLOCKING THE ARCHITECTURE OF THE COLONIZATION WINDOW: ICHNOFABRICS FROM TIDE-INFLUENCED MEANDER LOOP DEPOSITS (UPPER CRETACEOUS OF THE SPANISH PYRENEES)

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Keywords: Ichnofabric, bioturbation control, tide-influenced meander loop, colonization window, redbeds

Tide-influenced meander loop deposits from the Upper Cretaceous Tremp Formation (Pyrenees, Spain) show a heterogeneous ichnofaunal distribution that reflects the variety of processes operating along the point bar lateral accretion and overbank colonization surfaces. Of the six ichnofabrics identified, *Taenidium* 1, *Taenidium* 2, and *Loloichnus* ichnofabrics are present in all the outcrops studied, whereas the *Arenicolites-Taenidium*, *Loloichnus-Taenidium*, and *Planolites* ichnofabrics are less common. Ichnofabrics differ, for instance, in bioturbation index (higher in the upper point bar), inferred behaviour (dominance of dwelling or feeding structures), tiering, ichnotaxonomic composition (Díez-Canseco et al., 2016), or the number of superimposed suites. The key factor controlling ichnofabrics is the morphology of the lateral accretion surfaces and its evolution through time, which determine the architecture of the colonization window linked here to the helicoidal pattern and the velocity of the flow in a meander loop and the successive development of point bars.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
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Presentation Preference: Oral Preferred

Calibrating trace fossil models through geologic time: Macroevolution as a factor in applied ichnology

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Keywords: Applied ichnology, trace fossils, bioturbation, ichnofacies, facies analysis, paleoenvironmental reconstructions

Ichnology has been extremely successful in facies analysis and paleoenvironmental reconstructions. So far, trace fossil models used in applied ichnology (e.g. the ichnofacies model) have largely been viewed as time-independent in the sense that behavioral convergence has been underscored to the detriment of macroevolutionary innovations. For example, the core of the ichnofacies model highlights those animals facing similar problems (i.e. environmental factors) respond with the same set of solutions (i.e. behavior). As a result, studies analyzing secular changes in ichnofaunal composition (Mángano and Buatois, 2016a,b) have captured, for the most part, the attention of those interested in macroevolutionary aspects but not of those working on sedimentologic and stratigraphic analyses using ichnologic tools. However, we argue that calibrating trace-fossil models according to geologic time is fundamental for applied ichnology. The impact of macroevolutionary trends on trace fossil models used for paleoenvironmental reconstruction is seen at a wide variety of temporal and spatial scales. First, and regardless of the recurrent responses of the benthos to fluctuating environmental conditions, evolutionary innovations have played a paramount role in the type of solutions adopted by organisms to environmental challenges (e.g. the diversification of farming strategies in the deep sea during the Ordovician Radiation). Second, increased ichnodiversity through geologic time reflects the emergence of new key characters (i.e. producers), prompting for calibration of the available models to accommodate these secular changes in the taxonomic richness of animal-substrate interactions (see Buatois and Mángano, 2018). Third, temporal increases in depth and extent of bioturbation impact on the nature of substrates, the preservation potential of discrete events, the degree of decoupling between the sedimentary record of environmental conditions and bioturbation episodes, and the likelihood of the generation of firmground suites without associated erosional exhumation, among other issues. Fourth, onshore-offshore patterns of ichnotaxa through geologic time (e.g. Zoophycos) has been historically problematic from an ichnofacies perspective. Fifth, the resetting of the evolutionary clock during mass extinctions provides a cautionary note on the use of available trace-fossil models in the aftermath of mass extinction episodes. We conclude that evaluation of secular changes in trace fossils is an integral part of the conceptual ichnologic toolbox, not only for those interested in evolutionary paleoecology but also for anyone working in sedimentary geology.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-3: Using bioturbational structures to understand sedimentological and geochemical processes in modern and ancient marine environments
Presentation Preference: Oral Preferred

Marine ichnofossils as a record of major bio-environmental events in the Phanerozoic

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Keywords: Phanerozoic, biodiversification event, trace fossil, responsive mode, bio-environmental event

In this paper, we analyzed the trace fossil records of the major Phanerozoic biodiversification events, including the Cambrian Explosion, the Great Ordovician Biodiversification Event, and the Mesozoic Marine Revolution. The ichnodiversity and ichnodisparity of marine trace fossils show a positive correlation with biodiversity during these three biodiversification events. The intensity and depth of bioturbation both increased distinctly. The feeding strategies and the behavior of marine trace-makers became more complex. The most prominent change in the trace-making behavior during the Cambrian Explosion is the appearance of vertical burrows (or vertical elements in burrows). The shallow-marine ichnofauna expanded to the deep-marine environment during the Ordovician, as represented by the appearance of morphologically complex deep-marine trace fossils. The marine biodiversity reached the highest in the Cretaceous during the Mesozoic, contributing to increased survival pressure, intensified intraspecific and interspecific competition, and further exploitation of the ecological niches for the benthic communities. Characteristic change during this period is the significant diversification of deep-marine graphoglyptids, with the development of multiple morphological types and feeding strategies. Under the influences of the environmental and biotic changes, marine ichnofaunas became more complicated in morphology and ethology and adopted progressively wider environmental distribution during the Phanerozoic. The marine ichnofaunas displayed increasing penetration depth, transferred from two-dimensional to three-dimensional structures, and radiated from the shallow shelf to the deep sea. These features may be attributed to the adaptive radiation of the marine ichnofaunas along with biodiversity increases during the major biodiversification events.

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-3: Using bioturbational structures to understand sedimentological and geochemical processes in modern and ancient marine environments
Presentation Preference: Oral Preferred

Integrating ichnological and geochemical proxies to assess redox conditions during the Early Toarcian: new insights from the Asturian Basin (N Spain)

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Keywords: T-OAE, trace fossils, molybdenum, euxinia, Early Jurassic

During the Early Toarcian (Early Jurassic), massive atmospheric inputs of volcanogenic CO_2 led to a rise in atmospheric and seawater temperatures, with subsequent worldwide deposition of black shales. This event, known as the Toarcian Oceanic Anoxic Event (T-OAE), was associated with a major biological crisis in marine environments and widespread anoxia/euxinia in bottom-waters. This work integrates ichnological and geochemical proxies to assess redox conditions across the T-OAE, based on a detailed bed-by-bed study of two outcrops from the Asturian Basin (northern Spain), Lastres and Rodiles. These sections consist largely of limestone and light/dark grey marl beds deposited under oxic to dysoxic conditions, alternating with dark grey marls and black shale intervals deposited under suboxic to anoxic conditions. Different ichnoassemblages are present in the dark grey marls deposited during the T-OAE versus before and after that interval, which are mostly laminated with only rare traces. Integrating ichnological data with molybdenum (Mo) content allows assessment of the variable relations between redox conditions and trace maker activity. We recognised several recurring motifs:

A) Within the T-OAE interval, some dark grey marl beds exhibit an absence of bioturbation, indicating oxygen depletion, but low Mo content (< 2 ppm), showing that suboxic rather than euxinic conditions prevailed.

B) Most laminated dark grey marls and black shale beds deposited during the T-OAE exhibit modest authigenic Mo enrichment (mostly 5-18 ppm), consistent with euxinic pore-waters although bottom-waters may have remained suboxic. Contemporaneous trace fossils are absent in these beds, and only scarce, small, light-infilled *Chondrites* and/or *Planolites* occur. They occasionally overprint the primary lamination but do not deform it, indicating their later appearance during deposition of light grey marls.

C) Below and above the T-OAE interval, underlying light grey marls and overlying dark grey marls are bioturbated by contemporaneous trace makers, showing downward-penetrating dark-sediment-filled burrows into light-bioturbated marls, evidencing that trace makers occupied the benthos during the deposition of these dark sediments, thus indicating generalized oxic bottom- and pore-waters. The dominant ichnoassemblage is mostly the same as that in the light sediments, formed mainly by *Chondrites*, *Diplocraterion*, *Thalassinoides* and *Planolites*. In these sediments, Mo content is very low (lower than crustal average), thus in conformance with the ichnological data indicating oxic bottom-waters.

D) The uppermost black shales, which correspond to the last anoxic episode of the T-OAE, are penetrated by light-sediment-filled burrows from overlying light grey marls deposited under oxic conditions, recording rapid re-establishment of an infaunal community following the anoxic event. This ichnoassemblage, which overprints and erases lamination in these black shales, is similar to that from before the T-OAE, dominated by *Diplocraterion*, *Arenicolites*, *Thalassinoides*, *Planolites* and *Chondrites*. Mo content in these black shale beds is mainly 3-5 ppm, indicating weakly euxinic pore-waters before recolonisation.

In summary, this study highlights the usefulness of an integrative ichnological and geochemical approach in more precisely assessing concurrent bottom-water and pore-water redox conditions. The ichnological data facilitate differentiation between oxic/dysoxic and suboxic/anoxic conditions, while geochemical proxies, in particular Mo content, serve to calibrate reducing intensity in anoxic environments.

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-3: Using bioturbational structures to understand sedimentological and geochemical processes in modern and ancient marine environments
Presentation Preference: Oral Preferred

Ichnology of the Upper Cretaceous Buda Limestone of Texas: Exploring the trace-fossil content of carbonate lagoonal shelf deposits

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Keywords: Chalk, Ichnology, Cenomanian, Buda Formation, Gulf Coast

The Buda Limestone is a lower Cenomanian chalk (e.g., Loucks et al., 2019; Valencia et al., 2021), deposited in a broad lagoonal shelf setting developed on the Comanche Shelf of the Texas Gulf Coast Basin (e.g., Martin, 1967, Young, 1972; Valencia et al., 2021, 2022). This formation is an excellent example of a highly bioturbated carbonate succession, with an ongoing debate about its depositional conditions, particularly whether it was deposited above or below storm-wave-base (e.g., Loucks, 2018; Minisini et al., 2018; Loucks et al., 2019; Valencia et al., 2021, 2022). Surprisingly, however, its ichnology has not yet been analyzed. Previous studies on this unit are largely sedimentology-focused, and thus, limited to reporting very few ichnogenera without further analysis of paleoecologic and paleoenvironmental implications (e.g., Reaser and Dawson, 1995; Reaser and Robinson, 2003). Herein, we report an ichnofauna comprising twenty ichnotaxa, which is widely dominated by *Thalassinoides* isp. and *Chondrites* isp. that overall illustrates the *Cruziana* Ichnofacies, with partial overprints of the *Glossifungites* and *Trypanites* ichnofacies. Variable degree of water interchange between the Buda Limestone paleo-shelf with the open sea, accompanied by highly variable physicochemical parameters inherent to lagoonal circulation (e.g., salinity, bottom-water oxygenation), highly influenced the resultant ichnofaunal content of this unit. The ichnologic features of the Buda Limestone from west and central Texas, including (1) dominance of the *Cruziana* Ichnofacies, (2) the common occurrences of overlapping *Glossifungite*s and *Trypanites* Ichnofacies, and (3) the absence of *Zoophycos* isp., suggest shallow-water carbonate deposition in lagoonal waters above SWB.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-3: Using bioturbational structures to understand sedimentological and geochemical processes in modern and ancient marine environments
Presentation Preference: Oral Preferred

Infaunal response during the end-Permian Mass Extinction: Evidence from trace fossils

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Keywords: End-Permian Mass extinction, Biotic recovery, Early Triassic, Trace fossils

The end-Permian Mass Extinction (EPME) has caused the largest loss of biodiversity in earth's history and re-shaped shallow-marine ecosystems. Although much has been learned about the mechanism and tempo of this event based on body-fossil record, the global infaunal response to the EPME, as represented by trace fossils, remains poorly understood. Here we undertook analyses of secular changes in ichnodiversity, ichnodisparity and tiering structures of trace makers from the Late Permian to the Middle Triassic based on a global trace-fossil dataset. Results show that global ichnodiversity and ichnodisparity maintained their levels during the EPME until Griesbachian, which then decreased sharply in the Dienerian. Notably, the Griesbachian interval exhibits an unusual dominance of shallower tiers. The discrepancy between body- and trace-fossil diversity is interpreted to be the result of taphonomic effects of trace fossils by the resurgence of widespread microbial matgrounds in the Griesbachian. Such dominance of matgrounds aided the preservation of surficial, semi-infaunal and shallow-tier trace fossils. Our study indicates that the EPME strongly affected the sediment mixed layer, allowing the preservation of shallower tier trace fossils. Disappearance of mixed layer combined with widespread anoxia in the earliest Triassic might have intensified substantial removal of sulfate in sea water by enhanced pyrite burial and inhibited its further re-oxidation, therefore impacting sea water sulfate concentrations.

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-3: Using bioturbational structures to understand sedimentological and geochemical processes in modern and ancient marine environments
Presentation Preference: Oral Preferred

Tide-Dominated Estuarine or Deltaic Deposits? Sedimentological and Ichnological Analysis of Lower Permian Dandot Formation, North Pakistan.

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Keywords: Estuary, Delta, Sedimentology, Ichnology

The lower Permian Dandot Formation (Salt range, north-west Pakistan) contains 35-40 m thick tide-dominated estuarine and tide-dominated deltaic, sand-dominated, heterolithic succession. Sedimentologic and ichnologic datasets have been integrated to characterize the depositional system of Dandot strata. The integrated facies analysis allows recognizing a tide-dominated estuarine (estuarine tidal bar, intertidal mud to mixed flat and supratidal deposits) and tide-influenced deltaic succession (prodelta, delta front, distributary mouth bar, and channels). Depositional processes and sedimentary facies in tide-dominated estuaries and deltas are remarkably similar. Common Sedimentological characteristics (spring- neap cycle, single and double mud and mica drapes, soft-sediment deformation structures, syneresis cracks, rare wave ripples, bidirectional paleocurrent, coal seams, and fragments) and ichnological signatures (sporadic bioturbation, low diversity-low intensity impoverished trace fossils suite, the dominance of deposit-feeding traces, and rare occurrence of suspension-feeding traces) indicate several physicochemical stresses, such as fluctuations in hydrodynamic energy, fluctuations in water salinity, turbid water conditions and heightened depositional rates affected the benthic communities of these tide-impacted settings.

Despite similarities in sedimentary facies, there are significant differences in longer-term processes. These include regressive vs transgressive conditions. This results in substantially different facies associations as well as stratigraphic architecture.

The tide-dominated estuarine succession shows a fining-upward trend in vertical profiles, whereas tide-dominated deltas form a coarsening-upward sequence. Typically estuarine deposits are much cleaner and have better sorting than deltaic successions.

The ichnological trend (regular heterogenous trace fossils distribution, variable bioturbation intensity, low diversity, diminutive traces, and characteristic traces fossils) points to several physiochemical stresses (seasonal fluctuations in sedimentary conditions, shifting substracts, turbid water, and anisotropic resources) that affected deposition in the estuarine setting.

Trace fossils in the deltaic deposits are sporadically heterogeneously distributed. The dataset shows an overall upward decreasing trend in bioturbation intensity and ichnological diversity in deltaic deposits. Trace-fossil typically displays comparably more diversity in contrast to estuarine deposits.

Session T4-5: Environmental-life coevolution during the Neoproterozoic-early Paleozoic transition

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-5: Environmental-life coevolution during the Neoproterozoic-early Paleozoic transition
Presentation Preference: Oral Preferred

New insight of the interactions between early Cretaceous volcanism and lake environment changes from high-resolution coring archive, NE China

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Keywords: tectonic volcanism,palaeoenvironment,redox fluctuations,mass mortality events

Tectonic volcanism is a manifestation of the vitality of the Earth, and it has a great impact on both environmental changes and biosphere evolutions. How tectonic volcanism regulates changes in earth surface, however, has not well presented. Here we present continuous high-resolution geochemical records of the early Cretaceous Jiufotang Formation, NE China, where the famous Jehol biota is discovered. Volcanic ash, gravity flow, and soft sedimentary structures related to tectonic volcanism are found in a 160-m shallow-deep lake section. Multiple geochemical analyses including elemental concentrations, XRD, and SEM are performed to trace volcanic ash layers and reconstruct records of changes in paleoredox and paleoproductivity of the lake. We find that the input of volcanic materials significantly improves productivity and consequently results in anoxic environment in semi-deep and deep lake facies of the Jiufotang Formation. U-Mo and Mo-organic carbon show a covariation pattern, suggesting that the water column has undergone dramatic changes in redox states from oxic to anoxic. This is further proved by the existence of manganese-rich carbonate rocks, an indicator of oxidation stages in the bottom water. Numerous soft sedimentary deformation structures were found in the cores, indicating the frequent occurrence of paleoseismicity. We therefore propose a new model of the terrestrial lake basin environment changes: (1) the hypoxia is mainly controlled by high productivity and deepen of the lake basin and (2) relative oxygenated bottom water could be caused by stronger water mixing which was contributed by ancient earthquakes induced mass wasting event or relative lake depth changes. This dynamic environmental interaction among deep lithosphere activity -lake and surrounding environments - redox state provide new insights to the mass mortality and fossil preservation mechanisms of Jehol biota preserved in fine-grained shale is triggered not by pyroclastic flow but more likely fluctuate redox condition of the bottom of the lake.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-5: Environmental-life coevolution during the Neoproterozoic-early Paleozoic transition
Presentation Preference: Oral Preferred

Reconstructing Late Ediacaran Carbon and Sulfur Cycles in South China

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Keywords: Sulfur cycle, CAS, South China, DOUNCE/Shuram, OOE

The carbon and sulfur cycles play an important role in governing and regulating oxygen, climate and environmental shifts of the Earth's surface system, with implications for the evolution of life. The South China Craton (SCC) has provided a relatively complete and intensely researched rock record of the Ediacaran Period, which makes it an ideal place to understand redox coupling between the C and S cycles during that interval. Previous studies on the SCC revealed multiple Ocean Oxygenation Events (OOE) after the Marinoan glaciation. To study the best known OOE, which is associated with the late Ediacaran DOUNCE/Shuram carbon isotope excursion and radiation of aerobic biota into the deep marine realm, this study looks into carbonate carbon and carbonate-associated sulfate (CAS) sulfur isotope data from three representative sections (Lianghong, Sishang, and Qinglinkou sections) on the SCC. Sulfate sulfur isotope values show a coupled decreasing trend with the carbonate carbon isotope values (~ -10‰), reaching near modern levels (~ +21‰) during the DOUNCE/Shuram. Moreover, the $\Delta^{34}S_{sulfate\text{-}sulfide}$ and the estimated maximum seawater sulfate concentration show similar values to modern levels. However, after the DOUNCE/Shuram, the sulfate reservoir shrank back to pre-excursion levels and influenced the S cycling pathways, which resulted in a decoupled C-S trend and ocean deoxygenation. The rises and falls of the estimated seawater sulfate concentration show a coupled shift with Sr isotope values, suggesting that the DOUNCE/Shuram was likely to be tectonically controlled, possibly via weathering-derived nutrient input. Global correlation indicates that the CAS sulfur isotope profile can be used as a global chemostratigraphic correlation tool at times when sulfate concentration is relatively high.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-5: Environmental-life coevolution during the Neoproterozoic-early Paleozoic transition
Presentation Preference: Oral Preferred

Sulfur and oxygen isotope compositions of Ediacaran seawater sulfate

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Keywords: Ediacaran, Shuram, sulfate, isotope compositions

The Ediacaran Period (~635–539 Ma) witnessed the largest negative inorganic carbon isotope excursion in Earth's history (i.e., the Shuram Excursion, SE), which has been interpreted as reflecting the oxidation of marine organic carbon due to rising oxidant levels. The oxidant sources previously hypothesized include atmospheric O_2, local dissolved [O_2], and sulfate deriving from continental evaporites or sulfide oxidation. However, which oxidant being responsible and the mechanism behind still remain elusive. In this study, we investigated the sulfur and oxygen isotope compositions of the carbonate-associated sulfate (CAS) of Ediacaran rocks from three paleocontinents (South China, South Australia, and Tarim). It shows a parallel decrease in both $\delta^{34}S$ and $\delta^{18}O$ of the CAS during the SE from the three localities and a good positive correlation between them. These observations indicate a mixing between two end-member sulfate populations: pre-existing sulfate and newly-supplied sulfate. We interpret that the pre-existing sulfate, subject to vigorous microbially cycling, is characterized by higher $\delta^{34}S$ and $\delta^{18}O$ values, while new sulfate having lower $\delta^{34}S$ and $\delta^{18}O$ values, may have derived from the oxidation of sulfides. Furthermore, our mixing model suggests that a rise of sulfate by ~20 times was supplied to oceans during the SE, resulting in great oxidation of the marine organic carbon and subsequent oceanic ventilation as well as the radiation of the Ediacaran biota.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-5: Environmental-life coevolution during the Neoproterozoic-early Paleozoic transition
Presentation Preference: Oral Preferred

Spatial heterogeneity in carbonate carbon isotopic values during the Cambrian ZHUCE event on the southwestern Yangtze platform

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Keywords: chemostratigraphy, Cambrian, ZHUCE, carbon isotopes, isotope gradient

The sedimentary record of carbonate carbon isotopes ($\delta^{13}C_{carb}$) is the primary window into Earth's ancient carbon cycles and provides one of the best methods for correlation of marine strata. A prominent positive carbon isotope excursion (named Zhujiaqing Carbon isotope Excursion (ZHUCE) on the Yangtze block) is recognized globally at the lower part of Cambrian Stage 2 and has been utilized extensively for chronostratigraphic correlation and environmental reconstruction. However, substantial variability in magnitude and shape of this excursion among different continents and even within a single basin has hampered high-resolution correlations and led to divergent reconstruction of ocean chemistry and carbon cycle. In order to understand the spatial variation and the genesis of the ZHUCE event, sedimentologic, petrographic, and geochemical investigations have been carried out in two sections from Yunnan, Yangtze platform. Petrographic and texture-specific isotope analyses revealed that the mixing of dolomite minerals to limy mudstone has resulted in variations in $\delta^{13}C_{carb}$ up to 1.8‰ and $\delta^{18}O_{carb}$ up to 3.6‰ across individual beds, which together imply that small-scale variability in the ZHUCE may result partly from local diagenetic overprinting. High-resolution and sample screened $\delta^{13}C_{carb}$ profile from the Laolin section reveals a distinct ZHUCE event with its magnitude and stratigraphic distribution different from previous studies in the same section. The shape and trend of the ZHUCE of the Laolin section can be correlated in detail with that of the Xiaotan section regionally and the northwestern Siberia sections globally, whereas the discrepancies in the magnitude and peak-excursion values of the ZHUCE among the sections and regions might be interpreted as the effects of isotope gradients due to stratification of the depositional basins. In contrast, no positive carbon isotope excursion is recognized from time equivalent strata at the Dapengzi section where $\delta^{13}C_{carb}$ values first fall gradually to -3‰ (V-PDB) and then oscillate between 0‰ and -2‰. This is the first record of the disappearance of the ZHUCE event in a stratigraphically equivalent carbonate-dominated sequence. The sedimentologic, petrographic and geochemical data suggest that the disappearance is likely resulted from the generation of ^{13}C highly depleted water mass relative to the open ocean by oxidation of the organic matter in a hydrologically restricted environment, representing an extreme case of marine redox stratification, which is further supported by the rare earth elements and Yttrium data.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-5: Environmental-life coevolution during the Neoproterozoic-early Paleozoic transition
Presentation Preference: Oral Preferred

Dynamic evolution of marine productivity, redox, and biogeochemical cycling linked to wax and wane of the Cryogenian glaciations

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Keywords: redox, restricted basin, glaciation, Datangpo, Neoproterozoic

The Cryogenian Period of the Neoproterozoic was characterized by two Snowball Earth glaciations, which were potentially tied to the diversification and proliferation of eukaryotes and culminated with the appearance of animals. The break-up of Rodinia in the early Neoproterozoic resulted in emergence of numerous rift basins marked by dynamic chemical evolution likely controlled by the waxing and waning of the two global climate upheavals and associated eustatic change and nutrient cycling. The Nanhua Basin, as a marginal restricted basin in South China, provides a unique window to the key cause-and-effect relationships with implications for the radiation of complex life. We focus on an exceptional shale sequence—the Datangpo Formation consisting of a lower black shales and upper gray shales/siltstones—which captures the complete Cryogenian non-glacial interval and likely the onset of Marinoan glaciation. Highly coupled total organic carbon (TOC) and total sulfur concentrations in combination with iron speciation and pyrite sulfur data suggest TOC-rich, euxinic deep-water deposition for the lower black shales but TOC-lean, persistently oxic conditions for the upper gray shales/siltstones associated with relatively shallow-water deposition. We argue that this dramatic shift in water chemistry was primarily governed by the extent of restriction for the Nanhua Basin as a consequence of eustatic variation tied to the glaciation events. Specifically, the highstand in the wake of the Sturtian corresponded with elevated nutrient fluxes delivered from the open ocean and the resultant highly productive, euxinic conditions, while the lowstand linked to the onset of the Marinoan was accompanied by reduced nutrient supplies that led to low productivity and ventilated settings. This model of local redox dynamics tied to the hydrological variations is supported by trace metal distribution patterns. Moreover, our data show that the TOC-lean gray shales/siltstones are characterized by a lack of correlation between TOC and total nitrogen contents. Further investigations demonstrate that nitrogen is predominantly bound by clay minerals for these rocks, which suggests that terrestrial delivery, as a potential source of nitrogen dramatically elevated in response to sea-level fall. This study will inform better understanding of the intrinsic relationships among glaciations, eustatic change, nutrient availability, and redox dynamics within the Earth system over this critical transition, along with implications for other climate upheavals in Earth's deep past.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-5: Environmental-life coevolution during the Neoproterozoic-early Paleozoic transition
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Interaction of Shibantan Biota and environment in the terminal Ediacaran ocean: evidence from I/Ca and sulfur isotopes

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Keywords: dissolved oxygen, superheavy pyrite, sulfate, bioturbation, Dengying Formation, South China

The terminal Ediacaran (~551-539 Ma) was a crucial period in Earth's history that witnessed the first appearance of skeletonized animals and complex ecosystems (e.g., the Shibantan Biota) in the ocean. However, the trigger for such biological innovations and their feedbacks to the environment are still poorly understood. Here, to explore possible interactions between the Shibantan Biota and the oceanic environment, we carried out an integrated investigation of I/Ca along with sulfur isotopes of carbonate-associated sulfate ($\delta^{34}S_{CAS}$) and pyrite ($\delta^{34}S_{py}$) in the Shibantan Member of the Dengying Formation at Wuhe in the Three Gorges area of South China. Our I/Ca profile yields fluctuating values in the range of <0.1 to >1.0 μmol/mol, corresponding to oxygen concentrations between 1-3 μM and 20-70 μM in the water column of the study area. The variably high $\delta^{34}S_{CAS}$ values (+31.8‰ to +55.7‰, mean +41.0±5.2‰) may imply low sulfate concentrations in the terminal Ediacaran ocean, consistent with contemporaneous expansion of seawater anoxia. Superheavy pyrites (i.e., $\delta^{34}S_{py} > \delta^{34}S_{CAS}$) are present in the lower Shibantan Member, concurrent with the appearance of bioturbation in the sediments, suggesting control by microbial sulfate reduction (MSR) in sulfate-limited porewaters followed by preferential re-oxidation of ^{32}S-bearing H_2S under the influence of burrowing organisms. Our study reveals that oxygen levels in shallow-water environments of the terminal Ediacaran ocean were generally low but still sufficiently high to sustain the physiological requirements of the Shibantan Biota. In turn, burrowing activity of infaunal members of the Shibantan Biota may have enhanced sediment porewater oxygenation, thus expanding the ecosystem space available to early animals.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-5: Environmental-life coevolution during the Neoproterozoic-early Paleozoic transition
Presentation Preference: Oral Preferred

Abiotic anoxic iron oxidation, formation of Archean banded iron formations, and the oxidation of early Earth

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Keywords: banded iron formation, early Earth, iron cycle, green rust, hydrogen escape

Iron in the early anoxic oceans of Archean age is believed to have been oxidized to form banded iron formations (BIF). Previously, it has been proposed that iron was oxidized either by free oxygen, H2O2, microbial oxidation, or photo-oxidation. However, these mechanisms are difficult to reconcile with evidence for the oceans at that time having been largely devoid of dissolved oxygen and oxidants, together with the rarity of microbial remains in BIF and restrictively slow rates of photo-oxidation. I will discuss recent experimental work which shows that ferrous iron readily oxidizes in analogues of Archean anoxic seawater following the precipitation of ferrous hydroxide. Once precipitated, ferrous hydroxide undergoes decomposition to elemental iron that reacts with water at room temperature to form ferric iron and release hydrogen gas. This ferric iron may then be incorporated into green rust, a mixed ferrous-ferric phase that ages into iron minerals commonly found in BIF. Our finding suggests that anoxic iron oxidation may have contributed to the formation of oxide-facies BIF, especially Algoma-type BIF that likely formed in semi-restricted basins where ferrous hydroxide saturation was more easily achieved. Additionally, hydrogen production during ferrous hydroxide decomposition would have contributed to early Earth's oxidation, as a result of hydrogen escape to space, thus switching ferrous iron from an oxygen sink to an oxidation pathway prior to the GOE.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-5: Environmental-life coevolution during the Neoproterozoic-early Paleozoic transition
Presentation Preference: Oral Preferred

Marine anoxia change as a driver of late Cambrian SPICE Event shown by Ba & U isotopes

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Keywords: Cambrian, SPICE, barium isotopes, uranium isotopes, marine anoxia, marine productivity.

The late Cambrian SPICE event (~500-496Ma) represents one of the largest positive carbon isotope excursions (CIEs) during the Paleozoic, with magnitudes up to +4%. The beginning of the CIE coincident with a rapid trilobite turnover event. The SPICE is considered to be related to increased organic carbon burial, driven either by the expansion of oceanic anoxia or enhanced primary productivity. However, the main driver of the event and its relationship to the concurrent biotic event remains to be explored and constrained. Here, we use Ba isotopes (δ^{138}Ba) and uranium isotopes (δ^{238}U) in carbonate rocks to assess changes in marine primary productivity and marine redox chemistry across the SPICE. Two widely-spaced carbonate sections in China, Duibian A section in Zhejiang Province and Baijiashan section in Liaoning province, have been studied. Our data show a fluctuation of δ^{138}Ba excursions in a range of ~0.4‰ with a negative excursion to -0.2‰ of δ^{138}Ba corresponding to the peak of δ^{13}C, and a negative excursion of δ^{238}U with ~-0.7‰ at the beginning of the CIE. The negative excursion of δ!"#Ba can be interpreted to be caused most probably by marine anoxia, which can be associated with the upwelling of anoxic bottom seawater, while the negative excursion of δ^{238}U correspond to the trilobite turenover event, consistent with the previous results, showing a servere global anoxia event at the beginning of SPICE. Our new δ^{138}Ba and δ^{238}U results provided critical evidence that expanded marine anoxia was likely a primary trigger of organic carbon burial events that led to the SPICE event.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-5: Environmental-life coevolution during the Neoproterozoic-early Paleozoic transition
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Spatial pattern of the Ediacaran Shuram Event in Huangling-Shennongjia region, Hubei Province, South China

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Keywords: Ediacaran, Shuram Excursion, South China, Spatial Pattern

The Ediacaran Period (~635-539 Ma) witnessed major changes in Earth's system including rapid early animal radiations, dramatic environmental changes and the largest carbonate carbon isotopic ($\delta^{13}C^{carb}$) excursion in Earth history known as the Shuram Excursion (SE; Li et al., 2018, 2020). Despite of various patterns, the SE has been identified globally in Ediacaran strata (Grotzinger et al., 2011). However, their spatial pattern has not been well documented at present, impeding our understanding of the formation mechanism of the SE. In the region of the Huangling Anticline of Hubei Province (South China), the SE occurs in the upper part of the Ediacaran Doushantuo Formation (also named as "DOUNCE") and increasingly shows various patterns (Zhu et al., 2007; Lu et al., 2013; Li et al., 2017). In this study, we collected high-resolution $\delta^{13}C_{carb}$ data of the Doushantuo Formation from a large number of sections (n=28) in Huangling and its adjacent Shennongjia region. Based on our paleogeographic reconstruction of the Doushantuo Formation in study region (Gu et al., 2021), our results show a clear coupling between the paleo-water depths and the SE pattern in the Huangling-Shennongjia region. In shallow-water platform area, the SE is not obvious, which typically has a $\delta^{13}C_{carb}$ nadir of about 0‰ within thin strata (<30m). In contrast, the SE is prominent in the deep-water continental shelf basins, with the nadir reaching -10‰ lasting within much thick strata (up to 60m). In the mid-depth zone between the two area, the SE pattern falls in between. Our finding demonstrates that a spatial pattern for the SE may have existed in single craton basin, thus providing new insights into the nature of the largest $\delta^{13}C^{carb}$ excursion in the Earth history and its possible relationship with coeval major changes in Earth system.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-5: Environmental-life coevolution during the Neoproterozoic-early Paleozoic transition
Presentation Preference: Oral Preferred

Heterogeneous sulfide reoxidationin the Ediacaran Shuram ocean

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Keywords: Shuram Excursion, C-S cycles, Sulfate oxygen isotope, H2S reoxidation, COPSE model, Neoproterozoic

Ediacaran carbonate rocks (635-539 Ma) record the largest negative carbonate isotope excursion in Earth history, termed as the Shuram Excursion (SE). This event has been attributed to anaerobic oxidation of oceanic dissolved organic carbon as a result of enhanced weathering inputs of sulfate to the oceans during the amalgamation of Gondwana. However, the effect of carbon-sulfur cycle interplay on the net redox state of the ocean-atmosphere system remains unclear, impeding our understanding of life-environment co-evolution during the Ediacaran. Here, we generate high-resolution records of paired sulfate sulfur and oxygen isotopes and phosphorus concentrations for the SE interval in the Parachilna Gorge (South Australia) and Jiulongwan and Xiang'erwan sections (Three Gorges, South China), and we evaluate these data in the context of COPSE biogeochemical model simulations to explore net long-term redox changes. Our results support widespread H2S reoxidation in shelf areas during the SE, managing net oxygen budget. Varying degrees of H2S reoxidation on different cratons is likely to have led to high spatial heterogeneity in local oceanic redox states as well as in nutrient availability, representing the transition from low-oxygen Proterozoic oceans to more extensively oxygenated and nutrient-rich Phanerozoic oceans that promoted the rise of the Ediacara Biota.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-5: Environmental-life coevolution during the Neoproterozoic-early Paleozoic transition
Presentation Preference: Oral Preferred

A short-lived oxidation event during the early Ediacaran and delayed oxygenation of the Proterozoic ocean

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Keywords: Dissolved Organic Matter, carbon isotope perturbations,strontium isotopes, sulfur isotopes,uranium isotopes,metazoans

The Ediacaran Period was characterised by major carbon isotope perturbations. The most extreme of these, the 570 Ma Shuram/DOUNCE (Doushantuo Negative Carbon isotope Excursion) anomaly, coincided with early radiations of benthic macrofauna linked to a temporary expansion in the extent of oxygenated seawater. Here we document an earlier negative excursion (the 610 Ma WANCE (Weng'An Negative Carbon isotope Excursion)) anomaly in the Yangtze Gorges area, South China, that reached equally extreme carbon isotope values and was associated with a similar degree of environmental perturbation. Specifically, new uranium isotope data evidence a significant, but transient, shift towards more oxygenated conditions in tandem with decreasing carbon isotope values, while strontium and sulfur isotope data support an increase in continental weathering through the excursion. We utilize a biogeochemical modelling approach to demonstrate that the influx of such a weathering pulse into an organically-laden, largely anoxic ocean, fully reproduces each of these distinct isotopic trends. Our study directly supports the hypothesis that a large dissolved marine organic pool effectively buffered against widespread oxygenation of the marine environment through the Proterozoic Eon, and in doing so, substantially delayed the radiation of complex aerobic life on Earth.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-5: Environmental-life coevolution during the Neoproterozoic-early Paleozoic transition
Presentation Preference: Oral Preferred

Potassium isotope fractionation during clay adsorption and implications for reverse weathering in the Precambrian

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Keywords: K isotopes, reverse weathering, clay, adsorption

The Earth's habitability and climate stability are thought to be regulated by a negative feedback between atmospheric CO2 and the silicate weathering in geological timescales. This carbon-weathering feedback can be out of balance in certain geologic periods such as during the Neoproterozoic-early Paleozoic transition during which multiple Snowball Earth episodes occurred. This period is also marked by a substantial rise in atmospheric oxygen levels and a rapid evolution of multicellular eukaryotes, accompanied with significant perturbations in global carbon cycle. Chemical weathering flux controls the delivery and recycling of nutrients that can greatly influence marine productivity and redox conditions. A critical feature of silicate weathering during the Neoproterozoic is that the authigenic clay formation on the seafloor (termed reverse weathering) could have been greatly enhanced prior to the origin of silica-precipitating organisms in the Precambrian. However, the mechanism, extent, and rate of reverse weathering in the Precambrian are still poorly constrained. Models based on integrated C-Si cycle suggest that the enhance reverse weathering could result in warmer climate than if reverse weathering is ignored. Potassium isotope system is an emerging tool to trace silicate weathering as K is a major element that resides mostly in silicates. One outcome of the enhanced reverse weathering is an intensified clay-seawater interaction during which cations such as K, Ca, Na and Mg could be scavenged and adsorbed that alters the biogeochemical cycles of key nutrient elements.

Here we present K isotope results of cation exchange reactions between clay minerals (illite, smectite, kaolinite) and aqueous solutions to constrain the mechanisms and degree of K isotope fractionation. Series of experiments under different conditions were conducted in order to capture various factors that controls the isotopic fractionation of K. The adsorption rate of K on clay minerals is fast and can reach steady state within hours from initial mixing in our experiments. Isotopically light K is preferentially adsorbed onto the clay minerals. Our results indicate that preferential uptake of lighter K isotopes by seafloor clay minerals from the seawater may explain the observation that modern seawater is ~0.6‰ heavier than the bulk silicate Earth. If the reverse weathering was more extensive in the Precambrian than today, the seawater K isotopic composition could have been even higher than modern value due to removal of light K isotopes from clay adsorption. Potassium isotopic fractionation between clay and seawater during adsorption thus can help better quantify the reaction kinetics and refine estimates of reverse weathering fluxes that allows for better assessment of the effect of reverse weathering on Earth's climate evolution.

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Session T4-5: Environmental-life coevolution during the Neoproterozoic-early Paleozoic transition
Presentation Preference: Oral Preferred

V isotope evidence for seawater contribution to the early Cambrian polymetallic Mo-V mineralization in South China and widespread oceanic oxygenation

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Keywords: Polymetallic mineralization, Metal source, Seawater scavenging, Redox reconstruction, Yangtze Block

The early Cambrian black shales in the Yangtze Block hosts a polymetallic Ni-Mo sulfide layer with extreme metal concentrations, which grade laterally into V-rich shale. It is still controversial whether the source of ore-forming metal elements is seawater or hydrothermal fluid. In order to discriminate the origin of V, we measured the V isotope compositions ($\delta^{51}V$) of the Ni-Mo polymetallic sulfide layer and host black shale samples from Dazhuliushui and Maluhe sections in Guizhou province, as well as the V-rich shale and host black shale samples from the Sancha and Caojiaping sections in Hunan province. The $\delta_{51}V$ values of host black shale and V-rich shale are consistently heavy (from -0.62 to 0.09‰, avg. -0.23‰), indicating V elements are from seawater. But the polymetallic Ni-Mo sulfide ores have relatively light $\delta^{51}V$ values (from -0.77 to -1.33‰, avg. -1.00‰), which likely resulted from the adsorption of Fe-Mn oxides to V. In light of the above observations, we propose a V geochemical cycling model in the continental margin of the Yangtze platform in South China during early Cambrian. Furthermore, based on the $\delta^{51}V$ values of three sets of samples deposited in various conditions and the V isotopic offset between seawater and these sediments, we reconstruct a global seawater V isotope composition ($\delta^{51}V = 0.17\pm0.36$‰) during the early Cambrian, which is consistent with the $\delta^{51}V$ value of modern oxic seawater (0.20±0.15‰). This demonstrates that early Cambrian open ocean may be already in an oxygenated state closed to that of the modern marine. Oxic seawater may provide suitable environment for Cambrian Explosion. Meanwhile, the result of sensitivity analyses imply that the fraction of hydrothermal flux has little impact on the fraction of oxic flux.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-5: Environmental-life coevolution during the Neoproterozoic-early Paleozoic transition
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

The basal Cambrian carbon isotope excursion revealed in the Central Iberian Zone, Spain

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Keywords: basal Cambrian carbon isotope excursion, Spain, Ediacaran-Cambrian boundary

The patterns and causes of early metazoan diversification across the Ediacaran-Cambrian transition remain controversial, and geobiological evidence from less well-known sections can help shed light on the issue. Here, we report carbon and nitrogen isotope data from two fossiliferous sections straddling the Ediacaran-Cambrian interval in the Central Iberia Zone, Spain. Carbon isotope chemostratigraphy of both sections reveals prominent negative excursions, which are interpreted to correspond to the global Basal Cambrian Carbon Isotope Excursion (BACE). The Ediacaran-Cambrian boundary is therefore proposed to sit in the upper part of the Villarta and laterally correlative Cíjara formations. Nitrogen isotope data reveal a similar trend to that found from contemporaneous strata of South China, but lower values indicate a change in nitrogen cycling from anaerobic to aerobic in Central Iberia. In Spain, the treptichnids and Treptichnus appeared above the BACE while Cloudinia appeared below the BACE, which is consistent with an emerging picture of macroevolutionary trend through the Ediacaran-Cambrian interval. Integrated geochemical and biotic records suggest that early metazoan evolution across the Ediacaran-Cambrian transition was possibly mediated by complex environment-ecosystem feedbacks.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-5: Environmental-life coevolution during the Neoproterozoic-early Paleozoic transition
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Floating microbial mats from the Mesoproterozoic Wumishan Formation, North China

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Keywords: Microbial mat, cyanobacteria, Mesoproterozoic

Microbial mats were well established and widespread during the Proterozoic eon, playing a pivotal role in early marine ecosystem. Especially, microbial mats dominated by cyanobacteria are responsible for the oxygenation of the atmosphere and oceans, which may have contributed to the evolution of eukaryotes. The migration of microbial mats from benthic to floating forms is quite common in modern aquatic environments. However, in the Precambrian ocean, well-preserved benthic microbial mats are rich in sedimentary record, while floating microbial mats remain poorly known. This may be caused by lower preservation potential of floating microbial mats due to degradation in water column.

Here, we systematically investigated cherts and silicified microbialites from the Wumishan Formation (~1480 Ma) Jixian Group, North China. The microbial mats in this study are mainly composed of coccoid microfossils that are simple in morphology and uniform in size. They show different degrees of degradation. A few of them are well preserved, but most are degraded severely with only molds left. Moreover, the microbial mats exhibit alternating light-dark laminae. Interestingly, dark layers on the top of the light layer microbial mats (TLMM) and the bottom of the light layer microbial mats (BLMM) are characterized by different types of microbial mats. A “fossils bridge” connecting the two types of microbial mats can be found in the light layer occasionally. These microbial mats are preserved in cryptocrystalline quartz, while microbial mats and “fossils bridge” are surrounded by chalcedony. This phenomenon indicated that microbial mats preserved in-situ forms. Meanwhile, we found hemispherical structures with convex downward in the TLMM. The height and width of these hemispheres are about 0.1-0.4 mm and 0.4-3 mm respectively, and their ratios are relatively constant. After calculations and simulations, we speculated that the hemispherical structure might be caused by the buoyancy of seawater on the floating microbial mats. Our study provides strong evidence for the existence of floating microbial mats in the Proterozoic, promoting the understanding of early shallow marine biosphere.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-5: Environmental-life coevolution during the Neoproterozoic-early Paleozoic transition
Presentation Preference: Oral Preferred

The origin of the oldest, extremely 13C-depleted calcite: A snowball Earth legacy

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Keywords: Cold seep carbonate, isotope, snowball Earth

The 635 Ma Marinoan glaciation is the most severe global glaciation in Earth history. After onset of the deglaciation, the Earth system went through a series of dramatic changes. Amid these changes, extremely 13C-depleted limestones (CDLs) stands out as the most unusual geochemical events of all. The origin of calcite is critical for us understanding the carbon cycle and ocean redox condition after the global glaciation, while the origin is lingering debates. The CDLs has been alternatively interpreted as evidence for anaerobic oxidation of methane during early diagenesis or oxidation of methane resulting from late diagenetic interaction with hydrothermal fluids. Here, we pin down the origin of these calcites to a process driven by sulfate reduction coupled with anaerobic oxidation of methane. Our evidence comes from multi-isotope study for the CDLs and in their host dolostones in the basal Doushantuo Formation, including sulfur and oxygen isotopes of carbonate associated sulfate (CAS), multiple sulfur isotopes of pyrite, carbonate and organic carbon isotopes. The low δ13Corg values down to –46‰ with high δ34Spyirte up to +74‰, positive δ34SCAS– δ18OCAS, δ34SCAS–δ34Spyrite correlations and negative δ13Corg– δ34Spyrite, δ34Spyrite–Δ33Spyrite correlations of these limestones are identical to those of the modern cold seep carbonates formed by microbial anaerobic oxidation of methane using sulfate. This basal Ediacaran, CDLs is the oldest known cold seep carbonates, suggesting that that the earliest Ediacaran peak in marine sulfate concentration is a regional and likely transient event.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-5: Environmental-life coevolution during the Neoproterozoic-early Paleozoic transition
Presentation Preference: Oral Preferred

Biological response to oxic pulses during the Cambrian

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Keywords: Cambrian, redox, metazoans, evolution

Oxygenation during the Cambrian Radiation interval probably progressed via a series of short-lived oxic pulses, each lasting 1-3 million years (Myr). But the biotic response of metazoans to this episodic oxygenation has not been quantified, nor the causal processes constrained. Here we present high-resolution metrics from benthic metazoan communities on the Siberian Platform over 20 Myr through Cambrian stages 2 to 4 (~530-510 Million years ago; Ma). During the oxic pulse ~521 Ma, we document increased body size, species diversity, and rates of origination. But during the succeeding phase of expanded marine anoxia (~519-516 Ma), metazoan body size reduced, as did diversity driven by increased rates of extinction. A later oxic pulse ~515 Ma shows a further increase in body size and diversity. The Sinsk Extinction event, ~514 Ma, likely driven by widespread anoxia, caused the 'Lilliput Effect' (body size decrease) in some groups, but the 'Brobdingnag Effect' (body size increase) in others. These metrics confirm that oxygenation events created short-lived pulses of evolutionary diversification, with intervening intervals of partial or widespread anoxia notably enhancing extinction rates.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-5: Environmental-life coevolution during the Neoproterozoic-early Paleozoic transition
Presentation Preference: Oral Preferred

Mechanistic evaluation of sulfur and oxygen isotope fractionation during microbial sulfate reduction

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Keywords: microbial sulfate reduction, sulfur isotope, oxygen isotope, triple oxygen isotopes

Microbial sulfate reduction (MSR) dominates the organic carbon mineralization in anaerobic sediments globally. Sulfur and oxygen isotope compositions in sulfate have been widely used to trace the MSR process, and many experimental and theoretical investigations have been done to reveal the underlying mechanisms regulating sulfur and oxygen isotope variations during MSR. However, most previous efforts are designed for closed systems, while sedimentary environments are often open. Here we developed a numerical model incorporating the metabolic reactions and diffusion-transport processes to investigate the factors controlling sulfur and oxygen isotope fractionations, especially focusing on the relationship between sulfur and oxygen isotope fractionation relationship and triple oxygen isotope variations. Our results show that the relationship between sulfur and oxygen isotope fractionation, i.e., the slope of 18O and 34S, is inversely correlated with the cell specific sulfate reduction rate, and the triple oxygen isotope fractionation relationship, i.e., the θ value of MSR, cannot be larger than equilibrium θ value 0.524. The implications of our results will also be presented.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-5: Environmental-life coevolution during the Neoproterozoic-early Paleozoic transition
Presentation Preference: Oral Preferred

How can dolomite Mg isotopes tell the terminal Ediacaran seawater chemistry?

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Keywords: Seawater Mg/Ca, Mg isotopes, Dolomites, Animal biomineralization

Among the key advances in animal evolution, the development of calcified skeletons is one of the most important innovative revolutions since it fundamentally changed the ecological system. A lot of drivers have been proposed, including the increasing predation pressure and variation in seawater chemistry. Regarding the potentially involved environmental contexts, there are still many uncertainties, such as the seawater Mg/Ca variation during this period due to the lack of reliable archives. Therefore, Mg isotopes of dolomites from the lower member of the Dengying Formation, which is right below the calcified fossil-bearing succession, here are investigated to constrain the coeval seawater Mg/Ca variation since the seawater Mg budget can be reflected by seawater Mg isotopic compositions. Results show that the microbialites with well-preserved sedimentary structures are widely developed in dolomites as the matrix, and fibrous dolomite cements with abundant types show delicate growth zones, which both are formed during the syn-sedimentary stage. The geochemical signatures of these components display the primary signals of the coeval seawater and reveal a relatively anoxic shallow platform setting. Furthermore, the correlated elemental ratios and Mg isotopic compositions of these well-preserved components indicate the pervasive mixture of freshwater in the shallow seawater, and the heavier Mg isotopic compositions in the freshwater endmember imply a silicate-dominated riverine input. This enhanced silicate weathering may relate to the extensive dramatic chemical weathering at the late Ediacaran, which may favor the high Mg/Ca ratio and alkalinity in the oceans on the eve of the earliest animal biomineralization.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-5: Environmental-life coevolution during the Neoproterozoic-early Paleozoic transition
Presentation Preference: Oral Preferred

Synchroneity and causality of biotic and abiotic processes during the Neoproterozoic-Cambrian transition

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Keywords: Cambrian Explosion, Biotic processes, Abiotic processes, Causality, Synchroneity

Surficial Earth is an integrative system of biotic and abiotic components, which is traditionally called ecosystem. Biotic and abiotic components have interacted with each other since life orgin and the ecosystem itself has evolved ever since. The interplay of biotic and abiotic processes crossing the critical trasitions of Earth's history has long been extensively and intensively investegated by scientists from multidisciplines. Increasingly, more scientists have tended toward more abiologically based explanations for biotic events, generally identifying abiotic changes in tectonics, sedimentation, climate, and redox as the planetary drivers of discontinuous biotic change and viewing biotic changes as passive responses to abiotic changes (Erwin, 2015). The explanations, in most cases, are based on the synchroneity of biotic and abiotic changes seen in the studied geological sections or recognized through global stratigraphical correlations. However, the current correlation resolution is generally insuficient to establish the synchroneity. More critically, simultaneously or successively happened events do not necessarily have causal relationships. Here, I review biotic and abiotic events crossing the Neoproterozoic-Cambrian transition (Zhang et al., 2014; Zhang and Shu, 2021; Li et al., 2021) and discuss challenges in defining their synchroneity and causality.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-5: Environmental-life coevolution during the Neoproterozoic-early Paleozoic transition
Presentation Preference: Oral Preferred

Geological and geochemical constraints on the genetic relationship between the different phosphorus layers in the Zhangcunping area, South China

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Keywords: Ediacaran, Doushantuo formation, Phosphorite, Zhangcunping

Worldwide phosphogenic events took place in the immediate aftermath of the Neoproterozoic glaciation period, resulting in formations of some of the largest phosphorus deposits in the word. The Zhangcunping area in Western Hubei represents one of the most significant phosphatized ore belt in China and the Ediacaran Doushantuo Formation hosts two high-grade phosphatic beds known as the lower phosphorite and upper phosphorite beds. In this study, elemental concentration analysis were investigated in association with a detailed petrographic investigation of the different layers to assess the association between the lower phosphorite and upper phosphorite beds and better constrain the redox condition during the formations of the phosphorus deposits in the Zhangcunping area.

The lower banded phosphorite layer overlies the thick organic-rich shales, and is conformably overlain by dolostone, with an erosional surface at the top, following the upper phosphorites interbedded with dolostone. These two phosphorite layers show different petrographic and geochemical characteristics. On the one hand, framboid pyrite can been observed in the lower phosphorite ores, whereas authigenic iron oxide and fossils, such as spherical algae and cyanobacteria-like microfossils, are common in the upper phosphorite ores. On the other hand, these two ore layers have obvious difference in elemental concentrations: 1) The upper phosphorites have much lower Zn, Ba, Cd contents than the lower phosphorites, but higher Cu contents; 2) The lower phosphorites shows slightly "right inclining" REE pattern and no Ce anomalies (average 0.97), while the upper phosphorites show "hat-shaped" REE plots with negative Ce anomalies (average 0.68); 3) The lower phosphorites have a low Y/Ho ratios with an average of 32.92, but this up to around 42 in the upper phosphorite ores. In the sum, the lower phosphorite ores show higher LREE/HREE, lower Y/Ho, no Ce anomalies and upper phosphorites show lower LREE/HREE, higher Y/Ho with Ce anomalies, suggesting that lower phosphorite ores formed in anoxia bottom water condition and the upper phosphorites deposited in suboxic depositional condition. Therefore, our study suggests a transition from a generally anoxia environment to a suboxic environment during the formation of the two phosphorite layers through the Doushantuo Formation.

Session T4-6: Biomarker and isotopic proxies for reconstructions of paleoclimate and paleoceanography

ID: T4-60231

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-6: Biomarker and isotopic proxies for reconstructions of paleoclimate and paleoceanography
Presentation Preference: Oral Preferred

Global scale production of brGDGTs by benthic marine bacteria: Implication for developing ocean bottom environmental proxies

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Keywords: Branched GDGTs, in-situ production, marine sediment, global scale, paleoclimate reconstruction

The in-situ production of branched glycerol dialkyl glycerol tetraethers (brGDGTs) in marine environments has been generally accepted. However, whether it takes place in the water column or the sediments remains elusive. Here, we compiled a dataset composed of globally distributed marine sediments from continental shelves to hadal trenches to address this important knowledge gap. Firstly, a cutoff of ΣIIIa/ΣIIa ≥ 0.92 was applied to distinguish the marine vs. terrestrial signals of brGDGT production. For marine derived brGDGTs, the cyclization of branched tetraethers (CBT) index, related to ambient pH, displays a large variability, suggesting that marine derived brGDGTs in sediments are mainly produced within sediments where the pH of sediment porewater is highly variable, rather than in the water column where pH is relatively constant. This is also supported by good correlations between the bottom water temperature and the methylation of branched tetraethers (MBT') index, between the water depth and the ΣIIIa/ΣIIa index, as well as between the brGDGT-based proxies and sediment redox conditions during glacial/interglacial cycles. We thus propose that the benthic production of brGDGTs in marine sediments is ubiquitous on a global scale, and is largely affected by the ambient temperature and pH. Our findings support that brGDGT-based proxies have potential of recording environmental conditions of the ocean bottom.

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-6: Biomarker and isotopic proxies for reconstructions of paleoclimate and paleoceanography
Presentation Preference: Oral Preferred

Carbon and hydrogen isotopes of taraxerol in mangrove leaves and sediment cores: implications for paleo-reconstructions

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Keywords: Mangroves, Taraxerol, Hydrogen isotope, Carbon isotope, Early diagenesis, Paleoreconstruction

Reconstructing past climate change in mangrove swamps contextualizes ongoing and future developments in these globally important ecosystems. Taraxerol, a well-recognized lipid biomarker for mangroves, is a promising target compound for calibration since it is relatively refractory and well preserved in sediments and since mangrove lipid δ^2H and $\delta^{13}C$ values have been shown to respond to salinity changes. Here we investigate the δ^2H and $\delta^{13}C$ values of taraxerol in leaves of two mangrove species (Rhizophora mangle and Laguncularia racemosa) and three dated mangrove cores along a spatial transect from the Shark River Estuary of South Florida, USA, to constrain its applicability for hydroclimate reconstructions. The net 2H discrimination between surface water and taraxerol increased by 1.0‰ ppt-1 over a salinity range of 0.7-32 ppt for both R. mangle and L. racemosa. Although the $\delta^{13}C$ values of taraxerol showed a significant positive correlation with salinity in L. racemosa, the inverse trend was observed in R. mangle. The isotopic signature and spatial trends of taraxerol observed in mangrove leaves were well imprinted in mangrove surface sediments.
In addition, we further tested if the isotopic signal of taraxerol from mangrove leaves could be preserved in sediment cores on a time scale of ca. 300 yrs. No strong evidence of significant diagenetic alteration was observed for δ^2H values of taraxerol. In contrast, an increase up to ~1.1‰ was observed for $\delta^{13}C$, excluding the Suess effect. Considering the consistent salinity-dependent discrimination of 2H to salinity, and no significant diagenetic alteration of taraxerol δ^2H values on centennial time scales, taraxerol H isotopes are a promising proxy for hydroclimate reconstruction in mangrove and mangrove-adjacent systems. However, the interpretation of $\delta^{13}C$ values of taraxerol should be treated with caution since its correlation with salinity may be species-specific and a slight diagenetic enrichment in 13C may occur.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-6: Biomarker and isotopic proxies for reconstructions of paleoclimate and paleoceanography
Presentation Preference: Oral Preferred

Effect of "plant types" on terrestrial leaf wax biomarkers

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Keywords: Terrestrial biomarkers, Leaf wax, GDGTs, Cellulose, Coupling

Terrestrial biomarkers are widely studied to indicate the paleoclimate and paleoenvironmental signals. However, almost all prior studies focused on the identification of an alternative proxy such as leaf wax, GDGTs, cellulose etc. Each biomarker has inherent strengths and weaknesses, therefore coupled proxy based upon independent biomarkers is desired. In this study, we try to couple more than one biomarker from a suite of samples for implicating paleoclimate (e.g., RH) and paleoelevation. We found that the coupling of leaf wax δ2H values and brGDGTs along arid elevation transects such as Chinese Loess Plateau and Tibetan Plateau would be better to indicate the altitudinal changes, which could reduce and ambiguity and errors derived from single proxy. Additionally, the coupling of three forms of leaf wax biomarkers such as n-alkanes, δ2H and δ13C values could be used to reflect various climate and environmental information. We also try to couple leaf wax δ2H values and cellulose δ18O values, which can be used to indicate the RH variation. The coupling biomarkers will be a hot research direction for biomarker researchers and paleoclimate/paleoenviornmental reconstruction.

Reference

ID: T4-60273

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-6: Biomarker and isotopic proxies for reconstructions of paleoclimate and paleoceanography
Presentation Preference: Oral Preferred

Productivity Controls the Deposition of High-Quality Oil Shale in Wushi Sag, Beibuwan Basin, South China Sea: Evidence From Unusual Carbon Isotope of Kerogens

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Keywords: oil shale, carbon isotope, productivity , algae bloom, lacustrine, Beibuwan Basin

Eocene Liushagang-2 section in Wushi sag, Beibuwan Basin has been proved to deposit lacustrine algal-rich oil shales consisting of sapropel kerogens dominated by lamalginites. Our new study reveals that kerogens of Eocene lacustrine oil shales in Wushi sag demonstrate wide-raging $\delta^{13}C_{org}$ values (-30‰~-17.7‰). Oil shales with heavier carbon isotope anomaly ($\delta^{13}C_{org}$ -23‰ to -17‰) are characterized by more organic richness and hydrocarbon potential compared to oil shales with more negative $\delta^{13}C_{org}$ value (-30‰~-25‰).These findings draw attentions of geologists and raise interesting questions about the cause of anomaly and variation of carbon isotope of oil shales in Wushi sag.

In this paper, we integrate carbon isotope of organic matter ($\delta^{13}C_{org}$) and carbonate ($\delta^{13}C_{cab}$) with molecular and fossil results of oil shales to establish the relationship between molecular biomarker and isotopic composition. It is observed that carbon isotopes of kerogens of oil shales ($\delta^{13}C_{org}$) are strongly and positively correlated with abundance of C_{30} 4-methylsterane. This observation suggests that the unusual ^{13}C enrichment of oil shales is possibly related with algae bloom in Wushi paleolake.The parallel and positive shifts of carbon isotope of organic matter ($\delta^{13}C_{org}$) and carbonates ($\delta^{13}C_{carb}$) further support the hypothesis that bloom-related CO_2(aq) drawdown in photic zones contributes to dissolved inorganic carbon ^{13}C enrichment in surface water (perhaps HCO_3^-) that is utilized by phytoplankton during photosynthesis as carbon source, ultimately resulting in the ^{13}C enrichment of oil shales.Thus these oil shales with heavier carbon isotope represent the products of elevated productivity under CO_2-limiting condition in Wushi paleolake. Conversely, the ^{13}C-depleted oil shales were formed during episodes of decreased algal production, when CO_2 concentration in surface water was so enough that uptake of dissolved CO_2 by phytoplankton enhanced algal ^{12}C discrimination. Therefore, we propose that the observed isotope variation ($\delta^{13}C_{org}$) records the change in productivity of surface water that controls the organic richness of oil shales in Wushi sag.The sharp variation of carbon isotope of oil shales in less than 100m intervals implies that productivity of Wushi paleolake was not stable possibly as the result of paleoclimate fluctuation or nutrient availability during the period of Eocene Liushagang-2 .

The deposition model of Eocene lacustrine oil shales in Wushi sag is reconstructed on the basis of their $\delta^{13}C_{org}$ values. At the early stage of Eocene Liushagang-2 period, nutrient influx (Phosphorus) from the surrounding highlands triggered algae blooms in Wushi paleolake. The elevated productivity caused the more oxygen-depleted environment at the bottom of the lake, which is supported by evidence of higher sulfur in oil shales, contributing to form ^{13}C-enriched oil shales with higher TOC content. Subsequently, productivity of the paleolake decreased resulting in the formation of ^{13}C-depleted oil shales with relatively low organic carbon concentration. At the late stage of Eocene Liushagang-2 period, possible changes of paleoclimate triggered the absence of water-column stratification leading to deposition of organic-lean mud shale in Wushi sag.

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-6: Biomarker and isotopic proxies for reconstructions of paleoclimate and paleoceanography
Presentation Preference: Oral Preferred

Carbon and hydrogen isotope variability of microbial fatty acids reveals a wide range of metabolic diversity in various environments

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Keywords: carbon isotope, hydrogen isotope, fatty acids, microbial metabolism

The carbon ($\delta^{13}C$) and hydrogen ($\delta^{2}H$) isotope compositions of microbial lipid biomarkers are a useful tool for tracing microbial metabolism in modern environments, and are one of the few ways to reveal past biogeochemical processes in sedimentary settings. Understanding the isotopic fractionation factors associated with expected biogeochemical processes in natural environments is important to ensure the reliable use of these isotopic tracers. However, the $\delta^{13}C$ and $\delta^{2}H$ characteristics of microbial lipids and their fractionation factors remain less constrained in modern natural environments. Here, we investigated the $\delta^{13}C$ and $\delta^{2}H$ characteristics of microbial fatty acids in natural topsoil samples from a subtropical subalpine basin that includes wetland, meadow, and forest habits. The $\delta^{13}C$ values of microbial fatty acids in meadow and forest topsoil were similar and varied from –22‰ to –32‰, while the $\delta^{13}C$ values of microbial fatty acids in wetland topsoil were more depleted (–24‰ to –40‰). The kinetic carbon isotope fractionation factor ($\varepsilon_{FA/bulk}$) between microbial fatty acids and bulk organic carbon ranged from 10‰ to –3‰ in meadow and forest topsoil, indicating the dominant heterotrophic microbial metabolic activity. The $\varepsilon_{FA/bulk}$ of wetland topsoil had a wider range, with the $\varepsilon_{FA/bulk}$ of monounsaturated fatty acids as low as –10‰, suggesting greater variability of microbial metabolism and potential methanotrophic activities on top of the heterotrophy in wetland environments. Consistent with the difference in carbon metabolism between wetlands and meadows/forests, the molecular distribution of microbial fatty acids suggests a distinct microbial community structure, with Gram-negative bacteria more prevalent in wetlands compared with meadows and forests. The kinetic hydrogen isotope fractionation factor ($\varepsilon_{FA/water}$) between microbial fatty acids and source water ranged from –80‰ to –220‰, and had no significant differences in the three environments, indicating similarities in microbial central metabolism in these topsoil environments. Nevertheless, the $\varepsilon_{FA/water}$ values of anteiso fatty acid were lower than those of other microbial fatty acids, especially in wetland environments. This phenomenon may be related to photoautotrophic metabolism or the preferential synthesis of anteiso fatty acids. In summary, these results suggest a wide range of microbial metabolic diversity in various environments and the potential of microbial lipids $\delta^{13}C$ and $\delta^{2}H$ to track biogeochemical processes.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-6: Biomarker and isotopic proxies for reconstructions of paleoclimate and paleoceanography
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Response of microbial community to depositional environment and climate change in Liaohe Delta since the Last Glacial Maximum

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Keywords: GDGTs, microbial community, sedimentary environment, climate change

Dramatic changes have taken place in global climate since the LMG, which have a strong impact on global environment. As transitional region between sea and land, the estuary delta area is sensitive to sea level change and climate change. The transgression and regression could strongly influence the coastal sedimentary environment. The evolution of sedimentary environment in Liaohe delta (LHD) since 32 ka BP was divided into four stages: fluvial deposition at 32-25 ka BP, lacustrine deposition in flood basin at 25-8 ka BP, shallow sea deposition at 8-5 ka BP and delta deposition at 5-0 ka BP. Here, we analyzed the concentration of iGDGTs and bGDGTs and found that the microbial communities, as the inhabitant, was sensitive to the environment and climate change. In fluvial sedimentary environment, the archaea and bacteria are not abundant. In lacustrine sedimentary environments, the abundance of methanogens decreased/increased with the increase/decrease of dissolved oxygen in the water column. Then rapid increase in the abundance of marine Thaumarchaeota in shallow seas. The abundance of marine Thaumarchaeota in delta depositional environment decreased gradually. Since 1.5ka BP, the delta has gradually transformed into coastal wetland. In the lacustrine deposition stage, the microbial community had obvious response to climate change. The warm climate of B/A stimulated the abundance of archaea and bacteria in the lake. Stable lake evolution and enhanced monsoon precipitation elevate lake water level and decreased DO of water column, which stimulated the growth of methanogens. In YD, global cooling suppressed microbial abundance. The weakening EASM has reduced precipitation amount, and caused lake levels to drop rapidly. Meanwhile, strong wind caused by EAWM increased the water mixing in shallow lakes, which resulted in the water column DO content increasing and further inhibiting methanogens produce.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-6: Biomarker and isotopic proxies for reconstructions of paleoclimate and paleoceanography
Presentation Preference: Oral Preferred

Evaluation of the wider applications of the alkanol index BNA15 in a global distribution of peat deposits

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Keywords: peat,branched fatty alcohols,BNA15,paleotemperature

The biomarker-based BNA_{15} proxy, the degree of branched C_{15} alkan-1-ols over normal C_{15} alkan-1-ol, was recently proposed as a novel terrestrial paleothermometer. It was calibrated using a limited number of Chinese mineral soils. Whether the BNA_{15} ratio can be applied more generally is currently unknown and the calibration of BNA_{15} using modern peat samples so far does not exist. Here we analyzed 129 surface and downcore peat samples from 18 globally distributed peatlands with a broad mean annual air temperature (MAAT) range (-3.2 to 26.5℃) and pH range (3 to 8) to test the wider applicability of the BNA_{15} proxy in peat deposits. Our results show that the BNA_{15} differs significantly between depths within the same peat core, with higher values in the anoxic catotelm in mid/low latitude peatlands and slightly higher in the acrotelm in high latitude/altitude peatlands. Combined with the evidence of the absolute concentration of alkan-1-ols in a peat core retrieved from the Dajiuhu peatland, we suggest that more branched alkan-1-ols are from the acro/catotelm boundary. BNA_{15} has a moderate correlation with the growth temperature in surface samples, which is affected by temperature and water table together. Besides, a positive correlation can be observed between BNA_{15} and MAAT in the catotelm part in Chinese peatlands (R^2=0.95, $p<0.01$), as well as in other peatlands beyond China (R^2=0.99, $p<0.05$), but the slopes and intercepts differ. We find no clear correlation between BNA_{15} and pH in any of the peatlands. The regional difference in the slope and intercept of the correlation between BNA_{15} and MAAT suggests that this proxy is affected by other factors beyond the temperature, e.g. vegetation type, peat nutrient status, and/or microbial community.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-6: Biomarker and isotopic proxies for reconstructions of paleoclimate and paleoceanography
Presentation Preference: Oral Preferred

Prolonged drying on the southeast coast of China during the mid-to-late Holocene transition

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Keywords: Holocene, hydroclimate, biomarker, δD

China experienced significant hydrological changes during the mid-to-late Holocene transition. However, the nature of the hydroclimate anomaly on the southeast coast of China remains elusive. Here, we present a leaf wax record from the Shuizhuyang (SZY) peat deposit on the southeast coast of China spanning the Holocene. The δD values of C_{29} *n*-alkane (δD_{C29}) showed a large positive shift from 4.7 to 3.8 ka with an amplitude up to 24‰. As δD_{C29} changed independent of vegetation proxies and could not be solely explained by variations in precipitation δD values, it is more likely to reflect prolonged drying during the mid-to-late Holocene transition. This prolonged drying is probably to be primarily shaped by a more El Niño-like state over the tropical Pacific Ocean, which would decrease the rainfall on the southeast coast of China by shifting the western Pacific subtropical high (WPSH) more southwestward.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-6: Biomarker and isotopic proxies for reconstructions of paleoclimate and paleoceanography
Presentation Preference: Oral Preferred

The brGDGT-based paleothermometer; proxy development and application

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Keywords: biomarker, brGDGT, temperature, terrestrial, paleo climate, organic

Branched glycerol dialkyl glycerol tetraethers (brGDGTs) are bacterial membrane lipids. The distribution of brGDGTs in mineral soils, lakes, and peats is correlated with temperature through a decrease in the degree of methylation with increasing temperature. This empirical observation forms the basis of the brGDGT paleothermometer. In my presentation I will present and discuss recent advances in our understanding of the brGDGT-based paleotherometer, including recent culturing successes and molecular dynamics simulations, which together allow us to confidently apply this proxy to reconstruct terrestrial temperature to the geological past. I will also present new data to demonstrate how the brGDGT-based paleotherometer can revolutionize our understanding of the operation of Earth's System in general and the terrestrial realm specifically.

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-6: Biomarker and isotopic proxies for reconstructions of paleoclimate and paleoceanography
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

The occurrence of hydroxylated isoprenoid GDGTs in soils and peats: implications for OH-GDGT-based proxies

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Keywords: Hydroxylated isoprenoid GDGTs, soil, peat, temperature,Thaumarchaeota

Hydroxylated isoprenoid glycerol dialkyl glycerol tetraethers (OH-GDGTs), a class of lipids that widely occur in the global marine and lacustrine environments, have been used as tools for temperature reconstruction. However, their occurrence in terrestrial environments is rare. Here, we investigated the downward variation in distribution and concentration of OH-GDGTs in three soil profiles (SP) from Mount Yujiashan in Wuhan, central China as well as the distribution of OH-GDGTs in Chinese peatlands where the mean annual air temperature (MAT) varies from 2℃ to 14.2℃. In soils, the OH-GDGT content showed significant correlations with that of crenarchaeol and decreased with total organic carbon content (TOC), likely in relation to the decreased supply of organic nutrients downwards in these SPs. Crenarchaeol was likely to be produced primarily by Thaumarchaeota Group I.1b whereas OH-GDGTs by Thaumarchaeota Group I.1a based on 16S rRNA gene sequencing. This suggests that Thaumarchaeota Group I.1b and I.1a occupy similar niches in these soils. OH-GDGTs were dominated by OH-GDGT-2 in soils and OH-GDGT-0 was dominant in peats, differing significantly from aquatic settings. RI-OH' showed a significant correlation with temperature in the combined data set of soils and peats, with a different intercept yet a similar slope to that of the global marine data set. Applying the marine RI-OH and RI-OH' calibration to these soils and peats yielded markedly higher temperatures than local MAT, suggesting a different response of terrestrial OH-GDGTs to temperature and (or) a significant bias of RI-OH/RI-OH' towards summer temperature.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-6: Biomarker and isotopic proxies for reconstructions of paleoclimate and paleoceanography
Presentation Preference: Oral Preferred

Resolving the biosynthesis of tetraether lipids: potential implications for deciphering the sedimentary biomarker record

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Keywords: Lipid biomarker, Tetraether lipids, GDGTs biosynthesis, paleoenvironment

Microbial lipids can be preserved for geological time periods within sediments and provide a unique tool that allows the reconstruction of paleoenvironment and paleoecology. A unique group of microbial lipids, glycerol dibiphytanyl glycerol tetraethers (GDGTs), are archaeal membrane lipids that are correlated with archaeal community and environmental fluctuations, leading to the use of GDGTs as taxonomic markers and paleoproxies for studies of microbial ecology and past global climate fluctuations. In our studies, by identifying genes responsible for GDGTs biosynthesis, including GDGT-0 formation, GDGT cyclization, and GDGT caldital head group alternation, we have a better understanding of the biological sources of GDGTs fossils in sediments, that allows GDGTs to become a more reliable taxonomic marker. This genetic basis could also provide insight into the regulation on GDGTs profiles in archaea, and thus establish a more robust correlation between lipid profiles and environmental fluctuations.

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-6: Biomarker and isotopic proxies for reconstructions of paleoclimate and paleoceanography
Presentation Preference: Oral Preferred

Significant contribution of petrogenic organic carbon in the Taiwan Strait

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Keywords: Taiwan Strait, Organic Carbon (OC), Petrogenic OC, Four-end member model

The marginal seas occupy only 20% of global ocean area, but contribute around 80% of organic carbon (OC) burial in sediments, thus, are significant to the ocean carbon cycles and budgets (Hedges and keil 1995; Burdige, 2005; Zhao et al., 2021). The input of terrestrial OC to the continental shelves increases due to the global climatic change and anthropogenic activities, which is an important yet undetermined proportion of global carbon budget. The Taiwan Strait receives abundant terrestrial OC from the Taiwan Island. To better understand the sources and controls on the OC burial in the Taiwan Strait. We measured the lignin and hopanoid molecular biomarkers in the Taiwan Strait. Together with the N/C and δ13Corg data (Liao et al., 2018), we estimate the proportions of OC derived from soil, plant, petrogenic and marine using a four end-member mixing model. The results indicate that the fractional contributions of soil, bedrock, plant and marine OC are 9–28%, 31–61%, 7–31%, and 13–46%, respectively. Petrogenic OC is the main component of the burial OC in the Taiwan Strait, with buried carbon budget up to 0.19×106 t C yr−1. This finding highlights the need for better constrain of terrigenous OC to better understand the carbon cycling and burial in marginal seas with high-standing islands and/or highly eroded mountains.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-6: Biomarker and isotopic proxies for reconstructions of paleoclimate and paleoceanography
Presentation Preference: Oral Preferred

Metabolism variation of heterotrophs recorded by compound-specific hydrogen isotopes over the past 3000 years in Antarctica

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Keywords: Lipid biomarkers, Hydrogen isotope ratios, Metabolism, Paleo-ecological changes, Antarctica

Hydrogen isotopes ratios of lipids are strongly correlated with metabolism: strongest 2H-depleted in chemoautotrophs, moderately 2H-depleted in photoautotrophs and slightly 2H-enriched in heterotrophs (Zhang et al., 2009; Wijker et al., 2019). These features highlight the potential using compound-specific hydrogen isotopes to provide meaningful insights into the metabolism of modern and ancient microorganisms. Up to now, however, there is no study concentrating on whether such isotope signals can be used to infer the metabolism on geologic times. Furthermore, what environmental factors affect the changes of central metabolic pathways in heterotrophs remain elusive. Here we performed the analysis of the compound-specific hydrogen isotopes in two lacustrine sediment profiles (IIL3 and IIL9) sampled at Inexpressible Island, western Ross Sea, Antarctica. We show that mid- and long-chain n-alkanoic acids all display “inverse” or reduced hydrogen isotope fractionations throughout these two explored sediment profiles, suggesting these compounds are predominantly originated from heterotrophic microbes. Large D/H fractionations indicate the central metabolic pathway of heterotrophs changed significantly during the past 3000 years. Compared with other proxies in the same cores, the central metabolic pathway of heterotrophs is driven by lake/pond productivity, which response to air temperature changes. Our results suggest that D/H variation in heterotrophic lipids has great potential as a proxy for inferring paleo central metabolism, which may provide curial information about ecological changes and carbon cycle on geologic times in Antarctica.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-6: Biomarker and isotopic proxies for reconstructions of paleoclimate and paleoceanography
Presentation Preference: Oral Preferred

Climate-induced wildfires during end-Permian and end-Triassic mass extinctions

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Keywords: polycyclic aromatic hydrocarbons,aridification,wildfire-climate-biota

The frequency and intensity of wildfires have a significant impact on landscapes and terrestrial ecosystems. Evidence of enhanced wildfires has been reported from both Permian-Triassic (P-Tr) and Triassic-Jurassic (Tr-J) transitional strata, which considered to be causally related to the Siberian Traps and Central Atlantic Magmatic Province, respectively. However, it remains unclear whether the enhancement of wildfires at sites distal to these volcanic sources was the result of climate change at a global scale (e.g., volcanically induced warming and aridification) or a regional scale (e.g., aridification linked to hydrological cycle changes). Here, we utilize pyrolytic polycyclic aromatic hydrocarbons (PAHs) to generate a high-resolution record of secular variation in wildfire frequency for terrestrial sections in China during the end-Permian (Dalongkou) and end-Triassic (Hechuan and Guangyuan) biotic crisis, with which we compare floral and faunal records of the same sections in order to evaluate wildfire-climate links. Two episodes of increased pyrolytic PAH concentrations and ratios of combustion origin in the subtropical terrestrial Dalongkou section of northwestern China during the P-Tr transition were linked to increased wildfire frequency, one triggered by climatic hyperwarming and the other by aridification, as revealed by spore-to-pollen ratios (S/P). Increased abundances of pyrolytic PAHs of wildfire origin found in the Hechuan and Guangyuan sections were also linked to increased wildfire frequency during the Tr-J transition, probably triggered by regional aridification. Our data demonstrate similar terrestrial ecosystem stresses from climate-induced wildfires outside of their respective regions of large igneous province (LIP) emplacement, as well as major floral turnovers, during the P-Tr and Tr-J events. We also compiled proxy data at a global scale to examine the geographic distribution of wildfires during each boundary event (Fig. 1), revealing a link between wildfire frequency and coal occurrence that was presumably mediated by the geographic distribution of forests. Although volcanism is likely to have been the ultimate cause of climate change during the P-Tr and Tr-J events, we infer that rapid local climate change (aridification) was the main cause of wildfires in South China. These results are highly significant in providing new insights into wildfire-climate-biota relationships in terrestrial systems during the two largest mass extinction events in Earth history.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-6: Biomarker and isotopic proxies for reconstructions of paleoclimate and paleoceanography
Presentation Preference: Oral Preferred

The impact of Labrador and North Atlantic currents in modulating sedimentation and climate on the northwest Atlantic Ocean during the last 40 ka

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Keywords: Labrador Current, Sea-Surface temperature, Laurentide Ice Sheet, Scotian Shelf, Newfoundland Basin

The SE Grand Banks and Scotian margin of the northwest Atlantic Ocean is the most dynamic region due to bathing by two distinct seasonal water masses: the equator flowing cold and fresh Labrador Current and northeast flowing warm and salty North Atlantic Current (NAC). Both regions witness dramatic changes in the sea-surface temperature and salinity and seasonal sediment-bearing plume and nutrients primarily derived from the neighboring landmasses and sea-ice melt freshwater. In the modern oceanographic setting, the Nova Scotia margin is mainly influenced by the NAC, whereas the SE Grand Banks is perturbed by a mixture of Labrador Current and NAC. Here we report changes in the sediment dynamics and sea-surface characteristics using five sediment cores, namely 93026-07, 96018-20 and 87003-07 from the Scotian margin and 2001043-027 and 9007-08 from the SE Grand Banks for the past 40 ka. Our data suggest two distinct dichotomies between the Scotian margin and SE Grand Banks in which glacial sediments were found in the upper slope of both regions, whereas the Holocene sediments were only reported from the former. The difference in sediment dynamics reflects erosion and sediment remobilization by the Labrador Current.

Further, the first application of the isoprenoid glycerol dibiphytanyl glycerol tetraethers (GDGTs) proxy TEX86 in these two regions revealed changes in two distinct thermal structures (i.e., sea-surface temperatures). Secondly, the branched GDGTs index (∑IIIa/∑IIa and BIT) and sediment bulk geochemical proxies (CaCO3% and Ca/Ti) were used to assess change in the terrigenous input.

Our TEX^{L}_{86}-derived temperature suggests the opposite trend between the two regions during the early Holocene and deglacial period, in which cooler sea-surface temperatures (SSTs) prevailed on the Scotian margin than on the SE Grand Banks. The difference in the SSTs reflects that the Labrador Current mainly influenced the Scotian margin during the early Holocene and deglacial period. However, it is hypothesized that the SSTs were most likely influenced by a mixture of the Labrador Current and NAC on the SE Grand Banks, which needs to be affirmed by additional proxies.

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Session T4-6: Biomarker and isotopic proxies for reconstructions of paleoclimate and paleoceanography
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Quantitative Holocene temperature evolution revealed by lacustrine brGDGTs record from southwestern China

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Keywords: Holocene, temperature, GDGTs, southwestern China

Holocene temperature cooling or warming is highly controversial, partly due to the lack of high-quantity temperature record. Here, we present a high-resolution, no seasonal bias and no hydrology affected Holocene temperature record from southwest China. The temperature record showed an overall cooling trend during 10-0 ka BP, accompanying with several centennial scale abruptly cold events. These signals are supported by other temperature records from China monsoon region and global synthesized temperature records. Our result indicates that the seasonal bias might not be responsible for the discrepancy between the large region synthesized results and model simulated results. In addition, we find the human activities in the Anthropocene have not only cause a rapid increase in temperature during the background of a long cooling trend in the Holocene, but also led to a decouple between temperature and precipitation in southwest China.

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-6: Biomarker and isotopic proxies for reconstructions of paleoclimate and paleoceanography
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Seasonal imprint of Holocene temperature reconstruction on the Tibetan Plateau

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Keywords: Seasonal temperature, Holocene, Tibetan Plateau, Insolation, Greenhouse gas forcing

The Tibetan Plateau (TP) is one of the most sensitive areas to global climate changes. Quantitative paleotemperature reconstructions on the TP since the Last Deglaciation provide a prominent opportunity not only for assessing the position, but also for better understanding the mechanism of recent warming. In this study, we first present a well-dated, high-resolution (~70 years), ice-free-season temperature (from March to October, TM-O) record over the past 19 ka from a small alpine lake on the southeastern TP based on brGDGT proxy. Our reconstructed TM-O record displays a long-term ~4 ◦C warming trend during the past 19 ka with a deglacial increase of ~3 ◦C and Holocene increase of ~1 ◦C. To better understand the pattern and mechanism of postglacial temperature changes on the TP, we review 16 published paleotemperature records since the Last Deglaciation. The results show a general warming pattern during the Last Deglaciation but divergent trends of seasonal temperatures during the Holocene with a gradual cooling pattern in summer temperature, an overall warming pattern in winter temperature, annual temperature, and TM-O as well as a warming-cooling-warming pattern in TMJJAS (temperature from May to September). Data-model comparison indicates that the long-term warming trend in deglacial temperatures are primarily driven by rising atmospheric greenhouse gases (GHGs) on the TP. In contrast, Holocene temperature changes are mainly controlled by local seasonal insolation and additional radiative forcing of GHGs on the TP, thereby resulting in divergent patterns of seasonal temperature changes. Our study highlights the necessity of taking into account the seasonal bias when reconstructing temperatures, especially in high latitudes and high altitudes where the freezing occurs.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-6: Biomarker and isotopic proxies for reconstructions of paleoclimate and paleoceanography
Presentation Preference: Oral Preferred

Enhanced precipitation in the Gulf of Mexico during the Eocene–Oligocene transition driven by interhemispherical temperature asymmetry

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Keywords: Gulf of Mexico, Compound Specific Isotope Analysis, Lipid wax, Eocene-Oligocene Transition

Studies reveal that the sea-surface temperature (SST) of the Northern Hemisphere decreased at a smaller amplitude than that of the Southern Hemisphere during the Eocene–Oligocene transition (EOT). This interhemispheric temperature asymmetry has been associated with intensified Atlantic Meridional Overturning Circulation (AMOC) that may have driven enhanced precipitation and weathering in low latitudes and the subsequent drawdown of atmospheric carbon dioxide. However, no quantitative constraints on paleo-precipitation have been reported in low latitudes to characterize the AMOC effect across the EOT. Here, we present the results of high-resolution (ca. 6 k.y. per sample) isotopic and biomarker records from the Gulf of Mexico. Reconstructed precipitation using leaf wax carbon isotopes shows an increase of 44% across the EOT (34.1–33.6 Ma), which is accompanied by a secular increase in SST of 2 °C during the latest Eocene. We attribute the enhanced precipitation in the Gulf of Mexico to the northward shift of the Intertropical Convergence Zone that was driven by an enlarged polar-tropic temperature gradient in the Southern Hemisphere and an invigorated AMOC. Our findings link changes in meridional temperature gradient and large-scale oceanic circulation to the low-latitude terrestrial hydroclimate and provide paleohydrological evidence that supports CO2-weathering feedback during the EOT “greenhouse” to “icehouse” transition.

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-6: Biomarker and isotopic proxies for reconstructions of paleoclimate and paleoceanography
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Spatial distribution of n-alkanes in the catchment and sediments of Lake Lugu, Southwest China: Implications for palaeoenvironment reconstruction

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Keywords: n-Alkanes, Lake surface sediment, Spatial distribution, Water depth, Palaeoenvironment reconstruction

n-Alkanes have been widely used to reconstruct palaeoenvironmental variations in lacustrine environments. However, for robust reconstructions, improving the understanding of the origin of n-alkanes and their distribution within the lake is essential. Therefore, we examined the distribution pattern of n-alkanes in the aquatic plants within Lake Lugu (a deep alpine lake on the southeastern margin of the Tibetan Plateau, southwest China), and terrestrial plants and topsoils in the catchment, to unravel the origin of sedimentary n-alkanes and further investigate the spatial distribution of n-alkanes from surface sediments in this lake. The aquatic plants are dominated by mid-chain C23 and C25, terrestrial plants and soils by long-chain C29, and 76% of the surface sediment samples show C29 predominance. The average chain length (ACL) and the aquatic plant proxy (Paq) values of surface sediments are between those of aquatic and terrestrial plants and soils. Thus, n-alkanes from autochthonous (aquatic plants) and allochthonous (terrestrial plants and soils) sources were apparent in the surface sediments. A substantial spatial distribution of n-alkanes exists within Lake Lugu: the n-alkane concentrations of total, aquatic, and terrigenous origins are concentrated in the northwestern portion of the lake's north basin, which may be attributed to the underwater topography and increased human-induced soil erosion in this area. Similarly, the clear spatial heterogeneity of ACL21-33 and Paq may suggest that the sedimentary n-alkanes comprise a mixture contribution of autochthonous and allochthonous production, which might be the major source of n-alkanes in the lakeshore, and a higher proportion of autochthonous n-alkanes is present in deep water. However, there is no significant correlation between the Paq of sediments and water depth in Lake Lugu; thus, the application of Paq as a lake-level indicator should be used with caution in deep-water lakes similar to Lake Lugu.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-6: Biomarker and isotopic proxies for reconstructions of paleoclimate and paleoceanography
Presentation Preference: Oral Preferred

Late deglacial methane leak from low latitude northern hemisphere

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Keywords: Glycerol Dialkyl Glycerol Tetraethers, Shenhu hydrate zone, methane leak, late deglacial

Released methane to sea water and atmosphere, marine hydrate dissociation is a vital issue on discussing global climate. Understanding the last glacial and interglacial cycle hydrate leak helps us depict the future. In this study, we take Northern Hemisphere low latitude hydrate zone as an example, trying to reveal the geological records of hydrate leak, especially from deglaciation which is a mirror-like recent period of modern climate. We conduct this work using biogeochemistry proxies from Glycerol Dialkyl Glycerol Tetraethers (GDGTs) and foraminifera stable carbon isotope. Our results from Shenhu hydrate zone in the South China Sea record cold periods methane release during Last Glacial Maximum, that is known to be a result of hydrostatic pressure reduction. Interestingly, we found obvious methane leak in deglacial period. Abrupt intermediate water temperature increase might probably be one of the reasons that trigger this warm period methane release. Northern Hemisphere high latitude (near Arctic) also featured by deglacial hydrate dissociation. However, records from north pole is a little bit earlier. This might be caused by lagged drastic changes in low latitude ocean circulation when global climate abruptly warming up after long cool period. Our study shows that low latitude Northern Hemisphere marine CH4 leakage likely contribute to deglacial and early Holocene warm period air CH4 optimum.

Session T4-7: Carbon, nitrogen and sulfur cycles and Earth systems evolution

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-7: Carbon, nitrogen and sulfur cycles and Earth systems evolution
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Characterization of the sediments in a gas hydrate reservoir in the northern South China Sea: Implications for gas hydrate accumulation

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Keywords: Gas hydrates, sedimentary processes, sediment physical properties, microbial abundance, South China Sea

As a potential major energy resource, gas hydrates are widely found in sub-oceanic sediments and could play an important role in the future of fuels. Many studies have been applied on gas hydrates reservoir to understand its accumulation as well as potential industrial values, while the characteristics of sediments favoring gas hydrates accumulation are still unclear. Here, we investigate a gas hydrates reservoir in Shenhu area, Pearl River Mouth Basin, South China Sea (SCS), studying reservoir sediments features to understand controlling factors of gas hydrates accumulation. We sampled sediments of drilling site W19 in this area, which has thick, high saturation gas hydrate layers, and analyze sediments' physical properties (including the grain size, mineral composition, and specific surface area), and microbial abundance in the gas hydrate-bearing and adjacent layers. The results show fine-grained turbidite sediments characterized by poor sorting, high foraminifera abundance, and low clay mineral content, are beneficial to gas hydrate accumulation, while suspended sediments characterized by fine sorting, high calcareous ultra-microfossil abundance, and high clay mineral content, are not conducive to gas hydrate accumulation. Based on these results, we propose multiple factors, including the sedimentary processes, sorting, microbial abundance, mineral composition, and specific surface area, has been controlling the gas hydrate accumulation in the SCS and it could potentially reveal the regularity of gas hydrate accumulation on a global scale.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-7: Carbon, nitrogen and sulfur cycles and Earth systems evolution
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Diagnostic multiple sulfur isotope patterns of sulfate-driven anaerobic oxidation of methane

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Keywords: Methane, Anaerobic oxidation of methane, Organoclastic sulfate reduction, pore-water sulfate; Sulfide

Sulfate-driven anaerobic oxidation of methane (SD-AOM) is ubiquitous in sedimentary environments, leaving an imprint in pyrite sulfur isotope ratios. However, the $\delta^{34}S$ values of pyrite alone are insufficient to discriminate SD-AOM signals from organoclastic sulfate reduction (OSR). Here, we investigated the multiple sulfur isotope ratios ($\delta^{34}S$ and $\Delta^{33}S$ values) of pore-water sulfate and sulfide, and authigenic pyrite of two piston cores and one push core from the continental slope of the South China Sea. Multiple sulfur isotope systematics reflect methane fluxes at the site. At a low methane flux site, a positive $\Delta^{33}S_{SO4}$ - $\delta^{34}S_{SO4}$ correlation of pore-water sulfate is observed in the upper, OSR-dominated zone, whereas they are negatively correlated in the sulfate-methane transition zone (SMTZ). At high methane flux site, the whole sulfate reduction zone is dominated by SD-AOM and own a negative $\Delta^{33}S_{SO4}$ - $\delta^{34}S_{SO4}$ correlation typified by different slopes under variable methane flux. The multiple sulfur isotope systematics of pyrite in methane-bearing sediment depend on the relative contribution of SD-AOM and OSR to the sulfide pool. This study provides a revised $\Delta^{33}S$ - $\delta^{34}S$ systematics of sulfide and sulfate minerals for tracing past SD-AOM activity and the different origins of pyrite.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-7: Carbon, nitrogen and sulfur cycles and Earth systems evolution
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Timing of fluid and gas expulsion on the northern Gulf of Mexico continental slope

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Keywords: Authigenic carbonate, cold seep, AMS 14C, U/Th dating, Gulf of Mexico

Anaerobic oxidation of methane (AOM), mostly taking place at cold seeps, represents the major present-day sink for this important greenhouse gas that generated in marine sediments. This process often leads to formation of authigenic carbonates close to the seafloor along continental margins. Authigenic carbonates from hydrocarbon seeps are thus unique archives of past seepage and associated environmental parameters. Here, we applied accelerator mass spectrometry (AMS) radiocarbon (14C) and Uranium/Thorium (U/Th) dating to carbonates collected at nearly 50 seep sites from the northern Gulf of Mexico continental slope. The resulting ages indicates that carbonate from sites with water depth over 500 m usually much younger than 50 ka whereas carbonates from sites with water depth less than 500 m are often older. Although a wide range of frequencies was observed for gas and fluid expulsion events, it is suggested that enhanced seepage occurred following a sediment loading cycle. Our results highlight that sediment loading can have a strong impact on gas and fluid expulsions affecting slope stability and the carbon cycle.

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-7: Carbon, nitrogen and sulfur cycles and Earth systems evolution
Presentation Preference: Oral Preferred

Biomarker and isotopic signatures of bacterial sulfate reduction at oil-seeps in the southern Gulf of Mexico

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Keywords: Oil seeps, Oil degradation, Sulfate-reducing bacteria, DAGEs, Gulf of Mexico, Makran accretionary prism

Hydrocarbon seeps are ubiquitous along continental margins and can exhibit varying fluid compositions. Most seeps are dominated by methane, but different contributions of short- and long-chain hydrocarbons, as well as crude oil are common. The Campeche Knolls in the Southern Gulf of Mexico are known for extensive oil seepage, which has an inhibiting effect on life at seeps. However, short- and long-chain hydrocarbons have been shown to be degraded by a range of heterotrophic sulfate-reducing bacteria. Here lipid biomarker and carbon isotope data from authigenic carbonates from the Campeche Knolls in the southern Gulf of Mexico are presented, indicating sulfate-reduction of oil-derived hydrocarbons and associated carbonate precipitation. The carbonates show $\delta^{13}C$ values in the range of -31.3‰ to -21.9‰, agreeing with carbon derived from oil-derived hydrocarbons. The occurrence of a particularly high amount of bacterial non-isoprenoidal ether lipids (DAGEs) with a wide variety of alkyl chain lengths was observed. Additionally, bacterial biomarkers show heavier carbon isotopic signatures than their counterparts at methane seeps. Mixing calculations revealed that a substantial part of the local sulfate reduction is coupled to the oxidation of non-methane hydrocarbons at oils seeps, contributing to authigenic carbonate precipitation. These data imply the possible characterization of bacterial oxidation of oil-derived hydrocarbons in modern and, in cases of moderate to good biomarker preservation, ancient environments, allowing for the estimation of the influence of fluid composition on chemosynthesis-based communities at seeps.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-7: Carbon, nitrogen and sulfur cycles and Earth systems evolution
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Seepage activity archived in the sedimentary fabric of microcrystalline seep carbonates: a case study from the Shenhu area, South China Sea

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Keywords: Bioturbation, burrows, seep carbonates, South China Sea

Seepage is widely distributed along continental margins worldwide, emitting methane and other reduced compounds into seawater or even the atmosphere. Since methane is an energy source on the one hand and greenhouse gas on the other hand, tracing seep activity is of environmental significance. Past seep activity is recorded by authigenic seep carbonates, the formation of which is induced by the high alkalinity produced by sulfate-driven anaerobic oxidation of methane (SD-AOM). Microcrystalline high-Mg calcite, in addition to botryoidal aragonite, is the common sedimentary fabric of seep limestones. The microcrystalline matrix is commonly pierced by burrows, which are subsequently filled by newly formed carbonate cement at later stage of seep activity. Here, we report infilled burrows in seep carbonates from the Shenhu area, occurring as longitudinal, winding and branched fabrics with a width of 400 to 700 μm. The infilled burrows and surrounding matrix are both cemented by microcrystalline seep carbonates. The carbonates in burrows show overall lower relative contents of dolomite, Mg/Ca ratios, and higher carbon isotope values. Since SD-AOM promotes the formation of carbonates with higher $MgCO_3$ contents and results in lower carbon isotope values than carbonates forming from marine dissolved inorganic carbon, the early stages seep carbonate formation in the matrix were more strongly controlled by SD-AOM, whereas the carbonate precipitating in burrows was influenced to a higher degree by marine conditions after the ingress of seawater into burrows.

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-7: Carbon, nitrogen and sulfur cycles and Earth systems evolution
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Element geochemistry of a diagenetically altered Jurassic seep deposit

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Keywords: Hydrocarbon seeps, Authigenic carbonate, Diagenesis, Clotted micrite, Trace elements

Geochemical analyses of ancient seep limestones provide information on the chemical composition of seep fluids, facilitating for the reconstruction of the early evolution of chemosynthesis-based faunal communities. However, diagenetic processes often mask the primary composition of seep carbonates, impeding a reliable reconstruction of formation environments. The potential for the preservation of primary element patterns in microcrystalline carbonate, which is typically the volumetrically dominant phase of seep limestones, is poorly constrained to date. This study investigates ancient seep limestones collected from the Blue Mountains of eastern Oregon, USA, where seep limestones are composed of three different carbonate phases, including clotted calcite, banded and botryoidal cement, and equant calcite. Mineralogically, these three carbonate phases are now calcite characterized by low magnesium/calcium (Mg/Ca) ratios. The fibrous crystal habit of the botryoidal and banded cement indicates that the precursor mineral was originally aragonite. However, low strontium (Sr) contents and positive europium (Eu) anomalies of botryoidal cement suggest that this phase was affected by diagenetic alteration. Equant calcite exhibits the largest crystal size and the highest manganese/strontium (Mn/Sr) ratios, suggesting that this phase was the product of later-stage diagenesis, probably having precipitated during progressive burial. High Sr contents and low Mn/Sr ratios of clotted micrite suggest that this phase was less affected by diagenetic alteration, and has the highest preservation potential with respect to the original seep fluid composition. Shale-normalized rare earth elements and yttrium (REY) patterns of clotted micrite are similar to those found for modern seawater, agreeing with a close to primary composition of clotted micrite. Despite of its small crystal size, our study suggests that clotted micrite may have the potential to preserve information on fluid composition.

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-7: Carbon, nitrogen and sulfur cycles and Earth systems evolution
Presentation Preference: Oral Preferred

Trace element distribution in methane-seep carbonates: The role of mineralogy and dissolved sulfide

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Keywords: Black Sea, Methane seeps, Trace elements, Carbonate mineralogy

Trace elements are widely used to constrain environmental conditions and biogeochemical processes. Authigenic carbonates in particular are a reliable archive due to their ability to take up and store trace elements over geologic timescales. Here we present new data on the effect of ambient redox conditions on trace element distributions in authigenic seep carbonates forming in different geochemical and hydrographic environments. Carbonates from shallow and deep-sea hydrocarbon seeps of the Black Sea are compared to seepage sites from the northern Gulf of Mexico and the northern South China Sea, revealing that trace element inventories are to some extent site-specific and depend on carbonate mineralogy. Strongly euxinic conditions at Black Sea deep-water seeps favor the formation of low-magnesium calcite, whereas fluctuating redox conditions favors aragonite cement precipitation. The trends in mineralogy are accompanied by distinct enrichments and depletions of specific trace elements including uranium, iron, and manganese. Aragonite cements exhibit lower magnesium to strontium ratios and manganese contents than their low-magnesium calcite counterparts. Moreover, trace elements in Black Sea carbonates are enriched in barium, manganese, zinc, and nickel, and are depleted in iron. The new trace element data suggest that the presence of dissolved sulfide influences carbonate mineralogy, and, accordingly, trace element speciation and content. The results of this study have implications for trace element-based paleoenvironment reconstructions beyond seep environments, and may initiate a reassessment of authigenic carbonates as a trace element archive, in particular for carbonates from ancient and modern euxinic environments.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-7: Carbon, nitrogen and sulfur cycles and Earth systems evolution
Presentation Preference: Oral Preferred

Orbitally-driven nutrient pulses linked to early Cambrian oxygenations and animal radiation

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Keywords: Cambrian Radiation, Coupled C-S isotopes, Orbital Cycles, Redox Cycles.

During the Cambrian Explosion, episodic radiations of major animal phyla occurred in concert with repeated carbon and sulfur isotope excursions. These isotope patterns are thought to reflect oscillations in atmospheric O2, which promoted animal diversification events. However, the driver for isotopic and redox variation is unclear. Here we show that these synchronous carbon and sulfur isotope cycles, as well as marine oxygenation pulses, can be driven by long-period orbital forcing and its effects on weathering and nutrient delivery. We use spectral analysis to confirm that the isotope periodicities correspond to the long-period eccentricity obliquity cycles, and then explore the effects of this orbital forcing using a combined climate-biogeochemical model.

The model produces a fluctuating bioavailable phosphorus flux, which results from the varying latitudinal distribution of temperature, which drives pulses of oceanic photosynthetic productivity and organic carbon burial. The model also reproduces the unusual co-variation of carbon and sulfur isotopes, which occurs due to low seawater sulfate concentration and highly variable rates of pyrite burial.

We conclude that the oxygen-driven evolutionary changes in the early Cambrian can be explained by recurrent nutrient inputs to the ocean, which probably resulted from climate change caused by long-period orbital cycles. Such long-period cyclicity may explain other time periods that saw biogeochemical oscillations on these timescales.

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-7: Carbon, nitrogen and sulfur cycles and Earth systems evolution
Presentation Preference: Oral Preferred

The paleoceanic environment and exceptional fossil preservation in the Middle Triassic Luoping Biota from South China

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Keywords: Luoping biota, productivity, exceptional preservation, anoxia, Middle Triassic

The Luoping Biota is a typical representative of the full recovery of marine ecosystem after the Permian–Triassic Mass Extinction (Hu et al., 2011; Chen and Benton, 2012; Benton et al., 2013), yet the paleoenvironment background and ultimate cause of fossil preservation is still not well understood (Bai et al., 2010; Zhou et al., 2014; Ma et al., 2021). Here we presented sedimentary facies and multi-geochemical proxies (TOC, TN, δ13Ccarb, and δ13Corg, P/Al, Cuxs, Nixs, Baxs, MoEF, UEF, and VEF) in Member II of the Middle Triassic Guanling Formation at the Xiangdongpo section from Luoping County, Yunnan Province, to unravel the evolution of sedimentary environment, primary productivity, paleoredox condition and their link to the exceptional preservation of Luoping biota. The abundant exceptional preserved fossils mainly occur in two intervals from intra-platform depression environment, with high productivity and anoxia. Relatively low C/N ratios and distributed Δ13Ccarb-org indicate the source of primary productivity is derived from a mixture of eukaryotic algae and prokaryotic microbes. Based on the results of this study and regional correlation, it is concluded that when the sea level rose, nutrients were supplied to the Luoping area by Megamonsoon induced upwelling from the open ocean, fueled high primary productivity in surface water and oxygen consumption in the water column, causing bottom water anoxia. The lack of oxygen in the bottom water reduced the rate of biomass degradation and bioturbation, promoted the growth of microbial mats, and led to the exceptional preservation of macrofauna fossils.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-7: Carbon, nitrogen and sulfur cycles and Earth systems evolution
Presentation Preference: Oral Preferred

Terrestrial carbon cycle implications from compound-specific carbon isotopes in Southwest China during the Permian-Triassic mass extinction

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Keywords: Permo-Triassic transition, Southwest China, compound-specific carbon isotopes

Anthropogenic emissions disrupt modern global carbon cycle perturbated potentially far greater in magnitude and rate than variations in the recent past. The deep-time analogue through the Permo-Triassic (P-Tr) transition, which witnessed the largest mass extinction in Phanerozoic with substantial carbon perturbations and climate warming (Sun et al., 2012), could provide potential insights into the impact CO_2 on ecosystems. This extinction is thought to have been triggered by Siberian Traps large igneous province magmatism (Burgess et al., 2017). Multiple investigations have identified a large negative carbon isotope excursion of 3‰-6‰ in both marine carbonate and bulk sedimentary organic matter during the P-Tr boundary (Korte and Kozur, 2010). However, ultimate trigger mechanisms of the CIE remain dispute and bulk organic $\delta^{13}C$ is mixed signals of organic matter from different sources. The source uncertainty would be removed by compound carbon specific isotope compositions in *n*-alkanes, which offers a more specific proxy to distinguish different organic source and has been employed to interpret carbon cycle and paleoclimate (Diefendorf and Freimuth, 2017). Here, we undertake a survey of *n*-alkanes $\delta^{13}C$ values in a P-Tr boundary sequence ZK4703 in Southwest China. *n*-alkanes $\delta^{13}C$ are more negative but highly correlated with $\delta^{13}C_{org}$, $\delta^{13}C_{cuticle}$ and $\delta^{13}C_{charcoal}$ (R^2 = 0.62, 0.71, 0.64, respectively) published data from (Chu et al., 2020). *n*-alkanes $\delta^{13}C$ shows values around -25‰ in the Xuanwei Formation, then decreased to -30‰~-36‰ in the lowest part of the Kayitou Formation. It is suggested that massive volcanic CO_2 release, and large quantities of ^{13}C-depleted carbon emission from organic matter and methane are triggers of the carbon cycle perturbation as a global control, though some regional controls existed, e.g., effective moisture and methane oxidation. The carbon perturbations presented here would provide insights into the climate of future due to global warming and high greenhouse gases caused by anthropogenic emissions.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-7: Carbon, nitrogen and sulfur cycles and Earth systems evolution
Presentation Preference: Oral Preferred

Carbon sequestration of the middle Miocene Sunda Shelf facilitated global climate change

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Keywords: Sunda Shelf, Carbon cycle, Middle Miocene, Climatic transition

Extensive land-sea redistribution of the low latitudes could induce significant climatic change at regional and global scales. The Sunda Shelf (SS) exposure has been proven to drive the tropical climatic evolution during the Last Glacial Period by geological records and modeling. However, due to the lack of scientific drilling, its role in much older geological periods remains unclear and has been generally ignored in previous studies, even though periodical flooding and exposure have occurred since at least the early Miocene. To resolve this issue to a certain extent, we compile the sedimentary records of the SS basins during the middle Miocene, which was characterized by a crucial transition from climatic optimum to profound global cooling. Sea level stayed high during the middle Miocene Climatic Optimum (MCO) and dropped in steps along with high-latitude cooling events of the middle Miocene Climatic Transition (MMCT). In this sequence framework, organic carbon amounts of the SS sediments deposited during the two crucial periods were qualified and further used to estimate atmospheric CO2 sequestration considering these immature source rocks had not undergone large-scale hydrocarbon generation and migration. Our results indicated that carbon sequestration took place at the fastest rate in paralic environments during the MMCT. Compared with the MCO, the increased sequestration rate is equivalent to a drawdown of ca. 100 ppm atmospheric CO2 per Myr, accounting for about 30 % of the global atmospheric CO2 decline rate through the MMCT. This study certified that gradual exposure of the SS during the middle Miocene could likely facilitate the climatic transition via altering global carbon cycles.

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-7: Carbon, nitrogen and sulfur cycles and Earth systems evolution
Presentation Preference: Oral Preferred

Linkage of the late Cambrian microbe-metazoan transition (MMT) to shallow-marine oxygenation during the SPICE event

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Keywords: Sulfur isotopes, Framboidal pyrite, Ocean oxygenation, Microbialite, Metazoan reefs, North China

Microbe-metazoan transitions (MMTs), representing a switch from microbe-mediated to metazoan-mediated carbonate production, have been linked to major changes in Earth-surface conditions. The 'late Cambrian MMT' (nomen novum), during which microbial reefs were replaced by maceriate and lithistid sponge reefs, coincided with a sharp rise in atmospheric O_2 levels attributed to the Steptoean Positive Carbon Isotope Excursion (SPICE) at ~497-494 Ma. However, relationships between atmospheric oxygenation, marine redox conditions, and the MMT have not been thoroughly investigated to date. Here, we conducted paired analyses of carbonate carbon isotopes ($\delta^{13}C_{carb}$), sulfur isotopes of carbonate-associated sulfate ($\delta^{34}S_{CAS}$) and pyrite ($\delta^{34}S_{Py}$), pyrite morphologies, and fossil assemblages of two upper Cambrian shallow-marine sections on the North China Platform (Tangwangzhai and Huangyangshan). The sulfur isotopic composition of framboidal pyrite ($\delta^{34}S_{FrPy}$) was calculated from that of total pyrite ($\delta^{34}S_{TPy}$) assuming a varied fractionation with euhedral pyrite based on pyrite morphological analyses. Modelling of S-isotope fractionations ($\Delta^{34}S_{CAS\text{-}FrPy}$) indicates that contemporaneous seawater had low sulfate concentrations (i.e., $[SO_4^{2-}]$sw ~4-6 mM) with locally high spatial heterogeneity during the Rising SPICE (early to middle Paibian), which were the product of massive burial of pyrite (together with organic matter) as a consequence of extensive oceanic anoxia. Immediately following the SPICE, a reduced pyrite burial rate and an increased flux of terrestrially sourced, ^{34}S-depleted sulfate to shallow-marine environments resulted in lower $\delta^{34}S_{CAS}$ values. At that time, $[SO_4^{2-}]$sw rose to a maximum of ~9-16 mM and became more uniform during the Post-SPICE (middle to late Jiangshanian), suggesting a more oxidized condition of seawater and the atmosphere. Rising O_2 levels in both the atmosphere and marine environments triggered the late Cambrian MMT and set the stage for the subsequent Great Ordovician Biodiversity Event.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-7: Carbon, nitrogen and sulfur cycles and Earth systems evolution
Presentation Preference: Oral Preferred

Progressive expansion of marine anoxia linked to decline of invertebrate diversity in the Middle to Late Ordovician Yangtze Sea

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Keywords: Nitrogen isotopes, Mo isotopes, ocean redox, climatic cooling, GOBE

The Great Ordovician Biodiversification Event (GOBE) achieved its peak during the Middle Ordovician, likely in association with climatic cooling and a rise of atmospheric O_2. However, unstable redox states developed widely in contemporaneous epeiric seas, challenging previous assumptions about sustained oceanic oxygenation driven by deep-ocean ventilation in the aftermath of Ordovician cooling. Herein we investigate two Middle-Upper Ordovician shale-dominated successions from intra-shelf basin and slope settings of the Yangtze Sea, South China. Negative shifts in bulk $\delta^{15}N$ and productivity proxies reveal temporal changes in the pattern of nutrient cycling under moderate-to-high productivity conditions, which is probably sustained by increased cold and nutrient-rich upwelling in pace with the pulse of climatic cooling. As a result, marine anoxia likely expanded in deep-waters of the Yangtze Sea, as reflected in enrichments of highly reactive iron and redox-sensitive metals (Mo, U). Although moderate Mo abundances (25-50 ppm) and $\delta^{98/95}Mo$ values (+0.4 to +0.8‰) within the euxinic interval suggest the possibility that bottom waters were featured by low sulfide concentrations, the $\delta^{98/95}Mo$ values are comparable to those of coeval euxinic facies (~ +0.6‰). Weak operation of particle shuttle may have also contributed to low $\delta^{98/95}Mo$ values, but this influence is considered quite limited given no consequent correlation between the enrichment of Mo relative to U and $\delta^{98/95}Mo$ for euxinic sediments. Furthermore, modeling results show that low seawater $\delta^{98/95}Mo$ can be produced when sulfidic sinks dominate Mo removal, and suggest the ocean was not such oxygenated as previously assumed for the Mid-Late Ordovician. Our findings thus, for the first time, potentially link the pulse of expanded marine anoxia and climatic cooling to a decline in the species diversity of marine invertebrates following the peak of GOBE.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-7: Carbon, nitrogen and sulfur cycles and Earth systems evolution
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Analysis of integrated C-S-Fe cycling along the Panthalassic transect across the Pliensbachian-Toarcian

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Keywords: Toarcian Oceanic Anoxic Event, C-S-Fe cycling, Panthalassa

The early Toarcian Oceanic Anoxic Event (T-OAE; ~183 Ma) (Jenkyns, 1988) was one of the most significant environmental perturbations of the Mesozoic, characterized by a pronounced carbon cycle perturbation, widespread deposition of organic-rich sediments and seawater deoxygenation, as well as a minor mass extinction. Similar climate and environmental perturbations likely occurred across the Pliensbachian-Toarcian (Pl-To) boundary. However, the extent and significance of deoxygenation from the late Pliensbachian to early Toarcian is unclear due to the lack of records, especially deep-water archives outside of Europe. Here, we present high-resolution stable sulfur isotopes of reduced metal-bound sulfur ($\delta^{34}S_{pyrite}$), pyrite sulfur concentrations (S_{PY}), Fe-speciation and trace element concentration data from two Panthalassic Ocean sections across the Pliensbachian–Toarcian boundary (Pl/To) and the T-OAE, one deposited in deep water (Sakahogi section, paleo-water depth >~2.7 km) and the other on a shallow margin (Sakuraguchi-dani section, paleo-water depth likely <~50 m). Marked positive $\delta^{34}S_{pyrite}$ excursions of >10‰ across both the Pl-To and the T-OAE at Sakahogi, and a positive excursion of >20‰ at the onset of the T-OAE at Sakuraguchi-dani are most likely controlled by increased organic matter supply to seafloor and sedimentation rates, respectively, while expanded anoxic/euxinic conditions may have played a significant role in the enrichment of pyrite. Fe-speciation and trace element data from the deep-water site indicate that anoxic/ferruginous conditions characterized the open Panthalassic Ocean from the late Pliensbachian to the end of the T-OAE. This site shows evidence for potentially euxinic pore waters near the Pl-To boundary, and euxinic bottom water across the T-OAE, with a transition towards more oxygenated conditions after the T-OAE. Fe-speciation data from the shallow water site also ostensibly suggest anoxic/ferruginous conditions across the T-OAE, but trace element and sedimentological data indicate oxygenated to possibly suboxic conditions. This ambiguity can be attributed to the upwelling of waters from the deep ocean, which brought ferruginous water to the shelf, whereupon Fe^{2+} was oxidized in oxic shallow waters and deposited largely *in situ*.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-7: Carbon, nitrogen and sulfur cycles and Earth systems evolution
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Geochemical characteristics of cold seeps in southern South China Sea

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Keywords: geochemistry, cold seeps, sediment, pore water, southern South China Sea

Cold seep, characterized by active material circulation and methane seepage, is of great importance to reconstruct the paleo-marine environment and trace the origin of life and the occurrence of minerals. Southern South China Sea (SCS) with ample oil and gas resources is an ideal platform for cold seep study, but information and researches on cold seeps here are rather deficient. We studied the geochemical characteristics of sediment cores and pore water combined with seismic profile information in the Beikang Basin, aiming to further understand the nature of cold seeps in this area. The extremely low δ13CDIC of pore water at each core indicates a strong anaerobic oxidation of methane (AOM) function and a major source of biogenic methane. The sulfate methane transition zone can be characterized by profiles of SO42-, the high content of inorganic carbon (DIC) and the corresponding minimum δ13CDIC in pore water. The kink-type depth profiles of Sr, Ba and Ni enrichment factors and Sr/Mg in the sediments of BH-CL37 indicate the depth of the paleo SMTZ, denoting a past enhanced methane flux or the modern weakened cold seep activity. The features of Mo, U and REE constrain the reducing sedimentary environment. Combined with the seismic profiles, we conclude that fluid fluxes and tectonic settings greatly influence the sedimentary environment and geochemistry, leading to the prominenet regional differences in the properties and activities of cold seeps. This study of cold seep in southern SCS proves the variation of cold seep in time and space, stressing the necessity of further region-specific analysis towards different cold seeps; and the complex conditions of SCS do function well in offering multiple types of cold seeps.

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-7: Carbon, nitrogen and sulfur cycles and Earth systems evolution
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Integrated signatures of secondary microbial gas within gas hydrate reservoirs: a case study in the Shenhu Area, Northern South China Sea

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Keywords: hydrocarbon biodegradation, biomarkers, secondary microbial gas, gas hydrate

A series of highly saturated pore-filled gas hydrate deposits were recently discovered in the Shenhu area of northern South China Sea. However, the main hydrocarbon sources of the gas hydrates remain controversial. The main hypotheses include a shallowly buried microbial gas source or a deeply buried thermogenic hydrocarbon source. In this study, an integrated geochemical-microbial-geological analysis of gas hydrate and sediment samples from sites SC1 and SC2 in the Shenhu area was conducted to investigate the possible hydrocarbon sources, and to identify the signatures of the secondary microbial gases in the gas hydrate reservoirs. The results show that the gas hydrates from sites SC1 and SC2 exhibit the geochemical characteristics of secondary microbial gas ($C_1/(C_2+C_3)$ >100, –50.2‰<$\delta^{13}C$-C_1<–47.4‰), and the propane (C_3) component and liquid thermogenic hydrocarbons (C_{15+}) have been severely biodegraded (a strongly elevated $\delta^{13}C$-C_3 value and a high abundance of 25-norhopanes). In addition, we discovered that the in-situ Quaternary marine sediments exhibit relatively low generation potential of primary microbial gas because of the extremely low organic matter richness (total organic matter content (TOC)<0.3%) and low in-situ temperatures (5–18°C). Furthermore, a relatively high abundance of methanogens (~7%–15%) were detected within the gas hydrate reservoir, which may be attributed to the methane generation process of hydrocarbon biodegradation. Moreover, the geological-geophysical interpretations indicate that the distributions of the gas hydrate accumulations and the shallow gas pools are strictly controlled by the effective faults connecting them with the deeply buried thermogenic source rocks. These lines of evidence suggest a significant contribution of secondary microbial methane to sites SC1 and SC2, which further indicates that the main contribution was from deeply buried thermogenic hydrocarbon sources. Our results suggest that the secondary microbial methane within gas hydrates is an important terminal product that has been converted from thermogenic hydrocarbons via microbial degradation, which helps explain why the geochemistry of most of the hydrate-bound gas indicates a microbial origin even though the geological evidence indicates that the gas is mainly sourced from deeply buried thermogenic hydrocarbons.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-7: Carbon, nitrogen and sulfur cycles and Earth systems evolution
Presentation Preference: Oral Preferred

Petrographic features related to former presence gas hydrate in ancient seep carbonates: preliminary observations on modern and fossil material

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Keywords: Gas hydrates, authigenic carbonates, petrography, diagenesis

Carbonate formation at cold seeps occurs when methane is anaerobically oxidised by a consortium of methanotrophic archaea and sulfate reducing bacteria, in a process known as anaerobic oxidation of methane (AOM). The methane oxidised can be released from gas hydrates. Gas hydrates have recently received increasing attention due to their potential energy value and possible environmental impact such as greenhouse effects, slope instability etc.

In modern marine settings, seep carbonates commonly occur in close association with gas hydrates. Gas hydrates, however, are not preserved in the geological record. Therefore, hydrate-related authigenic carbonates (clathrites) represent quite specific seep carbonates and they are the only physical archives preserving evidence of the former presence of gas hydrates. Unfortunately, petrographic criteria typical of clathrites in the sediments that no longer contain gas hydrate are ambiguous. In fact, even though gas hydrates are common in modern marine sediments along continental slopes in all oceans and were very likely present at least throughout the Phanerozoic, there are surprisingly few records of ancient clathrites Compaction of cavities originally occupied by ice and/or gas bubbles as well as dissolution of metastable phases of methane-derived carbonates leads to fabric and petrographic changes obliterating or even extinguishing diagnostic features.

To develop petrographic criteria for clathrites, recent methane-derived gas hydrate-fed carbonates precipitated at seep sites of the Hydrate Ridge (Pacific, offshore Oregon) were compared with fossil counterparts. Among the few examples of paleoseep areas in which the former presence of gas hydrates has been suggested are the Piedmont Basin and the Northern Apennines (both Miocene in age and located in Italy) as well as the Outer Carpathians (Oligocene, Poland). The preserved features in the fossil authigenic carbonates depend on the diagenetic path experienced by those rocks, therefore their investigation is fundamental to understand the physical and chemical processes involved in carbonate precipitation. Here, some preliminary observations of these rocks can be shown.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-7: Carbon, nitrogen and sulfur cycles and Earth systems evolution
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Rising bottom-water temperatures induced methane release during the middle Holocene in the Okinawa Trough, East China Sea

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Keywords: anaerobic oxidation of methane (AOM), sulfate-methane transition (SMT), authigenic carbonates, Okinawa Trough, East China Sea

It is not currently well understood how a changing climate controls methane releases in the Okinawa Trough. In this study, a piston core was collected from a seep-impacted area at a water depth of approximately 1000 m from the Okinawa Trough, East China Sea, and was studied using comprehensive analyses of carbon and oxygen stable isotopes, lipid biomarkers, and major and trace element geochemistry. Extremely low δ13C values of total inorganic carbon and organic carbon, increased Methane Index, and molybdenum (Mo) and uranium (U) enrichments at depths of 225–255 cm below the sea-floor (bsf) and 75–142.5 cm bsf were found. Combined with published pore water data, fossil and current sulfate-methane transitions (SMTs) were identified. Mass balance equations were applied to estimate the fraction and content of authigenic carbonates at the two SMTs and their corresponding δ18O values. The calculations revealed that the estimated δ18O values of authigenic carbonates for the fossil SMT (from 4.9‰ to 5.8‰) and the current SMT (from -2.1‰ to 4.4‰) were higher and lower than the theoretical equilibrium δ18O value (4.8‰), respectively. These results suggest that fossil seepage is possibly induced by the dissociation of gas hydrates. The fluids of the current seepage may be derived from the equilibrium between the ambient seawater and the fluids of gas hydrate dissociation. Based on the accumulation of authigenic carbonate in sediments, previously published pore-water calcium and magnesium fluxes, and foraminifera 14C dating, the fossil methane seepage was confirmed to have occurred during the period 8.2 to 4.5 ka B.P., with its SMT depth less than 105 cm bsf, while the present-day methane seepage with a low fluid intensity was estimated to have started before 1.0 ka and formed its SMT at approximately 250 cm bsf. The timing of this fossil methane seepage suggests that the rising temperature of the North Pacific Intermediate Water during the early and middle Holocene mainly controlled the methane release in the Okinawa Trough, whereas the ongoing methane emission was likely induced by decreased pressure driven by back-arc extension. The geochemical data demonstrate past methane release as a response to environmental changes and suggest that the Okinawa Trough gas hydrates were sensitive to temperature fluctuations during the middle Holocene.

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Session T4-8: Biogenic minerals and rocks: formation mechanisms and their mineral resource and paleoenvironmental significances

ID: T4-80244

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-8: Biogenic minerals and rocks: formation mechanisms and their mineral resource and paleoenvironmental significances
Presentation Preference: Oral Preferred

Classification of biogenic carbonate rocks

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Keywords: Biolith, macrobiolith, microbiolith, framelite, bafflelite

All rocks formed by macroorganisms and microbes belong to bioliths, which are divided into macrobioliths and microbioliths. The macrobioliths are divided into the biolithites, i.e., reef rocks formed by macroorganisms, and the bioallolites composed of the skeletal grains and micrites formed by macroorganisms. The microbioliths are divided into calcimicroliths, ferromicroliths, mangamicroliths, and claymicroliths. The calcimicroliths are divided into microlithites (i.e., the reef rocks formed by microbes), microbialites, and the microallolites consisting of the grains formed from microlithites and microbialites and the micrites formed by microbes. The microlithite includes the framelite with a framework built by in situ skeletons of up-growing benthic microbes, bafflelite, and the filalite having a framework built by the in situ skeletons of soft filamentous microbes. Dendrolite is a specific kind of framelite. The microbialite includes stromatolite, laminate, thrombolite, crustolite, and oncolite. The crustolite is characterized by laminated fabrics encrusting on some skeletons or grains.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-8: Biogenic minerals and rocks: formation mechanisms and their mineral resource and paleoenvironmental significances
Presentation Preference: Oral Preferred

The amorphous and crystalline carbonate biomineralization in cyanobacterial biofilms induced by Synechocystis sp. PCC6803 cultured in CaCl2-MgCl2-SrCl2 mediums

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Keywords: cyanobacteria, biomineralization, carbonate, Sr/Ca, Mg/Ca, acidic amino acids

Ca^{2+}, Mg^{2+}, and Sr^{2+} are elements with similar ionic and hydrochemical characteristics, yet the microbial mineralization behavior in their coexisting environments is seldomly introduced [1,2]. In this study, a cyanobacterium *Synechocystis* sp. PCC6803 was used to induce the formation of minerals in mediums with various Mg/Ca and Sr/Ca ratios (Ca^{2+}=0.01 M). The medium hydrochemistry, including cell density, solution pH, and alkalinity, was recorded periodically. The bioprecipitates were characterized with X-ray diffraction (XRD), scanning and transmission electron microscopy (SEM and TEM), Fourier Translation Infrared spectroscopy (FT-IR), and Thermal Gravimetric Analyzer (TGA). The results showed the growth of *Synechocystis* sp. PCC6803 was inhibited by the increased ionic strength, while the final accumulated alkalinity and pH of the medium were not affected. Two crystalline minerals, calcite ($CaCO_3$) and strontianite ($SrCO_3$), were precipitated in the mediums with low ionic strength; those were transformed from the early amorphous precipitates by a dissolution and re-precipitation mechanism. The morphology of the present cyanobacterial strontianite was changed from column to dumbbell shape and finally into a spherical shape. High concentrations of Sr^{2+}, like Mg^{2+}, could prolong the stabilization of amorphous carbonate precipitates. The acidic amino acids (Glu and Asp) in EPS of *Synechocystis* sp. PCC6803 cultured in high Sr^{2+} and Mg^{2+} concentrations were significantly increased, compared to those cultured in medium without Sr^{2+} and Mg^{2+} (p<0.005). The density functional theory (DFT) calculations results showed that the binding between the two acidic amino acids and ion-H_2O complexes ($Ca[H_2O]_6^{2+}$, $Mg[H_2O]_6^{2+}$, and $Sr[H_2O]_6^{2+}$) are all thermodynamically-favored processes. Consequently, lower energy was needed in the subsequent precipitation and the nucleation on the EPS of *Synechocystis* sp. PCC6803. This inferred process was also supported by the appearance of amorphous particles on the EPS of *Synechocystis* sp. PCC6803.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-8: Biogenic minerals and rocks: formation mechanisms and their mineral resource and paleoenvironmental significances
Presentation Preference: Oral Preferred

Biomineralization of rhodochrosite induced by halophilic Virgibacillus dokdonensis WLR1 bacteria

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Keywords: Rhodochroite, Sedimentary biogenesis, Microbial biomineralization, Halophilic microorganism, Virgibacillus dokdonensis,Intracellular and extracellular biomineralization

Rhodochroite is the main mineral type of manganese ore with sedimentary genesis. Studies have shown that biological action contributes to the formation and deposition of rhodochrosite. Here, biomineralization of rhodochrosite under the action of halophilic Virgibacillus dokdonensis WLR1 bacteria was studied. The biotic rhodochrosite had diversified morphologies, such as spherulite, long rod, butterfly and dumbbell, etc. The EDS results showed that the rhodochrosite contained organic elements such as S and P besides the Mn, C and O elements. FTIR analyses further proved that the rhodochrosite had protein secondary structures such as α-helix, β-sheet, β-turn, and 3(10)-helix. The stable carbon isotope analyses revealed that δ13CPDB values changed from -16.148‰ to -17.827‰, further proving the biogenesis of the rhodochrosite. The intracellular and extracellular rhodochrosite could be formed after ultra-thin sections of WLR1 bacteria were analyzed by HRTEM and SAED. Under the action of WLR1 bacteria, the Mn2+ concentrations decreased from 49.58, 103.02, 157.39, 201.65 mg/L to 9.57, 11.38, 15.05, 19.06 mg/L on 24th day, the Mn2+ precipitation ratios were 82%, 89%, 90%, 91%, and the Mn2+ sedimentation rates were 4, 8, 13, and 17 mg/L/d. The results show that bacteria significantly promote the precipitation of rhodochroite. On this basis, the contribution of bacteria in the process of manganese biomineralization is further discussed. This experiment has enriched the study on the microbial genesis of manganese rich ores deposition.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-8: Biogenic minerals and rocks: formation mechanisms and their mineral resource and paleoenvironmental significances
Presentation Preference: Oral Preferred

High Mg/Ca molar ratios promote protodolomite precipitation induced by the extreme halophilic bacterium Vibrio harveyi QPL2

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Keywords: protodolomite, extreme halophilic bacterium, Vibrio harveyi, amino acids, polysaccharides

Bacterial activities have been demonstrated as critical for protodolomite precipitation in specific aqueous conditions, whereas the relationship between the various hydrochemical factors and bacterial activity has not been fully explored [1]. In this study, biomineralization experiments were conducted using a newly isolated extreme halophilic bacterium from salina mud, Vibrio harveyi QPL2, under various Mg/Ca molar ratios (0, 3, 6, 10, and 12) and a salinity of 200 ‰. The mineral phases, elemental composition, morphology and crystal lattice structure of the precipitates were analyzed by XRD, SEM and HRTEM, respectively. The organic weight and functional groups in the biominerals were identified by TG-DSC, FTIR, and XPS analysis. The amounts of amino acids and polysaccharides in the EPS of QPL2 cultured at various Mg/Ca molar ratios were quantified by an amino acid analyzer and high-performance liquid chromatography. The results confirm that disordered stoichiometric protodolomite was successfully precipitated through the activities of bacteria in a medium with relatively high Mg/Ca molar ratios (10 and 12) but it was not identified in cultures with lower Mg/Ca molar ratios (0, 3, and 6). That bacterial activity is critical for protodolomite formation is shown by the significant bacterial relicts identified in the precipitated spherulite crystals, including pinhole structures, a mineral coating around cells, and high organic matter content within the crystal. It was also confirmed that the high Mg/Ca molar ratio affects the composition of the organic components in the bacterial EPS, leading to the precipitation of the protodolomite. Specifically, not only the total EPS amount, but also other facilitators including the acidic amino acids (Glu and Asp) and polysaccharides in the EPS, increased significantly under the high Mg/Ca molar ratios. Combined with previous studies [2], the present findings suggest a clear link between high Mg/Ca molar ratios and the formation of protodolomite through halophilic bacterial activity.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-8: Biogenic minerals and rocks: formation mechanisms and their mineral resource and paleoenvironmental significances
Presentation Preference: Oral Preferred

Correlative micro-analytical strategies to elucidate complex formational and diagenetic processes in Precambrian stromatolites

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Keywords: stromatolites, biogenicity, micro-analysis

Stromatolites are fossilised records of laminated microbial communities. The oldest examples date to almost 3.5 billion years; however, controversy continues to surround these most ancient forms because of generally poor preservation, the lack of retention of syngenetic fossils derived from their architect organisms, and ambiguity surrounding the morphogenesis of simple macrostructures, such as the domical and conical stromatolites that dominate the early Precambrian record. I will present new high-resolution datasets from two Precambrian stromatolite horizons with the objective of demonstrating that multi-scalar, multi-technique characterisation sheds light on the biogenesis, taphonomy, and diagenesis of even simple stromatolitic forms.

1) 3.48 Ga Dresser Formation. Flat-laminated and domical stromatolites of the Dresser Formation are widely considered the earliest convincing morphological evidence for life on Earth but have been heavily altered by iron oxidation. We have conducted sub-micron-scale analyses of these stromatolites coupling morphological evidence from microscopy, laboratory X-ray μCT and synchrotron μCT (resolution = 0.9 μm) with chemical evidence from laser ablation ICP-MS, Raman spectroscopy and SEM-EDX. Our 2D–3D morphological reconstructions highlight numerous biological micromorphologies: undulatory layers, non-isopachous laminations, crestal thickening through domes and vertically oriented fabric elements interpreted as microbial palisade structure. Combined with palaeoenvironmental indicators of shallow marine deposition, these indicators strongly suggest phototrophic dominance of the stromatolite ecosystem. The exceptional preservation of these microfabrics is best explained by early and rapid silicification, as evidenced by the mineralogy and texture of stromatolitic layers, and by strong Eu anomalies in penecontemporaneous chert. These high-resolution data shed new light on Earth's oldest traces of life and reinforce their biogenic interpretation, also providing a taphonomic model for the ecosystem.

2) 790 Ma Skillogalee Dolomite. Flat-laminated and domical stromatolite-like structures of the Skillogalee Dolomite are widely used for Neoproterozoic chronostratigraphy across Australia. We performed spatially correlated microscopy, and Raman and Fourier transform infrared microspectroscopy of rare organic-rich layers within these stromatolites. Organic-rich layers are concordant with the sequence of formation of the stromatolitic macrostructure, suggesting syndepositional growth. They comprise weakly laminated fabrics with evidence of plastic deformation and early diagenetic organic staining, and preserve an archive of microbe–sediment interaction in the form of oriented sediment particles. Raman and FTIR show that the organic fraction comprises aromatic and aliphatic moieties tied to specific microstructures. As in the Dresser Formation, the association of organic-rich layers with silicified domains suggests that early silicification played a role in the preservation of these rare features. The identification of such spatially restricted organic fabrics in contemporaneous and more ancient stromatolites may serve as a means of establishing biogenicity of simple stromatolite morphologies in the absence of microfossil preservation.

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-8: Biogenic minerals and rocks: formation mechanisms and their mineral resource and paleoenvironmental significances
Presentation Preference: Oral Preferred

New insights on the palaeoenvironments, biogeochemistry and palaeoecology of Palaeoarchaean microbial mat ecosystems

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Keywords: microbial mats, Archaean, geobiology

The Palaeoarchaean (3.6–3.2 Ga) fossil record is dominated by microbial mats that formed in shallow marine settings, suggesting that phototrophic ecosystems were important components of Archaean global biogeochemistry [1]. This presentation describes Palaeoarchaean microbial mats and their local environments using advanced in situ organic–inorganic geochemical approaches, focussing on the Barberton greenstone belt.

Depositional environments of Palaeoarchaean ecosystems. High-resolution optical petrography shows that microbial mats exhibit subtly different growth and deformation phenomena depending upon their substrate: in microcrystalline cherts, mats have undulatory morphologies with well-preserved growth and deformation textures [2]; in sandstone horizons, mats are less well-preserved but show responses to sedimentation phenomena, i.e. trapping, binding and orienting sand grains and forming micro-tufted morphologies [3,4]. 3D visualisations of mats using X-ray μCT corroborate these textural phenomena [5]. Laser ablation ICP-MS shows that the chert phase within which mats occur preserves rare earth element plus yttrium (REE+Y) compositions denoting a complex confluence of marine, hydrothermal and riverine chemistries [6]. This suggests productive microbial biomes in epicontinental settings as early as ~3.5 Ga.

Biogeochemical networks in Palaeoarchaean ecosystems. Correlated micro-analysis of microbial mats yields insights into the communities responsible for the formation of microbial mats in deep time and the mechanisms by which they were preserved. Raman geothermometry of kerogen indicates thermal histories consistent with lower greenschist grade temperatures, reflecting regional metamorphism. FTIR microspectroscopy shows that mat kerogen includes diverse aromatic and aliphatic moieties, including C–H, COOH and other groups [2,3,7]; this richness of preservation indicates extremely rapid preservation and entombment of biomass by silica. Quantifying CH3/CH2 ratios in kerogen has also enabled discrimination between mats dominated by Bacteria and by Archaea [7]. Finally, in situ organic δ13C signatures show a diversity of clustered values that may shed light on the origins of multiple metabolic pathways.

The results of this multi-technique, high-resolution approach to microbial mat palaeobiology demonstrate that advanced analytical capabilities have the potential to re-evaluate our understanding of Palaeoarchaean ecosystems and sustain the validity and significance of authentic biogeochemical signatures in deep time.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-8: Biogenic minerals and rocks: formation mechanisms and their mineral resource and paleoenvironmental significances
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Paleobiological Characteristics and its Hydrocarbon Significance of Bioclastic Migmatite in Bohai Sea

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Keywords: Bohai Sea,Paleogene,bioclastic migmatite,palaeontology,reservoir

Lacustrine migmatite is widely distributed in the first member of Shahejie Formation of Paleogene in Bohai Sea. The bioclastic migmatite is the high-quality reservoir with good physical properties and high productivity. In this paper, a systematic paleontological study of bioclastic components in bioclastic migmatites is carried out. It is confirmed that gastropods are the most important bioclastic types in the first member of the Shahejie Formation in Bohai Sea. 21 genus and 27 species of gastropods and 19 genus and 74 species of ostracoda are identified. They are mainly miniaturized types suitable for living in a certain salinity and shallow water environment. It is found that the gastropods are easily to accumulate in high energy environment, while the content of ostracods is relatively high in low energy environment combined with paleoenvironmental studies. The analyses of casting thin section, SEM and EPMA show that bioclasts plays an important role in the evolution of migmatite reservoir. The reservoir space is directly provided by the cavity hole of the bioclastic body, the mold hole of the shell, the shielding hole and the differential contraction joint. Early dissolution of bioclasts can effectively improve the permeability of the reservoir, promote dolomitization of the bioclastic enrichment section, and form a high-quality reservoir of bioclastic dolomite. Bioclasts form a stable mud crystal set with the action of microorganism, which plays a supporting role of pore lattice. The physical properties of the bioclastic migmatite mainly composed of gastropods are better than the others, as influenced by the differences of shell composition and various kinds of biological sedimentary environment.

Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-8: Biogenic minerals and rocks: formation mechanisms and their mineral resource and paleoenvironmental significances
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Late Ordovician Restrict platform facies of Ordos plate, north of China

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Keywords: Ordos Basin, Late Ordovician, platform margin reef-shoal facies, restricted platform, lagoon.

The paleontology and sedimentary facies of three main Ordovician sections in the southwest edge of Ordos basin, Shijiezigou, Longmendong and Tiewadian, have been studied. It was revealed that the Ordovician in the Shijiezigou section was composed of packstone and wackestone of open platform facies with coral and dasycladacean bioclasts, the Longmendong and the Tiewadian sections are composed of three types of breccia. One is limestone of reef and shoal facies with abundant late Ordovician coral, stromatoporoid and dasycladacean fossils and bioclasts, the second is micritic limestone of tidal facies with bird's eyes structure, and the third is micritic limestone of lagoon facies with cyanobacteria and Tetradiids. The breccia rocks of the three sections are bedded, composed of limestone debris of platform margin reef-shoal facies and restricted platform tidal and lagoon facies without roundness, and contain no sandy silt, and are interpreted as resultant from the conglomerates formed from the erosion of the Upper Ordovician carbonate platform marginal reef and shoal faces and the inner restricted platform facies limestone, deposited by gravity flow. The Upper Ordovician platform marginal facies in the Tazhong platform in Tarim Basin, Xinjiang, consist of reef-shoal facies and open platform facies, and the inner part of the Tazhong platform consists of restricted platform facies and open platform facies. Comparison of the fossils and facies between the Ordos platform and Tazhong platform shows that not only the late Ordovician platform margin reef-shoal facies developed in the southwest margin of Ordos platform, but also the open platform and restrict platform developed behind the reef-shoal facies. The restrict platform included tidal flat facies and lagoon facies, and its range may cover the whole Ordos plate.

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Session T4-8: Biogenic minerals and rocks: formation mechanisms and their mineral resource and paleoenvironmental significances
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Research status and prospect of banded iron formation in early Earth

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Keywords: banded iron formation,biogenic,microorganism

BIF is a type of banded iron formation widely distributed in the Precambrian, which is the most dominant deposit type in the world. Its formation occurred before and after the Great Oxidation Event, and the deposition of BIF was abruptly terminated after the "Snowball Earth" event. There are two main theories on the genesis of BIF: abiogenesis and biogenesis, and clarifying the genesis of BIF has been an important academic issue in the study of mineral deposits. The theory of continental material weathering and submarine hydrothermal theory are abiogenic, but in recent years, with the advancement of analytical tests, the theory of biogenesis has gradually emerged, and most scholars believe that microorganisms played an important role in the deposition of BIF. The high concentration of HCO-3 in seawater provides a large amount of CO2 for photosynthesis of cyanobacteria, which induces cyanobacteria to aggregate and produce the oxygen required for iron precipitation. Photosynthetic bacteria provide oxygen for the oxidation of iron bacteria, and the oxidation and reduction of iron bacteria is the key to the formation of BIF. Magnetosomes in magnetotactic bacteria degrade to iron or are preserved directly in the sediment to form iron minerals. Since it is difficult to preserve the microbial activity remains, the presence and type of microorganisms can be studied by the distribution pattern of rare earth elements, Fe isotope tracing and other technical means to find the characteristics of microbial activities, which can enrich the research theory of BIF biogenesis and provide information for finding BIF iron ore resources and guiding iron ore exploration. It has both high research value and economic value.

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How to reconstruct seawater trace metal concentration in Earth history: Insights from Abiotic Synthesis experiments

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Keywords: Abiotic synthesized pyrite, nickel partition coefficient, trace metal concentration of paleo-seawater

Trace metals actively participate in various cycles in the ocean and play critical roles in biogeochemical cycles, while it is a big challenge to reconstruct seawater trace metal concentration in deep time. It has been proposed that the trace metal contents in pyrite, through ion replacement or adsorption, may record trace metal characteristics of paleo-seawater (TMsw). However, the partition coefficients of these trace metals between pyrite and water column during pyrite formation have never been figured out, which impedes the quantitative reconstruction of TMsw from trace metal contents in pyrite. For this purpose, we investigated the partition coefficients of Co and Ni between pyrite and water column by doping these elements during the abiotic synthesizing of pyrite under ambient temperature. We observed a close positive relationship between the trace elemental concentrations in the solution and the precipitated pyrite, supporting previous inference. Furthermore, our experiments suggest that nearly all the Ni and Co were sequenced by pyrite, and the amount of pyrite precipitated is a principal factor affecting the concentration of pyrite. In summary, our work demonstrates that the trace metal concentration of sedimentary pyrite cannot be directly converted to trace metal concentration of paleo-seawater, and the abundance of sedimentary pyrite should be considered in order to quantitatively reconstruct seawater trace metal concentration in deep time.

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Iron oxyhydrxides in subsurface dolostones: biomineralization and crystal morphologies

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Keywords: Iron oxyhydroxides, Biomineralization, Nonclassical crystallization, Nanoparticle, Amorphous

Iron oxide/oxyhydroxide precipitation in nature can involve various mechanisms that are dictated by ambient environmental conditions. Amorphous and crystalline Fe oxyhydroxides associated with extracellular polymeric substances (EPS) are commonly distributed in some of void space of subsurface Ordovician dolostone (Jinan, North China Block). These precipitates, dominated by ferrihydrite nanogranules (20–30 nm), acicular goethite nanorods and nanofibers (>200 nm), and various twinned goethite polymorphs (~1–3 mm), display different crystallization stages that reflect the processes of iron mineralization. The development of iron oxyhydroxide involved: (1) biogenic ferrihydrite and goethite nanoparticle formation, (2) ferrihydrite–goethite transformation and development of nanogranule-attached goethite, (3) goethite twinning, and (4) multi-generation overgrowths on twined goethite. The process demonstrates that the Fe was fixed biogenically with crystallization taking place via a nonclassical nanogranule-aggregation pathway. The study sheds light on the complex mechanisms of crystal growth and morphological development associated with iron oxyhydroxide mineralization in geological records. The distribution of the precipitates, concentrated in larger voids ~11 m below ground surface, reflects their sensitivity to ambient conditions such as redox and Fe supply.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
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The origin of biogenic dolomites from Mesoproterozoic Jixian System in Ordos Basin

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Keywords: Jixian system, dolomite, biogenic

During the development of long earth history, microbial rocks, as a kind of geological record of primitive life activities, have been widely distributed and spanned a wide range of times, dating back to the earliest Paleoproterozoic, while the abundance, distribution range and morphology of the Middle Neo-Proterozoic strata have reached their peaks. Microbial carbonate rocks are not only related to the formation and enrichment of metal deposits, but also important objects for oil and gas exploration. The Jixian carbonate marine formation is well exposed on the western and southern margin of Ordos Basin, and the Longjiayuan, Xunjiansi, Duguan and Fengjiawan formations are exposed from the bottom to top. With good exposure and convenient transportation, it provides abundant material for microbial carbonate petrology and genetic research. Through field section measurements, hand specimen identification, combined with sedimentological, petrological, and geochemical analysis and research, it is concluded that mud-crystalline dolomite, siliceous dolomite, stromatolite and a small amount of sparry dolomite are developed in Jixian system of Ordos Basin. The stromatolites structures present at Jixian system are identified as stratifera, columnar, conical, domal, spheroidal and lobate types, which indicate that the whole period was in a tidal flat with deep local water bodies. Abundant microbially induced sedimentary structures (MISS) have been recognized in these rocks, indicating diversified microbial activities and a high organic production. With the aid of SEM observation, a large number of extracellular polymeric secretions, nanoglobules, polyhedrons, and their aggregates were found in the stromatolite. These filaments and well-preserved spherical bacteria (possibly cyanobacteria) are distributed in the bright or dark layers. Acicular aragonites which were found in some sample suggests authigenic carbonate precipitation from anaerobic oxidation of methane. Silicification protects the microstructure of some microbial mats. At the same time, extracellular polymeric secretions can combine with other elements such as Si, Mg and Ca, making them more suitable for bacterial mineralization and dolomite crystallization, providing some intuitive evidence for the biogenesis of stromatolite in Jixian system.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
Session T4-8: Biogenic minerals and rocks: formation mechanisms and their mineral resource and paleoenvironmental significances
Presentation Preference: Oral Preferred

Formation and environmental instruction of the bacterial-mediated nodular carbonate-bearing fluorapatite (CFA) in the lacustrine shale of Shahejie Formation in Dongying Depression, Bohai Bay Basin

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Keywords: Carbonate-bearing fluorapatite, Rare earth elements and yttrium, Trace elements, Hydrogenetic Fe-Mn oxyhydroxides, Shale oil, Dongying Depression

A significant abundance of bacterial-mediated carbonate-bearing fluorapatite (CFA) nodules in the lacustrine shale of the Dongying Depression in Bohai Bay basin was found with variable occurrence on drilled core samples. However, there is no systematic description and analysis, and the lack of mineralogical and geochemical studies limits specific understanding of the formation process and environmental instruction of the nodular CFA. In this study, CFA nodules obtained from three boreholes were analyzed to specify their petrology and chemical composition of trace elements (TEs), Rare earth elements and yttrium (REY). An integrated approach, including Scanning Electron Microscope (SEM), Cathode luminescence (CL), Micro Fourier Transform infrared spectroscopy (Micro-FTIR), electron microprobe analyzer (EPMA), and Laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS), were carried out. The result suggests that Ca (25.85 to 39.95 wt.%), P (17.19 to 29.35 wt.%) and F (0.71 to 2.99 wt.%) are the dominant components of the CFA nodules, with very low Mn/Fe ratios and few incorporations of CO32-. They always present as black nodular shape, and lie within both the micritic calcite lamina (Type A nodules) and clay and organic-rich lamina (Type B nodules) of the laminated shale. Electron microscopic observation of a porous nanostructure corresponding to substantial nanoscale micro-crystals and occasionally pellet (1 to 3 μm in diameter) for the CFA, probably related to the bacterial activities. REY concentration was normalized against the Post-Archean Average Shale (PAAS), showing weak negative Ce anomalies, obvious negative Y anomalies and typical “hat-shape” patterns, in which type B nodules obtain strong depletion of HREE. Contents of typical transitional elements such as Co, Ni, Cu, V and Zn are extremely low compared with the marine CFA nodules, while Sc, Sr, Zr, Ba, Th and U are relatively enriched. All of the petrology and geochemical compositions suggest that the formation of the CFA nodules is correlated with the terrigenous inputs of hydrogenetic ferromanganese oxide, especially for the Fe-oxides, which prefer absorption of the REY components with low Y/Ho ratios (18.4 to 28.9, average of 23.9) in the water column before deposits. Once the Fe-rich oxide components settled within the oxic/suboxic interface, dissolution of the Fe-oxides occurred with the release of magnitude P and REY with MREE enrichment to pore waters. It seems to be the significant process that resulted in the recapture of the inherited P and REY due to favorable precipitation of carbonate-bearing fluorapatite. The circumferential pellet of the microcrystals of the CFA reveals the bacterial activities, mostly like the sulfate-reducing microorganism that framboidal pyrite was also observed within the CFA nodules. Our data points to the fact that the nodular CFA in lacustrine shale in Shahejie Format of the Dongying Depression probably formed during the early-stage diagenesis beneath the suboxic zone with bacterial mediated, and utilize of the weak Ce negative anomalies and “hat-shaped” REY patterns should be cautious for lake ecology study.

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Scientific Themes: Theme 4. Biological Process in Sedimentation
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Widespread Putrefaction After the Marinoan-Nantuo Snowball-Earth Glaciation

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Keywords: phosphorite, botryoid, granule, fossil, Neoproterozoic, Raman

The Neoproterozoic Nantuo glaciation was followed by atmospheric oxygenation, phosphogenic events and the rise of animals, all well-recorded in South China. While the origin of ^{13}C-depleted carbonate in these rock formations suggests the oxidation of organic matter, there lacks a sedimentological connection with the Neoproterozoic Oxygenation Event. Here we show that various self-similar patterns occur in diagenetic spheroids such as botryoids, rosettes, granules, and concretions, which are widespread in the Ediacaran Doushantuo Formation. The distinct radial and circularly concentric geometry in diagenetic spheroids spans several orders of dimension size, as do fractal patterns. These rounded mineralised self-similar objects are also composed of mineral assemblages variably including quartz, apatite, carbonates, oxides, sulphates and sulphides. Cations and anions in these compounds are suggested to represent redox-sensitive analogues to reactants, intermediates, and products in chemically oscillating reactions. In addition, diagenetic spheroids are associated with structurally highly variable forms of organic matter, suggesting out-of-equilibrium conditions during diagenesis and sub-greenschist metamorphism, consistent with chemically-oscillating reactions soon after deposition. The new observations and model lead to the suggestion that post-snowball oxygenation caused widespread oxidation of biomass, and that this produced diagenetic spheroids through the oxidation of biomass and preserved through a combination of putrefaction and later diagenetic fluids enriched with residual phosphate, carbonate, halogens and sulfide. The role of TiO_2, as commonly detected in anatase and rutile inside diagenetic spheroids remains uncertain, but appears linked to the degradation of organic matter. We conclude that diagenetic spheroids link sedimentology and organic geochemistry, and in turn, elegantly but imperfectly explain post-snowball perturbations in biogeochemical cycles and the exceptional preservation of fossils

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Lower-Permian Lacustrine Microbial Buildups in a Cyclostratigraphic Context from Bogda Mountains, NW China

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Keywords: Microbial buildups, Lacustrine Microbialite, NW China

Microbial buildups in lake deposits of lower Permian Lucaogou low-order cycle in Zhaobishan, Bogda Mtn., NW China, occur in 12 high-order cycles (HC) in a 20-m succession. They overlie transgressive oolite or conglomerate and underlie regressive deltaic sandstone. They are mound-shaped and coalesced, 10s of cm wide and 10-50 cm high. Data from 40 thin sections show that mounds contain thrombolite, stromatolite, wackestone, and packstone. Thrombolites consist of lumps separated by cements and sediments. Lumps comprise clustered clots and calcite cements, are 1-4 cm in size, and show upward and lateral growth patterns. Clots are 10-100 microns in size and equant. Sediments between lumps include micrite, extra- and intraclasts, and patches of clots without a growth pattern. Stromatolites are laminated or digitated, domal or wavy. Wackestone is mud rich and contains extra- and intraclasts and clots. Packstone contains oncoids and extraclasts, lumpy micritic matrix, and calcite cement. Oncoids are mm in size, have uneven cortices of clotted micrite and rare sparry calcite with a wrinkly surface. Micro-analysis shows that generally all lithofacies contain copious nano-globules (50-200 nm) and muscus-like films. Globules assemblage to form micrite crystals in micritic matrix, thrombolitic clots, and coating of oncoids. Stromatolites also have voids (1-5 μm in diameter) in laminations. In a mound, thrombolite is dominant; stromatolite and wackestone are mainly in the lower part; and packstone in the top part. Upward in the lower part of the succession, mounds become larger and higher in relief; the amount of extraclasts decreases. In the upper part, the trend reverses and the amount of oncoids increases upward. The nano-globules and muscus-like films have similar texture of microbially-induced carbonate precipitation in modern and ancient analogues. The voids in stromatolitic laminae are similar to relicts of carbonate-replaced EPS alveolar structure. These suggest that basically all lithofacies in buildups are closely related to on microbial-induced carbonate. The thrombolites formed in quiet shallow lake; and episodic storm agitation and clastic influx and water depth change produced stromatolite and wackestone. The presence of clastic nuclei, agitated water, and fast micritic precipitation induced by microbial activities formed oncoids. Lake water was likely rich in Ca to provide nutrients for microbes and precipitate calcite. The mounds occur in the maximum-transgressive interval of HCs when the lake was deepest and clastic influx smallest. The thickness of buildups is inversely related to that of overlying deltaic deposits in HCs. The increased flux of freshwater and clastics during delta formation reduced the Ca concentration and hampered calcite precipitation and microbial activities. Thus, climate was relatively arid during transgression and humid during regression during the formation of both the lower and upper parts of the succession.

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Microbial Origin of botryoidal dolostones in the Dengying Formation, Sichuan Basin

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Keywords: Botryoidal, Dengying, Filament, Extracellular polymeric substances (EPS), Microbialite, Sichuan Basin

Microbialites are abundant in the upper Sinian Dengying Formation of the Sichuan Basin, SW China; and are important exploration objects for deep oil and gas. Although they have been extensively discussed because of the old strata, deep burial and complex evolution history. However, there is no consensus on the microbial impact on their deposition and reservoir origin mechanism. This study focuses on botryoidal dolostones in the Dengying Formation from typical outcrops and wells of the Sichuan Basin. The botryoidal dolostones in Dengying Formation are classified and evaluated by means of core-outcrop observation, thin section identification, cathodoluminescence (CL) and field emission scanning electron microscopy (SEM). The mechanism of microbial coating and its influence on reservoir quality are discussed. The main understandings are as follows: (1) There are three macroscopic morphological types of botryoidal lamination: stromatoid lamination, cavity-lining lamination, and spherical-encrusting lamination. They are all composed of interbedding bright-dark lamina. The deposition mechanisms can be divided into two categories: microbial mat and biofilm growth. The botryoidal lace structure was mainly formed by biofilms. (2) Evidences of microbial origin, including tubular sheath bodies and forms of EPS, are observed under the high resolution SEM. Three mineralization methods, microbial controlled, microbial induced and microbial influenced are classified according to the occurrence and morphology of microbial activities evidence. (3) Mineralization of sulfate reducing bacteria is divided into three evolution processes. Phase 1 with less than 1 μm micro dumbbell shaped ball attached to cleavage plane; the second phase mainly 5~25 microns' dumbbell and single ball attached to dolomite crystal plane; the third phase with diameter greater than 25 microns of ball aggregation growth within the pore space. (4) The microbial mineralization mechanism determined the dolomite crystal distribution and primary pore structure, and influenced the subsequent diagenetic transformation. From the perspective of reservoir formation mechanism, microbial coating formed rock skeleton resistant to compaction and beneficial to the subsequent karst. (5) The microbial coating formed different reservoir rocks. Reservoir space in cavity-lining lamination and spherical-encrusting rocks are dominated by cavity dissolved pores, mold pores and intergranular pores, while the reservoir space of stromatoid lamination is dominated by fenestral pores and bird's eye pores. In general, the cavity-lining lamination and stromatoid lamination formed better reservoir rocks than spherical encrusting. The results are useful in understanding the origin and formation mechanisms of the Neoproterozoic microbialites. The new findings may also shed new light on the occurrence and evolution of early life on Earth in the Precambrian Era.

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Assessing the biogenicity and the environmental implications of non-marine carbonates of the Late Paleozoic Eastern Equatorial Pangea

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Keywords: microbial deposits, Paleozoic, non-marine, carbonate precipitation, eastern Pangea

Western Europe continental basins of the late Carboniferous–Permian period formed in Eastern Equatorial Pangea during a major climate and geodynamic changes: the icehouse–greenhouse transition corresponding to the demise of the long-life Late Paleozoic Ice Age, and the dismantling of the Variscan belt. Siliciclastic sedimentary successions corresponding to fluvial, deltaic and lacustrine deposits are increasingly studied to understand their environmental response to climate and geodynamics at low paleolatitudes.

These basins are punctuated by scarce periods of carbonate sedimentation, potentially induced by microbial development; however, the origin of these deposits is still poorly addressed to that day, while it implies very peculiar environmental and climate conditions. We selected such carbonate deposits from four French Late Paleozoic basins (Autun, Aumance, Decize–La Machine and Brive basins) to address two main questions, regarding (i) their biogenicity, still unclear for these specific deposits because of the diagenetic overprint, and (ii) the driving factors of such deposits, formed in a carbonate-free continental setting.

At the scales of the macrofabric (crusts, domes, cauliflowers and flat-to-wavy structures) and the mesofabric (laminated, clotted, structureless, columnar and branching), microbial-related structures appear clearly, but at the microfabric scale, an intense recrystallization (dolomite or silica) prevents the observation of direct biological evidence. Features such as oncoids and irregular peloids, combined with the observation of a lateral replacement of irregular micritic laminea by diagenetic cements, are in line with a biotic origin, whereas shrubs and spherulites are more indicative abiotic processes. Therefore, these structures seem to result from a biotic-abiotic continuum.

We suggest that the high regional volcanic and hydrothermal activities, attested by contemporaneous volcanogenic rocks and specific mineralizations, as well as high-resolution climate modifications (e.g., humidity-aridity variations), have triggered episodic physical and chemical modifications in the lake, favoring the carbonate precipitation and the mineralization of microbial mats.

Beyond understanding Eastern Equatorial Pangea environments and climate, these deposits also address questions largely debated in the microbialite scientific community for deep-time non-marine carbonate precipitation.

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Phytoreef-building and algal reef dolostone: A case study of more than 30 years of exploration Wells in Xisha Islands

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Keywords: Xisha Islands, Reef building of plants, Red algal reef framework rock, Chlorella and raeanum nodule schist, Algal reef dolomite

This paper reviews 49 years of exploration and discovery, 39 years of exploration and 30 years of algal reef research in the South China Sea, focusing on the frontier, hot spots and weak links of basic research. It is pointed out that China has already formed the algae research enthusiasm of family exploration Wells in Xisha Islands, and obtained the main discoveries of three family exploration Wells in two major atolls and the identification of algae species and comprehensive research understanding of core samples. The characteristics of the fossil types of phytoalgal reefs are clarified, and the observation of one hole forms the observation of three holes. A variety of reef-building calcareous algae and their fossil types were identified, and they formed different structures and rock types of calcareous algae. This paper compares the results of algae reef, algae reef-building and case studies at home and abroad, and points out that the relevant theories have been established and reached the first class level since the formation of the Miocene reef in Xisha Islands, the formation of the early Miocene red algae coral reef, the formation of the late Neogene green Halimeda sp algae reef, and the formation of the algae reef dolomite since the formation of the reef.

Theme5

Continental Siliciclastic Depositional Systems

Session T5-2: Deep-lacustrine sedimentary processes and products

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
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Sedimentary evolution and control factors of beach bar sand body of the Upper Ganchaigou Formation in Zhahaquan area, western Qaidam Basin

1*

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Keywords: Beach bar,Paleogeomorphology , Upper Ganchaigou Formation,Neogene,Zhahaquan slope,Qaidam Basin

In order to further evaluate the oil and gas exploration prospect of the beach bar of the Upper Ganchaigou Formation in Neogene in Zhahaquan area, western Qaidam Basin, and predict the favorable exploration zone and exploration target, based on the comprehensive analysis of core observation and drilling / logging data, combined with the analysis results of rock slice, cumulative grain size probability curve, mud-land ratio of dark mudstone and sand-land ratio sensitive parameters, this paper carried out a detailed study on the development and evolution characteristics of beach bar of the Upper Ganchaigou Formation in this area. It is believed that the development and evolution of beach bar in Zhahaquan area is mainly controlled by the development and evolution of paleogeomorphology. The results show that : The braided delta-shallow lake sedimentary system was developed in the Upper Ganchaigou Formation in Zhahaquan area. The beach bar was developed, and the lithology was mainly lithic feldspar fine sandstone-ultrafine sandstone. The composition maturity was medium-poor, and the sorting roundness was medium-good. The particle size probability curve was mainly composed of two-stage jump and suspension reflecting wave action. Sedimentary structure types are diverse, mainly developed wave sand ripple cross bedding, wavy bedding, hilly cross bedding and lenticular bedding. During the sedimentary period of the Upper Ganchaigou Formation, the development scale of beach bar in the study area first increased and then decreased. From the early to the middle period, the development scale of beach bar continued to increase. Among them, the nearshore bar mainly expanded in the south and east directions, and distributed in the north-west direction. The farshore bar mainly expanded in the north-south direction, and distributed in the northwest-southeast direction. From the middle stage to the late stage, the development scale of beach bar decreases continuously. Among them, the nearshore bar mainly shrinks in the north-south direction and extends eastward, and the distribution direction changes from southeast to northeast. The farshore bar mainly shrinks in the north-south direction.During the deposition period of the Upper Ganchaigou Formation, the study area paleogeographic background of high in the west and low in the east, low in the north and low in the south, and high in the middle part. From the early to the middle, the paleogeomorphology highs in the middle of the study area continued to expand significantly to the east and southeast, and the scope was expanding. From the middle stage to the late stage, the range of paleogeomorphology high points continued to shrink in the north and northwest directions, and the range of paleogeomorphology high points in the southeast corner of the study area continued to expand northward. Comprehensive analysis shows that the development and evolution of beach bar of the Upper Ganchaigou Formation in Zhahaquan area is controlled by the source scale and the development and evolution of micropaleogeomorphology. Among them, the development and evolution of micropaleogeomorphology is the main control factor of the development and evolution of beach bar .

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Sedimentation and sedimentary model of Fine-Grained Gravity flow Deposits within Lower Permian Fengcheng Formation, Mahu depression, Junggar Basin, Northwestern China

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Keywords: Fine-grained gravity flow deposits, episodic rifting, rise and fall of lake-level, salinized rifted lacustrine Basin, Fengcheng Formation (P1f), Junggar Basin.

Mahu depression in Junggar Basin is an early Permian salinized rifted lacustrine Basin. Three third–order sequences are identified in lower Permian Fengcheng Formation (P1f). There are plenty of fine-grained gravity flow deposits in pro-delta to deep lake within the three sequences. Research on the fine-grained gravity flow deposits in Fengcheng Formation (P1f) has broad application for understanding the sedimentary processes and pattern of the fine-grained gravity flow systems, predicting the presence of “sweet spot” reservoirs in rifted lacustrine Basins for shale oil. The six kinds of fine-grained gravity flow deposits are identified by this research. They are concentrated density flow deposits characterized by normally graded bedded coarse-grained siltstone with mud-clasts; debris flow deposits characterized by deformed lumps of light grey siltstone, and silty clasts surrounded by laminated, or veined mudstone, soft sediment deformation structures, silty injectites, dykes and liquefied structures; mud flow deposits characterized by irregular, angular, and rotated silt clasts in the dark grey mudstone and the silt clasts contain small mud clasts as well; turbidity surge-like flow deposits characterized by normally graded bedded siltstones with scour surface; transitional flow deposits characterized by high frequency interbedding of laminated thin siltstone and mudstone; hyperpycnal current deposits characterized by a coarsening-upward interval and a fining upwardinterval couplet. The fine-grained gravity flow deposits in slope fan fringe show eight kinds of sedimentary associations: concentrated density flow deposits via transitional flow deposits to debris flow deposits; hyperpycnal current deposits; concentrated density flow deposits to debris flow deposits; turbidity surge-like flow deposits via transitional flow deposits to deep lake fallout deposits; transitional flow deposits to debris flow deposits, debris flow deposits to mud flow deposits; debris flow deposits to turbidity flow wake deposits; transitional flow deposits. Each sedimentary association represents a specific depositional process and transition of gravity flow rheology. There are many dolomite and calcite aggregates within the fine-grained deposits too. The research results indicate that the intensive episodic rifting of border faults and stretching of basement of Mahu depression during Early Permian Fengcheng period (P1f) , and climatic changes resulted in rise and fall of lake-level, volcanic eruption and deep-seated hot brine rising along faults. The tuff and the hot brine were mixed into the lake to salinize the lake. The fine-grained gravity flow deposits caused by the fall of lake-level and structural movements are “sweet spot” for shale oil, and deep lake mudstone with organic matter and turbidites deposited during rise of lake-level are good source rock and “sweet spot” reservoirs for shale oil.

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Sedimentary characteristics and main controlling factors of thick sublacustrine fans in Dongying Formation, Bohai Sea

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Keywords: sublacustrine fan, delta front, slump deformation, sand-richness, Dongying Formation, Bohai Sea

During the depositional period of the Dongying Formation in the Bohai Sea, a large number of sublacustrine fan deposits developed. In recent years, a large amount of oil and gas has been discovered in the sublacustrine fan sandstone. Compared with thin sublacustrine fans, more hydrocarbons with commercial value are found in thick sublacustrine fan sandstones. Through casting thin section, scanning electron microscope and physical property analysis, it is found that thick sandstone is more conducive to the preservation of primary pores and the development of dissolved pores. Therefore, finding thick sublacustrine fan sandstone is the main problem to be solved in the future oil and gas exploration of Dongying Formation sublacustrine fan in the Bohai Sea. On the basis of 3D seismic comprehensive interpretation, using drilling data and seismic sedimentology, the sedimentary characteristics, distribution characteristics, triggering mechanism and sand-richness of sublacustrine fans are comprehensively studied. The following conclusions are obtained: (1) On the seismic profile, large-scale delta deposits with foreset reflection structures developed during the depositional period of the Dongying Formation in the Bohai Sea. A series of worm-like or lenticular sedimentary bodies developed in the deep lakes at the front of the delta. (2) Core observation shows that these sedimentary bodies are mainly composed of fine-coarse sandstone and a small amount of siltstone and gravel-bearing sandstone. It generally contains brown-dark gray mud-gravel and mudstone torn debris, and develops massive and graded bedding. Among them, the size and shape of the gravel are different, often elongated, sausage-shaped, intermittent, and potato-shaped. Some mud-gravel are rounded to a certain extent, and mud-gravel often develops on the top of positive-grained graded bedding. Mudstone tearing debris developed. The wrap deformation structure can be seen. It has Bowmar sequence and obvious slump deformation structure. Sublacustrine fan deposits are mainly caused by slump gravity flow. (3) Normal faults, strike-slip faults or abruptly steep terrains often develop between large deltas and sublacustrine fans. As the large delta continues to accumulate towards the lake basin, an unstable slope is formed in front of the delta front. Under the action of flood or earthquake, the unstable sandstone of the delta front slides towards the lake basin along the front slope. When encountering faults or suddenly steep terrain, it will continue to transport towards the lake basin. These sliding sandstones do not stop transporting until they encounter the blocking action of depressions or local uplifts, and accumulate in depressions or local uplifts to form slump-type sublacustrine fan deposits. The sandstone thickness of the sublacustrine fan is mainly controlled by the sand-richness of the delta front and the scale of the transported sandstone. The results can provide a basis for the prediction of sand-richness of sublacustrine fans in lithologic exploration.

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Sedimentary Facies and Insights on Architectural Elements of the Deep-Lacustrine Chang 7, Ordos Basin, at TongChuan Area, China

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Keywords: Ordos Basin, Yanchang Formation, Chang 7, slope channel-levee, terminal splays, turbidity currents

As part of an effort to identify deep-lacustrine facies and architectural elements of the prolific Upper Triassic Yanchang Formation, Ordos Basin, China and provide some theoretical guidance about deep-water gravity flow deposit and conventional and unconventional oil and gas field exploration and development in the Ordos basin, seven outcrops in the Tongchuan area have been observed in detailed. The Yanchang Fm. is loosely subdivided into 10 oil bearing horizons, from 1 to 10 youngest to oldest respectively, and the focus of this research is the Chang 7, with some outcrops comprising portions of the underlying Chang 8, and the overlying Chang 6. Amongst the deposits, 10 lithofacies have been interpreted based on their lithology, grain size, bed thickness, presence of sedimentary structures, beds associations, and interpreted flow mechanisms. The dominant transport mechanism is interpreted as high- and low-density turbidity currents, with subordinate debris flow. Large sandstone deposits, previously described as massive sandstones and interpreted as sandy debrites, have been re-evaluated in detail and re-interpreted as amalgamated sandstones deposited by high energy high-density turbidity currents, mostly related to lacustrine slope channels. Inverse- to normal-graded deposits, potentially related to hyperpycnal flow deposits, have not been observed and though hyperpycnal flows might have triggered, they have been interpreted as indistinguishable from turbidity current deposits. Two outcrops Jiaquhe and Yanquhe sections dominated by interbedded deposits of disturbed and not disturbed graded sandstone to mudstones, ranging from few to tens of centimetres, interbedded with 1 to 3 metres thick amalgamated sandstones, forming intervals ranging from 6 to 20 metres thick, and laterally ranging from 600 to 1200 metres, have been interpreted as lacustrine slope channels. These deposits seem to decrease in thickness and amalgamation away from an axial area, until complete pinchout, forming U-shaped sandstone-rich geobodies. Deposits composed dominantly by interbedded thin-bedded graded sandstone to mudstone, with common occurrence of cross-ripple lamination 70-90% of the beds, interbedded with sporadic medium to thick sandstones, have been interpreted as levee deposits. Interbedded thin- to medium-bedded graded sandstones to mudstones, neither related to a confining surface nor adjacent to a slope channel, have been interpreted as terminal splays. The remaining fine-grained dominated deposits have been interpreted as slope to basin floor deposits.

Lacustrine and marine slope channels have similar characteristics, especially geomorphologically. However, they are substantially different in scale and in their architectural fill, with marine systems' fill highly depending on different orders of sea-level changes, and lacustrine systems probably more susceptible to positioning on slope and accommodation space changes.

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Sedimentary characteristics of tuffaceous laminae in high gamma shale in Chang 7 Member of Yanchang Formation, Ordos Basin, China

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Keywords: Tuffaceous laminae, High gamma shale, Yanchang Formation, Ordos Basin

A large number of tuffaceous laminae have been found in the high-gamma shale in the Chang 7 Member of the Yanchang Formation in the Ordos Basin. The thickness of these tuffaceous laminae is mainly in the order of millimeters, and the thickness is mainly distributed between 1 and 5 mm. Through the observation of rock slices, it is found that three types of tuffaceous laminae are mainly developed in the high-gamma shale of Chang 7 Member. The three types of tuffaceous laminae are wavy laminae dominated by volcanic dust, horizontal lamina dominated by angular volcanic vitreous debris, and horizontal lamina dominated by volcanic crystal debris. Multi-stage reverse-order bedding can be seen in the horizontal laminae with volcanic crystal debris as the main component, indicating that its formation is related to gravity flow deposition. Under the condition of oil immersion blue fluorescence, the light oil flow with green fluorescence is enriched in the crystal particles, indicating that its storage properties are good. The total organic carbon content of the adjacent high-gamma shale can be greater than 20%, but the analysis of main and trace elements and the analysis of pyrite particle size show that its depositional environment is a sub-oxidative to sub-reducing environment (Yuan et al., 2017; Chen et al., 2020), but the traditional view is that organic-rich shale deposited in a reducing environment Fluorescence observation shows that the macerals in the organic-rich shale laminae are mainly stratiform algae. However, if the depositional environment is under absolute reducing conditions, it is impossible for so many stratiform algae to grow and reproduce in situ. Based on this, we believe that gravity flow deposition not only brought volcanic tuff rich in nutrients, but also brought an appropriate amount of oxygen, which ultimately promoted the development of stratiform algae in the shale of the high gamma section. Studying the sedimentary characteristics of organic-rich laminae and tuffaceous laminae is not only of great significance to the study of the depositional environment, but also of tuffaceous laminae can provide favorable storage space for shale oil.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Oral Preferred

New discovery of sandy clastic flow sand body and its significance of oil and gas exploration in Junggar basin, NW China

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Keywords: Junggar basin, Sangonghe formation, sandy debris flow, lithologic trap, Oil and gas exploration

Jurassic which shallower buried was the most important field to find high-efficiency oil and gas reservoirs in the hinterland of Junggar basin. After the breakthrough of lithologic reservoir exploration of well SN31 in 2004, a number of exploration wells were deployed according to the lithologic trap pattern of well SN31, all of which were declared to be unsuccessful1. At present, there had been no major breakthrough in the exploration of oil-gas in the abdomen in the past 15 years. The key problem restricting the breakthrough in the exploration of oil-gas was that the lateral shielding conditions of sandbodies are not implemented, and the lithologic traps were not implemented. According to the current situation of oil-gas exploration in the abdomen, the exploration degree of low convex was higher than that of depression area. Were effective sand bodies developed in the depression? Does the sandbody had lateral shielding conditions? Was lithologic trap implemented? These key problems restricted the next step of exploration. Therefore, it was urgent to reorganize the genetic types and lithologic trap conditions of the sand bodies in the southern depression, established a new lithologic trap model, and found a new replacement field. On the basis of fully absorbing the previous research results, through core observation, heavy mineral analysis, reservoir characterization and seismic reflection characteristics analysis, the paleogeomorphology, sedimentary microfacies, reservoir properties and oil-gas properties of the second member of Sangonghe Formation in the western Pen-1 depression were analyzed, and the typical sandy clastic flow sand bodies, top, bottom and side, were proposed The directional blocking condition was better, and the lithologic trap condition was superior. The results showed that the second member of Sangonghe formation around the western Pen-1 depression develops multi-stage ring-shaped slope break, the sand body of delta front was developed above the slope break, and under the trigger of Yanshanian tectonic activity, the sand clastic flow sand body was formed under the slope break. Compared with other basins at home and abroad, the identification mark of sandy clastic flow sand body retained the reservoir physical properties and oil-gas properties of the front facies sand body, which was the most favorable exploration field for the next oil-gas exploration. This recognition had been applied to the well location deployment of oil field and achieved good application results. According to this understanding, well QS2 was deployed for the sandy clastic flow sand body under the slope break in the oilfield, and a major breakthrough was made after drilling. The breakthrough of well QS2 broke the deadlock of exploration for lithologic reservoir in the abdomen, opened up a new scene of exploration for large-scale lithologic reservoir in the depression, and confirmed that the sandy clastic flow sand body under the slope break had the conditions for forming large-scale lithologic reservoir.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
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Sedimentary response of transitional flow transformation revealed in shallow lacustrine hyperpycnites

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Keywords: hyperpycnal flow,transitional flow,sedimentary response,flow transformation

In recent years, hyperpycnal flow has become a hot topic in gravity flow sedimentology research. Most past work concerning sedimentary dynamics interpretation has been founded on concepts based on fully turbulent flows. In recent years, flume tank research has revealed that hyperpycnal flow can transform from turbulent flow to laminar flow influenced by clay minerals. However, interpretation of transitional flows in ancient sedimentary rocks is still a question to be answered. In this study, lacustrine hyperpycnal flow generated channel-lobe deposits were interpreted in the Cretaceous Nenjiang Formation in the southern Songliao basin. The sand-mud mixed deposits are formed under river flood events which reflect waxing and waning sedimentary process. Typical transitional flow related sedimentary structure are also found in those channel-lobe deposits. Using cores and well log data, sedimentary interpretation is conducted to reveal the controlling mechanism of flow transformation in lacustrine hyperpycnal flow deposits. The flow transformation could be related to the erosion process which bring mud deposits to the hyperpycnal flows. The yield strength of the flows is modulated with the flow types of the transitional flows in the depositional process. At last, flow transformation process model and controlling factors in hyperpycnites will be proposed based on the lacustrine sedimentary records.

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Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Oral Preferred

Outcrop analysis of architectural elements in a deep-lacustrine fan. A case study from the Triassic Yanchang Formation, Ordos Basin, China

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Keywords: Architectural elements,Lithofacies associations,Turbidite channels and lobes,Deep-lacustrine fans,Ordos Basin,China

Turbidity currents are the main process responsible for the delivery of sediment to deep marine and lacustrine environments. Turbidite sandstones form favorable petroleum reservoirs worldwide, commonly in marine successions, but in some cases also in lacustrine successions. Compared to marine environments, lacustrine systems differ significantly in terms of processes and sequence stratigraphy. The frequency, rate and magnitude of lake level fluctuations may be higher, and water salinity can be considerably different than in marine settings. As such, the main characteristics of turbidites in lacustrine environment may differ from those of their marine counterparts. The recognition and analysis of turbidites in deep-lacustrine fans from the Triassic Yanchang Formation (Ordos Basin, China) can guide the establishment of an effective criteria for understanding turbidity current deposition in lacustrine basins. These criteria can aid palaeogeographic restorations, which are critical for guiding subsurface exploration and exploitation of hydrocarbons.

During the late Triassic, the Ordos Basin was occupied by a huge lake. The rapid subsidence in the southern part of the Ordos Basin (foreland basin) was a consequence of the rapid uplift of the Qinling Mountain. The Yanchang Formation is dominantly composed of fluvial-deltaic-lacustrine deposits, and is internally subdivided into 10 Members. Deep-lake turbidites are mostly found in members Ch-7, Ch-6 and Ch-1.

This work mainly focuses in the analysis of architectural elements recognized in a turbidite fan outcrop succession of the Yanchang Formation located at the southeast of Ordos Basin. From outcrop studies, a new classification scheme of lithofacies and lithofacies associations for lacustrine turbidite fan strata has been proposed. Different deep-lake channels (i.e., slope channel, leveed channel), and lobe subenvironments have been identified. These architectural elements are juxtaposed vertically and laterally. The controlling factors for the development of lacustrine turbidite fans in the Yanchang Formation are also discussed. Based on the above observations and interpretations, a new depositional model for lacustrine turbidite fans (including the evolution of architectural elements) in the Late Triassic Ordos Basin has been proposed.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Sedimentary System Distribution and Lithologic Trap Characteristics of the 2nd and Lower 1st Members of Shahejie Formation in the South of Western SagLiaohe Depression

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Keywords: Western Sag,Shahejie Formation,Sedimentary System,Lithologic Trap

Western Sag of Liaohe Depression is a typical Mesozoic and Cenozoic oil-rich fault sag which have been explorated for many years with very high exploration degree. In order to promote the process of tapping potential and increasing reservoir in the south of western sag, under the isochronous stratigraphic framework of 1st and 2nd Members of Shahejie Formation, the sand units are finely divided according to the sedimentary cycle and flooding mudstone. Combined with core, logging and seismic data, the types and distribution characteristics of sedimentary system are analyzed, and the development characteristics of lithologic traps are studied. The results show that the 2nd and lower 1st Members of Shahejie Formation in study area can be divided into 5 sand units, including 3 in 2nd Member and 2 in lower 1st Member. There are mainly three types of sedimentary facies: fan delta, slump turbidity fan and lacustrine. In study area, the fan delta mainly develops the underwater distributary channel sand body, and the lithology is gray cross bedding, parallel bedding sandstone and sandy conglomerate with scouring surface relatively developed, which is poorly sorted and moderately rounded; at the far side, anti grain sequence silt-fine sandstone estuary bar and far bar are often developed. The lithology of slump turbidity fan is mainly dark gray argillaceous sandy conglomerate, and crumpled and torn argillaceous gravel are developed. The main lithology of lacustrine facies is gray dark gray mudstone, and gray anti grain sequence silt-fine sandstone beach-bar sand bodies are locally developed. Laterally, controlled by paleogeomorphology, fan delta sand bodies are developed in a large area on both steep and gentle slopes, and the gentle slope extends further to the lake than the steep slope. In Yuanyanggou sub-sag, the fan delta front sand bodies collapse at fault slopes which caused by the development of synsedimentary faults, and a large number of slump turbidity fans are deposited under the fault slopes. Because the existence of basement strike slip, an inherited underwater low uplift developped in the south of Shuangtaizi structural belt mainly depositing beach-bar sand bodies . Vertically, controlled by the evolution of lake level, a process of water entering and sand retreating from bottom to top is presented. The scale of fan delta and beach-bar are gradually reduced, and slump turbidity fan is increasing.Three types of lithologic traps are mainly developed in study area: lithologic updip pinch out traps, widely distributed in the structural inversion zone of steep slope fan delta; beach-bar lens traps, mainly distributed in the south of Shuangtaizi structural belt ; slump turbidity fan lens traps, mainly distributed in Yuanyanggou sub-sag . Yuanyanggou sub-sag and steep slope structural inversion zone are potential areas for lithologic reservoir exploration and storage.

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Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Evolution of the depositional environment of the early to middle Permian Roseneath-Epsilon-Murteree strata in the Cooper Basin, Australia: a multidisciplinary revisit with new data

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Keywords: Facies analysis, Paleogeographic Reconstruction, Roseneath Shale, Epsilon Formation, Murteree Shale, Cooper Basin

The Early to Middle Permian Roseneath-Epsilon-Murteree (REM) strata of the Cooper Basin in Australia host substantial conventional and unconventional resources, and are believed to be the most feasible shale gas play in Australia. Despite their potential resource significances, the REM strata are poorly understood with regard to regional facies architecture and paleogeographic evolution. Using a multidisciplinary approach with robust data (facies analysis, petrology, wireline logs, and geochemistry), the sedimentary evolution of the REM strata is described within a new sequence stratigraphic framework defined by key surfaces identified from cores and wireline logs. Detailed facies analysis of over 1400 m of cores and wireline logs from nine wells identified twelve lithofacies and eight facies associations for the first time which reveal various depositional processes and environments. The REM strata are interpreted as a fluvial-deltaic-lacustrine system with glacial influences. 1st-order and 2nd-order Maximum Flooding Surfaces (MFS) define a regional sequence stratigraphic framework which subdivides the REM strata into four sequence units, among which two Transgressive-Regressive (T-R) cycles can be observed. Paleogeographic maps of four depositional phases suggest that the REM strata were dominated by a lacustrine system with some delta and mire deposits. Rivers primarily drained from the Gidgealpa, Merrimelia, Packsaddle and Innamincka ridges (GMI Trend) in the north or northeast as indicated by sandstone percentage and gross unit isopach maps. Possible marine incursions into the lake probably came from the east when eustatic sea level was high. Far field effects from thermal subsidence of Eastern Australia and paleoclimate (glaciation, interglaciation) primarily controlled deposition of the REM strata. A similar multidisciplinary approach should help elucidate the evolution of other fluvial-deltaic-lacustrine systems in other basins and aid in resource prediction.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Sedimentary characteristics and oil and gas geological significance of the Lower Cretaceous Bashijiqike Formation in the Xinhe-Sandaoqiao area, Tarim Basin

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Keywords: Sedimentary characteristics ,sand-body distribution, Lower cretaceous Bashijichik Formation,Tarim Basin,Xinhe-Sandaoqiao area;

Abstract: In recent years, the discovery of Keshen and Kela gas pools indicates the great hydrocarbon exploration potential of the Cretaceous clastic rocks in Tarim Basin,NW China. Based on logging data, marcoscopic and microscopic petrology characteristics of lower Cretaceous Bashijiqike Formation in Xinhe-Sandaqiao area, sedimentary facies evolution and reservoir characteristics are comprehensively studied. The results show that:(1) Controlled by the provenance of the Southern Tianshan mountains and Xinhe-Yingmaili uplift, the cretaceous Bashijiqike Formation in Xinhe-Sandaqiao area is mainly characterized by brownish red,light brown and other oxidized colors. Two types of sand bodies are mainly developed: "thick sand" with large thickness and good transverse continuity and "thin sand" with thin thickness and poor transverse continuity. It is found that "thick sand" and "thin sand" developed at the bottom (Ba 1 and 2) and the top (Ba 3 and 4) of bashijiqike Formation, respectively. (2) the sedimentary facies analysis shows that the Bashijiqike Formation is shore- shallow lake and braided river delta sedimentary environment. "thick sand" developed in the delta front sedimentary subfacies.at the bottom, while the "thin sand" developed in shallow lake sedimentary facies on the top. The delta and lake sedimentary developed superimposly ,with the scope of lake basin grew and the delta was gradually reduced from early to late period(3) combined with physical properties and sedimentary facies analayses, high quality reservoirs in Bashkortostan Formation mainly developed in the underwater distributary channels of braided river delta front and littoral and sand dams of shore-shallow lake , which generally belongs to low porosity and high permeability reservoir.With the widely distributed thick sand body, and reconstruction from the Sandaoqiao fault , low-rising structure trap developed with good petrolem accumlation conditions.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Gravity Flow Geomorphology and its Controlling Factors in the Gently Sloping Zone of the Intra-sag High of the Liaodong Bay Depression

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Keywords: gravity flow, sequence stratigraphy, sedimentary morphology, control factors, gently sloping zone of intra-basin, Liaodong Bay Depression

The stratigraphic traps formed by gravity flow have gradually become the focus of hydrocarbon E&P. The Eastern slope of Liaoxi uplift or western slope of the Liaozhong Sag is still in early exploration stage. Recently drilled gravity fan of high density turbidite is the potential target for future exploration. This study firstly established the high-resolution sequence stratigraphic framework for the 3rd member of Dongying Formation. The comprehensive study on the morphology and controlling factors of gravity flow sedimentation was then conducted within the systems tracts integrating seismic, well logs and core data interpretation. The results show four types of slope fans are mainly developed in the gentle slope zone of eastern Liaoxi uplift: tongue-shaped fan, petal-shaped fan, leaf-shaped fan and channelized-fan. The study indicates that the degree of slope gradient and the sand-richness of the gravity flow source (the braided river delta front) control the morphology of the fans. The more complex the slope break and the steeper the slope, the larger the aspect ratio of the sub-lake fan, which is long tongue-shaped, and the simpler the slope break and the gentler the slope, the smaller the aspect ratio of the sub-lake fan, which is leaf-shaped. The higher the sand content, the channel is unorganized, and the higher the mud content, the more stable and the more organized the channel. Therefore, the steep slope and sand-rich fan is easy to form a tongue-shaped fan, the gentle slope and sand-rich fan is easy to form a leaf-shaped fan, the gentle slope and mud-rich fan is easy to form a channel-shaped fan, and the petal-shaped fan is a transitional type.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Discovery and exploration potential analysis of the beach-bar sand in Shawan Sag, Junggar Basin

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Keywords: exploration potential, beach-bar sand, Upper Urho Formation, Shawan Sag, Junggar Basin

Recently, Well ST1 in the Shawan Sag of the Junggar Basin has achieved major breakthrough in the Upper Urho Formation, of which the geological characteristics regarding hydrocarbon accumulation and reservoir forming are clearly different from those of the Mahu Sag, and present typical features of the beach-bar sand deposition. In order to explore the new frontier of hydrocarbon exploration, confirm the planar distribution and exploration potential of the beach-bar sand, this paper, on the basis of high-resolution three-dimensional seismic data combined with data collected during drilling, formation testing, well logging and core analyses. Elaborately depicts the planar distribution pattern of the beach-bar sand in the Upper Urho Formation of the shawan sag, and discussed its hydrocarbon accumulation potential, using seismic analysis techniques such as attribute extraction and stratal slicing. The results show that: (1) the target layer of the study area presents apparent characteristics of the beach-bar sand, which is distributed along the shore lake in a strip-like; and (2) it forms good hydrocarbon accumulation condition and has a huge area for exploration. The discovery and confirmation of the “beach-bar sand” field provides a model to shed light on exploration of the “beach-bar sand” oil and gas reservoir across the Shawan Sag, as well as a new exploration frontier for the “Greater Mahu” area in the Junggar Basin.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Evolution and Seismic reflection Characteristics of Subaqueous Distributary Channel Sand Bodies in the Braided River Delta

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Keywords: paleogeomorphology,subaqueous distributary channel,evolution,seismic reflection characteristics,Junggar basin

The sand bodies of subaqueous distributary channel in the braided river delta are superimposed vertically and vary greatly horizontally. At present, it is difficult to analyze the evolution and prediction of channel sand bodies. Taking the Jurassic Sangonghe Formation in the west slope of Mahu Depression, Junggar Basin as an example, evolution and seismic prediction of subaqueous distributary channel sand bodies in the braided river delta were researched. According to the lithological cycle characteristics, the strata of the Sangonghe are divided into J_1s_1, J_1s_2 and J_1s_3 from the bottom to the top. J_1s_3 is the main target stratum with a thickness of about 140m. It is mainly composed of gray mudstone, gray glutenite, a small amount of fine sandstone together with gray argillaceous siltstone. In order to better research the evolution and seismic prediction of the J_1s_3 channel sand body, the J_1s_3 are subdivided into three super short-term cycle according to the lithological cycle characteristics. From the bottom to the top, they are $J_1s_3^3$, $J_1s_3^2$ and $J_1s_3^1$ respectively. Each super short-term cycle is a positive cycle. $J_1s_3^3$ lithology is mainly thick glutenite and located in the inner zone of the braided delta front, and the channel sand bodies are distributed in a large area. $J_1s_3^2$ lithology is mainly fine sandstone and mudstone and located in the inner and outer transition zone of the braided delta front, and the channel distribution is relatively limited. $J_1s_3^1$ lithology is mainly siltstone and mudstone and located in the outer zone of the braided delta front, and the channel distribution is obvious. As a whole, $J_1s_3^3$ to $J_1s_3^1$ is a process for water transgression, the channel shrinks gradually, and the channel sand bodies migrate from south to north. Paleocurrent direction and channel distribution range are determined by restoring the palaeo-geomorphology and combining with dip logging data. Along the paleo-current direction, the channel sand bodies mainly show three seismic response characteristics: The first is the reflection characteristic of “flat top and convex bottom”. Downcutting erosion is caused by water flow, and gullies are formed. Due to the strong hydrodynamic force, flowing water carries a large amount of coarse particulate matters to the middle and lower reaches, and the channel sand bodies deposit in a little amount. The second is the filling reflection characteristic of “flat top and convex bottom”. As the hydrodynamic force weakens, the particulate matters deposit partially, which is shown to be an increase of seismic event. The third is the multiple stages sand bodies superposition characteristic of “flat top and convex bottom”. As the hydrodynamic force becomes weak, the sand bodies deposit in the river channel. Under the guidance of this model, the spatial distribution of the channel sand bodies is predicted by using strata slicing, seismic attributes, frequency division inversion and other methods. The newly drilled wells prove that the prediction methods for the channel sand bodies are effective and feasible.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
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Huge lake-tsunamis and related tsunami deposits in the Cretaceous Songliao Basin, NE China

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Keywords: lake-tsunamis, tsunamiites, deep-water deposits, the Songliao Baisn

AbstractTsunami deposits (tsunamiites) in lacustrine settings are some of the most understudied facies associations in the ancient or modern rock record. In recent year, three giant sublacustrine landslides (volumes of 1.5×10^9 to 3×10^{10} m^3) have been identified in the Songliao paleo-lake (SLPL), NE China. To understand the possible consequences of these landslides, we conducted tsunami simulations showing that these sediment failures could generate waves >2.5 m high, hitting the west lakeshore of the SLPL in approximately 95 min. What is even more devastating is that the disaster would magnify exponentially when three landslides with same direction of motion occurred simultaneously. This worst-case scenario may cause tsunami waves of up to 32 m, and most parts of adjacent land would have been inundated. Moreover, based on seismic geomorphology, we investigate the external morphology and internal architecture of the tsunamiites caused by this huge lake-tsunamis. Seismic facies reveals that the tsunamiites can expressed several distinguishing seismic characteristics in different parts of the SLPL. Large sediment waves, with wavelength 1-2 km, were identified in the lake centre. In onshore or offshore, tsunami deposits may consist of inflow and backflow deposits. The new depositional model built from the SLPL is vital to understanding the distribution of tsunami deposits in a sublacustrine settings.

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Session T5-2: Deep-lacustrine sedimentary processes and products
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Difference of depositional characteristics and its controlling factors of deep-water gravity flow in the first member of Liushagang formation, in northern steep slope, Weixinan Sag

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Keywords: difference of depositional characteristics, controlling factors, deep-water gravity flow, the first member of Liushagang formation, Weixinan Sag

Integrating 3-D seismic data, logging data, drilling cores and testing data, Using core observation, paleogeomorphology restoration, seismic facies analysis, seismic attribute extraction and analysis, depositional types and distribution features of deep-water gravity flow in the first member of Liushagang formation, in northern steep slope, Weixinan Sag has been analyzing in detail and the controlling factors of depositional fans' development have been discussed.

Deep-water gravity flow deposition in north steep slope of Weixinan sag is zoning obviously. Nearshore subaqueous fan developed in the west of the steep slope. The lithology is manly glutenite which particle size is coarse. The seismic profile is wedge-shaped along the direction of sediments transportation. Perpendicularly to the direction of sediments transportation the seismic profile is lentoid with thickness in the middle and thinness on the sides. Average energy seismic attributes of each stage fan show low energy band which is along fault strike in the fault root. While the high energy band shows fan-shaped from the fault root to the basin. Hyperpycnites developed in the middle of the steep slope. Hyperpycnal channel is mainly filled in sandstone and pebbly sandstone, while the lobes are mainly fine sandstone and siltstone which are rich in terrigenous plant debris. In vertical, each sequence shows normal-reverse graded structure. The amplitude attribute shows the characteristics of narrow channel and lobe in front which energy is stronger than surrounding rock obviously. Small scale hyperpycnites and mass transport deposits developed in the east of the steep slope. The MTDs shows isolated teardrop-shaped area with strong energy. Vertical to the transportation, the seismic reflection shows pit with strong amplitude. Along the transportation, the seismic reflection shows isolated strong amplitude. Structural characteristics reacting block transportation such as thrust fold and thrust fault have been presentation.

The factors difference of source-to-sink systems including type of parent rocks in source area, distance of sediment transportation, terrain differences and fault throw are the key to the difference of hyperpycnites north steep slope of Weixinan Sag. The parent rock in the west is mainly metamorphic sandy shale which is easy to weathering. This parent rock can supply large number of sediments. Large gullies develop and the No.1 fault throw is big. The sediments can be deposited by transporting short distances. Thus, large nearshore subaqueous fan can be developed in the terminal of the source-to-sink system. The parent rock of the middle and east source-to-sink system is magmatite that is hard to physical weathering, which can only supply lesser sediments. In the middle of the slope, because of the intersection of fault, the drainage is well which can transport large amounts of sediments over long distances. As a consequence, at the end of the middle source-to-sink system, hyperpycnites develop. However, since sediments need to be transported long distance via small valley and the fault fall is small in the east source-to-sink system, small scale of hyperpycnites and mass transportation deposits develop.

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Characteristics and genesis of tight oil reservoir sandbodies in Chang 6 Oil Member of Yanchang Formation, Ordos Basin

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Keywords: Ordos Basin, Chang 6 Oil Member, Tight oil, Reservoir sandbody, Genetic model

Chang 6 Oil Member of Triassic Yanchang Formation in Ordos Basin is one of the tight oil rich intervals in the basin. The study on the characteristics and genesis of tight oil reservoir sandbodies has important guiding significance for the further exploration and development of tight oil in the basin. Therefore, based on many previous research results, this paper takes the Chang 6 Oil Member in Huachi-Qingyang area in the middle of the basin as the research object, focuses on the characteristics and genesis of tight oil reservoir sandbodies, and expounds the types and characteristics of tight oil reservoir sandbodies of Chang 6 Oil Member through detailed observation and description of many drilling cores and comprehensive analysis. Then, the superimposition relationship of different types of reservoir sandbodies is analyzed, and the genetic model is established. The results show that there are four types of tight oil reservoir sandbodies: delta front sandbody, seismite sandbody, clastic flow sandbody and turbidite sandbody, which form different superposed relationships in vertical direction, mainly including: seismite sandbody and delta front sandbody; The superimposition of seismic sand body and clastic flow sand body; The clastic flow sandbody overlaps with turbidite sandbody; Seismic sandbody, clastic flow sandbody and turbidite sandbody are superposed. On this basis, the genetic evolution models of the four types of tight oil sand bodies are established.

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Sedimentary Sequence of Geological Events under the Influence of Tectonic Activities: A Case from Chang 7 Oil Member of Yanchang Formation in Ordos Basin

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Keywords: Ordos Basin, Chang 7 Oil Member, Sedimentary Event, Sedimentary Model

Under the background of tectonic activity that the Middle-Late Triassic Indosinian Orogeny led to the uplift of Qinling Mountains, the geological events caused by earthquake and volcano are frequent. The Change 7 Oil Member of Triassic Yanchang Formation in Ordos Basin has typical sedimentary characteristics of large depression lacustrine basin, among which many geological event sedimentary layers are preserved. Taking the event sedimentary layers in the Change 7 Oil Member of Triassic Yanchang Formation in Ordos Basin as the research object, and guided by the relevant theories of sedimentology, stratigraphy and event sedimentology, the field section around the basin and the event sedimentary layers in the drilling core inside the basin are studied. The main types of geological event deposits found in the stratum of Chang 7 are summarized. Through the analysis of the sedimentary types of the events, the sedimentary types of the main geological events found in the stratum of Chang 7 are summarized. The superimposition relationship of the seismicity, turbidite, tuff and organic shale corresponding to the earthquake events, turbidite events, volcanic events and anoxic events are analyzed, and the coupling relationship of various geological events is discussed, the formation and evolution of Ordos Lake Basin in the Chang 7 period are recognized from a new perspective. Finally, the sedimentary sequence and sedimentary model of geological events in Change 7 Oil Member of Triassic Yanchang Formation in Ordos Basin are established.

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Lithofacies and typical sedimentary cycle model of penesaline lacustrine shale association: A case study of the Yingxiongling Depression, the Qaidam Basin

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Keywords: lithofacies, sedimentary cycle, mixed sediments, chemical deposition

The sedimentary records of shale formation in penesaline lacustrine basins are distinctly different from those in freshwater lacustrine basins and marine basins, and are unique. Taking the Paleogene of the Yingxiongling Depression in the Qaidam Basin as an example, this paper shows the rock and mineral composition, lithofacies types and associations of the shale formation in the penesaline lacustrine basin by dissecting a large number of drilling cores, whole-rock X-ray diffraction, thin sections, scanning electron microscopy and other test data. And an ideal model of sedimentary cycle is proposed. The results show that the mineral composition is dominated by dolomite, calcite, clay minerals, quartz, albite and anhydrite, and also contains a small amount of pyrite, glauberite, halite and potassium feldspar. Among them, clay minerals, quartz and feldspar minerals are all terrigenous mechanical deposits, and most carbonate and sulfate minerals are chemical deposits. That is to say, the penesaline lacustrine shale system is formed by the interaction of terrigenous mechanical and chemical depositional mechanisms. According to the differences in mineral composition, sedimentary texture and structure, the penesaline lacustrine shale formation are classified into 7 types of typical lithofacies, i.e., massive inequigranular sandstone, massive argillaceous siltstone, massive mudstone, felsic shale, calcareous shale, lamellar dolomicrite, and patchy gypsum-bearing dolomicrite. The above seven lithofacies depositing from bottom to top form a typical complete sedimentary cycle on meters scale. Among them, inequigranular sandstone, massive argillaceous siltstone and massive mudstone constitute an ascending semi-cycle, dominated by turbidite depositional systems. On the other hand, felsic shale, calcareous shale, lamellar dolomicrite, and patchy gypsum-bearing dolomicrite constitute a descending semi-cycle, reflecting the gradual increase in the dominance of chemical deposition. The Paleogene shale formation of the Yingxiongling Depression in the Qaidam Basin are the sedimentary records formed by high-frequency superposition of this complete cycle or a part of its. The results of this study have theoretical significance for the application of high-resolution sequence stratigraphy in penesaline lacustrine shale formation, and have certain enlightenment significance for the current evaluation of shale oil resources.

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Major Factors Controlling Quality of Nonmarine Shale Reservoir in the Lower Jurassic in Sichuan Basin, China

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Keywords: nonmarine shale reservoir,controlling factors,pore type,compaction,Sichuan Basin,Lower Jurassic

Industrial gas flows have been yielded in the lower Jurassic nonmarine shale in Sichuan Basin in recent years, indicating that the great potential of shale gas resources in the shale reservoir in China. The purpose of this study is to determine the major controlling factors of nonmarine shale reservoir quality in the Lower Jurassic of Sichuan Basin. The study based on an integration of thin-section observation, whole-rock X-ray diffraction, helium gas for pore permeability, elemental geochemistry, organic geochemical analysis and scanning electron microscopy. The type and composition of rocks, the structure, type and storage capacity of the pores as well as the factors controlling the pore growth were revealed. Results show that the main constituent minerals of the Lower Jurassic nonmarine shales in the Sichuan Basin are clay minerals, quartz and carbonate minerals. Clay minerals and quartz are generally high in content, and carbonate minerals are locally enriched. The lithology of the shale reservoir are mainly clay shales, quartz shales, shell shales and silt shales. Clay shales and mesoscopic shales in Da'anzhai and Dongyuemiao member are high-quality shale reservoirs with relatively high organic matter content and high reservoir capacity of an average porosity about 3.9 %. Pores in the shales are mostly intergranular pores between clay minerals and other terrigenous debris, followed by organic-matter pores and some local micro-cracks. The intergranular pores show signs of strong influence of clay mineral and compaction intensity. Compaction is the main factor controlling the quality of shale reservoir. Semi-deep lake is favorable depositional environment for preservation of organic matter. Accordingly, we propose a new method for predicting high-quality shale reservoirs: finding the undercompacted zones in semi-deep lacustrine shale formations.

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Study on Reservoir Diversity Controlled by Multiple Factors:An example from Liushagangzu 3rd member of Northern Steep Slope Zone in Weixinan Depression ,Beibuwan Basin, South China Sea

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Keywords: Weixinan Depression,Reservoir,Multiple Factors

Combined with a series of analysis and test data such as seismic, core, drilling, logging and carbon oxygen isotope, this paper analyzes the reservoir differences of the East Zone, middle zone and West zone of the third member of Liushagangzu in the steep slope zone of Weixinan Sag, Beibuwan Basin, analyzes the main reservoir controlling factors of the three zones, and summarizes the reservoir development model. In the study area , reservoir diversity is mainly affected by five factors; 1) Structural factors: structural factors control trap types. In the study area , West zone and middle zone fans mainly develop glutenite deposits controlled by linear provenance, and structural traps are developed; The East zone mainly develop glutenite deposits controlled by point provenance, and lithologic traps are developed. 2) Sedimentary facies factors: sedimentary facies types control reservoir characteristics. Fan delta sedimentary system is developed in the three zones in the study area. The main dominant sedimentary microfacies are underwater distributary channel, with large sand body thickness, low matrix and cement content The main characteristics are the development of primary and secondary pores. 3) Sand thickness factors: sandstone thickness mainly controls the oil and gas bearing property of the reservoir. Taking the oil and gas bearing property of 50% as the boundary, the sand thickness of the West Zone in the study area is 3m; The sand thickness of the middle zone is 5m; The sand thickness of the East Zone is 8m; 4) Physical factors: physical factors mainly control reservoir classification. In the study area ,type I conventional reservoirs (porosity > 12%, permeability > 10md) are mainly developed in the West Zone; middle zone mainly develops type II low permeability reservoir (porosity 6-12%, permeability 1-10md); West Zone mainly develops type III tight reservoir (porosity < 6%, permeability < 1md) 5) Diagenetic facies factors: diagenetic facies factors control the reservoir type. In the study area, West Zone mainly develops weakly compacted and weakly cemented diagenetic facies (type I diagenetic facies); middle zone mainly develops medium compaction medium dissolution and strong compaction medium strong dissolution diagenetic facies; East Zone mainly develops strong compaction medium strong dissolution diagenetic facies. Combined with reservoir control factors and reservoir differences in steep slope zone, two types of multi-factor control reservoir prediction models are summarized: steep slope zone prediction model and conversion zone prediction model. The high-quality reservoir in the steep slope zone is mainly in the middle of the sand body, mainly medium coarse sandstone. The organic acid + atmospheric fresh water two-stage acid fluid is active, the dissolution is strong, and the dissolved substances migrate out of the system. The intergranular dissolved pores, intragranular dissolved pores and matrix dissolved pores are developed, and the physical properties are the best. The high-quality reservoirs in the conversion zone are mainly located in the middle of the sand body, mainly medium coarse sandstone, dissolved by organic acid fluid, developed intergranular dissolved pores, intragranular dissolved pores and matrix dissolved pores, and have the best physical properties.

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Discovery of hyperpycnites and its petroleum geological significance in paleogene of Jiyang Depression

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Keywords: hyperpycnites, Jiyang Depression, gravity flow, turbidity channel, deep water tubidites

Researches show that not only fine suspended sediments, but also hyperpycnites are developed in deep basin. Hyperpycnal flow is a kind of stable layered undercurrent formed by transporting flood of long distance with density higher than that of lake/sea water.

Compared with the marine environment, continental lake basin is more prone to the occurrence of hyperpycnal flow due to the characteristics of intense tectonic activity, large difference of topographic height, low salinity and density of lake basin water, and the main source of medium and small rivers. Many researchers have found hyperpycnites in nenjiang Formation of Songliao Basin, Chang 7 Member of Ordos Basin, Sha1 Member of Qikou Sag, Huagang Formation of Xihu Sag and Sha 3 Member of Jiyang Depression.

Previous studies on sedimentary characteristics in Jiyang Depression have been carried out, and corresponding evidences have been found. And the depositional models of hyperpycnites have been established. In the Exploration of Shengli Oilfield, some sandbodies with shape of bands or fans from long distance transport have been found in the deep sag. These sandbodies are often called turbidite channels and deep-water turbidite fans, etc.. However their genesis and depositional characteristics are lack of study. Different from the slumping turbidites, large delta or other near-source deposits do not develop in the root of these sandbodies, Such as the area of niu876 well, wang 58 well, li 988 well, etc..

Preliminary analysis suggests those turbidity channels and deep-water turbidity fans widely developed from the upper of Es4 formation to the lower of Es3 formation in Jiyang Depression are related to the hyperpycnal flow. A lot of simulation experiments and theoretical analyses of hyperpycnites have been carried out, but few studies on sedimentation process and distribution law of hyperpycnites in faulted lake are carried out.

In jiyang Depression, the climate was humid from the upper of Es4 to the lower of Es3 formation, and flood was widely developed. In this period, the basin was wide and deep. The near-source deposition was relatively undeveloped. In such, Carrying out the study of hyperpycnites is significant to the origin of fine-grained sediments and filling mode in the deep sag.

lithological reservoirs of turbidites have been found in Jiyang Depression. These reservoirs are mainly slumping turbidite from delta front. The study of hyperpycnites will expand the exploration potential of conventional hydrocarbon reservoirs in areas which are far away from the delta. Some isolated channels and fan-lobes can form lithological reservoirs. Fan-lobes can form fault-block reservoirs in sand-rich background. Channel-embankment complex can form "fault-cut sausage" structural lithological reservoirs.

As an important source of fine-grained sediments in the basin, hyperpycnal flow can bring rich organic matter, which is in favor of hydrocarbon generation. Meanwhile, lobes at the front of hyperpycnites may be the sweet spots of interbedded shale oil which can guide the selection of favorable exploration areas for sandy interbedded shale oil.

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Paleolacustrine environment and high-quality source rock development model of Eocene Wenchang Formation in Yangjiang Sag of Pearl River Mouth BasinNorthern South China Sea

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Keywords: Yangjiang sag,paleolacustrine environment, lake-basin type, high-quality source rock

Yangjiang sag is a newly confirmed hydrocarbon generating sagwhere several oil fields were found, signified great breakthrough on oil exploration in the past four years in the Pearl River Mouth Basin, Northern South China Sea. However, the controlling factors for the formation of high-quality source rocks in long-neglected small rift basin are not clear. Based on comprehensive analyses of organic, element geochemical and seismic data, we revealed the source rock characteristics, restored the paleoenvironment and lake-basin types, and established high-quality source rock development models of Eocene Wenchang Formation in Yangjiang Sag of the Pearl River Mouth Basin. The research found that: (1) The Wenchang Formation in Yangjiang Sag has developed thick middle-deep lacustrine source rocks with high abundance of organic matter. The organic matter types are mainly I-II1 types. The lower part of Wenchang Formation has strong lateral heterogeneity, with an average TOC of 2.2 -3.5%, the upper part of the Wenchang Formation has strong homogeneity, with an average TOC of 2.3-2.6%. The original organic-matter input is mainly bacterium and algae materials in the basin, whist with some contribution of high terrestrial plants in the steep slope. (2) The coupling of small- and medium-sized provenance input and rifting activities in Yangjiang Sag creates accommodating space that is conducive to the development of middle-deep lakes. Warm and humid climate conditions are the prerequisite for the blooming of aquatic plankton algae. Volcanic eruptions promote the increase of local initial productivity in the lake basin , The highly reducing water environment makes the organic matter storage conditions good. (3) Three lake-basin types are classified. Among them, the balanced-fill lake basins develop a fluctuating deep lake lithofacies combination of thick mudstone and thin sandstone in the depression zone. The underfilled lake basins have full basins and wide coverings. With the characteristics of homogeneous mudstone, over-filled lake basins basically do not develop medium-deep lacustrine source rocks. (4) The balanced-fill lake basin has a high-quality source rock development model controlled by the dual factors of "productivity + preservation conditions". The lake has high initial productivity and is generally in a medium reduction environment, forming a good type of source rock with high organic matter abundance. The abundance of organic matter on gentle slopes is better than that on steep slopes. The underfilled lake basin has a high-quality source rock development model controlled by a single factor of "preservation conditions". The lake has a medium productivity, but the water level has strong reducibility, forming medium-organic abundance source rocks. Comprehensive analysis suggests that Enping 21, Enping 20 and Enping 27 sub-sag are superimposed with high-quality source rocks in the balanced and under-filled lake basins, and they have high exploration potential. This study has important guiding significance for the prediction of source rocks in the Yangjiang Sag and other similar sags in the Pearl River Mouth Basin.

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Study on the development and preservation of shore-shallow lacustrine beach and bar in Mesozoic Yanchang Formation of Ordos Basin based on the modern sedimentary characteristics of Qinghai Lake

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Keywords: beach and bar, modern sedimentation,Qinghai Lake,Yanchang Formation,Ordos Basin

Employing the basic principle in geology that "the present is the key to the past", this research carried on the comparative study of the beach and bar sediments in modern Qinghai Lake and ancient Ordos Basin. The study suggests that the development of beach and bar sediments was mainly controlled by the provenance, (wind) hydrodynamic force, topography of lake basin, lake shoreline and lake level cycle (base level)in which the fluctuation change of lake level (base level) is the key factor which determines the preservation of beach and bar sediments, only the sand deposits at the early stage of the second-order sequence or lacustrine transgression phase of the third-order sequence can be well preserved. Through the comparative study, the research confirmed that only Chang 9-8_2-7 member of Mesozoic Yanchang formation situated at the early stage of the second-order sequence, meanwhile, at the lacustrine transgression phase of the third-order sequence, which is conducive to the preservation of the terrigenous clastic beach and bar, and thus this research establishes the prediction model of sand distribution of shore-shallow lacustrine beach and bar in Mesozoic Yanchang formation and points out that the southern basin (including southwest and southeast) in Chang 9-8_2-7 period is the favourable areas for formation and preservation of the beach and bar sand bodies, which is the favourable beach and bar reservoirs in the future. Because beach and bar sediments may have certain universality in continental lacustrine basin, this paper also points out that this research has a certain reference significance for the exploration and development of lithologic oil and gas reservoirs in other basins in China (including fault depressions and depression basins).

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Hybrid event beds in deep-lacustrine basins

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Keywords: turbidity currents, debris flows, hybrid event bed, geological significances, lacustrine basin

Hybrid event beds are common in lacustrine basin, their formation and distribution is significant for understanding the evolution processes of gravity-flow and the conventional and unconventional oil and gas exploration and development in their deposits. Taking the gravity-flow deposits in the first member of the Liushagang formation in the Weixinan sag and the seventh member of Yanchang formation in the Ordos basin as examples, the sedimentary characteristics, types, formation mechanisms, depositional model as well as the oil and gas geological significances of hybrid event beds in lacustrine basin are discussed. The gravity-flow deposits in lacustrine basin including slide and slump deposits, sandy and muddy debris flow deposits, high and low density turbidity-current deposits, and the common hybrid event beds. Three types of hybrid event beds are subdivided, which include sandwich structure, bipartite structure, and banded structure. The bipartite structured hybrid event beds can further subdivided based on the thickness difference between the upper and lower division. Sandwich structured hybrid event beds are mainly caused by flow erosion or liquefaction and located in the proximal of hybrid event beds. Bipartite structured and banded structured hybrid event beds, which located in the distal of hybrid event beds, are mainly attributed to flow decelerate and expand, the different settling of detrital grains in muddy debris flow. The vertical stacking of different beds with the same internal depositional unit composition in core is the reliable identification mark for hybrid event beds. If we couldn't reveal the formation processes of these hybrid event bed, it may cause misunderstanding of the depositional information. At the same time, the development of hybrid event bed will add the depositional heterogeneity of gravity-flow deposits, which is bad for conventional oil and gas preservation. However, the fine-grained deposits caused by hybrid event beds are the good lithofacies associations, which is the sweet spot for unconventional oil and gas development.

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Sedimentary character of gravity-flow deposits in a lacustrine depression basin: examples from the late Triassic Chang 7 Member of Yanchang Formation, Ordos Basin, Central China

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Keywords: Gravity-flow deposits, depositional model, lacustrine depression basin, Yangchang Formation, Ordos Basin

Understanding the flow processes that form gravity-flow deposits is vital for modeling and predicting sandstone bodies in the subsurface, which is of great significance for conventional and unconventional oil and gas exploration and development in lacustrine basins. This study analyses gravity-flow deposits in the Late Triassic Chang 7 member of Yanchang Formation in the Ordos Basin, using a combination of well-log analysis, core observations, thin section analysis, and laboratory measurements. The sedimentary facies, formational mechanisms, distribution patterns, and depositional models of gravity-flow deposits are investigated. Thirteen facies and eight-bed types are recognized in the gravity-flow deposits. Bed types represent deposits of sandy slides, sandy slumps, muddy debrites, sandy debrites, hybrid event beds, transitional flow deposits, surge-like low-density turbidites, and quasi-steady low-density turbidites. Gravity-flow deposits, particularly those caused by sediment failure, are composed of slides, slumps, sandy debrites, hybrid event beds, transitional flow deposits, and surge-like low-density turbidites. These deposits form as isolated lenticular sand bodies, with retrogradational internal stacking patterns. Gravity-flow deposits caused by hyperpycnal flow are composed of sandy debrites, hybrid event beds, transitional flow deposits, and quasi-steady low-density turbidites. These deposits exhibit elongate morphologies in the southern part of the basin, with progradation internal stacking patterns. The collision between the North China Block and the South China Block, which occurred during the closing of the Qinling Ocean, lead to frequent volcanic eruptions and earthquakes. This likely promoted the development of gravity-flow deposits associated with sediment failure from delta fronts in both the northeastern and southwestern parts of the basin. Concurrently, extremely humid climatic conditions promoted increased fluvial drainage, leading to enhanced hyperpycnal flows into the deep-lacustrine basin depocenters. This study emphasized that detailed facies analysis and distribution pattern analysis are the fundamental way to identify the formation mechanisms of gravity flow deposits in lacustrine depression basins.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Oral Preferred

Sedimentary Characteristics, Origin and Model of Gravity Flows in a Lacustrine Rift Basin, Eastern China

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Keywords: Gravity flow deposits, Sedimentary model, Sedimentary characteristics, Bohai Bay Basin, Shahejie Formation

Gravity flow deposits play an important role in petroleum exploration and development. The genesis and sedimentary architecture of lacustrine gravity-flows deposits (LSGFs) influenced by multiple provenances are ongoing questions requiring persistent attention and investigation. Based on the lithology observation, logging data, and three-dimensional seismic data from the southern Bohai Bay Basin, this study analyzes the characteristics, fluid types, genesis, and models of LSGFs. Twenty lithofacies types are classified into nine lithofacies associations caused by five genetic types: cohesive flows, inflated sandflows, concentrated-density flows, turbidity currents and hybrid events. LSGFs is divided into sublacustrine fan deposits caused by floods and slump olistolith induced by sediment failures. The sublacustrine fan can be subdivided into the inner, middle, and outer fans. Inner fan deposits are dominated by thick massive coarse debris and are mainly created by cohesive flows and inflated sandflows. The middle fan primarily features channel-filled deposits, which are composed of organized sandstones. Hybrid event beds with rich mud clasts caused by particles of cohesive debris flow rearrangement develop in middle fans. The outer fan deposits are characterized by turbidite lobes extending to the center of the lake basin. Hybrid event beds with sharp contact and that with gradual contact caused respectively by turbidity current deceleration and turbidity current erosion jointly develop at outer fans. Classified by the distance from slumps, the slump olistolith without channel deposits can be further divided into proximal lobes and distal lobes. The proximal lobe deposits mainly consist of slumps at their beginning and high-density frictional flow deposits at their end. The distal lobe deposits are composed of thin concentrated-density flow deposits and turbidites. Hybrid event beds with sandball construction and rip-up clasts caused by slumping develop at transition zones between proximal lobes and distal lobes. Based on the analysis results and the probe of sedimentary characteristics, the sedimentary model and triggering mechanism of LGSFs caused by 4 types of flows and hybrid events under the influence of multiple provenances and the paleogeomorphology has been established. This paper provides some insights about LSGFs with multiple provenances.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
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Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Multi-scale Quantitative Characterization and Fractal Evaluation of Pore Structure of Mixed Rock Reservoir in Bohai Bay Basin

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Keywords: lacustrine mixed rock,pore-throat combination,fractal evaluation,sedimentation,Bohai Bay Basin

Bohai Bay Basin is one of the most developed areas of continental mixed rocks in China. This study investigates the mixed-rock reservoir of the Shahejie Formation in the steep slope of the Shijiutuo uplift in the Bohai Sea area. The macroscopic understanding is established by observing the core and thin sheet, mineral composition and distribution of mixed rock reservoirs is quantitatively evaluated by QEMSCAN, multi-scale selection and evaluation across order of magnitude is established by Maps technology, submicron pore size distribution is quantitatively characterized by using high pressure mercury data, three-dimensional distribution and seepage capacity of reservoir space is precisely characterizated by using multi-scale CT. Based on the capillary pressure data, the key parameters of pore-throat distribution in mixed rock were evaluated by fractal characterization. The quantitative relationship between reservoir physical properties, pore structure parameters and fractal dimension is further studied, classification and evaluation of pore structure of mixed rock in study area is established.

The results show that: There are various rock types, strong heterogeneous properties and complex pore-throat structure in the mixed rock reservoir in the study area. The millimeter-micron pore-throat network is mainly developed in high porosity, medium to high permeability bright crystalline dandruff dolomite. Dissolution pores and biological cavity holes contribute greatly to the expansion of reservoir space, the fractal dimension of pore-throat is the lowest. Submicron-micron and micron pore-throat is mainly developed in medium-high porosity, medium-low permeability dolomitic lithogenic sandstone and continental dolomite. The main storage space types are inter-granular dissolved pore, mold hole, inter-crystalline pore and so on. The pore-throat fractal dimension is medium. The pore-throat of nanometer-submicron is mainly distributed in mud crystal sand dolomite and calcareous siltstone. Inter-granular pores and micro-cracks are the main types of reservoir space. The fractal dimension of the pore throat is the highest. Multi-scale characterization and evaluation of pore-throat combination characteristics of lacustrine mixed rock reservoir provide basis for fluid identification and effective development of mixed-rock reservoirs in Bohai Sea area.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Geological characteristics and paleoenvironmental evolution of fine-grained sedimentary rocks in the third member of Xujiahe Formation in Western Sichuan Depression

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Keywords: 3rd member of Xujiahe Formation,Geochemical characteristics,Paleoenvironment, Paleoclimate, Fine-grained rock

The Xujiahe Formation is an important stratum that records the tectonic transformation of the western margin of the Yangtze Plate and the early formation process of the Longmenshan foreland basin, and is also an important set of hydrocarbon-bearing strata. In order to clarify the palaeoenvironmental evolution characteristics of the third member of Xujiahe Formation in the western Sichuan depression during the deposition of fine-grained sedimentary rocks, and to provide basic geological data for the in-depth study of the third member of Xujiahe Formation and the exploration and development of shale gas in the western Sichuan region. The mineralogy, petrological and geochemical characteristics of the fine-grained sedimentary rocks of the third member of Xujiahe Formation in the Western Sichuan Depression in the Late Triassic were studied in detail by using the analysis methods of mineral petrology and whole-rock geochemical elements. The research results show that the mineral types in the fine-grained sedimentary rocks of the third member of Xujiahe Formation are mainly brittle minerals such as quartz and feldspar, the main type of clay minerals is illite, and siderite is more developed in some areas, and the content of carbonate minerals is relatively small, and the rock type is mainly felsic dark fine-grained sedimentary rocksThe discovery of multiple siderite strips indicates that there were multiple warm periods in the paleoclimate at the time of deposition, and combined with geochemical analysis, it is shown that the paleoclimate type during deposition was mainly warm and humid, but there have been several climate changes in the vertical direction, and the northern part of the basin was warmer and humid than the southern part; The paleoproductivity shows a cycle of increasing-decreasing-increasing vertically, and it is high in the north and low in the south in the plane distribution; The sedimentary water body is dominated by marine salt water, and fresh water is injected at the same time; The redox environment of the water body is mainly sub-oxidative-sub-reduction environment; The chemical weathering degree of the provenance area is moderate weathering, and the climate is similar to that of the sedimentary area.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Development mechanism and sedimentary model of gravity flow in the west area of Fushan Sag, Beibu Gulf Basin

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Keywords: Beibu Gulf Basin,Fushan Sag,gravity flow,Continental lake basin

Development mechanism and sedimentary model of gravity flow in the west area of Fushan Sag, Beibu Gulf Basin

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Two sets of gravity flow sediments with different provenances and different genesis are developed in the west area of Fushan Sag, Beibu Gulf Basin, and mixed in the center of the basin, forming a large set of gravity flow sand bodies in Yong'an area. According to the latest drilling, the gravity flow sand body in this area has high reservoir forming potential. Taking the west of Fushan sag as the research area, this paper systematically analyzes the gravity flow sand body of Liushagang Formation Weizhou formation of Paleogene by using core, logging, high-precision three-dimensional seismic, heavy ore, zircon and other provenance analysis. Through the careful observation 218m long cores from 4 wells in the deep lake area of Yong'an area, three types of deep lake gravity flow sedimentary lithofacies are identified in the sedimentary period of Liushagang Formation, namely argillaceous clastic flow deposition, sandy clastic flow deposition and turbidity flow deposition. They not only represent the fabric of sediments with different grain sizes, but also have different genetic mechanisms and rheological characteristics. The lateral distribution and vertical combination of the three gravity flow sedimentary lithofacies can also be used as the characterization of the two sets of sedimentary systems in the study area.

The north and south parts of the study area develop delta front gravity channel system and pure gravity flow system respectively. There is no obvious sand transport channel in the north, which is mainly due to the activity of the fault slope, resulting in the spontaneous collapse of the sand body in the northern fan delta or sand rich part under the action of gravity. The scale is small, there is little overlap between the fans, and it is mainly dominated by the alternating distribution of argillaceous debris flow and turbidity flow. There are sufficient Braided River Delta provenances in the south. Under the action of two major fault slopes, a large-scale waterway gravity flow system is formed. There are many overlaps between gravity flow fans, and due to the difference of provenance supply intensity in different directions, there is a large lithologic gap between different fans. The lithofacies is characterized by the development of sandy debris flow and turbidity current. At the intersection of the two gravity flows, a good reservoir cap combination with sandy debris flow, turbidity flow as reservoir, argillaceous debris flow and deep lake mud as cover is formed.

This paper studies the development mechanism and sedimentary model of two sets of gravity flow sand bodies in the north and south of the west area of Fushan Depression, which has positive geological significance for further reservoir exploration in the study area, and can also provide a theoretical basis for the study of gravity flow sand bodies in similar continental lake basins.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Oral Preferred

Glutenite depositional distributary-controlling mechanism of rifted lacustrine basin in the northern actic region of Chexi Depression

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Keywords: glutenite deposition, distributary-controlling mechanism, rifted lacustrine basin, Chexi Depression

Glutenite reservoir with rapid horizontal change, strong heterogeneity and complex main control factors has difficulties in exploration and development. In order to solve the difficulty of glutenite reservoir exploration in faulted lacustrine basin caused by sand bodies distributary controlling mechanism, the glutenite deposition in lower Es3 subsection of rifted lacustrine basin in the northern actic region of Chexi Depression as the study target, the effects on glutenite distribution of various controlling factors are analyzed emphatically such as base type, fault pattern, sediment supply and the scale of depositional accommodation. In addition, according to determined stratigraphic sequence framework, sedimentary facies markers are identified by using core analysis data and logging response characteristics. Moreover, the combination of following flow profiles and across flow profiles is used to carry out sand body correlation between wells guided by sedimentary facies and the framework of quaternary sequence (sand group). The sand body distribution patterns are determined based on paleogeomorphology, and the distribution scale of glutenite sedimentary is quantitatively described by fine sand body characterization. The main results and understanding are as follows.

(1) Stratigraphic division makers are identified by core and logging data. The lower subsection of the third member of the Shahejie Formation in Chexi Sag develops a positive cycle and a counter-cycle divided by the maximum lake flooding surface and is divided into four sand-layer groups, while, the stratum as a whole is thick in the north and thin in the south. Moreover, through facies identification of single well and stratigraphic correlation between wells, four types of conglomeratic fan determined in the study area: distal neritic subaqueous fan, proximal neritic subaqueous fan, fan delta and slump turbidite fan.

(2) Based on fine glutenite characterization carried out by combined seismic interpretation with logging data, four types of sand body distribution pattern based on constructional morphology are defined: slope break model, shallow slope model, graben fault step compound model and slope-fault step model.

(3) Comparing the distribution sizes of various sand bodies which quantitatively characterized by logging and seismic association in horizontal and vertical direction, a rule is indicated that: the fan type mainly controlled by the provenance transport system, the sand body size mainly controlled by the fault pattern, and the sand body distribution range mainly controlled by the base type.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Impact of sedimentary environment on the development of continental shale laminae Insights from the XRF core scanning

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Keywords: continental shale, sedimentary environment, laminae, XRF core scanning

Laminae refers to the smallest or thinnest original sedimentary layer that can be distinguished in sediments or citrine, and is the smallest unit that constitutes a spread. Shale laminae are usually 0.02 ~1.00 mm. Formation of shale laminae is a complex physical and chemical process involving biological productivity, bottom water redox state and deposition rate in the sedimentary evironement and post-deposition degradation process. The shale laminae is one of factor that could influence the properties shale reservoirs because it controls the material composition, distribution, and heterogeneity of shale reservoirs. XRF core scanning measurement technology is used to conduct high-resolution elemental measurement in a rapid, non-destructive, and continuous manner, with resolution range from 0.1–10 mm,.

The Jurassic Qianfoya Formation in the Sichuan, China, was chosen as the research object. This strata is primarily a terrigenous clastic shallow lacustrine sediments with siliceous clastic laminae, carbonate laminae, clay laminae, and organic matter laminae.

The analysis revealed that in the early stages of lake formationin arid climates the water body gradually becomes shallow due to strong evaporation, forming a relatively closed lake basin. The terrigenous input gradually decreased as water depth increased, and bivalves proliferated in large numbers. The lake water body was shallow, and the oxygen content at the bottom of the lake was high. The loss of reducibility had a negative impact on organic matter production and preservation. As a result, shale with carbonate and siliciclastic laminae developed more frequently in arid climates,.

The river could recharge a large amount of fresh water into the lake when the climate changed from arid to warm and humid, the water body gradually deepened, the land source inputs (such as clay minerals) gradually increased, the lake basin gradually opened up, and the clay minerals gradually increased as the climate changed from arid to warm and humid due to input of terrestrial materials. The water body was relatively quiet due to the deep lake water, creating conditions for the production and preservation of organic matter. Thus, terrigenous siliciclastic laminae, clay laminae, and organic laminar shale were primarily formed. The depth of the water body reached its maximum after the climate became warm and humid, terrigenous inputs brought abundant clay minerals. The lake had the characteristics of water stratification, implying that the upper water body had sufficient oxygen content, the lower water body was oxygen-poor or anoxic. So that the lake bottom was a strongly reducing environment and well preserved organic matter. The carbonate minerals were less developed, resulting in more homogeneous structures. Therefore, the shale was mainly massive under humid climate conditions, with occasional laminae.

When the warm and humid climate transitioned to the arid climate, the water body gradually became shallow. The water environment was relatively calm with high organic content. Occasionally, carbonate laminae formed by storms breaking up shoal carbonates. When the study area transitioned from a warm and humid climate to an arid climate, the shale mostly developed carbonate and clay laminae, with occasional organic laminae.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Control mechanisms of tectonic paleogeomorphology on the Lower Cretaceous sedimentary basin fills in Tanan Sag, Tamtsag rift basin, Mongolia

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Keywords: syndepositional faulting movement,transfer zones, structural slope-break zones, control mechanism of sand distribution,; Tanan Sag

Tanan Sag is a typical faulted lacustrine basin during the early Cretaceous, which experienced multi-stage episodic faulting activities. Tectonic activities are an important factor for the formation of paleogeomorphology and sand distribution. However, the controls of paleogeomorphologies generated by synsedimentary tectonic activities on sequence architectures, sedimentary system and sand body distribution are still unclear. Based on seismic, well logging and core data, under the guidance of sequence stratigraphy theory and paleogeomorphic sand control theory, the sequence stratigraphic frameworks of the lower Cretaceous in Tanan sag are established. Combined with the analysis of the major fault activity during different rifting stages, the controlling effects of different paleogeomorphologies on sedimentary system and sand body distribution are clarified. The investigation of the tectonic evolution and sediment fill of Tanan Sag during the early Cretaceous indicated that the episodic rifting and various activities of major faults created complex paleogeomorphologies including transfer zones and structural slope-break zones, which significantly controlled the development and distribution of both depositional systems and sand bodies. The transfer zones including transverse uplift and relay ramp were the sites for drainage catchment, and controlled the locations of sedimentary provenances, entry points of sedimentary material into the basin, and the resultant development of depositional systems. According to fault geometry and the location of the slope-break zones, the structural slope-break zones of Tanan Depressoion during the climax rifting stage would be subdivided into four types, they are fault scarp zone, fault terrace zone, gentle slope zone and intrabasinal fault break zone, which played significant roles in controlling the changes in accommodation and the distribution of depositional systems and sand bodies. Three syndepostional faults arrangement patterns were identified according to their distribution on the structure map, which are “comb-like”, “fork-like and “parallel” faults. Areas where the structural slope-break zone overlapped with transfer zones are sites for major drainage systems and the optimum locations of fan deltas and sublacustrine fans. The sand bodies deposited here are favorable targets for the exploration of litho-stratigraphic traps in Tanan Sag. The results have important theoretical significance and practical value for deepening the theory of source-to-sink system and guiding the prediction of sand body distribution in faulted lacustrine basins.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Oral Preferred

Lamina characteristics of lacustrine shale and its influence on reservoirs in the first member of Shahejie Formation in Nanpu Sag, Bohai Bay Basin

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Keywords: lamina, lacustrine shale, physical properties, Shahejie Formation, Bohai Bay Basin

The development of lacustrine shale lamina makes the shale heterogeneity change obviously, and the degree of lamina development has an important influence on the quality of shale reservoirs. Based on nitrogen adsorption, X-ray diffraction, total organic carbon, pyrolysis experiments and scanning electron microscopy experiments, the lamina characteristics and their influence on shale reservoirs in the first Member of Shahejie Formation were studied in the Nanpu Sag, Bohai Bay Basin. Combined with ImageJ software(binarization, mean filtering and map value conversion), the purpose of this paper is to systematically study the types and assemblages of lamina, the structure of lamina, and the factors controlling the development of lamina. According to the mineral composition and lamina thickness, the laminas were divided into organic-rich-felsic laminae and organic-rich-clay laminae. The thickness of the organic-rich-clay lamina was 25-210μm, and its total organic carbon content was about 1.2%. The thickness of organic-rich-felsic lamina was 15-170μm, and its total organic carbon content was about 0.9%. The development of lamina had a good effect on reservoir. The number of lamina and areal density had a good positive correlation with the physical properties and specific surface area of the reservoir, and had a negative correlation with the total pore volume and average pore size. However, the lamina thickness showed the opposite trend with the above reservoir parameters. The development of lamina was controlled by the content of total organic carbon and mineral components. The lamina shale were characterized by rich in organic matter and high clay or felsic mineral content. As the total organic carbon content and carbonate mineral content increased, the lamina was more developed.

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Session T5-2: Deep-lacustrine sedimentary processes and products
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Genetic model and reservoir prediction of braided river delta prograding body in the middle submember of 3rd member of Shahejie formation in the Laizhouwan

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Keywords: Laizhouwan depression, Shahejie formation, braided river delta, prograding body

The discovery of oil and gas in braided river delta prograding body in the middle submember of 3rd member of Shahejie formation in the Laizhouwan depression have confirmed its large lithologic exploration potential. Through the combination of well and seismic data, PaleoScan software was used to intelligently identify the interface of parasequence sets inside the prograding body, and strict isochronous high-frequency sequence stratigraphic framework was established to divide the prograding body into five parasequence sets. The fine characterization of topset beds, foreset beds and bottom beds in prograding body were conducted with the paleogeomorphology restoration of each parasequence set. Furthermore it was founded that the relationship among foreset angle and sand content follows the uniform inverse function .The spatial distribution patterns of sand bodies in each parasequence set were clarified, one is the high-angle S-type prograding body sand enrichment model which the favorable reservoirs mainly distribute in the deltaic front subaqueous distributary channel in steep foreset beds of parasequence set I-II, and another one is the low-angle oblique type prograding body sand enrichment model which the favorable reservoirs mainly distribute in the prodelta turbidite body in gentle bottom beds of parasequence set III-V. Those reservoirs have favoured the formation of lithologic oil–gas reservoirs by means of good trap sealing conditions, excellent oil–gas reserving performance, and effective oil source communication of high-quality source rock.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
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Lamination Texture and Its Effects on Reservoir and Geochemical Properties of the Palaeogene Kongdian Formation in the Cangdong Sag, Bohai Bay Basin, China

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Keywords: unconventional geology,lacustrine shale oil,sweet spot,fine-grained sedimentary,nano-pores

The characteristics of laminae are critical to lacustrine shale strata. They are the keys to the quality of source rocks and reservoirs, as well as engineering operations in shale plays. This study uses organic geochemistry, thin section identification, X-ray diffraction, field emission scanning electron microscopy, and other analytical methods, to reveal the detailed lamination texture and vertical distribution of laminae in the second Member of the Kongdian Formation in Cangdong Sag. The principal results are as follows: (1) A classification of laminae is proposed to characterize reservoir and geochemical properties. The five types of laminae are as follows: feldspar-quartz laminae (FQL), clay laminae (CLL), carbonate laminae (CAL), organic matter laminae (OML), and bioclastic laminae (BCL). There are also four significant lamina combinations (with the increasing TOC values): FQL-CLL combination, FQL-CLL-BCL combination, FQL-CLL-OML combination, and FQL-CAL-CLL-OML combination; (2) differences between laminae occur because of the variability in pore types and structures. There appears to be a greater abundance of intercrystalline pores of clay minerals in the FQL, CAL, BCL, and OML, and well-developed organic pores in the CAL and CLL, and the counterparts of intragranular pores of bioclastic material in the BCL. This detailed characterization provides the following comparative quantification of the thin section porosity of laminae in the second Member of the Kongdian Formation can be differentiated: CAL > FQL > OML > BCL > CLL; (3) differentiation between vertical distributions of laminae is carried out in a single well. The FQL and CLL are widely distributed in all the samples, while the BCL is concentrated in the upper part of the second Member of the Kongdian Formation, and CAL is concentrated in the lower part. This detailed classification method, using geochemical analysis and vertical distribution descriptions, offers a detailed understanding of lamination texture and its effects on reservoir and geochemical properties, which will provide a scientific guidance and technical support to better estimate reservoir quality and to identify new sweet spots in the second Member of the Kongdian Formation in the Cangdong Sag.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Oral Preferred

Discovery of Late Cretaceous Tidal fearture – new evidence of marine transgression in the West African continental rift basin Termit, Niger

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Keywords: Niger,Termit basin, Late cretaceous, Tidal, marine transgression,prototype basin

Termit Basin belongs to West African continental rift system, and formed in early Cretaceous as lacustrine depositon system. According to literatures, transgressive activity across the Sahara seaway happened in the Late Cretaceous global sea high level period, and including Termit baisin. And none of marine deposition evidence was reported in these area, perhaps because the basin is under the Sahara desert, and lack of outcrops. In this paper, based on the cores recently obtained in the Termit Basin, typical sedimentary facies marks such as herringbone cross-bedding, double mud drapes, tidal rhythm, and tidal bedding (flaser bedding, wavy bedding, and lenticular bedding) were identified. And then the tidal-generated superimposed transgressive succession was interpreted. Accordingly, the existence of tidal flat deposits was confirmed in combination with palaeontological fossils (e.g., fossil foraminifera) and trace fossils, which illustrates the generality of tidal action in the Late Cretaceous Termit Basin. Based on the above, the prototype basin of the Termit Basin is restored with the aid of thorough data integration. It is considered that the Termit, Iullemeden, Tefidet, Tenere, Grenin, and other basins were within a unified basin setting in the Late Cretaceous that was wide in the east-west direction and connected with Tethys and South Atlantic in the north-south direction. The prototype basin constitutes the central main part of the Saharan seaway. The paleogeographic conditions of this seaway, which is affected by oceanic action (especially tidal action) and contains abundant marine deposits, may be similar to the Late Cretaceous North American Western Interior Seaway.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Oral Preferred

The evolution and characteristics of sublacustrine fan types in different stages during the process of delta progradation in rifted lacustrine basin, Liaozhong Sag, Bohai Bay Basin, China

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Keywords: sublacustrine fan, delta progradation process, rifted lacustrine basin, spatial evolution, Liaozhong sag

Liaozhong sag in the Bohai Bay Basin is a graben-type rifted lacustrine basin with east-west double faults. During the Paleogene period, the ancient Daling River and the ancient Liao River entered the basin along the long axis of the fault depression, forming two large-scale meandering river deltas superimposed with each other. During the progradation process of the two deltas, 14 sublacustrine fans deposits were formed, with the characteristics of vertical superposition and horizontal connection. Drilling revealed that these sublacustrine fans coexisted with sand-rich and mud-rich types, with complex spatial evolution laws, and unclear correspondence between sublacustrine fans and deltas. To solve these problems, on the basis of clarifying the relationship between each sublacustrine fan and the two deltas, starting from analysis of the sand-rich changes in the delta progradation process, this paper defines the types, characteristics and mechanisms of sublacustrine fans formed at different stages in the delta deposition process.

The study shows that: The two deltas have different foreset directions and heavy mineral assemblages. The ancient Daling River enters the basin from north to south, and the heavy mineral combination was zircon-magnetite-limonite-tourmaline; the ancient Liao River entered the basin from northeast to southwest, and the heavy mineral combination was tourmaline-magnetite-zircon-limonite. The thickness trend of the sublacustrine fans has obvious affinity with the provenance. The trend of No.1-4 sublacustrine fans is between 195° and 202.17°, which is consistent with the ancient Daling River delta; The thickness of No.5-14 sublacustrine fans strikes between 230.4° and 262.5°, which is consistent with the ancient Liao River delta. The sublacustrine fans can be divided into 3 types with non-channelized sandy-debris-flow(SDF) sublacustrine fan, non-channelized turbidite-current(TC) sublacustrine fan and channelized fan. SDF sublacustrine fans and TC sublacustrine fans have no evident channel, and the SDF sublacustrine fans are rich in sand, TC sublacustrine fans are rich in mud; channelized fans have evident channel, and the sand is main in the channel. Sand-richness of provenance plays a major role in controlling sublacustrine fan types. The sand rich provenance, which is non-viscous and easy mixed with water when slumping, cannot form the channel easily; the mud rich provenance, which is viscous and hardly mixed with water when slumping, can form the channel with ease. Therefore, when the sand content of the delta front is greater than 30% in the early stage, non-channelized sublacustrine fans will be formed. When the sand content is less than 30% in the late stage, it is easy to form a channelized sublacustrine fan. The scale of the slope break zone plays a secondary role in controlling the sublacustrine fan types. Under the sand-rich provenance background, due to the long transportation distance with large scale of the slope break, the sand and mud are fully differentiated, both SDF sublacustrine fan and TC sublacustrine fan can be formed. However, only SDF sublacustrine fan can be found in the condition that the slope break scale is small.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Oral Preferred

Topset-to-foreset rollover trajectories and stratal stacking patterns: Their relation to sediment and sand dispersal to southern Bozhong deep water, Bohai Bay Basin

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Keywords: rollover trajectories, stratal stacking patterns, sand dispersal, sequence stratigraphy, southern Bozhong sag of Bohai Bay Basin.

The analysis of stratal stacking patterns and shelf-edge trajectories is considered as a recent advancement in sequence stratigraphy and they are reliable predictors of sand dispersal to deep water. Using 3D seismic and borehole data, the current research documented Oligocene topset-to-foreset rollover trajectories and explored their sequence stratigraphic significances and implications to sand dispersal to southern Bozhong deep water, Bohai Bay Basin. Two main types of topset-to-foreset rollover trajectories and their associated stratal stacking patterns were recognized: (1) flat and then rising trajectories and associated progradational-aggradational stacking patterns, and (2) initially rising, and then flat, and finally turn to descending trajectories and associated aggradational-progradational-degradational stacking patterns. The former has low trajectory angles (T_r) (0.32°-1.07°, averaging 0.72°), topset-to-foreset rollover aggradation to progradation ratios (d_y/d_x) (0.01-0.03), and differential sedimentation on the slope and basin (A_s/A_b) (0.14-0.23, averaging 0.18), whereas the latter is with higher Tr (0.57°-1.17°, averaging 0.94°), d_y/d_x (0.02-0.04) and A_s/A_b (0.47–2.31, averaging 1.16). Each trajectory regime represents a specific stratal stacking patterns. Moreover, flat and then rising topset-to-foreset rollover trajectories and progardational-aggradational stratal stacking patterns were related to massive, extensive, and sand-rich sub-lacustrine fan systems that were linked to straight channels updip. Initially rising, and then flat, and finally turn to descending topset-to-foreset rollover trajectories, however, were fronted by laminated, diminutive, and sand-rich sub-lacustrine fan systems that were fed by sinuous channels. Therefore, given a constant sediment supply, T_r, d_y/d_x and A_s/A_b are negatively correlated with the amounts of sand dispersal to deep water. These relationships between topset-to-foreset rollover trajectories (or stratal stacking patterns) and depositional characteristics of sub-lacustrine fan systems provide a quantitative method to predict the sand dispersal to deep lake in continental rift basins.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Oral Preferred

Sandbody distribution and tight sandstone genetic mechanism in a rift basin with strike-slipA case study from Shuangyang Formation of Chaluhe Fault Depression in Yitong Basin

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Keywords: rift basin, strike-slip, provenance, tight sandstone, genetic

The Yitong graben represents a rift basin under a typical strike-slip setting. In recent years, its deep tight sandstone gas reservoirs have shown good exploration prospects.However, the distribution of sand bodies and the characteristics of tight sandstone reservoirs are unclear. In this study, taking the Shuangyang Formation in the southern part of the Chaluhe fault depression in the Yitong Basin as the research object, on the basis of seismic and logging analysis, combined with various experimental methods such as rock thin sections observation, scanning electron microscopy, and micro-CT, three findings were obtained as follows:(1)The Shuangyang Formation develops two provenances, the fan delta in the northwest margin and the braided river delta in the southeast margin, and is dominated by the southeast provenance. The sand body in the southeast margin covers 2/3 of the area of the fault depression, and the fans are distributed obliquely along the depression-controlling fault.(2) The tight sandstone of the Shuangyang Formation is in the middle diagenetic stage B, dominated by detrital feldspar sandstone, mainly siliceous cementation, with porosity of 4-10% and permeability of 0.02-5×10-3μm2. Mechanical compaction, conversion of clay minerals to illite and the formation of secondary minerals are the main porosity reduction effects.(3) The sandstone of the Shuangyang Formation changed into tight sandstone at the E2y period (about 35 Ma) , while the main gas accumulation period is the E3w (about 30 Ma). Therefore, the tight sandstone gas reservoir was formed after the sandstone reservoir densificated. These findings could provide guidance for tight sandstone gas exploration in rift basins.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Sedimentary microfacies, diagenetic process and reservoir quality of sandstones from the No. 1 structural belt in Nanpu Sag, Bohai Bay Basin, China

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Keywords: Sandstone reservoir quality, Sandstone diagenesis, Sedimentary microfacies, Nanpu Sag

Reservoir quality is generally evaluated by porosity and permeability, which are critical parameters for petroleum and natural gas exploration and production (Shang et al., 2022; Xie et al., 2021a). Reservoir porosity defines the hydrocarbon storage ability, whereas permeability limits hydrocarbon production capacity, and both have a significant impact on the economic feasibility of a petroleum accumulation (Worden et al., 2000, 2018; Xie et al., 2021b, 2021c). Prediction of rock properties must be based on integrated study of sedimentary and diagenetic processes.

Nanpu Sag is a petroliferous sag in the Bohai Bay Basin and has produced a significant quantity of industrial oil flows in shallow to deep layers (depth ranges roughly from 2500 km to 4000 km) (Chen et al., 2014; Jiang et al., 2018; Wang et al., 2020; Yang et al., 2022). The No. 1 structural belt is located in the southwestern Nanpu Sag. At present, many sets of oil-bearing strata have been found in Paleogene Shahejie Formation, Dongying Formation, and Neogene Guantao Formation, Minghuazhen Formation, and the primary exploration strata are Dongying Formation (28.5-23.8 Ma) (Hao et al., 2019).

To address the roles of sedimentary processes and diagenesis on reservoir quality, a study of the sandstones from the No. 1 structural belt in Nanpu Sag, Bohai Bay Basin, China, was undertaken based on wireline and core analysis data, petrography, scanning electron microscopy, and X-Ray diffraction of core samples. Five types of sedimentary microfacies are recognized: subaqueous distributary channel (fan delta), subaqueous interdistributary bay, subaqueous distributary channel (braided delta), distal bar, and turbidite fan. The major diagenetic processes, including compaction, cementation, and feldspar dissolution of the feldspathic litharenite sandstones, have been tested. The dominant diagenetic cement includes calcite, smectite, kaolinite, illite, and I/S mixed-layer minerals, with minor quantities of pyrite, chlorite, siderite, K-feldspar, and quartz cement. Reservoir quality is best in subaqueous distributary channel (fan delta) sandstones, followed by subaqueous distributary channel (braided delta). Subaqueous interdistributary bay, distal bar, and turbidite fan are of poor reservoir quality. The grain size is the primary reservoir quality controlling factor, highly affected by sedimentary microfacies. Subsequent controls are diagenetic processes such as mechanical compaction, clay minerals formation, grain replacement, and dissolution that collectively influence the porosity and permeability.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Genetic evolution and exploration significance of large restricted gravity flows: A case study of the second member of the Southeast slope belt in the Bohai Sea

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Keywords: Sublacustrine fan,Channel,Evolutionary characteristics, Developmental pattern,Bozhong sag

The Dongying formation in the Bohai Sea showed a paleo-tectonic pattern of post-rift transition period . Subsidence rate and filling thickness of the basin were much higher than those of the surrounding continental areas. Depression zone as a whole showed a process of rapid deposition and leveling, and gravity flow deposits were widely developed.

Large gravity flow deposits are developed in the lower second member of the Dongying formation in eastern section of the southeast slope belt of central Bohai depression, which has great potential for lithologic exploration. In view of the unclear genesis mechanism and temporal and spatial evolution law of the fan body under the condition of no well, the seismic data were comprehensively used to analyze the response characteristics and genesis mechanism of gravity flow deposition, clarify the plane distribution and vertical evolution characteristics of the sublustrine fan, and summarize its development model. Research results show that: (1) under early of the lower second member of the Dongying formationproximal deposit were given priority by the Bonan low bulge, under later period show the fault depression transformation stage, the Bonan low bulge gradually fadeout in underwater, mainly by Jiaoliao-Miaodao southeast of drainage system, the formation of braided river delta in the bulge high parts passing flow, under the lower parts of the sedimentary slope break in slope unload, controlled by the restricted paleogeomorphology under the slope break, the fan-shaped large gravity flow deposits were formed. Under the condition of sufficient material supply and long-distance transportation, the gravity flow sand body has good conditions for the development of sand-rich and high-quality reservoirs. (2) early restrictive paleogeomorphology can accommodate large space, from the top of the settlement of gravity flow sand body to select uninstall, formed A, B, C three big gravity flow deposits, due to space constraints on both sides, hydrodynamic conditions, formation of the channel characteristics of seismic facies cluttered with incised, lateral migration overlay, characterized by rich sandy debris flow characteristics of the sand. Mid with continuous replenishment gravity flow sand body, can accommodate space gradually decreases, and gravity flow along the supply channel in front of the overflow, to two steps under the open lake basin center handling, formed two gravity flow fan body, D, E, due to water concentration dilution and the ancient landform changes, energy gradually weakened, seismic facies with layered strong amplitude reflection characteristics, channel characteristic is not obvious. The late provenance supply and energy were weak, and the seismic facies showed weak amplitude reflection for local erosion and reconstruction of early fan body, which was dominated by muddy channel. The vertical gravity flow has a spatio-temporal distribution and evolution law of early restriction filling, mid-maturity overflow adjustment and late erosion reconstruction, which constitute the development characteristics of transverse connected and vertical multi-stage gravity fans.

Large restricted gravity flow sandbodies have favorable hydrocarbon migration, accumulation and accumulation conditions close to oil source and reservoir cap combination, which are important targets for lithologic reservoir exploration in Bohai Sea in recent years.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Deep-water gravity flow deposits in a lacustrine basin of in Yanchi area of Ordos Basin,Western China

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Keywords: gravity flow deposits in a lacustrine basin, sandy debris flow, turbid current, Chang 6 member of Yanchang Formation, Ordos Basin

Deep-water gravity flow deposits in a lacustrine basin is the focus of sedimentology research and the main target of tight oil exploration. Based on three-dimensional (3-D) seismic data, logging data, core analysis and laboratory data, the sedimentary characteristics, sand body distribution and sedimentary model of the Chang 6 member of Yanchang Formation are studied in Yanchi area of Ordos Basin. The results show that the gravity flow deposits in the study area is given priority to with mudstone, siltstone and fine sandstone deposition, grain size probability cumulative curves is given priority to with two stages on the arch arc. The gravity flow types are divided into sandy debris flow and turbidity current. The sandy debris flow is given priority to with gray, gray fine-grained sandstone, silty sand rock, massive bedding, normally graded and inverse graded; The turbidity current is mainly composed of gray and gray silt and silty clay with incomplete bauma sequence such as cross bedding, wavy bedding and normal graded bedding. The gravity flow deposit is sandy debris flow deposit with bandedsandstone beds in the proximal, and turbidity current deposit with sheet-like sandstone beds in the distal lobes.The thickness of sandy debris flow sand body is 20-30 meters, and it is in short strip shape. The turbidity current sand body is 2-5m, and it is distributed in the shape of lobes. The sediment of gravity flow in Yanchi area belongs to slump accumulation of Yanchi delta front.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Oral Preferred

Reservoir prediction for slope-controlled types of Eocene sandy sediment gravity flow deposits in the Dongying Depression, Bohai Bay Basin (E. China)

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Keywords: debrites, turbidites, hyperpycnites, Eocene, Dongying Depression, Bohai Bay Basin

The Dongying Depression in the Bohai Bay Basin (E China) is an asymmetric dustpan-shaped fault basin with a steep slope in the north and a gentle slope in the south. These differences in steepness controlled the sedimentary systems. Sedimentary systems with shallow lakes and deltas developed on the gentle southern slope, whereas deep subaqueous fan systems developed on the steep northern slope. Mass flows occurred in both slopes, but with different characteristics. The sandstones that they deposited and their depositional conditions nowadays attract much attention in the context of oil and gas exploration. The joint occurrence of various types of mass-flow deposits, their spatial distribution and their relationship with reservoir development are still badly understood, which hampers successful prediction of reservoir occurrences in the lacustrine sediments.

Well logs, cores and profiles based on seismic reflections have, in combination with datings, been analyzed to determine the characteristics and distribution of these sediments. It was found that, on the southern gentle slope of Dongying Depression, debris flows and turbidity currents (due to slope failure of delta fronts) and hyperpycnal flows (developed during high-discharge phases of ricers) reached the deep-water environment, building vertical successions of debrites, turbidites and hyperpycnites. On the northern (steep) slope of the Dongying Depression, debrites and turbidites did not existed because deltas were not or hardly developed. On the northern (steep) slope of the Dongying Depression, debrites were deposited from the lower parts of deltaic slopes to the slope toes; turbidites were deposited from the slope toes to the centre of the basin. Turbidites did not developed because deltas were not or hardly developed. Most sandstones on the northern sloped were deposited, however, by hyperpycnal flows. In the central graben of Dongying Depression, hyperpycnites were deposited simultaneously from flows that followed either the long axis or the short axis of the basin.

The results obtained concerning the characteristics and distribution of the various types of gravity flow deposits in the deep lake, as controlled by the steepness of the slope help effective reservoir prediction not only in the Dongying Depression, but also comparable basins elsewhere in the world.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Oral Preferred

Deep Lacustrine sedimentary systems interaction with breached relay ramp structures

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Keywords: breached relay, deep lacustrine, Early Cretaceous

Fault relay ramps serve as sediment delivery points along rift margins and often provide persistent flow pathways in deepwater sedimentary basins. Relay ramps first form as tilted rock volumes between en-echelon fault segments. Through progressive deformation the tilted rock volume becomes faulted and fractured. Eventually, a through-going fault may develop which breaches the relay ramp structure. It is well established that hinterland drainage (fluvial/alluvial systems) is greatly affected by the presence of relay ramps at basin margins, with these systems commonly exploiting the relay structures as a route into basins. However, the impact on deepwater (deep-marine/lacustrine) subaqueous sediment gravity flow processes, particularly by breached relay ramps, is less well documented. To better evaluate the complex geology of breached relay settings, this study examines a suite of high-quality subsurface data from the Early Cretaceous deep-lacustrine North Falkland Basin (NFB). The Isobel Embayment breached relay-ramp is an ideal example and was formed during the syn-rift. Using a 3D seismic volume, the structure and stratigraphy of the Isobel Embayment has been interpreted, providing the context for the study. The study analyses the transitional and early post-rift succession of the Isobel Embayment which contain Horizons A, B, C and D of this study. Seismic amplitude maps have been generated from a root mean square (RMS) amplitude interval of 20 ms (10 ms above and below the horizon) for each study horizon. Seismo-geomorphological analysis and interpretation of the study horizons identified a series of well-imaged fan systems and internal lobes at the breached relay location. These high amplitude, lobate features align with sandstone gamma ray responses intersected in wells 14/20-2 and/or 14/20-1. The breached relay ramp was progressively covered by a thick transitional and early post-rift succession. Major transitional and early post-rift fan systems are observed to have consistently entered the basin at the breached relay location. The systems were directed through a significant palaeo-bathymetric low which is likely to be associated with the lower, abandoned ramp of the structure. More minor systems also entered the basin across the structure-bounding fault to the north. Reactivation of basin-bounding faults is shown by the introduction of new point sources along the basin margin. This study shows the prolonged influence of margin-located relay ramps on sedimentary systems throughout the transitional and into the early post-rift phase. In particular, a palaeo-bathymetric low which is associated with the abandoned lower ramp of the structure, remains prominent into the early post-rift and appears to direct deep lacustrine sedimentary systems into the basin across the breached relay location. It suggests that these structures can become reactivated during post-rift times, providing continued control on deposition and sourcing of overlying sedimentary systems. Importantly, breached relays exert control on fan distribution, characterised by laterally extensive lobes sourced by widespread feeder systems, and hanging walls settings by small scale lobes, with small, often line-sourced feeders. Further characterising the likely sandstone distribution in these structurally-complex settings is important as these systems often form attractive hydrocarbon reservoirs.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Characteristics of Chang 8 Palaeo-lacustrine Basin of Yanchang Formation in Longdong Area, Ordos Basin and Its Controlling Effect on Sand Body Distribution

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Keywords: Ordos Basin,Longdong area,Yanchang Formation,Chang 8 sedimentary period, characteristics of palaeo-lacustrine basins,sedimentary environment

Major breakthroughs have been made in oil and gas exploration and development in Longdong area, southwest of Ordos Basin. The Longdong 10 million-ton oil and gas production base has been fully built in early 2022. Chang 8 oil-bearing formation of Triassic Yanchang Formation is one of the key oil bearing strata in Longdong area of Ordos Basin. The characteristics of palaeo-lacustrine basins include palaeoclimate, palaeobathymetry and palaeogeomorphology, which control the distribution of sedimentary facies, clastic composition, sand body and source rock. The study of palaeo-lacustrine basin features is the basis of the study of continental sedimentary basin. At present, there are few studies on the characteristics of palaeo-lacustrine basin in chang 8 sedimentary period of Yanchang Formation. In order to study the sedimentary facies and sand body distribution more finely, this paper analyzes the characteristics of the palaeo-lacustrine basin of Chang 8 sedimentary period, such as the palaeobathymetry and the bottom shape of it, and summarizes their control effect on the sand body type and distribution.

Based on core data, organic carbon isotope geochemical analysis, stratigraphic thickness correction, paleobathymetric recovery and 3D visualization techniques, the characteristics of the Chang 8 lacustrine basin in Longdong area are studied. The data show that the lacustrine basin of Chang 8 period in Longdong area is in humid climate and the water body is generally shallow, which accords with the sedimentation characteristics of shallow water braided delta front. The organic matter of Chang 8 mainly comes from terrestrial higher plants. Local water bodies deepened, mainly in Luopangyuan-Tiebiancheng and Chenghao-Qingcheng areas in the northeast of Longdong area, and Ningxian in the southeast and Jingchuan in the southwest. According to the diagram of lacustrine bottom shape in Chang 8, the lake bottom shape in Chang 82 and Chang 81 was higher in the west and south and lower in the northeast, and there were low-lying areas basically consistent with the above range. It is concluded that there are water downslope break zones in both Chang 82 and Chang 81 lakeside basins in Longdong area. The water downslope break zone of Chang 82 is widely distributed, mainly located in Luopangyuan - Mubo - Qingcheng - Heshui area, which plays an important role in controlling and influencing the development characteristics and flat distribution of Chang 82 sand body in the study area. The Chang82 sand body near the downslope break zone presents an obvious lenticular distribution, and the multi-stage sand body is superimposed and developed. The total thickness of the sand body in a single well is large, but the transverse connectivity is poor. However, the water downslope break zone of Chang 81 stage has a small distribution range and has little influence on the distribution of sand bodies in the study area.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Oral Preferred

New insights into hybrid event beds in deep-lacustrine fan systems

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Keywords: Hybrid event beds (HEBs), deepwater, flow processes, deep-lacustrine, hydrocarbon reservoirs, North Falkland Basin

Hybrid event beds (HEBs) are texturally and compositionally-diverse deposits formed by flows exhibiting ‘mixed behaviour’. These flow types typically form complex successions of sandstone and mudstone in the subsurface. HEBs tend to be clay-rich and are well-known for their ability to reduce reservoir quality/hydrocarbon pore-volume, as well as acting as vertical fluid transmissibility barriers and baffles in reservoir units. Consequently, their character and likely distribution within deep-marine hydrocarbon reservoirs has been studied somewhat extensively. However, (and by contrast) there are far-fewer studies that focus on HEB character and distribution in deep-lacustrine settings. Understanding HEBs within the context of deep-lacustrine fan models is therefore of great importance to continued hydrocarbon exploration success and efficient development of deep-lacustrine reservoirs in basins worldwide. To improve our understanding of these complex sedimentary successions, this study presents a detailed analysis of 3D seismic data, wireline logs and core from a series of ancient deep-lacustrine fan systems in the North Falkland Basin. Results of this study confirm that deep-lacustrine HEBs comprise a similar idealised sequence of the ‘H1–H5’ divisions as observed in deep-marine settings. However, in this study the H3 ‘debrite’ units is subdivided into three internal divisions (H3a, H3b, and H3c), based on: sharp or erosional intra-H3 contacts, bulk lithology, mud-content and discrete sedimentary textures. Spatially, HEBs are observed within lobe fringes, where flow types, energies, and transport mechanisms diversify as a result of flow transformation. The temporal context of HEBs is considered in-relation to stages of fan evolution, with HEBs being observed typically in either the initiation phase, where flow interaction and erosion of initial substrates promoted mixed flow behaviour, or in the abandonment phase, as facies belts retreated landward. The results of this study have important implications in terms of the prediction of HEB occurrence and character within ancient deep-lacustrine fan settings.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Seismites in shales: an exceptional case from the Early Cretaceous Tianjialou Fm. near Xiahouzhuang (prov. Shandong, E China)

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Keywords: seismites, soft-sediment deformation structures, earthquake magnitude, Early Cretaceous, Xiahouzhuang Formation

Seismites in shales: an exceptional case from the Early Cretaceous Tianjialou Fm. near Xiahouzhuang (prov. Shandong, E China)

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Abstract

Seismites are well known particularly from Quaternary silty and muddy sediments in lacustrine settings, but hardly from lithified ancient equivalents, because the uniform grain size in shales tends to obscure the deformation. The Early Cretaceous Tianjialou Formation, developed near the village of Xiahouzhuang (Shandong Province, E. China) in a shallow-lacustrine facies, is an exception. The sediments are predominantly silty mudstones, with a few thin intercalations of fine sandstone. The formation at this site shows a slightly shallowing tendency. Layering in the pure mudstones present in the lower part of the exposed section is difficult to trace, but it is obvious that some entirely deformed levels are present interbedded between non-deformed levels. In the upper part, where the layering is better discernible, it appears that even numerous completely deformed layers exist, intercalated between non-deformed levels. All deformed levels show the characteristics of seismites.
The seismic activity must be ascribed to fault activity along a zone that is now occupied by the Shuhe River. The rocks with the deformations dealt with here are cut by the river. Taking into account that the faulting was active already during the Early Cretaceous, this implies that the distance between the sediments under study and the contemporaneously active fault zone was only a few to maximally a few hundred metres. This explains not only the occurrence of seismites in these lacustrine sediments, but also the presence of deformed mudstones in not well discernable levels: even though many of the earthquakes may have had low magnitudes, the distance of the epicentre to the water-saturated muds was so small that locally deformation of the mud could take place. This implies that the magnitude of an earthquake required for seismically-induced deformation of soft sediments need not necessarily have been at least 4.5-5 as commonly mentioned in the literature, but may have been less if water-saturated sediments were located very close to the epicentre.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
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A research on relative lacustrine level changes and sedimentary characteristics of Paleogene Kumugeliemu Group in the Dibei-Dina area of Tarim Basin

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Keywords: lacustrine level changes, sedimentary characteristics, two-step lithological identification

The lower sand member of Paleogene Kumugeliemu Group in the Dibei-Dina area of Tabei Uplift in Tarim Basin is a favorable exploration target for lithological reservoirs in recent years. However, the shallow water deltas and beach bars deposits were superimposed, it is difficult to identify the high-resolution sequence stratigraphy characteristics, sedimentary microfacies, and temporal-spatial evolution laws. On the basis of core, drilling, logging and 3D seismic data, the quantitative analysis of relative lacustrine level changes is helpful to determine sedimentary fades type and reveal their distribution rules. The markers, sequence boundaries and flooding surfaces have been identified and isochronally tracked to construct a high-resolution sequence stratigraphy framework. Under the constraint of sequence stratigraphy, the types and characteristics of sedimentary micro-facies of each high-frequency sequence unit were analyzed and the temporal-spatial evolution laws of sedimentary microfacies have been revealed. Compared with previous results, we find that relative lacustrine curve on overall trend in this research was quite in accordance with previous results. Several subtle small-scale relative lacustrine level changes can be used as a theoretical basis for follow-up geological research in this area. The lithological identification charts are established using two-step lithological identification method according to multiple logging response curves sensitive to lithology, such as natural gamma ray, density, acoustic time difference and induction resistivity, providing foundation for further exploration for lacustrine lithological reservoirs.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Characteristics and classification evaluation of pore throat structure in Chang 7 tight reservoir of Yanchang Formation in Ganquan Oilfield

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Keywords: Ganquan Oilfield, chang 7 oil layer, tight reservoir, pore throat structure, reservoir classification

Abstract: Tight reservoir has become one of the most important fields of oil and gas exploration and development in China, and tight reservoirs typically developed in Chang 7 oil layer of Yanchang Formation in Ganquan Oilfield. Based on a series of method of thin section identification, casting thin section, scanning electron microscopy, mercury injection, etc, detailed characterization of petrological characteristics, reservoir physical properties, reservoir space types and pore throat structure characteristics of Chang 7 tight sandstone reservoir in Ganquan Oilfield are carried out. In addition, the tight sandstone reservoirs are classified and evaluated. The results show that the lithology of Chang 7 reservoir in Ganquan Oilfield is mainly lithic feldspathic sandstone and feldspathic lithic sandstone. Its median value of air permeability is less than 1 mD, and the median value of pressure permeability is 0.0554 mD, which is a typical tight reservoir. The reservoir space of sandstone is dominated by residual intergranular pores and feldspar dissolved pores, with a small amount of micro-fractures, and the average face rate was 3.45 %. The pore throat radius of reservoir sandstone is distributed in a wide range and large scale, and the pore diameter is generally 0.23 μm~57.35 μm. The pores are mainly small pores, and the average pore diameter is about 22.35 μm. The throat radius is generally 0.03 ~ 3.5μm, with an average of 0.35μm. Tight reservoirs in the study area generally show characteristics of complex pore throat structure and strong heterogeneity, mainly include small pore-fine throat type, small pore-fine throat type of reservoirs, which play a major contribution to reservoir physical property in study area. Finally, the classification and evaluation criteria of Chang 7 tight sandstone reservoirs were established, and the tight sandstone reservoirs in the study area were divided into five types. Among the five types of reservoirs, II and III types of reservoirs are widely developed in Chang 7 oil layer of the study area, which are favorable reservoir types, followed by I and IV types of reservoirs.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Autogenic and allogenic controls on the characteristics of meter-scale cycle in the Nenjiang Formation from the Cretaceous Songliao Basin (northeastern China)

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Keywords: sedimentary cycle, autogenic process, allogenic process, Songliao Basin

The characteristics of meter-scale sedimentary cycles, such as thickness, abundance, continuity and “missed beats”, are considered to be controlled by local topography and autogenic processes (depositional hiatus, erosion and differential compaction). However, it is difficult to distinguish the control of short-term local autogenic processes and long-term allogenic processes on sedimentary cycles. The cyclicity at this scale can be defined by stratal repetition of physical characters of sedimentary rocks, such as grain size which can be can be identified from natural gamma-ray logging (GR). The GR logs of multiple wells of the members 1 and 2 of lacustrine Nenjiang in the Songliao Basin are collected to study the control of autogenic and allogenic processes on meter-scale grain-size cycles. The number of meter-scale grain-size cycles in the collected GR logs and the maximum, minimum and average values of cycle thickness were counted. The power spectral analysis was performed to the GR logging data to the identify the Milankovitch cycles and then calculate the deposition duration of these logs. The results show that the number of grain-size cycles and the deposition duration vary between wells and that these differences are not spatially regular. This suggests that the difference in abundance and continuity of the grain-size cycles and the "missed beats" are caused by autogenic processes. However, when the the thicknesses of the cycles in each well are successively connected according to the form of change-point analysis in the Fischer plot, these GR-Fischer plots show the same pattern of variation. The same variations in these GR-Fischer plots are interpreted as being controlled by basin-wide relative lake-level changes, that is, by allogenic processes. Thus, we concluded that both autogenic and allogenic control of stratigraphic records can be reflected in the characteristics of meter-scale sedimentary cycles in the basal Nenjiang Formation.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Oral Preferred

New insights on the Late Pleistocene-Holocene evolution of a giant lake in the central Kalahari (Botswana)

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Keywords: Kalahari, playa lake, evaporites, ostracods, late Quaternary

The Makgadikgadi Basin in Botswana developed from the Late Pleistocene onwards due to gradual shrinking of the giant Lake Palaeo-Makgadikgadi (LPM). This lake, in the central Kalahari, is a key site to understand the climatic variability in southern Africa during the Quaternary and it holds an important role for the evolution of numerous species, including our own.

Four highstand phases were dated over the last 40 ka: 38.7 ± 1.8 ka, 26.8 ± 1.2 ka, 17.1 ± 1.6 ka and 8.5 ± 0.2 ka (Burrough et al., 2009; Schmidt et al., 2017). Today the Makgadikgadi Basin hosts the world's largest salt pans complex, including the Sua and the Ntwetwe Pans. This work is focused on the reconstruction of the evolution trends of the LPM between the penultimate highstand phase (17.1 ± 1.6 ka) and the current condition of ephemeral lake (playa). Here, a detailed sedimentological characterization (grain size and major elements) of shallow sediments from the Makgadikgadi Pans was combined, along cores, with the encountered ostracod fauna in order to track late Quaternary environmental trends. Ostracod assemblages are dominated by the Limnocythere ssp., an opportunistic taxa colonizing the littoral areas of shallow evaporative, ephemeral lakes, together with the subordinate occurrences of Sarcypridopsis ochracea, Sclerocypris cf. bicornis, Candonopsis spp. and Ilyocypris spp. The sediments from the pans show fluctuations in the Cl/K and Ca/Cl ratios, often in phase with the relative abundance of Limnocythere suggesting a cyclicity induced by changes of salinity and alkalinity in the water.

This multi-proxy study documents the occurrence of a Late Pleistocene shallow, playa lake environment typified by strongly alkaline waters. Between ~16 and 2 ka BP, a prolonged drought with sustained aeolian conditions affected the study area. A temporary shift toward more humid conditions is suggested by an increasing diversity of ostracod fauna atop the cored successions (around 20-30 cm core depth). This humid period is followed by an overall desiccation trend that likely started with the Little Ice Age and continues until the present day.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-2: Deep-lacustrine sedimentary processes and products
Presentation Preference: Oral Preferred

Changes of sedimentary style and its controlling factors in Heimahe delta of Qinghai Lake

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Keywords: Qinghai Lake,Hemahe Delta,Sedimentary pattern,Controlling factor,Quaternary

The Heimahe Delta is located on the south shore of Qinghai Lake, which is fed by five streams from the Xiangpi Mountain. The lower part of the sedimentary profile of this delta is dominated by gravels and the upper part is mud, showing diverse sedimentary facies and complicated formation processes. The lithofacies and their assemblages, architecture units, facies distribution and evolution stages of the Heimahe Delta in Qinghai Lake were studied by unmanned aerial vehicle, field outcrop measurements, and grain-size analysis. A total of 4 kinds of gravel facies, 4 types of sandstone facies, and 2 types of mudstone facies were classified. The delta plain has been developed with debris-, swinged-, migrated-channels, and vertical-, bilateral-aggradation bars; the delta front has been developed by migrated-, filled-channels, and bilateral-, lateral-aggradation bars, etc. Described from the field profiles, we reconstructed lake level and sedimentary evolution of Heimahe Delta which can be divided into three stages: low-stand, lacustrine transgression and forced lacustrine regression tracks. The stacking pattern in the low-stand stage present a sigmoid type high-angle progression with coarse-grained sedimentation dominating and por textural and compositional maturity. The stacking pattern of the lacustrine transgression stage is imbricated regression, fine-grained sedimentation, with medium textural and compositional maturity; the stacking pattern of the forced lacustrine regression stage is step-like progression, fine-grained sedimentation, with high textural and compositional maturity. Based on the interpretation of outcrop lithofacies association and architecture stacking pattern and analysis of fossils and bioclasts, we clarified diverse depositional association and constructed a sedimentary evolution model of the depositional system in this area. We suggest that the depositional system transitioned from an early single-provenance gravel-rich fan delta to a multi-provenance mud-rich delta and two factors mainly controlled the transition: southern boundary fault activities and Lake level variations. The early tectonic activities made the Nanshan Mountain uplift and Lake level strongly down, developing a large accommodation area providing space for gravel-rich coarse debris deposits. The strong activities of the Nanshan boundary fault in the mid-term caused the lacustrine basin to fall in the meantime the Lake level to rise, and large-scale lacustrine transgression occurred; The continuous activity of the Zongwulongshan-Nanshan Fault zone in the late stage caused Nanshan to continuously uplifting and the lacustrine continued sinking, resulting in the rapid retreat of the lacustrine and the formation of three-level terraces between the basin and the Nanshan Mountain.

Session T5-3: Aeolian depositional systems and desert basins

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-3: Aeolian depositional systems and desert basins
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Controls on Late Cretaceous aeolian desert systems in South China

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Keywords: subtropical highs, monsoon climate, water table, orogenic topography, desert depositional systems

Extensive aeolian desert systems were distributed in South China during the Late Cretaceous. These systems are characterized by alluvial, fluvial and aeolian deposits based on the sedimentological and facies architectural analyses. They reveal the evolution of paleoclimate and paleogeography in the South China hinterland during this period. The Late Cretaceous South China was marked by distinct basin-mountain systems due to subduction and retreat of the paleo-Pacific Plate. Intra- and epi-continental topography, combined with planetary-scale subtropical highs, obstructed the transport of moisture, enclosed the low-lying land, and caused the aridification in the South China interior and the development of desert depositional systems. The fault-dominated basins provided accommodation space for the preservation of the aeolian desert accumulation system. Furthermore, monsoon rainfall exerted an important role in the formation of desert depositional systems. Monsoonal water discharge carried extra-formational clasts into desert basins and led to variations in the groundwater level. Three types of aeolian deposits, dry, damp and wet aeolian systems developed. Periodic water influx to the Late Cretaceous desert margin systems can generate a cyclic aeolian–fluvial interaction system. The alternating wind and water activities driven by climate forcing created diverse wind- and water-related sedimentary facies types. Overall, the formation and development of Late Cretaceous aeolian desert systems in South China reflected the coupling result of subtropical highs, epi- and intra-continental orogeny, monsoon climate, tectonic subsidence, and variable groundwater level.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-3: Aeolian depositional systems and desert basins
Presentation Preference: Oral Preferred

Aeolian system subenvironments spatial variability, morphology characteristics and complexities, in modern desert system.

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Keywords: Aeolian system, Dune spatial variability, aeolian subenvironments, desert morphology, remote sensing , modern desert system

Significant advances in our understanding of the spatial arrangement of aeolian dune patterns have been made possible through the increasing availability of high-resolution satellite imagery in recent years. Major world desert systems are covered by the latest generation of public-release satellite imagery, which reveal spatially diverse dune patterns characterized by a varied range of dune types, the morphology, scale and orientation of which change systematically from central to marginal dune-field areas where non-Aeolian sub-environments become dominant within the overall desert setting. Analysis of geomorphic relationships between dune and interdune sub-environments within four regions of the Rub' al-Khali desert system reveals predictable spatial changes in dune and interdune morphology, scale and orientation from the center to the outer margins of dune fields. A quantitative approach is used to characterize the complexity present where large, morphologically complex and compound bedforms gradually give way to smaller and simpler bedform types at dune-field margins. Parameters describing bedform height, spacing, parent morphological type, bedform orientation, lee-slope expression, and wavelength and amplitude of along-crest sinuosity are recorded in a relational database, along with parameters describing interdune size (long- and short-axis dimensions), orientation and style of connectivity. The spatial rate of change of morphology of Aeolian sub-environments is described through a series of empirical relationships. Spatial changes in dune and interdune morphology have enabled the development of a model with which to propose an improved understanding of the sediment system state of the modern Rub' al-Khali desert sedimentary system, whereby the generation of an Aeolian sediment supply, its availability for Aeolian transport, and the sand transporting capacity of the wind are each reduced in dune-field margin areas.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-3: Aeolian depositional systems and desert basins
Presentation Preference: Oral Preferred

Ultra-long-distance transport of aeolian sand: the provenance of an intermontane desert, SE China

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Keywords: intermontane desert, provenance analysis, U-Pb zircon ages, sand supply mechanism, ultra-long-distance transportation

Intermontane deserts are an important type of arid-climate sedimentary system. They were common in the past greenhouse world, and they might re-develop in the near future in response to the intensification of global warming. Investigating the provenance and mechanisms of sand supply to intermontane deserts is important to demonstrate the potential impact of future climate on environmental evolution and change in arid and semi-arid regions. During the Late Cretaceous, a typical intermontane desert developed in the Xinjiang Basin, southeast China. In this study, the origin, spatial variability, and transport pathways of both aeolian and alluvial-fluvial sediments in this intermontane desert have been investigated by applying bulk-petrography analyses and detrital-zircon U-Pb geochronology. Our results demonstrate that the sand in the Xinjiang intermontane desert was mainly extraneous and wind-derived. The nearby South China Craton and South China Magmatic Belt were primary sources; the distant Western Yangtze Craton was an important secondary source, despite being ~1000 km away. It suggests that this ultra-long aeolian sediment transport pathway was enabled by two factors: (i) the strengthening of intermittent westerly winds during short-lived glacial episodes; (ii) the presence of a low-relief corridor that served as a sediment transport pathway from source to sink across South China during the Mid-Late Cretaceous.

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Session T5-3: Aeolian depositional systems and desert basins
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Sedimentary facies characteristics of Taiyuan Formation to Lower Shihezi Formation in Hangjinqi area, Ordos Basin

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Keywords: Sedimentary facies, Taiyuan Formation, Shanxi Formation, Lower Shihezi Formation,Hangjinqi, Ordos Basin

Sedimentary facies characteristics of Taiyuan Formation to Lower Shihezi Formation in Hangjinqi area, Ordos Basin

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Abstract: The main exploration horizon of the Upper Paleozoic in Ordos Basin is from Taiyuan Formation to Lower Shihezi Formation. The study of sedimentary facies and its evolution in this period has playing a guide role in oil or gas exploration. Based on the observation and description of cores, the types and characteristics of sedimentary, and logging curve characteristics, studying the aspects of petrological and sediment characteristics from Taiyuan Formation to Lower Shihezi Formation of Ordos Basin. The results show that the rock types are primarily composed of interbedded quartz sandstone and dark mudstone. It is developed fan delta deposit, which can be divided into braided distributary channel, flood plain and peat swamp microfacies in Taiyuan Formation. The rock types of Shanxi Formation are mainly gravelly medium sandstone, siltstone, mudstone and coal. During the period of Shanxi Formation, the provenance supply in the north and northeast of the basin is sufficient. Primarily developed braided river delta plain subfacies, which can be divided into main distributary channel, secondary distributary channel, depression and peat swamp microfacies. The sedimentary facies are greatly affected by landform. There are gravels of different sizes in the Lower Shihezi Formation, with poor sorting and roundness. Rock types are mainly coarse sandstone, siltstone, and mudstone. Due to the weaken of tectonic activity and the change of paleoclimate, the material source supply decreased continuously in this period. It mainly developed alluvial fan and braided river sedimentation, the microfacies such as heart beach, natural dike and flood plain can be identified. Controlled by the fault zone, the sedimentary facies of Taiyuan Formation are mainly distributed in the south of borjiang Haizi fault, the sedimentary facies of Shanxi Formation and Lower Shihezi Formation continue to advance southward.

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Session T5-3: Aeolian depositional systems and desert basins
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Late Permian laterites as paleoclimate proxies of Low-latitude continent of Eastern Tethys: South China

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Keywords: Late Permian, Paleoclimate, South China, Laterites

The climate of tropical Pangea in the late Permian was characterized by extremely aridity, while the contemporaneous South China, a typical low-latitude continental block of Eastern Tethys, had contrary humid climate condition (Tabor and Poulsen, 2008). The quantitative temperature and precipitation of South China is critical for understanding the global climate system in the late Permian. The paleosols developed from The Emeishan basalts of Late Permian, Guizhou, China, are used to investigate local paleoclimatic conditions. The paleosols are described in detail and analyzed for morphology, clay mineralogy, and bulk geochemistry. The majority of paleosols are typically dark red or red in color, has large thickness of 4-10 m and a dominant mineral assemblage of kaolinites, hematite, and anatase, with only few primary minerals. Moreover, these paleosols have high CIA values of 90–99 and evident Al_2O_3 and Fe_2O_3 enrichments. These pedogenesis features suggest that these paleosols are laterite, a highly weathered soil type commonly forms under tropical or subtropical warm and seasonally humid climate (Hill et al., 2000). Using Saf geochemistry climufunction (Zhang et al., 2022), the paleosols yield mean annual temperature (MAT) and mean annual precipitation (MAP) of 18-23 °C and 1800-2200 mm, respectively. The estimated MAT is mild than modern tropics, and may reflecting the low pCO_2 in late Permian (Godd´eris et al., 2014). The estimated MAP is consistent with existing geological evidence: coal, bauxite, and Cathaysian flora in late Permian strata in South China (Tabor and Poulsen, 2008; Guo, 1991), which suggested a tropical warm and humid climatic conditions with pronounced precipitation seasonality. The monsoon caused by thermal difference between ocean and South China continent may play important role for the high MAT with pronounced seasonality in South China.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-3: Aeolian depositional systems and desert basins
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Reconstruction of aeolian bedforms in the Late Cretaceous Xinjiang Basin

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Keywords: aeolian deposits, bedforms reconstruction, atmospheric circulation, Xinjiang Basin, paleoclimate simulation

The aeolian deposits system is an important carrier for the study of the ocean-land-atmosphere system, providing unique information of prevailing winds and atmospheric circulation. The Late-Cretaceous aeolian deposits is widely distributed in the South China Block basin group, indicating the extensive desertification events in the terrestrial system. However, studies on the formation process of ancient aeolian dunes, especially before the Cenozoic, are relatively weak. And the identification of aeolian dune types and its bedforms reconstruction remain poorly understood, which are the key to the reconstruction of original palaeowind direction and even the distribution of ancient aeolian deposits. The study takes the upper Cretaceous aeolian dunes in the Xinjiang Basin as the research object based on the division of aeolian bounding surface, the identification of sedimentary structure, the data set of dipping cross-bedding of multiple sections, reconstructing the two-dimensional architectural element panels of the aeolian dunes. On this basis, stereonet plots are drawn based on trend of the superimposition surface and crossing bedding, and the corresponding bedforms are depicted, indicating that the transverse dunes and barchan dunes are mainly developed in the Late cretaceous Xinjiang Basin. Besides, the original palaeowind directions are obtained by the mean azimuth of the transverse bedform, suggesting that the palaeowind in Xinjiang Basin was northeastward and the prevailing winds were westerlies. The work preliminary lays the foundation for reshaping atmospheric circulation and paleoclimate simulation of the South China Block and Asian interior.

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Session T5-3: Aeolian depositional systems and desert basins
Presentation Preference: Oral Preferred

Late Jurassic-Early Cretaceous eolian deposits in North China: implications for regional paleogeography and paleoecology

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Keywords: North China, Late Jurassic-Early Cretaceous, Eolian deposits, Eolian sedimentary system, East China Plateau, Biota succession

Late Jurassic-Early Cretaceous eolian deposits widely distributed in North China are characterized by temporal and spatial distribution in Shanxi in the early stage, western Shandong, northern Hebei and western Liaoning in the middle stage, and extended to the Ordos basin and the west region in the late stage. These eolian deposits develop various typical eolian stratigraphy and bounding surfaces, which are arranged into simple and compound dunes types and dry eolian sedimentary system with the subordinate wet eolian sedimentary system. Late Jurassic-Early Cretaceous eolian deposits in North China were controlled by the subtropical high belt and the rain shadow effect derived from the East China Plateau. Its temporal and spatial evolution shows a strong correlation with the die out of the Middle-Late Jurassic Yanliao biota and the radiation of the Early Cretaceous Jehol biota. We suggest that more attention should be paid to the high-precision age of the eolian deposits, detailed eolian sedimentary system, 3D/4D models and its implications for the major scientific questions (such as North China destruction, inland aridity in North China, biota succession) in future studies.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-3: Aeolian depositional systems and desert basins
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Cretaceous interior aridification and its driving mechanism in southeastern Tibetan Plateau

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Keywords: SE Tibetan Plateau, Cretaceous, eolian erg system, drainage system evolution, rain shadow, desertification

Trigger mechanisms of widespread aridification in the Cretaceous of southeastern Tibetan Plateau are is not fully understood. Intracontinental basins along the southeastern Tibetan Plateau suffered a profound transformation and commonly regarded as consequence of unclear interaction among allogenic controls including extreme greenhouse climate, general atmospheric circulation, tectono-magmatic processes, variations in sea level, and topography variability. The main factors are up to now ambiguous and the coupling correlation between the atmosphere-land-ocean system remains complex. The Lanping Bains in China constitutes a key junction in the southeastern (SE) Tibetan Plateau, and the integrate multidisciplinary datasets from Cretaceous depositional systems from this basin will help to constrain Cretaceous sediment provenance routes and reconstruct the paleotopography as well as to figure out the most probable drainage network throughout the Cretaceous. This research presents results dealing with the sedimentology, paleocurrents, and U–Pb detrital zircon geochronology in the Jingxing Formation, Nanxing Formationi, and Hutousi Formation in the Lanping Basin, and our results indicate that mid- to Late Cretaceous tectonically induced surface uplift occurred in the SE Tibetan Plateau, leading to the formation of the paleo-plateau landform, and resultant rain shadows in east Asia interior. Superimposition of this topographic pattern by uplands in the eastern margin of Asia meant that the Cretaceous topography of east Asia was characterized by an enclosed paleo-relief pattern that was high in both the east and west, with drainage from the east and west to the south, contrasting with previously proposed configurations. This topographic pattern interrupted climate systems and generated widespread intracontinental desertification and drainage network evolution in east Asia. Our study constrains a key part of the late Mesozoic growth of the Tibetan Plateau prior to the Cenozoic collision between India and Eurasia and improves our understanding of the paleoclimate, atmospheric circulation, and modern drainage system evolution of the East Asian continent.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-3: Aeolian depositional systems and desert basins
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Wet aeolian system: The impact of fluctuated water table on the lateral and vertical lithological elements of aeolian depositional setting

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Keywords: Aeolian, Water Table, Damp Interdune, Wet interdune

In aeolian depositional settings water table can play an important function in the formation of the system stratigraphic record. Aeolian sediment transport across wet and damp sediment surfaces is severely restricted, which limits the volume of sediment available for aeolian dune construction, i.e., more stable system. Moreover, fluctuations between relatively higher and lower water-table levels can allow system subenvironments (e.g., interdunes) to change from a dry, to damp, to wet state on a seasonal basis, the rate of fluctuation will also determine the thickness of the preserved elements.

The lithofacies distribution and the stratigraphic organization of the architectural elements at the Permo-carboniferous section highlight wet aeolian sub-environments. Wet and dry aeolian sub-environments are likely controlled by local topographic relief that governed a hybrid dry-wet aeolian setting. The wet sub-environment is represented by extensive sand flats, non-climbing dunes, and possibly continuously shallow water table, specifically the lower part of the succession.

The integrated analysis of core, petrography, image logs, and standard wirelines log data reveals the diversity of sedimentary facies, which were deposited under different wet and dry conditions. They occurred on a variety of vertical and lateral scales, ranging from areas where dune bedforms dominate to other arears where they interact with other systems. The resultant sedimentological signature gives rise to preserved stratigraphic heterogeneities that typically influence facies and rock type properties. Characterization of core and image log data help the reconstruction of the preserved rocks depositional setting, which in turn provides the optimum framework for describing and predicting subsurface facies properties and distribution.

This study demonstrates the sedimentological characterization of aeolian deposits that reflect features that were created by the wind and water actions, and the consequent impact on lithological elements lateral and vertical trends. The accumulation of thick packages of wet sand flats and mud flats strata in this setting is attributed to: (1) high rates of vertical accumulation of the sub-environment substrate due to high rates of sediment input for aeolian construction, and (2) progressive relative rise of the water table that covers large low relief areas. These conditions enabled the long-term accumulation and preservation of flat irregular laminated argillaceous sand associated to the aeolian system. The accumulation and preservation of interdune deposits for example, is favored by a reduction in the rate of dune migration and the trapping of sediment on the wet/damp accumulation surface. A relative rise in the level of the water table can enable vertical sand accretion. The wavy and planar-parallel bedded sandstone element is typical of the Permo-carboniferous aeolian subenvironments, it comprises three lithofacies: (i) planar-parallel laminated sandstone; (ii) undulated cross-laminated sandstone; and (iii) sandstone with ripple cross-lamination.

Understanding the behaviour of the continental fluctuating water table in aeolian setting in response to climate or sea-level is important to establish a correlation between aeolian stratigraphic sequences and external parameters of changing water table.

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Proterozoic proglacial aeolian dunes, permafrost and evidence of subglacial deformation in the Cu-bearing sandstones Cattlegrid Pit, South Australia

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Keywords: Proterozoic, australia, permafrost, aeolian

The sedimentary record of the geological transitions from snowball Earths to ice-free worlds and vice versa are still not well understood. The Cattlegrid Pit at Mt. Gunson in South Australia offers an exceptional opportunity of addressing this knowledge gap. Here, the Mesoproterozoic Pandurra Formation sediments, composed of cross-bedded sandstones of fluvial origin, are erosively overlain by large-scale cross-bedded aeolian sediments of the Neoproterozoic Whyalla Sandstone. The stratigraphic contact between both Proterozoic units is characterized by extensive Cu mineralization and deformation structures that have been interpreted as a result of permafrost cryospheric processes. We show that synsedimentary deformations at the top of the Pandurra Formation and the base of the Whyalla Sandstone occurred during the onset of the early deposition of the Whyalla Sandstone during the Marinoan glacial period. This subglacial deformation event affected a non-consolidated permafrost, incorporating fragments and clasts in the overlying sediments, including breccia injections. Subglacial deformation led to extensive sand blocks injected in the underlying permafrost system and active folding and shearing, showing shear bands and alignment of clasts. Sand intraclast morphologies and deformation structures are very similar to subglacial deformation of permafrost in the Mid-Pleistocene of north Norfolk (UK), the thermo-mechanics effects of the Weichselian ice sheet in Poland, and the ice-sheet marginal processes in the Ordovician of Libya. The deformations observed are compatible with repeated ice–bed decoupling and subglacial meltwater sediment deposition observed in recent analogues from Denmark. The progradation of the overlying proglacial aeolian dunefield of the Whyalla Sandstone occurred as a consequence of the retreat of the ice sheet front postdating the subglacial deformation stage.

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Session T5-3: Aeolian depositional systems and desert basins
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Tracking 79 myrs of high-altitude lithospheric and climate forcing on the Cretaceous deserts of China and Mongolia

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Keywords: Cretaceous, desertification, ice sheets, plateau, palaeoclimate

More than 96 climate-sensitive lithologies accumulated in Early, mid-, and Late Cretaceous basins have been tracked in east Asia, including China and Mongolia. Although the Cretaceous desertification of southeastern Eurasia has been proposed to be driven by deep changes in atmospheric circulation patterns, the spatio-temporal analysis of the paleoclimate proxies indicate that both cryospheric and lithospheric forcing may have played a fundamental role triggering high-altitude desert basin dynamics in the Cretaceous of south-eastern Eurasia. A shift in subduction style from an early Cretaceous Paleo-Pacific Plate slab roll back to a Late Cretaceous flat-slab mode triggered plateau formation and accelerated desertification of the overriding Eurasia lithosphere. The early Cretaceous rollback of the steep Pacific slab led to back-arc extension, creating plateau salars in the Eurasia plate similar to those of the Atacama Desert in Andes Cordillera. The transition to a flat-slab subduction mode during the Late Cretaceous triggered regional plateau uplift, blocked intraplate volcanism, increasing denudation and sediment availability, and created wind corridors that led to the construction and accumulation of extensive Late Cretaceous aeolian sandy deserts (ergs) that covered mid-Cretaceous plateau salars. Some of these plateau desert systems reached paleoaltitudes able to develop cryospheric processes. We attribute these cryospheric processes to the crustal uplift due to terrane accretion in the Tethyan collision zone although it could be exacerbated because of a global mid-Cretaceous cold snap. The drastic reduction in the number of mid-Cretaceous aeolian systems in China correlates with the build-up and expansion of an ice sheet which front could have reached the southern sector of Mongolia and northern edge of China. During Late Cretaceous, desertification speeded up and ergs prograded towards northern latitudes.

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A Late Cretaceous aeolian system dominated by sand sheetsa case study from the Tangbian Formation, Jitai Basin, South China Block

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Keywords: Intermountain desert, aeolian and aqueous processes, grain-size end-member, alluvial/braided fluvial deposits, sand sheet deposits

Differentiating pre-Quaternary aeolian depositional systems when they are dominated by the interaction with coeval aqueous environments is not that easy. The South China Block contains the sedimentary record of widespread intermountain deserts during the Late Cretaceous associated with paleotopography and rain shadow effects. These plateau-desert systems are characterized by complex assemblages of wind- and water-laindeposits, hosted wind-water interaction processes that generated a myriad of facies sometimes difficult to interpret in terms of physical processes and the relative role of wind and water agents during transport and deposition. In this study, we analyzed the Late Cretaceous Tangbian Formation in the Jitai Basin, from which parametric grain-size end-member analysis models were carried out. Four grain-size end-members related to aeolian and aqueous processes were identified. including alluvial/braided fluvial deposits, aeolian sand sheet deposits, sheet flood deposits and paleosoils. Locally superimposed dune facies with high-angle tabular cross-beds have been recognized and paleosoils developed over wadi channel facies. These environments highlight the wind-water interactions and depositional environments in semiarid-arid environments in the Jitai Basin during Late Cretaceous. where aeolian sand sheets facies are hegemonic compared with other nearby basins such as the Xinjiang basin, which is dominated by aeolian sand dunes.

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Aeolian sediments associated with Early Pleistocene aridification of inland Asian: the Qigequan Formation, Qaidam Basin

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Keywords: NE Tibetan Plateau, Early Pleistocene, aeolian deposition, lacustrine sediments, climate evolution, cyclostratigraphy

The Pleistocene epoch is characterized by global changes affecting both the atmosphere and oceanic realms, driven by climate forcing. Aeolian deposits constitute an excellent record of paleoatmospheric dynamics. Aeolian depositional systems in plateau settings constitute a good record of aridification. The recognition of windblown sediments in coeval sedimentary environments is crucial to decipher past desertification and aridification events that could have not been recorded in coetaneous continental aeolian dunefields. The majority of studies on aeolian systems in inland Asia have focused on the records of the Loess Plateau, while relatively few studies have been conducted on the Tibetan Plateau, of which only the relevant targets have been Cretaceous and Holocene deposits. In this study, the aeolian sedimentary record in the Early Pleistocene lacustrine sedimentary system was identified by grain size end-member and cyclostratigraphic analyses of the continuous and thick Qigequan Formation in the eastern Qaidam Basin on the northeastern margin of the Tibetan Plateau. The high proportion of the coarse dust component (EM2) transported by wind from short-distance sources corresponds to high values of the sedimentary noise model (DYNOT), indicating that the basin climate became arid during ~2.15-1.84 Ma, which is consistent with the climate records of the Loess Plateau and the South China Sea during the same period. Ice volume variability at high latitudes may be a major factor in the early Pleistocene arid climate of the Qaidam Basin and associated aridification and possible katabatic winds may have played a role on the transport of aeolian sediments to lacustrine plateau depositional systems. Our study provides a unique geologic record for the study of aridification in inland Asia since the Pleistocene.

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Terrestrial paleoclimate at the termination of Emeishan basalt eruption recorded by clay minerals in paleosols

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Keywords: Clay minerals, paleosol, paleoclimate

Clay minerals in soils are often used to qualitatively reflect paleoclimatic features (Churchman, 1980; Folkoff and Meentemeyer, 1985; Keller, 1970). The clay minerals in paleosols record the climatic characteristics during diagenesis. The paleosols developed on the last phase of volcanic ejected basalt (Emeishan Basalt) in the Emeishan Large Igneous Province are characterized by large thickness and wide distribution, representing the regional continental weathering process at the termination of the eruption of the Emeishan Large Igneous Province (ELIP). These paleosol profiles develop placic horizons that occur only in soils with a higher degree of soil development. The main clay mineral composition of the nine paleosol profiles collected in this study is kaolinite, with abundant hematite and small amounts of anatase. Kaolinite is a typical mineral of soils developed under modern humid and hot climatic conditions (Hobbs and Parrish, 2016), suggesting the climatic characteristics of the paleosol during soil formation. Diagenesis is essentially a process of primary mineral decomposition and elemental redistribution. The content characteristics of rare earth elements (REEs) in soils and sediments are indicative of the degree of chemical weathering during soil formation or in the source area (Lu et al., 2020; Marker and de Oliveira, 1994; Singh, 2009). There are two significant REE enrichment zones in paleosol profiles (∑REE between 88.2 ppm and 1684.2 ppm, mean 582.2 ppm), which are significantly higher than in bedrock basalts (mean ∑REE 271.2 ± 93.0 ppm). These paleosol profiles have similar REE enrichment characteristics to those of the South China REE deposits produced in the present-day subtropical climate. The clay mineral compositions and REE geochemical signatures indicate that indicate that there was a hot and humid climate similar to that of present-day South China at the terminal stage of volcanic activity in the ELIP area.

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Quantifying the Impact of Sedimentological Heterogeneity on Aeolian Hydrocarbon Reservoirs

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Keywords: Aeolian environment, Diagenesis, Dune, Sandsheet

Quantifying the Impact of Sedimentological Heterogeneity on Aeolian Hydrocarbon Reservoirs
[Text Box: Mouathe AlEssa and Mohammed Al-Masrahy, Saudi Aramco]

Abstract
The depositional studies of the aeolian environment have survived scientific scrutiny. This is hardly surprising given that they are one of the main siliciclastic hydrocarbon-bearing reservoirs worldwide. This study assesses the depositional setting and facies distribution of these terrestrial-based aeolian sediments. Attempts are also made to investigate diagenesis stages pertained to these sediments. The sedimentology and petrography analyses are conducted on cores from seven localities across the study area. Core samples were examined in detail to identify lithofacies, textures, facies, and facies association aspects. The ultimate aim is to have a comprehensive depositional setting of their aeolian packages. The petrography analysis entails description and interpretation of thin section, scanning electron microscope (SEM), and X-ray diffraction (XRD) samples. Such data are used in conjunction with borehole logs to achieve a scientific conclusion of their vertical and spatial configurations.
The analyses conclude the sediments were deposited in terrestrial arid to semi-arid aeolian settings, governed by a wide range effects of water table, post depositional processes, and aqueous fluids. Four prominent aeolian facies associations were recognized and are attributed to their sedimentological characteristics; aeolian dunes, aeolian sandsheets, aeolian interdunes, and playa lake deposits. The aforementioned facies associations commonly display three primary overprinting processes; silica overgrowth, clay minerals, and anhydrite cements. These diagenetic processes frequently disturb sediments' fabric and occlude intergrain spaces. The occurrence of silica overgrowth is observed interchangeably with the other diagenetic features and is mainly witnessed on grain surfaces. This suggests that the development of the silica cement is possibly subsequent to burial and compaction episodes. In contrast, the predominant post depositional clay minerals are narrow down to two main leading types; early-stage fibrous illite and later stage kaolinite cements. The tube-like geometry of the illite typically fills in permeability pathways. The intermittent presence of illite-coating sand grains, however, substantially protects the sediments from the significant destruction by silica overgrowth. Other identified cements, Kaolinite and anhydrite cements, are negatively impacting aeolian sand bodies in the form of sheet like and spherical nodules, respectively.

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Aridification on the western margin of South China Block during the Mid-Cretaceous: the sedimentary record of an aeolian system in the Chuxiong Basin, China

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Keywords: Mid-Cretaceous, South China block, aeolian erg system, east Asia, palaeoclimate, paleotopography

The Cretaceous has been traditionally considered as a greenhouse climate period with a duration of 79 myr Earth's history. The Cretaceous of China contains a varied record of different allogenic controls, including a complex interaction between palaeoclimate and paleotopography. The interplay between tectonics and climate contributed to a wide range of arid climate zones in East Asia that triggered the accumulation of widespread areas of sandy deserts and evaporite deposits. The Matoushan Formation has been formerly considered to be dominated by water-related deposits. This work provides a re-evaluation of the sedimentary environment of the Matoushan Formation of the Upper Cretaceous in the Chuxiong Basin on the western margin of the South China Block. Here, the reconstruction of aeolian bedforms based on field-data analysis indicates that the unit is a dominated by aeolian faciesincuding draas and crescentic dunes that accumulated and migrated in extensive intermontane desert systems, showing local aeolian-fluvial interaction deposits attesting for subordinate recurrent fluvial interludes. The uplift of north to south trending highlands on the west side of the Chuxiong Basin during the Early Cretaceous blocked the the input of water vapor from the Tethys Ocean to the South China Block, increasing the prevalence of inland aridification during the Mid-Cretaceous. Simultaneously, the abundant detrital input with tensional tectonics in the Chuxiong Basin also provided favorable conditions for accumulating and preserving the aeolian desert sands due to deflation of wadi channels in the inner erg margins.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
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Cretaceous aeolian sandstones in the Hunan Province; key clastic reservoirs for subsurface carbon sequestration under the Target of Carbon Emission Peaked and Carbon Neutral in China

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Keywords: Upper-Cretaceous, aeolian sandstones, South China block, palaeoclimate, Carbon Neutral

Aeolian sandstones have excellent poroperm values and are global targets for subsurface Carbon sequestration. This paper focused in Honghuatao formation Cretaceous units, that accumulates as large-scale sand desert dunes in the Hengyang Basin and Dongtinghu Basin, The petrophysical properties of these rocks are determined and their suitability as potential subsurface reservoirs for carbon capture and storage (CCS) and and underground energy storage (Compressed Air Energy Storage in Aquifers) is preliminarily evaluated. The Cretaceous units are a key element for the Target of Carbon Emission Peaked and Carbon Neutral in China. Inorder to evaluate the suitability of carbon dioxide geological storage and underground energy storage in Cretaceous basins in Hunan Province, it is necessary to carry out exploratory research on the petrology, geochemistry, rock mechanics characteristics and commercial development potential of aeolian sand bodies. At the same time, it is a natural laboratory for in-depth research on the earth's extreme greenhouse climate and its ecological response. The research on Cretaceous aeolian desert will bring us more enlightenment on long-term climate change studies in the future.

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Garnet geochemistry from aeolian sands in the Liujia section of Yibin confirms accelerated Late Cretaceous uplift and high denudation rates of the Longmenshan orogenic belt, eastern margin of the Tibetan Plateau

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Keywords: Late Cretaceous, Aeolian sands, Sichaun Basin, Longmenshan, Garnet geochemistry, Sedimentary Provenance

During the Late Cretaceous, the Yibin Liujia area in the southeast of the Sichuan Basin was covered by desert aeolian sands, but its source area is still unclear. Previous data, including limited clastic zircon U-Pb dating and heavy mineral assemblage, suggested a source area located to the western edge of the basin, but did not allow to establish a clear source-to-sink pattern. The Cretaceous aeolian sandstones of the Yibin Liujia area are rich in garnet, but the specific geochemical characteristics and the type of parent rock of these heavy minerals are not clear. In order to explain its provenance and establish a relationship with the tectonic evolution of the nearby orogenic belt, the detrital garnet geochemical analysis was carried out on 6 samples of the Liujia section in Yibin.Our results show that the garnets of the 6 samples predominantly scatter in the Bi and Bii region in the Fe+Mn-Ca-Mg triangular classification diagram but, nonetheless, show distinct characteristics. The clastic garnets from the Cretaceous Wotoushan to Sanhe Formation are mainly of type Bi (72%-82%) and Bii (12%-28%). In contrast, the Gaokanba Formation exhibits considerably higher amounts of Bii (75%), but lower percentage of Ci (13%) and A (8%) type grains with negligible amounts of garnet from type Bi (3%). Compositional data of garnets from the Wotoushan Formation to Sanhe Formation are very homogenous and suggest mainly intermediate to felsic igneous rocks as host lithologies. However, the Late Cretaceous Gaokanba Formatio show that the amphibolite-facies metasediments are absolutely dominant, which is closer to the metamorphic rock characteristics of the middle-south section of the Longmenshan orogenic Belt. These results indicate that the Late Cretaceous erosion of the Longmenshan Orogenic Belt is the source of the deposits in the Gaokanba Formation.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-3: Aeolian depositional systems and desert basins
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Luminescence chronology of alluvial and aeolian sands from the Island of Lopud, Croatia

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Keywords: Luminescence dating, alluvial-aeolian sand, Adriatic sea, Quaternary

The extension of Pleistocene alluvial and aeolian sediments along the eastern Adriatic coast and on the islands documents terrestrial environments during a time period of the lowest sea-level stand of the Adriatic Sea. On the southeasternmost Adriatic island of Lopud such deposits were studied along two lateral sections showing alluvial and aeolian sands intercalated with breccia lenses and a tephra interlayer. Alluvial deposits are represented mostly by recycled aeolian sands, accumulated by tractional sheet flows in a small-scale alluvial plain during a relatively long-lasting humid phase. Aeolian sands were probably deposited by sand sheet migration under the influence of the NNE wind during a more arid and relatively windy phase. Sporadically occurring breccia lenses composed of limestone fragments of the Cretaceous basement are the result of occasional high sediment concentration flows, and deposition in shallow stream channels(Kovačić et al., 2018). The reworked and pedogenically altered tephra belongs to the high-K calc-alcaline and shoshonite series having a trachyte-trachydacite composition indicating the Campanian Province in Southern Italy as the most probable source area (Kovačić et al., 2018). This suggests the influence of a southern wind during the humid phase of the Pleistocene.
The luminescence dating method was applied to these deposits to establish their chronological framework. Both quartz and feldspar grains were tested and measured to obtain the most reliable ages. While the OSL very likely implies to the maximum dating limits and shows problematic dose recovery test results, the pRIR290 ages can be correlated to the OIS4 and OIS5. The results imply that during that time the Island of Lopud in the south Adriatic was part of the mainland exposed to significant fluvial activity of the palaeo-Neretva river and its tributaries.

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Kovačić, M., Pavelić, D., Vlahović, I., Marković, F., Wacha, L., Kampić, Š., Rončević, S., Drempetić, D., 2018. Pleistocene alluvial and aeolian deposits with tephra on the island of Lopud (eastern mid-Adriatic, Croatia): Provenance, wind regime, and climate controls. Quaternary International 494, 92–104. doi:10.1016/j.quaint.2017.11.054

Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution

ID: T5-10061

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Oral Preferred

A holistic view on avulsion dynamics in a dryland river fan based on comprehensive geomorphological analysis

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Keywords: Autocyclic avulsion dynamics, dryland river, floodplain, crevasse splay

Dryland river fans form by repeated switching (avulsion) of an ephemeral stream as it progrades and accumulates sediment onto a low-gradient alluvial plain. Successive channel belts are organised in a radial pattern through a process of compensational stacking, where each consecutive river path avoids the positive relief left by its predecessors. Several criteria have been proposed for the likelihood of where and when an active channel in such a setting switches its path, including super-elevation, ratio of along-channel slope and cross-floodplain gradient, and hydraulic capacity of crevasses. A key role for the overbank domain is implied in each of these – largely interdependent – parameters for avulsion proneness, but the exact avulsion dynamics remain insufficiently understood.

In this study, we combine differential-GPS measurements and a resampled open-source global digital surface model (DSM) to quantify along-channel changes in hydraulic parameters and reconstruct subtle geomorphology across an undisturbed and non-vegetated dryland river fan. This approach allows us to propose a holistic view on autocyclic avulsion dynamics in prograding dryland river systems.

The results support the idea that the downstream gradient of an active river decreases over time as result of basinward lengthening (by both progradation and increased sinuosity) mirrored by near-channel deposition. This process gradually decreases the drainage effectiveness of the stream profile and elevates the channel belt relative to the surrounding floodplain. Crevasse splays play a key role in determining whether the river switches or not by effectively testing alternative flow paths. Crevasse channels develop along a local path of steepest descent across the floodplain and build out as long as their stream profile is hydrodynamically more favourable than that of their parent channel, after which they heal up. As the river profile lengthens and rises, crevasse splays extend further onto the floodplain until one reaches base level in a shorter distance than the river itself. At this point, it will receive an increasing proportion of total discharge and the parent river is abandoned. The avulsion process is gradual rather than abrupt and its frequency likely increases downstream, resulting in a dendritic pattern of abandoned river paths.

The process proposed here brings together existing criteria for autocyclic avulsion in prograding dryland river systems devoid of vegetation. It incorporates the role of subtle floodplain morphology and the evolution of crevasse splays and explains the resulting depositional architecture. Moreover, our findings enable us to predict when and where a next avulsion will take place, which could help flood risk analysis and mitigation in similar settings.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Oral Preferred

Architecture Model of Dryland Gravel Braided River Based on 3D UAV Oblique Photogrammetric Data: A Case Study of West Dalongkou River in the Eastern Xinjiang, China

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Keywords: UAV,Oblique photogrammetry,Gravel braided river,Architecture, Modern deposition,West Dalongkou River

Three-dimensional unmanned aerial vehicle (UAV) oblique photogrammetric data were used to infer mountainous gravel braided river lithofacies, lithofacies associations, and architectural elements. Hierarchical architecture and lithofacies associations with detailed lithofacies characterization were comprehensively described to document architectural model, architecture element scale, and gravel particle scale. (1) Nine lithofacies (i.e. Gmm, Gcm, Gcc, Gci, Gcl, Ss, Sm, Fsm, and Fl) are identified and classified as gravel, sand, and fine matrix deposits. There are typical deposit features of a dryland gravel-braided river. (2) Three architectural elements are identified, including channel (CH), gravel bar (GB), and overbank (OB). CH can be further divided into flow channel and abandoned channel, while GB consists of Central Gravel bar (CGB) and Margin Gravel bar (MGB). Different architectural elements are associated with distinctive depositional cycle styles and mechanisms. (3) Gravel bar is the most important architectural element of gravel braided river due to its favorable reservoir attribute. The dimensions of GBs and their particles are various, but exhibit good relationships with each other. The grain size of GB decreases downstream, but the dimensions of GB do not. The bank erosion affects the GB dimensions, whereas channel incision and water flow velocity influence the grain size of GB.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Oral Preferred

Dating geological Mars analogue using Luminescence technique

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Keywords: Luminescence, Geochronology, Mars, Analogues, Sedimentology

During the last 60 years, the robotic exploration on Mars has made many tantalizing geological discoveries, and retrieving rock samples from the Martian surface will be the next major goal for the scientific community. It is increasingly clear that accurate estimation of absolute ages is a fundamental step to understand the evolutionary processes that led to the formation of planet and its atmosphere. In this respect, occurrence and time frequency of surficial geological processes on Mars are needed to understand the Red planet's evolution. The chronology of recent geological events on Mars is a challenging task, due to uncertainties associated with the current dating methodology based on crater counting.

Luminescence dating could be a reliable method to date the recent deposits of Mars and better understand climate and tectonic changes occurred in the recent time. Knowledge of the luminescent properties of Martian sediments is necessary for the success of this purpose. The choice of a Martian analogue is therefore fundamental to validate the dating protocol. With Luminescence, we date the last moment sediments were exposed to sunlight and, therefore, the time of the formation of sedimentary deposits.

No area on Earth is similar to Mars, not even in the past. However, there are certain areas that, due to their uniqueness and geological significance, are of great importance in order to understand the processes occurred in the Red Planet.

Lanzarote (Canary Island, SP) was chosen as the best Martian analogue since its geological features and climatic conditions are similar to those of Mars: basaltic products, low quartz and k-feldspar concentrations, dry weather, very low vegetation.

The aim of the work is to reconstruct the late Pleistocene geological evolution of the Famara cliff area pointing out which have been the different depositional environments through time. The Famara cliff is the remnant of a Miocene caldera made of basalts. Ephemeral streams deeply incised the cliff rim and a suite of colluvial fans eventually evolving in alluvial fans developed. These alternate with aeolian deposits that become dominant toward the caldera centre. Sediments are all basalt derived except for some dust blowed from the Sahara during major storms. The described features could be considered similar to those developing on rim and floor of a Martian impact craters.

Ages of the colluvia and dunes were determinate using luminescence technique and 14C. The obtained results indicate that deposition occurred during Marine Isotopic Stage 3 (59 and 29 calendar (cal) kyr BP). MIS 3 is a cold interglacial characterized by high frequency, millennial climatic variability. In particular derived ages indicate that colluvial-alluvial deposition occurred during the wet and more humid Dansgaard Oeschger (D-O) events, while aeolian during the cold and dry D-O stadial and/or Heinrich events.

The obtained data are encouraging and prove that luminescence could be the correct and more suitable method to date the Martian basalt derived recent deposits.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Oral Preferred

Sedimentary architectures of seasonal braided river alluvial fans dominated by episodic floods and the controlling factors of its evolution — A Case Study of Quaternary Poplar Fan in Junggar Basin, Northwest China

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Keywords: Seasonal braided river alluvial fans dominated by episodic floods; Sedimentary architectures,Controlling factors, Architectures model,High quality reservoirs

Seasonal braided river alluvial fans dominated by episodic floods are common types of alluvial fans system. To elucidate our understanding of the sedimentary architectures and controlling factors, a study has been undertaken on the Quaternary Poplar Fan, in the endorheic Heshituoluogai Basin, China as the dissection of modern sedimentary. Based on observations from outcrops and trenches on the Poplar Fan, together with flume tank simulation, sedimentary evolution processes and architecture characteristics are systematically studied. The formation and reworking mechanisms under different types of flows in different units of sedimentary architectures are also researched. Then we clarified the sedimentary characteristics, established its depositional model and discussed the controlling factors of seasonal braided river alluvial fans dominated by episodic floods.

The results show that: (1) the 7th to 3th units of architectures have been studied. The 7th units of architectures are characterized by semi-lenticular composite fans, which are formed by superposition of the 6th architectures units. A single alluvial fan is formed by the superposition of 5th architecture units (high flow stage deposits and low flow stage deposits). At the proximal fan, there are two types of 4th architectures units, which are the downcut channels during the high flow stage and the hosting channels during the low flow stage. At the proximal to medial fan, three types of 4th architectures units (sheet-like flow deposit during the high flow stage, the hosting channels and braided channels with primary bifurcation) are seen in this sector. At the medial to the distal fan, unconfined braided streams deposits during the high flow stage and the braided channels with channel bars during the low flow stage are the types of 4th architectures units. At the distal fan, narrow and shallow channels deposits during the high flow stage and the braided channels with channel bars during the low flow stage are the types of 4th architectures units. The 4th architectures units are composed of different types 3th architectures units, which are various lithofacies. (2) Topography and provenance are the main controlling factors affecting the architectures. With the increase of the topography slope, the fan tends to grow in the axial direction, the length-width ratio increases, and the architectures units become narrower. When the provenance supply increases, the fan area and architectures units grow, but has little effect on the fan length-width ratio. As the number of provenances increase, the intersection area of fan enlarges, the length-width ratio of single fan decreases, and the architectures units become more mixed and difficult to distinguish. (3) Seasonal braided river alluvial fans dominated by episodic floods are associated with both high and low flow stages. From the proximal to the distal fan, incised channel deposits, sheet-like deposits, unconfined braided streams deposits and narrow with shallow channels deposits cover the high flow stage. And the braided channels with channel bars cover the low flow stage. The temporal and spatial variability in the occurrence of these flow processes controls the types and spatial distribution of different types of architectures units.

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Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
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Sedimentary facies analysis of the Upper Cretaceous Shendi Formation in Musawwarat-Naga area, Shendi-Atbara Basin, Sudan

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Keywords: Keywords: Facies, Architecture, Paleoenvironment, Upper Cretaceous Shendi Formation, Shendi-Atbara Basin

This study examines both vertical and lateral facies changes as well as petrographic characteristics of the outcropping section of the Upper Cretaceous Shendi Formation in Musawwarat-Naga area with a view of interpreting the depositional environment, provenance, and tectonic setting that prevailed during the deposition of the sediments. Field studies revealed the presence of Eight different sedimentary lithofacies. The predominant is the trough cross-bedded sandstone facies (St), representing 75% of the total succession. Four architectural elements were recognized: channel fill (CH), sandy bedforms (SB), gravelly bars, and bedforms (GB), and overbank fill (OF). Moreover, the mean value of paleocurrent directions was 285.3° which is suggestive of a southeasterly located source area. The majority of the sandstones are classified as quartz arenites with subordinate sublithic-arenites. Ternary plots of Quartz-Feldspar-Lithic fragments (QFL) revealed that the tectonic setting of the area is predominantly within the interior craton. It can be suggested that the sediments were sourced from the southeast region and associated with a braided, proximal, fluvial depositional environment. The results of this study provide outcrop analog data that might be useful in the exploration of hydrocarbons. Specifically, it can enhance the understanding and prediction of the proximal fluvial depositional styles in the subsurface deposits in the Shendi-Atbara Basin, Sudan, and the region.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Oral Preferred

Sensitivity Analysis in Stratigraphic Forward Modelling of Fluvial Distributary Channels Dominated Fan Delta

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Keywords: Stratigraphic Forward Modelling, Sensitivity Analysis, Sedimentary Factors, Experimental Design, Fan Delta

Traditional structure and sedimentary researches don't capture the measurable coherent relationship between the sedimentary architectures and factors. The four-dimensional stratigraphic forward modelling has facilitated a better assessment of the vertical and lateral sediment extent and connectivity in depositional basins. This paper presents a new quantitative approach for sensitivity analysis in the stratigraphic forward modelling of the terrestrial clastic reservoirs in the west branch of East African Rift on a field scale. A fluvial channels dominated fan delta in the upper Miocene formation in the south of Albert rift is used to exemplify the sensitivity analysis in the stratigraphic forward modelling. A reference base case model is calibrated to sedimentary parameters that derived from seismic interpretation and well data. The number of investigated factors is four (including initial bathymetry, eustasy, sand proportion in sediment supply, fluvial discharge) and they both have three levels, an orthogonal experimental design table helps to reduce the number of test cases from 81 to 9. Moreover, two response surface functions which use formation thickness and net-to-gross (NTG) distribution as the output of the simulator are constructed for uncertainty quantification respectively. The uncertainties analysis of the four sedimentary factors provides the variation range for each parameter. The facies belts and palynology results indicate a range of 0 to 20m for initial bathymetry. For eustasy, the relative lake level curve that is calculated from the GR spectrum gives a fluctuation of 10m. The statistical results of lithological interpretations from well logs are used to set the uncertainty of sand proportion in sediment supply. Fluvial discharge is usually given by a specific multiplier of sediment supply rate. The selected nine cases based on experimental design are conducted to the practical model realizations. Formation thickness and NTG distribution maps of the test cases show different sensitivity responses to the changes of sedimentary factors. The most sensitive factor is sand proportion in sediment supply because its slight variation plays a significant role in impacting a wide range of the thickness and NTG. Whereas, initial bathymetry is found to be the least sensitive parameter to affect the simulation results. The two functions built by response surface proxy model are used to quantitatively and directly estimate the thickness and NTG distribution from the four considered sedimentary factors.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
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Study on Sedimentary Architecture Model and Sedimentary Dynamic Mechanism of Channel Bar in Sandy Braided River

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Keywords: Sandy braided river, Channel bar, Sedimentary architecture, Numerical depositional simulation, Sedimentary evolution process

Through sediment numerical simulation and big data analysis, this project has obtained the following understandings: The general evolution process of sandy braided river(SBR) includes six stages, namely, the formation of the embryonic form of CB, rhombic bar(RB), tongue-shaped bar, unit bar(UB), composite channel bar(CCB) and transformed CCB. In this process, the scale of CB first increases rapidly, then increases slowly, and finally maintains stability. The evolution is dominated by flow patterns and their changes. On the flat bedform, the flow is blocked by the bank to generate a secondary flow and conducts to the opposite bank to form water wave interference, resulting in the formation of embryonic form of CBs and gradually grows into RBs. A RB constrains water flow and causes sediment and water flow to converge and then diverge, creating a tongue-shaped CB. Then, the tongue-shaped CBs grow to contact each other, causing the water flow to become irregular and gradually converge to form braided channels(BCs) and further lead to the formation of UBs. The UBs undergo differential downstream migration driven by different intensities of water flow in different BCs. The difference in the migration rates of different UBs causes the independent UBs to "catch up" with each other and eventually "collide", thus forming a CCB. Then, BCs gradually become stable, and water flows over the top of the CCB and transforms its morphology, forming a reformed CCB with many gullies on the top. The architecture patterns of RB, tongue-shaped bar and UB are relatively simple. It is composed of multiple upward-thinning progradational accretions in the downstream direction, while it is flat at the bottom and convex at the top in the transverse direction, and is composed of multiple upward-thinning aggradation accretions. CCBs and reformed-CCBs are complex in architecture, and are formed by repeated cutting and stacking of progradational and lateral accretions that gradually become thinner from bottom to top, and occasionally filled with BC deposits; The sedimentary evolution of SBRs is sensitive to sediment particle size and river discharge. Sediment particle size mainly affects the evolution rate of rivers. The larger the particle size, the faster the evolution rate, and vice versa. In addition, the scale of CBs is less correlated with sediment grain size. River discharge not only controls the evolution rate of SBRs and the scale of CBs. The larger the discharge, the faster the evolution rate and the larger the scale of the CB.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Oral Preferred

IDENTIFICATION METHOD OF CHANNEL SAND AND LITHOLOGIC TRAP BASED ON PHYSICAL SIMULATION RESULTS

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Keywords: Physical simulation,Channel sandstone,Lithologic trap,Recognition methods

As the most important hot field of oil and gas exploration, the research on channel sand body of deep-water channel deposition and fluvial facies deposition has been studied for decades.The research on the underwater distribute channel developed on the shallow Delta has gradually become the focus of attention. Domestic and foreign scholars have carried out research on its restrictive factors, but there is still a lack of in-depth analysis on the evolution of waterway configuration, sand body architectural structure and level, sand body heterogeneous distribution, sand body migration and superposition. This study analyzes the type, evolution, internal configuration and reservoir development characteristics of upper and lower distribute channels in shallow water delta through physical simulation experiments. Using the simulation results, the channel sand reservoirs in Linhe depression of Hetao Basin and Jizhong depression of Bohai Bay Basin are compared and analyzed. Based on the study of regional core, logging, logging, seismic, analysis and test data, it is considered that the paleogeomorphology from lin1 to lin2 of Linhe formation in Linhe depression and from sha1 to dong3 of Jizhong depression is relatively wide and gentle, the water body in the study area is wide and shallow, the lake water body fluctuates frequently, the material source supply is sufficient, and there are favorable sedimentary conditions for the formation of shallow water delta. In the study area, strong hydrodynamic sedimentary structures are mostly seen in the rock core, and the vertical progradation and aggradation sequences are developed. Parallel, subparallel and imbricate seismic reflection characteristics can be seen on the seismic profile. Taking the shallow water delta front subfacies as the research subject, the front subfacies are wide, and the inner and outer front deposits are identified according to the lake level and logging curve. The underwater distribute channel constitutes the main sedimentary framework sand body. The channel swings frequently laterally and the main reservoir sand body accumulates laterally, resulting in the thin thickness and small scale of the channel sand single layer. The instantaneous phase and 90°phase conversion are used to compare the weak reflection layer, identify the channel sand and reduce the multi solution of the horizon. Two typical seismic features are identified: "worm" seismic facies and "top flat bottom concave" filling seismic facies. Through the above analysis, the multi-stage channel range depicted by the stratigraphic slice is superimposed, and its external boundary and fault configuration form a trap. Drilling in the channel sand superposition area in the trap is preferred. To a certain extent, it has guiding significance for enriching the understanding of shallow braided river delta reservoir and expanding the new zone, even for the oil and gas exploration field of Linhe depression of Hetao Basin and Jizhong depression of Bohai Bay basin. It also provides a theoretical basis for the formulation of later development plan and resource evaluation of the oilfield.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Oral Preferred

Provenance versus weathering control on sediment composition in tropical monsoonal climate (South China) - Geochemistry and clay mineralogy

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Keywords: Sand and mud geochemistry, αAl indices, Clay mineralogy, Kaolinite as a weathering proxy, Pearl River catchment. Tropical monsoonal climate

This study presents an integrated mineralogical and geochemical database on mud and sand transported by the Pearl River (Zhujiang) and coastal rivers of SE China. Clay mineralogy and bulk-geochemistry of fluvial sediments are used to trace changes in weathering intensity across South China, a vast tropical to subtropical region characterized by a strong longitudinal rainfall gradient. The control of climate-induced weathering is manifest in the mineralogy and geochemistry of Pearl River mud, although mud and, to a greater extent, sand composition are also largely affected by the lithology of parent rocks. The depletion in mobile alkali and alkaline-earth metals increases steadily from the drier western part of the Pearl River catchment to the wetter eastern part and is most marked in easternmost tributaries of the Pearl River and in southern coastal rivers. Na and Ca are the most strongly depleted elements in Pearl River sediments, whereas the low concentration of Ca and Mg in river sand of coastal SE China also reflects the felsic character of parent rocks in the Cathaysia block. Eastward-increasing weathering conditions are most clearly highlighted by the progressive eastward increase in kaolinite across the Pearl River catchment, whereas the weathering effect in sand is blurred by quartz addition owing to widespread recycling of quartz-rich siliciclastic source rocks.

This actualistic case study from a region characterized by monsoonal climate underscores the care that should be taken while inferring climatic conditions from the geochemical composition of sediments and sedimentary rocks, which is controlled by multiple geological factors including the felsic versus mafic character of parent rocks and the presence of extensive carbonate or siliciclastic covers in source areas. Most reliable indications are provided by the kaolinite/(illite+chlorite) ratio and by αAl indices for Na, Ca, Mg and Sr, which consistently increase eastward across South China thus paralleling the marked eastward increase in monsoonal precipitation toward the coast.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Investigation of petrographic characteristics of glacio-fluival sandstones

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Keywords: glacio-fluival sandstone, dagenesis, quartz overgrowth, authigenic clay mineral

The sandstones in the study field was deposited in a glacio-fluival environment, mainly including fluvial facies, glacio-fluvial facies, landslide/debris flow facies and glacial shear zone facies. The sandstones are mainly quartzarenite with quartz making up ~75% whole rocks. Minor rock fragments are present. Grain sizes range from silt to gravel, but the majority of samples fall into fine to medium-grained sandstone categories. The grain size distribution is mainly near symmetrical skewed. The grain sorting varies from very well to poorly-sorted, mainly moderately to moderately well-sorted. The variation in grain size and sorting mainly reflect the changes in the depositional environment. Authigenic clay minerals, mainly illite (av. 1.5%) and kaolinite (av. 2.8%), occur as pore fillings, which bridge and block pore space and pore throat. Detrital clays often occur as patches filling intergranular space. However, most samples are well cemented by quartz overgrowths (av. 11.2%). In addition, minor amounts of authigenic chlorite, dolomite, siderite, barite and pyrite also occur locally. The initial sediments combined with further various diagenetic processes play a significant role in controlling reservoir quality. Petrographic characteristics elaborately illustrate the role played by sediments and diagenesis, which will facilitate successful reservoir quality prediction in hydrocarbon exploration.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Oral Preferred

Sedimentary Characteristics and Distribution of Modern Distributive Fluvial Systems around the Large Depositional Basins in northwestern China

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Keywords: Northwest of China, Nonmarine petroliferous basin, Distributive fluvial system, Sedimentary model

DFS is a depositional system which a river enters the basin from an apex in radial patterns, these include alluvial fan, fluvial fan and mega-fan etc., The earliest reports on DFS were a paper published in Geology by Weissmann et al. (2010), and Hartley et al. (2010) published the measurement of DFS in more than 700 sedimentary basins around the world. The concept of DFS has received a lot of recognition and support (Quartero et al., 2015; Zhang et al., 2017), but has also been criticized and questioned (Smith et al., 2010; Ashworth and Lewin, 2012; latrubesse, 2015) since the presentation.

The DFSs geometric and distribution in Qaidam Basin, Tarim Basin, Junggar basin, Zoulang basin and its adjacent mountainous and desert areas have been surveyed by using Google earth program and radar elevation data. The study built a DFS database of 2169 DFS in 50 DFS zones on the basis of delimiting the DFS boundary and measuring the area and perimeter of DFS and its drainage basin, the slope, the downstream profile and other DFS morphological parameters. The database collected DFS's geographical coordinates, tectonic condition, their geometry, the research cross sections and field trench information as well as experimental test data, some text and picture materials including the early research data and the village distribution have been stored in the database.

Heihe DFS, Yumen DFS, Dahalteng DFS, Huatugou DFS and Golmud DFS have been studied in detail about their sedimentary characteristics, facies and architectural element distribution with combination of UAV aerial photography and ground observation. DFS are classified based on the characters of their geometry, geographical location, termination and sedimentation.

The DFS anatomy in Permian-Triassic Mahu sag of Junggar basin proved that there are abundant DFS deposits in Chinese terrigenous petroliferous basins which can be important reservoirs for oil and gas migration and accumulation. The Study of DFS sedimentary system has great theoretical and applicational significance in sedimentary depositional model construction and new favorable reservoir exploration of terrigenous petroliferous basins.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Oral Preferred

The research of River Morphology transition and Sediment variation: Shule River, Northwest of China

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Keywords: Shule River, Fluvial Sedimentology, River Morphology, Sediment Variation, Gravel Refinement

Sediment grain size and river morphology are important objects in fluvial sedimentology. The research is well documented, but few prior studies have analyzed the response of Gravel Refinement and River Morphological. The downstream fining pattern observed in the Shule River is cited as a classic example of a morphology transition in a large alluvial channel. However, important questions regarding the River Morphology transition, Sediment variation unanswered. Here we present observations of the downstream change in bed gravel grain size, river morphology, and sediment element content through the reach within the Yumen fan. These observations indicate that the gravels are coarse in the bed of the braided river belt have a mean grain size of 36.09 mm, the element content of SiO2 was 69.34%, and Al2O3 was 17.00%. The grain size in the river transition belt is smaller than the upstream, with a mean grain size of 22.40mm, the element content of SiO2 was 65.01%, and Al2O3 was 19.41%. The mean grain size of gravel in the meandering river belt is 9.70mm, the element content of SiO2 is 63.55%, and Al2O3 is 25.96%. Through quantitative analysis of changes in river morphology, gravel grain size, and element content, we show that the changes of river morphology are mainly affected by slope, the grain size of gravel is mainly affected by hydrodynamic conditions, and element content changes are mainly affected by depositional environment. We also found that these three changes are interconnected, and not isolated. The Shule River is close to the apex, with a large slope and steep terrain. The river morphology is mainly braided river, the hydrodynamic conditions are strong, and the sediments are mainly coarse gravel. Downstream of the Shule Rive, the slope decreases, the terrain is gentle, the river morphology is mainly meandering river, the hydrodynamic conditions are weak, and the sediments are mainly fine gravel and sand. We propose that through a systematic study of the Shule River from macro to micro and from whole to local, it is of great guiding significance for the research of fluvial sedimentology.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Oral Preferred

Sedimentary characteristics of the Permian Upper Urho Formation distriblutive fluvial systems in the Mahu Sag, Junggar Basin, China

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Keywords: Junggar Basin, Mahu Sag, Upper Urho Formation; Distributive Fluvial System

Distributive Fluvial System (DFS) refers to deposits of a fluvial system exhibiting a radial planform and distributive channel pattern. This concept emphasizes the overall analysis of the sedimentary system and integrates alluvial fans, braided rivers, meandering rivers and deltas in an orderly transitional sedimentary system (Weissmann et al, 2010; Hartley et al, 2010; Zhang et al., 2017; Zhang et al., 2020, Zhao et al., 2021). Based on detailed observation of 2268.42m cores in 78 wells from the Upper Urho Formation in the Mahu Sag of the Junggar Basin, the characteristics of the DFSs of the Upper Urho Formation were analyzed in detail with the logging data. The study showed that there were two terminal styles of DFSs in the Upper Urho Formation, one is terminating at the alluvial plain on land, mainly developed in first and second members of the Upper Urho Formation; the other was carrying sediments into lake waters and forming deltas, mainly developed in third member of the Upper Urho Formation. Three zones, proximal, middle and distal of the DFS, can be identified in the subaerial sedimentary area, and two zones, delta front and prodelta, can be identified in the underwater sedimentary area. Braided channel lithofacies association and cohesive debris flow lithofacies association dominate the proximal zone of DFS. The lithofacies associations in the medial zone are mainly composed of braided channel and inter-channel. The lithofacies associations in the distal zone are mainly composed of braided channel, sheet flow and inter-channel. There are lithofacies associations in the delta front: underwater distributary channel, interdistributory bay and debris flow, lacustrine mud lithofacies association dominates the prodelta. The thicknesses of coarse-grained channel deposits and inter-channel fine-grained deposits in different zones are significantly different. In the proximal zone, the glutenite deposits in the braided channel are in the form of thick layer superposition, the cohesive debris flow deposits are in medium-thin layers, and the inter-channel deposits are rarely preserved and mostly occur as thin interlayers. In the middle zone, the superimposed glutenite deposits of the braided channel are interbedded with the fine-grained deposits of the inter-channel. The thin-layered braided channel deposits and sheet flow deposits in the distal zone are isolated in the thick fine-grained deposits of the inter-channel. In the direction of DFS along the provenance, the total thickness of conglomerate and sandstone has the trend of gradually thinning, the thickness of mudstone has the trend of gradually thickening. DFSs of Upper Urho Formation belong to regressive types. From the first member to the third member of the Upper Urho Formation, the lake area increases gradually, the extension range of DFSs decrease gradually in the lateral direction, and the grain size decreases gradually in the vertical direction.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Oral Preferred

Sedimentary filling evolution under paleoclimate transition — A case study of Jurassic Zhiluo Formation in Ordos Basin

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Keywords: Ordos Basin, Jurassic, Zhiluo formation, Sedimentary system, Paleoclimate, Tectonism

Abstract: Under a certain tectonic background, the change of paleoclimate can show different sedimentary response characteristics in sedimentary strata. The Jurassic Chinese mainland was one of the important areas for the transformation of paleo-Tethys tectonic domain to the circum-Pacifi tectonic domain, and its paleoclimate information was completely preserved in the continental sedimentary strata. The Jurassic Zhiluo Formation in Ordos Basin was just at the critical period of both paleotectonic domain and paleoclimate transition, which preserves a large amount of sedimentological evidence, while previous few sedimentological research on the Zhiluo Formation under the dual transition. In this study, based on the field outcrop survey, thin section observation, geochemical data, stratigraphic correlation and sedimentary facies analysis, and the paleotectonic transition, the paper reconstructs the sedimentary filling characteristics of Zhiluo Formation under paleoclimate transition. The results show that with the transition of paleoclimate from warm and humid to hot and arid, vertically, the sedimentary facies of Zhiluo formation is characterized by the transformation from braided river (braided river delta) to meandering river and meandering river delta, and lacustrine was deposited in the southeastern part of the basin in the late stage. The combined action of the Tethys-circum-Pacifi tectonic domain caused the overall uplift of Ordos Basin and prevented the southern super monsoon from entering the basin, thereby changing the climate in the basin from warm and humid to hot and semiarid/arid. This study provides an important basis for the exploration and development of uranium resources in the basin and the sedimentology and paleoenvironment research in East Asia during the Middle Jurassic.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Oral Preferred

Garnet, Cr-spinel, and zircon geochemistry as provenance indicators for the climatic and tectonic evolution of the Mesozoic southern Central Asia

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Keywords: Sikeshu Sag, source-to-sink system, Precambrian basement, Tianshan Orogenic Belt, Western Junggar Orogenic Belt

Sedimentary provenance analysis remains an efficient method for constraining the evolution of orogenic belts and paleoclimate. Intracontinental basins with multiple provenances exhibit diverse provenance evolution. The provenance evolution of the Mesozoic western Junggar Basin recorded climatic and tectonic evolution in Central Asia. Here we reconstruct a four-phase evolution model of the Mesozoic source-to-sink system in the western Junggar Basin, an intracontinental composite basin, by employing multiproxy provenance proxies — paleogeographic analysis, paleocurrent, heavy mineral data, geochemistry of detrital garnet, Cr-spinel, tourmaline, and ilmenite, and zircon U-Pb geochronology. Detrital ugrandite and pyrope, metamorphic ilmenites, dravite, epidotes, and Precambrian zircons were used to identify the Tianshan Orogenic Belt (TSOB) provenance to the south, and the Cr-spinel were used to identify the Western Junggar Orogenic Belt (WJOB) to the north.

The results suggest that the sedimentary environment transitioned from fluvio-lacustrine to alluvial in the Late Jurassic, and evolved into a lacustrine environment in the Early Cretaceous. The southern basin was stably fed by the TSOB in the Triassic during the syn-rift phase. The TSOB dominated and basin center move northward from the Early to Middle Jurassic during the post-rift sag basin phase; During the transpressional basin phase, the basin was mainly sourced from the WJOB and basin center moved, which was followed by the dominance of the TSOB provenance in Late Jurassic. The basin center moved southward in the late Middle Jurassic and northward in the Late Jurassic. Syndepositional volcanic materials provided a large amount of sediments in the Late Jurassic. During the sag basin phase, lake transgression happened and the basin center moved southward.

We concluded that the source-to-sink system experienced a significant change from the syn-rift phase to the post-rift phase. The WJOB experienced transpression and obvious denudation in the late Middle Jurassic, and the TSOB uplifted under transpression in the Late Jurassic. Precambrian basement in the TSOB was not largely exposed until the Late Jurassic. The transpression controlled the change of major provenances and basin center. The aridification in the Late Jurassic in Central Asia was responded by the decrease in the ZTR index and the increase in epidotes and magnetites. The humidification in the Early Cretaceous was in response to the lake transgression and sediment recycling.

ID: T5-40417

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Oral Preferred

Quantitative prediction of gravel diameter with transport distance: A case study of the Karaza Formation of the Honggou section of the southern rim of Junggar

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Keywords: gravel diameter,transportation distance,alluvial fan

Studying the quantitative relationship between gravel diameter and its transportation distance in sedimentary rocks is very important to predict the scale and distribution range of sedimentary system. The study of modern gravel riverbed shows that the relationship between gravel diameter and transportation distance is often in the form of negative index. Based on the gravel data of Kaidu River and Malan Hongshan fan and negative exponential fitting, the quantitative relationship between gravel diameter and its transportation distance is established. The average gravel diameter is calculated to be 22.8-62.9km away from the peak of upstream alluvial fan, and the maximum gravel diameter is calculated to be 10.8-43.8km away from the peak of upstream alluvial fan. According to this formula, the average gravel diameter of Kalaza formation of well Tian'an 1 located at the downstream of alluvial fan 40km northeast of Honggou section is about 1.4-4.6mm, and the maximum gravel diameter is about 4.1-13.2mm. According to this result, it is considered that the Kalaza formation is widely distributed in the south of Junggar Basin and has the sedimentary conditions for the formation of large favorable reservoirs. This result provides a theoretical basis for oil and gas exploration in this area.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Oral Preferred

Quantitative relationship between distributive fluvial system area and drainage basin area

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Keywords: terrestrial petroliferous basins,distributive fluvial system,influencing factors,source to sink,quantitative prediction

Distributive Fluvial System (DFS) refers to a channel and floodplain sedimentary system that radiates from a vertex, including alluvial fans, fluvial fans, or megafans (Weissmann et al, 2010; Hartley et al, 2010). DFS is widely developed in continental basins and controls the distribution of terrestrial oil and gas reservoirs, sedimentary minerals and soil types, so it has become a research hotspot in recent years. Using Google Earth, Global Mapper and other geographic information software and radar digital elevation data, 1224 DFS areas and their drainage basin areas developed around many mountain systems and lake basins such as Tianshan Mountain, Altun mountain, Qilian Mountain, Chaka Salt Lake and Suhaitu Gobi are measured. It is found that the DFS area has a positive correlation with the source area, and the relationship is in accordance with: $A_{dfs} = aA_{da}^{b}$, the average correlation coefficient is 0.88 (A_{dfs} is the DFS area; A_{da} is the drainage basin area; a and b are constants, a is between 0.3945 and 6.1929, and b is between 0.3816 and 1.702).

Due to the differences in the structure, climate, parent rock and other factors in each region, the constants a and b are different to some extent. In areas with basically the same factors such as structure, climate and parent rock, the size of the DFS area is mainly affected by the source area. The larger the source area, the larger the DFS area. The a and b values of the foreland basin fluctuate the most; climate has a certain influence on the size of the DFS area and its drainage basin area, and the correlation of the formula fitting under arid climate conditions is better; the influence of the source rock properties on the DFS area is mainly related to the parent rock. The ability of rock to resist erosion and differentiation. This study provides a reference for predicting the distribution of sedimentary systems in terrestrial petroliferous basins.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Oral Preferred

Study on characterization method of thin interbedded reservoirs

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Keywords: thin interbedded reservoirs, braided river delta, plane distribution

In the design stage of oilfield development plan, the distribution of reservoir determines the basic well pattern and well spacing. P oilfield is a shallow braided river delta deposit with a distribution area of 16.8km2. At present, there are 4 appraisal wells, and the average thickness of the reservoir is 2.1m, which is far less than the 9m sand body recognized by seismic data. The difficulty of reservoir characterization leads to high risk of development plan.

Referring to the modern sedimentary law, terrigenous materials are mainly transported by fluids, which is easy to form a large area of thin interbedding in the flood period. On the whole, the thin layer is attached to the thick layer. For thin interbedded reservoirs, this study proposes a method of gradually completing the plane distribution of reservoir from thick layer to thin layer. For reservoirs with thickness greater than 5m, the seismic attributes suitable for each oil formation are found by analyzing the correlation. Then, based on the well data, the plane characterization of thick layer is completed through the combination of well seismic and plane section. The plane distribution of thin layers is predicted by taking the sedimentary model based on thick layers as constraints and the actual drilled thin layers and seismic attributes as the reference.

The reservoir characterization results show that the delta in the oil field is unstable interbedding type due to the influence of source supply and channel plane migration. Thin sand bodies between channels change rapidly and have poor connectivity. In the low stand area period, the river channel is developed continuously, with large thickness and good connectivity. In the highstand period, the river channel is mainly narrow strip, with small thickness and poor connectivity. Based on the reservoir characterization results, 17 wells were optimized by focusing on thick layers, ensuring reservoir physical properties and connectivity, and taking into account thin layers. The actual drilling results show that the reservoir distribution is consistent with the description before drilling. The daily oil production of development wells exceeds the allocated production by 20%, and the oil production rate is increased by 1%.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Oral Preferred

Quantitative characterization of remaining oil based on fine reservoir characterization

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Keywords: braided river delta, horizontal well facies, remaining oil, tap the potential

S oilfield is a braided river delta deposit with large proved oil geological reserves. After more than ten years of water injection development, the oil recovery rate has been reduced from 1.2% to 0.4%. Horizontal well development has been tried in recent years, but the results are uneven. It is urgent to accurately characterize the remaining oil, guide the oilfield to tap the potential and improve the development effect.

According to the macro distribution of reservoir, the river channel, dam body and dam edge are characterized through multi-attribute optimization and well seismic combination. In view of the productivity difference of different horizontal wells on the dam body, starting from nearly 300 sample points, the dam body is divided into class I dam body and class II dam body according to physical properties, productivity and logging characteristics. Based on the sedimentary model, the horizontal well facies determination technology is adopted to complete the plane distribution of the main bodies of class I and II dams. The correlation of parameters such as the proportion of water flooded thickness and oil displacement efficiency of drilled wells is analyzed, and the connectivity coefficient G is introduced to quantitatively characterize the enrichment degree of residual oil at well points. On the plane, the plane distribution of connectivity coefficient is formed by combining the fault system, injection production well pattern and reservoir distribution, so as to realize the quantitative characterization of remaining oil

The results show that affected by the range of water drive, the main enrichment area of remaining oil is the phase transition area between class I dam body and class II dam body and dam edge. Based on the distribution of remaining oil, a horizontal well development model for developing the main body of class I dam is proposed. At present, 25 adjustment wells have been deployed and 14 have been implemented. The daily oil production of the oilfield has increased by 700 m^3, and the oil production rate has been doubled, which has successfully improved the development effect of the oilfield.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Sandy braided river architecture characteristics and evolution: A case study from outcrops in Yungang Formation of the Middle Jurassic in Datong, Shanxi Province, China

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Keywords: Yungang Formation, sandy braided river,architecture element, braided channel; lithfacies association sequences

There is typical sandy braided river deposition in Yungang Formation of the Middle Jurassic in Datong, Shanxi province. Through observation, field measurement, sand body interpretation and laboratory analysis, the geometrical morphology, scale, architecture, structure, lithofacies and lithofacies association sequences of 8 outcrops deposits in the Middle Jurassic Yungang Formation in the Datong Basin, Shanxi province, were systematically studied, 10 types of lithofacies in 8 associations and 5 typical 4th hierarchy architectural element including include braided channel, channel bar, flood plain, abandoned channel, and crevasse splay and chute falling which is 3rd hierarchy reservoir architecture element were identified. The comparative analysis of the comprehensive column of the section shows that channel bars is the major type in the sandy braided river deposits, which were alternately stacked with braided channel, abandoned channel, flood plain and crevasse splay. In terms of time evolution, ten stages sedimentary cycle had been developed below maximum dry water boundary surface forming 6 compound bars. The compound bars are presented in the form of “pan communicated sandy bodies”. The evolution process and rules of the sandy braided river are further summarized, and the strongly heterogeneous facies model with compound bars and main braided channels, which are the main body of deposition, is proposed. It will help to the further theoretical study and the quantitative parameters reservoir characterization and modeling of the sandy braided river.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Quantitative prediction of narrow&thin interbedded reservoirs based on waveform indication-vector sedimentary inversionA case study of Shahejie Formation in Bohai A Oilfield

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Keywords: Bohai bay basin,waveform indication inversion,well seismic coordination, vector information,thin interbedded reservoir,coincidence

For Shahejie Formation in Bohai A oilfield, there are thin interbedded reservoir , deep buried, thin and fast changing laterally, most of single layer thickness of less than 5m, and obvious sand -shale interbeds, so it is difficult to predict the reservoir. In this paper, the well seismic joint inversion technology based on waveform indication vector deposition is adopted. The waveform information in high frequency band of seismic data body is used to replace the variogram function, and the sensitive curve reflecting lithology is selected to participate in the simulation. The vertical resolution and horizontal accuracy of reservoir prediction are effectively improved, and the spatial distribution characteristics of sand body in the target layer are more accurately depicted. The high-resolution reservoir prediction with well seismic cooperation is realized Layer prediction. The application of seismic waveform indication inversion technology in thin interbedded reservoir prediction of Bohai A oilfield shows that the coincidence rate of single well reservoir prediction is more than 85%, and the coincidence rate of plane prediction is 78%, which has achieved good results. The research results provide technical support for the implementation of development wells and the understanding of injection production connection.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
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A New Viewpoint to Vine-type Shallow-water Delta of the Lower Member of Minghuazhen Formation in Laibei Low Uplift

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Keywords: Laibei Low Uplift, the Lower Member of Minghuazhen Formation, vine-type Shallow-water Delta,growth pattern.

In order to clarify the sedimentary model and characteristics of the dendritic shallow water delta in the lake basin during the shrinking period of the Bohai Bay Basin, based on core observation, thin section identification, particle size analysis, logging and seismic attribute analysis, and combined with palaeogeomorphology characteristics, a comprehensive analysis of the low-level shallow-water delta in the lower segment of the Minghuazhen Formation in the Laibei low uplift was carried out. The study shows that:(1) The river-controlled shallow water delta front deposits formed by meandering river entering the lake are developed in the study area. The growth pattern of the front skeleton sand body is mainly divided into three types : superposition type, interweave type and oscillating type.(2) The superposition type sandstones developed underwater distributary channel and estuary sandbar sequentially in the early stage, with poor channel stability and easy breakage, and developed isolated narrow channel sandstones in the late stage; Underwater distributary channel of the interweave type sandstones is reticulate and interwoven on the plane; The oscillating type sandstones have weak channel stability and are easy to cut and divert.(3)The study area was steadily tectonically subsided and filled by sediments during the shrinking period of the lake basin, resulting in an open lake surface and extremely gentle topographic slope during the deposition of the Minghuazhen Formation, which provided a geomorphic basis for the development of skeletal sandstonesDuring the deposition period of the low-level domain, there was sufficient supply of provenance and shallow water bodies in the lake basin, and the interaction process of river and lake deposition caused frequent river diversions and cross-cutting superposition, forming a large area of superimposed sandstones with vine-type distribution. The research results can be useful for oil and gas exploration and development in shallow water delta reservoirs.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Reservoir characteristics of wandering braided river in Guantao Formation of Nanpu 1-29 Area

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Keywords: Nanpu 1-29 Area, Guantao Formation, Reservoir characteristics

Based on the core and logging data of the study area, this study on the reservoir characteristics of the wandering braided river in Guantao Formation of Nanpu 1-29 Area was mainly carried out from four aspects, including reservoir petrology, pore structure, reservoir physical property and reservoir heterogeneity. The results showed that the reservoir lithology of Guantao Formation in Nanpu 1-29 Area was mainly fine-medium sandstone, pebbly sandstone and glutenite. The pore types of reservoir were mainly intergranular pores, the pore throat radius varies greatly, and the maturity of sediment composition and structure was low, which was characterized by rapid deposition near source and short channel. The physical properties of different reservoirs were different, and the main reservoirs had better physical properties, especially the two small reservoirs NgIV3-1 and NgIV3-2. The reservoir heterogeneity in the study area was strong, and it's mainly explained from the aspects of intra-layer heterogeneity, interlayer heterogeneity and plane heterogeneity.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
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Source Analysis of the Multi-Water Sedimentary Pattern in the Upper Part of the Huagang Formation in the North-Central Part of the X Depression of the East China Sea Basin

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Keywords: Xihu Sag,Huagang Formation,Source Analysis,U-Pb

The Huagang Formation of the Oligocene in the X Depression of the East China Sea Basin is in the stage of depressional evolution, with variable source systems and few analogous contemporaneous outcrops in the surrounding area. The source type and direction have been controversial, which poses a challenge to the understanding of sandstone genesis and type, and reservoir in the depression. In this paper, based on previous studies, the source type and direction of the north-central X depression are investigated by integrating principal component analysis and cluster analysis, in addition to comprehensive analyses using lithological features, heavy minerals, zircon U-Pb dating, clay mineral combs, FMI and seismic, and other multi-information tools[1-4].

The study shows that the East China Sea Basin is a metamorphic crystalline basement in the Yuan Dynasty, and a set of Yanshanian igneous rocks was developed in the X Depression and the surrounding local superposition under the influence of Yanshanian volcanic activity. The heavy mineral assemblage garnet-titanite-zircon-magnetite in the upper part of the flower section is characterized by a high percentage of zircon U-Pb in the metasedimentary period. The source of the QQ and EE tectonics in the eastern part of the X depression is self-contained, mainly from the eastern Diaoyu Island uplift zone and the source is farther away from the western slope and the YQ tectonics. The West Sub-Ambient WW structure is influenced by the short-axis sea reef uplift in the west and the long-axis tiger reef uplift in the north, and the long-axis source is dominant in the north of the structure, while the short-axis source is dominant in the south. The long-axis source affects the YQ structure from north to south, but the eastern source is dominant in this structure.

The comprehensive source analysis suggests that the source-sink pattern of "three-way source supply and axial convergence" is developed in the upper part of the north-central Hanhua depressionFig.1. In the context of the basin depression, the western slope and the eastern slope develop multi-point sources with short axes. In the middle of the depression, the small and medium-sized braided river and curved river sedimentary water system carries to the middle of the depression, and then converges with the large axial braided river system in the north and transports from north to south[5]. This forms a regionally widespread thick-layered sandstone. The large sandstone reservoir collective in the upper part of the flower developed in this source-sink mode has good parent rock type, coarse grain size, adequate elution and strong resistance to compression, forming a better sandstone reservoir. It provides a good basis for improving the exploration and development effect of X depression.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Oral Preferred

Study on reservoir prediction of thin interbed in middle deep layer based on crosswell seismic technology

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Keywords: Bohai Bay,corss well seismic,thin inter-bedded layer,sandbody distribution

The middle-deep buried reservoir occupies an important position in Bohai Bay, which is characterized by deep buring(buried depth is greater than 2500m), low seismic resolution, and thin interbedded, making it difficult for quantitatively description. In this paper, taking the A oilfield in East Bohai uplift as the target area, a new method is conducted to study the thin interbed of sandstone and mudstone between wells by using seismic data. In order to improve the quality and accuracy of the processing parameters, the ground seismic high resolution amplitude preserved processing is carried out.Based on which,reservoir prediction is established by using high resolution crosswell seismic data.With the combination of crosswell seismic data and geological model, the discontinuous boundary of reservoir is revealed,making it better for understanding of reservoir structure and connectivity relationship. In comparison with conventiona method,this method make it possible to predict the distribution and connectivity of sand bodies, and provides a new way for quantitative prediction and research of reservoirs in middle deep buried reservoir. Besides,it effectively lower the risk of reservoir prediction and improve the prediction accuracy,which provide guidance for well location and highly efficient development of the middle-deep buried reservoir in Bohai Bay.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Evolution from shallow-water deltas to fluvial fans in lacustrine basins

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Keywords: Architecture, shallow-water delta, fluvial fan, Shaximiao Formation, Sichuan Basin

The deposition of shallow-water deltas and fluvial fans in lacustrine basins is closely related to the tectonic activities and climate changes. Therefore, these sediments are ideal archives that can elucidate allogenic processes. However, distinguishing between shallow-water deltas and fluvial fans in lacustrine basins with subsurface conditions is difficult. A case study of the Middle Jurassic Shaximiao Formation (J2s) in the central Sichuan Basin was taken to make these points, based on core observations, seismic analyses, petrology analyses, and geochemical analyses. Fifteen sedimentary facies and eight facies associations were established, corresponding to fluvial channelized depositions, fluvial non-channelized depositions, and shallow-water delta depositions. Shallow-water deltas and fluvial fans are characterised by different characteristics, sediments in the first member of the Shaximiao Formation (J2s1) and the first sub-member of the second member of the Shaximiao Formation (J2s21) are dominated by shallow-water delta deposits. Conversely, sediments between the second and fourth sub-members of the second member of the Shaximiao Formation (J2s22 to J2s24) are primarily fluvial fan deposits. The channel widths in the shallow-water delta deposits are broader than those of the fluvial fan deposits and the opposite of channel-body density. The increased uplift of the Dabashan Mountains controls the paleocurrent direction and promotes the evolution from a shallow-water delta to a fluvial fan. Shallow-water deltas are developed in relatively humid environments, while fluvial fans are produced in a relatively arid climate. Highly frequent channel-width variations are controlled by short cycle climate fluctuation. Regarding both shallow-water deltas and fluvial fans, the channel width in the relatively humid environments are wider than those in arid environments. It is likely that sedimentary evolutions from shallow-water deltas to fluvial fans are relatively common in lacustrine basins in relatively arid climates with wide and gentle geological backgrounds.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

A study on fine description and well pattern infilling of braided river tight sandstone reservoirs —Take Block T of Sulige[1*] gas field as an example

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Keywords: Braided river deposition, Sulige gas field, tight sandstone gas reservoir, fine reservoir description, distribution law of residual gas

Block T is located in the southern part of the middle district of the Sulige gas field. The main horizon of Block T is the lower sub member of 8th Member of Middle Permian Shihezi Formation, which belongs to braided river deposition dominated by strong hydrodynamic conditions. The river channels in He8 member migrate frequently. The sedimentary sandbodies have strong heterogeneity and continuously developed in a large area on the plane, and show the characteristics of multi-stage channels cutting and overlapping by each other. In order to solve the problems of complex distribution law of effective sandbodies and difficult stable production of the block, we comprehensively utilize the rich drilling and logging data, three-dimensional seismic data and test production data in the area to carry out fine reservoir description for the main horizon of the whole block. By clarifying the characteristics and distribution law of effective reservoirs, the reservoir production, the development law of river channels and favorable residual gas distribution area, to provide reliable geological targets for the deployment of infill wells. At the same time, the effect of infill wells in the test area is analyzed and evaluated in combination with geological model, numerical simulation and production performance data in the infill test area. The results show that there is an obvious early pressure drop before the test infill wells are put into production. But the test production is relatively normal, the casing pressure remains good after putting into production, and the reduction of daily gas production is small, so it is considered to have economic benefits. By monitoring the production performance of adjacent wells of the test infill wells. It is considered that the infill deployment of class I reservoir area should avoid the high permeability layers with good connectivity and maintain a well spacing of at least 450m, which will have little impact on the production of adjacent wells. The well spacing requirements for class II and III reservoir areas or reservoirs with obvious interlayer sealing can be reduced to 350m. In order to maximize the utilization of the whole reserves in the process of well location, we should determine the reasonable well type according to the effective reservoir types and the well patterns. Therefore, the research results provide a practical and reliable basis for the next step of infill well location deployment in the block.

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Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Oral Preferred

Sedimentary characteristics of shallow water delta in seismic complex imaging area of BZ29 block

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Keywords: Huanghekou sag, Shallow water delta, Material supply, Paleotopography, Sedimentary model

Affected by gas cloud area and complex seismic imaging the study of reservoir distribution and connectivity is restricted, to the lower Minghuazhen Formation in block BZ29 block of Huanghekou sag in Bohai Bay. Systematically studied sand body genesis based on the regional sedimentary background, combined with the data of logging, core, logging facies, and seismic facies. The coupling between palaeotopography, transportation distance, and sand enrichment in a shallow-water deltaic depositional environment is explored.

The study shows that the paleomorphology of the Minghuazhen Formation is relatively gentle, and the seismic phase exhibits a planar dispersion of lobe shape. Through core observation, typical anti-rhythmic estuarine dam features and freshwater lake mesocosm paleontological fossils were found, and the mudstone color is mainly gray-green. All of these micron sedimentary features are indicative of a submerged depositional environment at the leading edge of the shallow water delta. Through the thickness statistics of the drilled wells, the thickness of sandstone gradually thins from the source area to the study area, and it is clear that the study area is a shallow water delta front end submerged sediment under the weak source supply condition. The paleotopography of the depositional area was recovered by using the impression method, and three pale grooves mainly exist in the study area, with locally uplifted. The ancient trench is the main accumulation area of sediments, Forming a distributary channel and sand dam, the thickness of the sand body is 8~14m, the uplift area forms a rapid distributary channel and Inter-Channel Bay deposits, the thickness of the sand body is 3~8m. The above research results have been successfully applied in the development evaluation project of the BZ29 block, The complex sedimentary phenomena in the gas cloud area are reasonably explained, The proved reserves have increased by 10 times compared with that before evaluation by the implementation of evaluation wells in the low potential area of paleotopography, and 10 adjustment wells have been deployed in high-quality reservoir areas, At present, five wells have been put into operation, with a daily oil production capacity of more than 100 m^3.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Oral Preferred

Detrital zircon U-Pb ages of the Eocene Pinghu Formation in the Xihu Depression of East China Sea Shelf Basin reveals the significant but limited provenance of the middle Yangtze River

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Keywords: Detrltal zircon U-Pb dating, Yangtze River, East China Sea Shelf Basin, Xihu Depression, Pinghu Formation

A key piece of evidence to verify the birth of the Yangtze River during the Eocene is tracing its provenance. However, few people can reveal the major sources area of the Yangtze River and its impact on the sedimentary filling of the East China Sea Shelf Basin. We compared the newly acquired detrital zircon chronological data of the Xihu Depression and compile the published detrital zircon U-Pb ages of the upper, middle, and lower Yangtze River and other potential source areas, then reproduced the provenance changes of sediments in the Xihu Depression of the East China Sea Shelf Basin during the key period of Eocene Pinghu Formation. Results showed that 446 zircons from 6 samples revealed the detrital zircon U-Pb age distribution of lower, middle and upper Pinghu Formation in the Xihu Depression is very wide that ranging from 36.1±0.7 Ma to 2954.0±30.2 Ma, and the age range is roughly similar with major age clusters at 100-200 Ma, 200-300 Ma, and 1700-2100 Ma and minor groups of 400-500 Ma, 700-1000 Ma, 2400-2600 Ma ages. However, the zircon age peaks of the lower Pinghu Formation is more monotonous, which are dominant in100-200 Ma, the population of 200-300 Ma, 400-500 Ma and 700-1000 Ma are significantly smaller than that of the middle and upper Pinghu Formation. Compiled zircon ages of the potential source areas showed the age peaks of the Yangtze River and the Subei-Yellow Sea Basin were similar to the Xihu Depression but the age population of 700-1000 Ma is relatively increased, the age group of other potential source areas including the North China plate, west Cathaysian plate, and Peral River Estuary were different from it. Detrital zircon U-Pb age non-negative matrix factorization of potential sources areas and Xihu Depression revealed that the lower Pinghu Formation is less related to the East Asia continent provenance, it may be supplied by local uplifts. While in the middle and upper Pinghu Formation, the relative contribution of the middle Yangtze River increased to approximately 90%, indicating the major provenance was mainly from the middle Yangtze River catchment during Eocene, which may be related to the complete connection of the modern Yangtze River. However, the U-Pb dating age peaks of the middle Yangtze River are similar to the northern of the Xihu Depression with relatively high 400-500 Ma and 700-1000 Ma clusters, but the small peaks of the two age groups in the middle and southern Xihu Depression showed it very different from the middle Yangtze River, indicating that the influence area of provenance from the Yangtze River is relatively limited. The Eocene significant but limited provenance of the middle Yangtze River catchment to the Xihu Depression indicated that the birth of the Yangtze River may occur during the sedimentary period of the middle Pinghu Formation.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Oral Preferred

The impact of floodplain heterogeneities on the morphodynamic evolution of coastal meandering rivers: insights from the Medieval Brenta River (NE, Italy)

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Keywords: coastal meandering rivers, fluvial sedimentology, channel morphometry, floodplain heterogeneity

Coastal plains developed through interaction between fluvial and marine systems that allowed the accumulation of a variety of morpho-sedimentary bodies. These bodies can strongly differ in terms of geometry and grain size, and contribute to forming complex and heterogeneous sedimentary successions, which are, in turn, carved by new river channels. The impact of substrate heterogeneities on morpho-sedimentary processes of channels draining these areas has been poorly investigated, and little is known about the fluvial response to topographic variability triggered by substrate differential compaction.

The present study contributes to filling this knowledge gap by analysing morphometry and sedimentology of a 14 km long Medieval-channel belt of the southern Venetian Plain (northeast Italy). In this area, paleochannel belts are clearly visible from satellite and aerial images, and they are easily accessible for investigation. The study belt is sited at about 8 km from the modern coastline of the Adriatic Sea, which is characterised by a microtidal range (i.e., +/- 1.0 m around mean sea level). The paleo-channel belt was almost 200 m-wide, shows a sinuous pattern and flowed within the backwater zone. The proximal and distal parts of the study portion of the belt overlay alluvial mud and sandy beach ridges, respectively. Morphometric analyses reveal that the bends of the channel belt experienced significant morphological changes moving from the proximal, cohesive, self-compacting alluvial substrate to the distal, cohesionless, poorly compactable beach ridges. Closely spaced sinuous bends developed on the muddy substrate, whereas bends are less sinuous and wider on the sandy beach ridges. Differently, from a sedimentological point of view, no relevant change in point-bar sedimentary features was observed moving downstream along the belt. Sedimentological analyses reveal that point-bar deposits of the study channel belt are homogenously made of sand, with rare muddy layers at the bar top. Additionally, these bars show poorly expressed vertical and downstream fining of the grain size. Results from this study reveal that downstream changes in channel substrate impacted mainly channel-bend morphometries, whereas no relevant variations occurred in terms of sediment transport capability of the river. The overall paucity of mud deposits in the distal part of the system could be explained in terms of a limited impact of tidal forcing on riverine transport processes.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Oral Preferred

Insights into Peak-Discharge Variability as control on planform and evolution of meandering rivers

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Keywords: Peak discharge variance, Meandering rivers, Planform analysis, Meander migration

Despite considerable advances due to the development of recent approaches, the study of river deposits through sedimentary facies models based on channel planform is facing a certain scepticism in fluvial sedimentology. The ability of these models to predict the geometry, internal structure, and grain size of alluvial sediment bodies preserved in the rock record has been questioned, and recent works highlighted that these models neglect the control exerted by hydrological variability on river depositional dynamics and accumulation of related deposits. In the midst of this discussion, a novel approach based on the categorization of rivers according to their variance in peak discharge was proposed by Fielding et al. (2018 - Sedimentary Geology), which turned out to be an effective and reliable basis for classifying the alluvial rock record. Although the latter study shed light on the importance of hydrological regime in fluvial processes and accumulation of related sedimentary bodies, knowledge is still missing on how precisely peak discharge variability influences river morphodynamics.

We investigated the role of interannual peak discharge variance (PDV), defined as the ratio between the standard deviation and the mean of annual peak discharges, to understand the impact of variable hydrological regimes on the evolution of meandering channels. We assembled a dataset of more than 5000 meanders from a suite of 27 long-term gauged, meandering rivers in different locations around the globe. Their PDV values range from 0.04 (very low) to 1.61 (very high) and were derived from continuous discharge data spanning at least 20 years. Digitization of river banks along selected reaches, from past and present freely distributed satellite imagery, allowed us to extract meander bend morphometric features (i.e. width, radius of curvature, sinuosity, amplitude, skewness and asymmetry). Migration rates and different types of cut-off processes were also monitored and assessed within the time interval between available satellite images by quantifying the displacement of both past and current channel centerlines. A joint analysis of these features was performed to unravel the fingerprint of hydrological unsteadiness on planform behaviour, and it is expected to contribute to the development of a new generation of facies models based on the signatures of flow discharge and its variability over time.

Preliminary results highlight that a difference in planform morphometry is provided by differing variability of peak discharge. Low PDV rivers, displaying a greater discharge stability, are characterized by greater sinuosity, curvature radius and asimmetry when compared to high PDV ones. Additionally, high discharge values experienced by high PDV rivers could be recognized as a cause of varying migration rates and development of different types of cutoffs, with respect to their low PDV counterparts.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
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Scaling relationships in fluvial systems and their application to the rock record

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Keywords: fluvial, DFS, scaling

Present day fluvial systems display well established scaling relationships between channel width to depth, channel belt width to depth and point bar width to channel depth. These relationships are important as they provide a potential mechanism for predicting channel body dimensions from one dimensional subsurface datasets such as wireline logs or core. Scaling relationships can also aid in reducing uncertainty associated with estimating fluvial channel body width in the rock record, which, for a given thickness can vary by between 2 and 5 orders of magnitude.

Here we report point bar, channel and channel belt width and depth data from fluvial systems in present day basins to establish dimensional trends for fluvial systems developed in distributive, axial and alluvial valley settings. We use these data to establish generic relationships applicable to all fluvial systems and which should also apply to the rock record. We also illustrate that simple linear relationships between channel width and depth and channel belt width and depth as reported previously are at odds with our data and that an exponential relationship is more appropriate.

Linking present day channel and channel belt dimensions to preserved channel belt sandstone bodies is difficult, as preserved channel belt stacking patterns are not easily observed in modern day basins. Stacking patterns are related to spatial location in basins and the type of fluvial depositional systems (distributive, axial or valley). We present preliminary dimensional data that allow distinction between these different fluvial systems types and place increased constraints on channel body dimensions for use in subsurface studies. Whilst dimensional data from modern day channels and channel belts are not directly transferable to the preserved rock record, this approach does provide generic relationships that could potentially form the basis for more accurately predicting sandstone body dimensions for subsurface fluid extraction and/or storage.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Sedimentary characteristics of arid shallow water delta in the Qaidam Basin: A case study of the Xiayoushashan Formation in Youshashan Oilfield, Qinghai

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Keywords: the Youshashan outcrop,arid climate,shallow water delta,modern deposition

Based on the Youshashan outcrop in Qinghai, comprehensive core, logging and modern sedimentary of Lake Gasku in Qinghai, many studies have confirmed that:The delta deposits in the Youshashan area of western Qaidam Basin were formed in a swollen and shrinking lake basin under arid climate conditions.research shows:Shallow lake basin supported by lake water in arid climate,It has the characteristics of widening water flow and low flow velocity,The sediments are mainly brown-red,Mainly controlled by the main river channel,A large number of detrital materials are deposited in the crevice channel, underwater distributary channel, and mouth bar area to form multiple composite channel-mouth bar lobes,Affected by the dry environment, the compound lobe has a small development scale and a wide distribution range.This type of delta consists of delta plains, frontal margins, and predeltaic subfacies,On the plain subphase, there are obvious divergent water channels in the composite buds;The front subfacies is the most active accumulation area of the regional delta, and the main channel frequently branches into multiple branch channels,The branch channels extend independently and overlap with each other, finally forming a composite channel-estuarine bar combination with a divergent distribution and local contiguousness.The regional pre-delta subfacies belt is very narrow and underdeveloped, and it is transformed by the effects of lake wave tossing, etc., and the shallow lake sheet sand mixed with it, and it is difficult to distinguish the interaction with the shallow lake subfacies.For this reason, the main channel and composite channel-mouth-bar tuft assemblages are the most important oil and gas reservoirs in regional deltas.

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Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
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A study on the Sequence Architecture and Paleohydraulics of the Upper Member of Bhuj Formation, Kutch Basin, India

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Keywords: Bhuj Formation, Kutch Basin, Fluvial Architecture, Paleohydrological parameters

The Early Cretaceous Bhuj Formation, which is the youngest formation of the Kutch Mainland stratigraphic sequence, consists predominantly of three stratigraphic intervals from bottom to top- a Lower Terrestrial Member, a thin Marine Member which pinches out towards the eastern part of the basin and an Upper Terrestrial Member. The Upper Terrestrial Member is a dominantly fluvial succession, which consists of the following characteristic architectural elements- Channel Element(CHE), Downstream Accretion Element(DAE), Lateral Accretion Element(LAE), Abandoned Channel Fill Element(ACE) and Overbank Fines including Levee Deposits(LV), Crevasse Splay Deposits(CS) and Floodplain Fines(FF). The channel elements can be further classified into several channel belts(characterized by concave-up base and flat top), depending on the hierarchy of the bounding surface. Overall the Upper Terrestrial Member can be sub-divided into five channel belts, stacked vertically from bottom to top. Each channel belt consists of several lenticular trough cross sets. A total of 463 trough cross-set thicknesses were measured from all the channel belts. Using these data, several paleo-hydrological parameters such as mean paleo-channel depth, mean paleo-channel width, mean annual discharge, paleoslope, bankfull channel discharge, drainage area, principal stream length, stream velocity, unit stream power etc. were calculated using established formulae. Graphs drawn to analyse the temporal variation of these paleo-hydrological parameters across the vertically stacked channel belts indicate gradual narrowing(decrease in bankfull width) and shallowing(decrease in bankfull depth) of the channels through time. The overall decrease in discharge rate, bankfull width and depth indicate that the entire fluvial system dried-up through time. This drying-up trend is also corroborated by the transition of fluvial channel deposits to a thick aeolian succession, especially at the topmost part of the third channel belt. The aeolian succession is marked by distinct dune and interdune fields. This drying-up trend could be due to the effect of either paleo-climatic variations or tectonism or an interplay of both.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Oral Preferred

Description of braided bar reservoir based on the integration of braided river sedimentary numerical simulation and spectral-decomposed and fused seismic attributes

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Keywords: Delft3d,Braided river deposits,Numerical simulation,Frequency division fusion,Reservoir description

The Guansan oil formation reservoir of Caofeidian C structure located in the east of Shaleitian uplift belongs to typical sandy braided river deposition. The reservoir changes rapidly and the structure is complex. Because there are few drilled wells in the study area, it is difficult to accurately describe the shape of braided bar and reservoir;

This paper creatively applies the combination of sedimentary numerical simulation and frequency division RGB fusion technology to the fine anatomy of braided bar reservoir. Firstly, based on the sediment hydrodynamics of the Dleft3D platform, this paper uses sedimentary numerical simulation technology to realize the dynamic numerical simulation of braided river sediments, sedimentary phenomena and evolution, clarify the evolution and transformation process of each micro phase of braided river, and summarize the development and evolution process of braided bar and the formation mechanism of braided bar from the mechanism, Furthermore, the quantitative parameters such as the scale and style of the braided bar in the study area are obtained; Then, the frequency division RGB fusion technology is used to identify the sedimentary microfacies of braided bar in the form of stratigraphic slices. Combined with the parameters such as sedimentary scale and style of numerical simulation, the reservoir of braided bar is finely characterized.

This method provides a new method and idea for the exploration and development of similar oilfields and fine reservoir evaluation.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Oral Preferred

Sequence stratigraphy and seismic geomorphology of Mid-Miocene fluvial systems in the northern shelf of South China Sea: Implication for climatic control

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Keywords: fluvial systems, sequence stratigraphy, seismic geomorphology, climate change

The development of fluvial systems, whether incised or unincised, has been proved to be regulated by the interaction of various forcing factors, including sea-level change, tectonics, and evolution of drainage basins. Recently, climatic control on fluvial systems has been a hotly-debated topic, while the coupling relationship between them hasn't been fully revealed.

Using vast 3D seismic data on the northern shelf of the South China Sea, this study identified multiple stages of widely-distributed fluvial systems within the Middle Miocene successions. According to core descriptions, well-log motifs, and seismic geomorphology, the fluvial systems can be categorized into braided or meandering types, which also correspond well with the subdivision of systems tracts. Furthermore, from cluster analysis of heavy minerals in a few wells, we found that there were two main trunk channels of the ancient Pearl River since 23Ma, which controlled the major depositional pattern of the entire Pearl River Delta.

Sequence stratigraphic analysis, combined with a systematic mapping of fluvial systems of various stages, indicated that their distributive pattern had changed significantly across a key sequence boundary, i.e., the SB17.1 with a geological age of ca. 17Ma. Beyond this surface, the fluvial systems displayed widespread pattern and very high efficiency of sediment delivery to the shelf margin. Previous studies have confirmed that climate change can significantly influence fluvial styles by controlling the fluvial discharge and vegetation cover beside. In this study, we attributed this dramatic change in fluvial systems to be mainly the upstream control, i.e., being climatically driven rather than sea-level change, which coincided with Mid Miocene Climate Optimum (MMCO: 17.2~15.5 Ma). The warm and humid weather during MMCO increased the fluvial discharge and the drainage areal extent might have significantly contributed to the dramatic increase in the distribution of fluvial systems across the northern shelf of the South China Sea.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Oral Preferred

Fluvial succession from the distal Lower Freshwater Molasse (LFM) in the Northern foreland basin of the Alps (Bern Area, Switzerland)

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Keywords: fluvial, meander, belt, molasse, foreland

The Swiss Molasse is formed by Tertiary sediments recording the evolution of the Northern Foreland Basin of the European Alps. The Lower Freshwater Molasse (LFM, Chattian to Aquitanian, ca. 30-20 Ma) is a thick group of alluvial to fluvial sediments. It contains conglomerates in the proximal zones near the Alps that evolve into a meandering fluvial system in the lowlands. Here, focus is put on deciphering the architecture and paleoflow directions of this fluvial meandering system in the region of Bern (Switzerland).

Field exposures are investigated from quarries and recent fluvial incisions in the upper part of the LFM (Early Miocene). They allow to depict the variety of sedimentary structures within coarse-sand fluvial channels, silt-dominated overbank levees, and weathered marl-dominated paleosoils. Drone-based photogrammetric reconstructions also enable to visualize the lateral and vertical stacking patterns of larger-scale fluvial channel belts. These surface outcrops depict sharp and unpredictable lateral changes in lithofacies associations, and the dominant lateral amalgamation of sandstone beds as meander belts. The apparent orientations of cross-bedding patterns are coherent within narrow zones (100's m), yet become contradictory at a larger scale. They thus seem to indicate local orientations of the meanders rather than any larger-scale trend.

A collection of >350 publicly available borehole logs, covering an area of ca. 20 x 20 km2, was analyzed in order to give insights into the 3D organization of the LFM. This reveals heterogeneous proportions of sandstone beds in the subsurface, including zones where sandstones are overrepresented on a lateral horizon, as well as narrow zones with a higher proportion of sandstone beds stacked vertically. Within the shallow subsurface, there seems to be a preferential W-E strip of sandstone beds throughout the investigated zone, although any interpretation is impeded by the interference of Quaternary glacial incisions. This trend would however align with the regional draining direction of the LFM. Furthermore, a shallow, laterally spreading cluster of coarse grained sandstone is identified in the uppermost part of the LFM within the city center of Bern. Vertically, two narrow areas with a very high proportion of sandstones over more than 150 m of thickness are identified, yet the data do not allow these clusters to be followed laterally or to be assigned any orientation. This suggests, however, that at least some fluvial channels are very stable over time and do not undergo lateral switching over extensive periods.

Scarce high quality boreholes down to >200 m depth did not allow to infer any vertical (time) evolution in the sedimentation dynamics. Instead, these boreholes depict relatively stable and regular heterogeneity with alternating sandstones, overbank levees, and paleosoils.

An attempt is currently underway to identify variations within the mineralogical and chemical signature of the paleosoils. This might yield a proxy for the degree of stability of channels, and/or a proxy for the proximal-distal situation at a given time.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Annual riverbed changes in the Lower Danube during the last decade: human impact versus morphodynamic feedbacks

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Keywords: river incision, bathymetry, bank erosion, sediment balance

Danube River is one of the largest fluvial systems in Europe in terms of length, drainage area, discharge and sediment load. Multiple anthropogenic pressures in the Danube River Basin have led to evident hydromorphological alterations, amongst which the most heavily disturbed component is the sediment regime. Like many temperate zone rivers, the sediment load of the Danube River has been substantially reduced due to the combined impact of flood protection, navigation and hydropower measures applied over a long period of time.

In this study, annual changes in riverbed morphology were analysed for a period of ten years (2010-2020) using various data recorded from single-beam bathymetry, river discharge and sediment load measurements. We investigated five reaches located downstream of the Iron Gates I and II Dams, displaying various representative landscapes for the Lower Danube sector such as wide sections with large or small islets, narrow sections or large meanders. The analyses revealed an accelerated riverbed incision compared to previous trends (i.e. 1985-2005 interval) which is discussed in relation to anthropogenic interventions such as dredging for ensuring optimal navigable conditions, floodplain embankment and hydropower generation.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Oral Preferred

Sedimentary characteristics of near provenance braided river delta in the upper 3rd Member of Shahejie Formation of KL A oilfield

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Keywords: Bohai Bay basin,Near provenance braided river delta,sedimentary characteristics,sequence stratigraphy

The upper 3rd Member of Eocene Shahejie Formation ($E_2S_3^U$) is the main oil bearing zone in KL-A oilfiled of Laizhou Bay sag ,Bohai Bay basin, East China. In order to revealing the $E_2S_3^U$ sedimentary characteristics and patterns in the study area, using seismic, core, grain size, casting thin section and logging data, the sedimentary facies types and distribution under the sequence framework in the $E_2S_3^U$ are summarized. The results show:(1) A typical near-source braided river delta sedimentary system in $E_2S_3^U$ of KL A oilfield was deposited which has the typical characteristics of progradational seismic reflectance signatures, incised channel and collapse deformation structures in core, as well as the low structural maturity and compositional maturity.(2)Based core and logging facies, three kinds of subfacies are recognized: braided river delta plain, braided river delta front and pro- braided river delta. Furthermore, it can divided into the following six sedimentary microfacies: braided channel, flooding plain, underwater distributary channel, underwater distributary interchannel, mouth bar and sheet sand.(3)Using sequence stratigraphy, divided $E_2S_3^U$ into a set of third-order sequence, the lowstand systems tract (LST) was deposited by thick sandstones of underwater distributary channel, and the transgressive systems tract (TST) and highstand systems tract (HST) were deposited by thin sandstones. (4) The sandstone thickness and distribution scale of different systems tracts are controlled by the elevation of the lake level and the rate of sediment supply rate. This rule provides an reference for the evaluation of sandstone reservoir in the gentle-slope zone of a faulted lacustrine basin.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
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Prediction of braided river delta front based on target processing and frequency division inversion

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Keywords: progradation,braided river delta front,multiples,generalized S-transform,sedimentary framework,frequency divisiong inversion

A oilfield in Bohai Bay belongs to river controlled braided river delta deposit, and the favorable reservoir is progradation in braided river delta front. The single stage progradars have the characteristics of thick thickness, high filling degree and limited distribution. The typical "small and fat" is the key direction of potential exploitation in oil fields. In order to describe the plane range of the precursor, the residual multiple wave suppression technology based on amplitude fitting and signal matching reconstruction is used to solve the problem of residual multiple waves in the near-channel. The extension technology based on generalized S transform is used to expand the low-frequency and high-frequency signals of earthquakes at the same time to obtain the real wide-frequency seismic signals. Based on the seismic data processed by the target, the single stage progradars are explained carefully under the constraints of geological model, and the fine vertical sedimentary framework and plane distribution form are established. Finally, the high resolution inversion density data body is obtained by using the frequency division nonlinear inversion and the formation frame of the single stage precursor is used to constrain the inversion density data body, and the accurate prediction and description of the plane distribution and thickness of the single stage precursor are realized. The prediction accuracy of reservoir is up to 90% by the new drilling development well, which effectively guides the implementation and rolling evaluation of the development well in the oilfield, and provides technical reference for other geological reservoir conditions, seismic data quality and similar buried depth.

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Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
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The Influences of Authigenic Minerals on the Quality of Nubian Sandstone Reservoirs

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Keywords: facies, Authigenic mineralogy, reservoirs quality

This paper presents the results of my sedimentological and petrographical study of Nubian Formation in north Gialo area in Sirte basin in Libya that used for identifying and recognizing the facies type and their changes through the studied interval. It also helped me to interpret the depositional processes and the depositional environments and describe the textural characteristics, detrital mineralogy, Authigenic mineralogy and porosity characteristics of the rocks within the cored interval, thus we can identify the principle controls on porosity and permeability within the reservoir sections for the studied interval.

To achieve this study, I described the cores of studied well and marked the all features that representing in color, grain size, lithology, and sedimentary structures and used them to identify the facies. Then, I chose a number of samples according to noticeable change in the facies through the interval for microscopic investigation.

The results of the microscopic investigation showed that the the authigenic clays and the authigenic cements have an important influence on the reservoir quality by converting intergranular macro pores to micro porosity and reducing permeability.

It is recommended to give these authigenic minerals more investigation in future studies since they have an essential influence on the potential of sandstones reservoirs.

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Research on the genesis of reservoir dissimilarity based on differences in petrology, physical properties, and diagenesis—A case study of Chang 82 reservoir in Jiyuan Oilfield, Ordos Basin

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Keywords: genetic differences of reservoirs, petrology, physical properties of reservoirs, diagenesis, diagenetic facies, Jiyuan Oilfield

There are significant differences between the eastern and western reservoirs of Yanchang Formation in Jiyuan Oilfield, Ordos Basin. Up to now, there is still a lack of specific analysis on the genetic differences of reservoirs. A large number of existing studies usually have not noticed the differences of reservoir characteristics between the east and the west caused by bidirectional provenance, resulting in the relatively poor guiding effect of reservoir research results on production and development. Therefore, based on the comparison of differences in petrology, physical properties and diagenesis, this paper studies the origin of the difference between the eastern and western reservoirs of Chang 8_2 in Jiyuan Oilfield through experimental means such as core properties, Graphic granularity analysis, Casting sheet image, SEM, cathodoluminescence and XRD. The differences of reservoir basic characteristics are carefully compared, and then the causes of reservoir dissimilarity are analyzed through diagenesis analysis, reservoir pore evolution, diagenetic facies division and reservoir formation mechanism discussion. The research results show that the clastic assemblage and rock structure characteristics reflect the difference in provenance supply between the east and the west. The content of interstitials in the west is slightly higher than that in the east, but the overall development of the reservoir space is better, and the surface porosity is also larger. The physical properties of the reservoirs in the west are much higher than those in the east. XRD shows that the content of clay minerals is significantly related to the physical properties. The reason for the deterioration of the physical properties in the east is that the pores are filled with kaolinite and chlorite. The western reservoir is poorly sorted and relatively more compacted, but the primary intergranular pores are well preserved under the action of chlorite film, and the eastern part has a higher degree of dissolution, but the ability to improve the reservoir is limited. And the middle and late cementation further led to a significant decrease in the porosity of the eastern reservoir. Because the number of residual intergranular pore facies on the chlorite lining far exceeds that in the east, the composition of diagenetic facies in the west is better than that in the east. Sedimentation is the basis for the development of higher-quality reservoirs in the west. Good mineral content composition and higher-quality diagenetic transformation are the reasons for the better quality of the reservoirs in the west and the east. This study is expected to provide a theoretical basis for deepening the subsequent exploration and development of Chang 8_2 reservoir in Jiyuan Oilfield.

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Oral Preferred

Study on seismic geomorphology of the second member of Jurassic Shaximiao Formation in Wubaochang area, Northeast Sichuan

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Keywords: Fluvial facies, Base level cycle, Stratal slicing, Seismic landform

Fluvial reservoir is an important reservoir type in continental basin. Due to its fast phase transition and strong heterogeneity, there are many problems to be solved on how to accurately characterize the distribution characteristics of fluvial sand body and study its reservoir distribution law. Taking the second member of Shaximiao Formation in Wubaochang area of Northeast Sichuan as an example, using the principle of base level cycle change, combined with drilling, logging curves and seismic reflection characteristics, this paper identifies that the study interval mainly develops one third-order and three fourth-order base level cycles; According to the characteristics of field outcrop, sedimentary structure and sedimentary sequence, the sedimentary facies of Sha2 member is studied. It is considered that braided river sedimentary system and meandering river sedimentary system are developed in the study area; Using seismic stratigraphic slicing technology, the distribution characteristics of sand bodies and facies belts in different periods in the longitudinal direction of Sha2 member are finely described, and the transformation law of "braid meander" in the fluvial facies strata of Sha2 member is revealed from bottom to top. Its specific characteristics are as follows: under the low accommodation space, the sand bodies are distributed in a large area to form mutually superimposed braided river channels; When the base level rises rapidly, the accommodation space increases and a relatively isolated meandering river channel is formed. The sedimentary characteristics and seismic geomorphic response changes of braided rivers and meandering rivers developed in the study area are the comprehensive response of base level cycle changes of accommodation space and sediment supply ratio (A / s) in the process of fluvial facies sedimentary evolution. A / S is mainly affected by tectonic movement and climate change factors.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Oral Preferred

Stratigraphic evolution and geophysical architecture of the Bambalo deposits during the Mesozoïc (Mayo Oulo-Lere Basin, North Cameroon).

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Keywords: Mayo Oulo-Lere, Bambalo Formation, sedimentary sequence, electrical resistivity tomography.

The Mayo-Oulo-Lere Basin is located in the northern Cameroon between the western extension of the Doba basin (Chad) and eastern edge of the Benue trough (Nigeria) in Africa. This study maps the depth and spatial development of Bambalo sedimentary sequences at the Mayo Oulo-Lere Basin. The depositional sequences present an exposure of crocodile fossils and plants evidenced by superficial alteration. The Bambalo Formation was described in terms of lithostratigraphy, vertical electrical sounding (VES) and electrical resistivity tomography (ERT) in order to bring out a better understanding of stratigraphic evolution and setting conditions during sedimentation. Sedimentary deposits in the Mayo Oulo-Lere basin are mainly fluvio-lacustrine deposits consisting of alternating claystone, siltstone and limestone. Lithostratigraphic log of Bambalo for the subsurface geology up to 25 m show three main depositional sequences (S1, S2 and S3). The sedimentary sequences are dominated by retrogradational depositional trends that describe short sequences of fining-upwards successions, as sediment supply fills the available accommodation space after each tectonic phase or/and rise of lake level.

The ERT image results obtained from geophysical analysis using Res2Dinv display local features associated with folding in the aforementioned sedimentary thickness. Additionally, the VES analyses using ipi2win software show that the upper 78 m part of the Bambalo formations is composed of four layers (L1, L2, L3 and L4) distinct by resistivity. L4 Layer correlated with the top of lithostratigraphic log S3, while L3 is a semi-resistive set of 78 ohm.m layering S1 and S2 lithostratigraphy sequences. Layer L2 corresponds to a conductive set with resistivity of approximately 27 ohm.m above the lower layer L1, a resistive sequence with resistivity greater than 1000 ohm.m.

The results of this study demonstrate that the combination of ERT and lithostratigraphic analysis is a powerful tool for a better understanding of the Bambalo sedimentary process and basin evolution. The lateral and vertical evolution of the layers being proven, a future deep excavation will certainly make it possible to bring to light new types of fossils from these deposits and in the neighbouring basins.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Depositional Environment of the Barren Measures Formation, Gondwana Supergroup, Damodar Valley Basins, Eastern India

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Keywords: Gondwana, Fluvial, Deltaic, Damodar Valley

The Gondwana succession in India records a long span of time from Carboniferous (~350 Ma) to end Cretaceous (~60 Ma). During this time span of about 300 million years the Indian peninsula recorded passage from high southern latitude to low norther latitude during which the entire Gondwana rocks were deposited. The Gondwanas characteristically include two major cycles of coal formation separated by a barren interval. The voyage of peninsular India across a wide latitudinal range witnessed major changes in climatic regime. Besides eustatic changes play an important role in the development of different depositional settings ranging from marginal marine to continental fluvial (Casshyap and Tewari, 1984, 1991; Veevers and Tewari 1995). In generalized stratigraphic classification, Indian Gondwana succession from the eastern Indian Damodar Valley Coalfields is classified into six formations, namely in ascending order, Talchir, Barakar, Barren Measures, Raniganj, Panchet and Suprapanchet Formations. The lowermost Talchir Formation record Permo-carboniferous glaciation event. Barakar and Ranigunj Formations are coal-bearing and represent predominantly fluvial depositional environment. Both these coal-bearing formations are sand-dominated and show multi-storey fining-upward cycles. In contrast, Barren Measures Formation is mud-dominated and includes mudstone and mudstone-sandstone heterolithics. The Barren Measures suggest deposition in a much quieter environment than the coal-bearing Barakar and Raniganj Formations. Overall facies sequence indicates deposition in a delta plain setting. The tectonics, as well as climatic factor, is likely to be important for such transformation.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Oral Preferred

Discrimination different sediment of rivers by using heavy and light minerals

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Keywords: heavy minerals, light minerals, fluvial sediments, Tigris River, Diyala River, Iraq

Quaternary sediments in the center of Iraq are weathered from igneous-metamorphic complex in the north and northeast of Iraq, northwest of Iran and southeast of Turkey. Different types of minerals and rock fragments from this complex are transporting by rivers in these areas downstream.

Twenty-one of sediment samples were taken from Tigris and Diyala rivers in Tikrit, Diyala, Baghdad, and Wassit governorates along the of Tigris and Diyala river sediments in the center of Iraq. The main focus in these samples was the change in mineralogical composition across two rivers in the studied area, and their valuables. Thus, this study focuses on identification the light and heavy mineral assemblages and their spatial distributions, maturity, provenance in the collected samples.

Examination of the heavy mineral content shows that most samples are dominated by opaque minerals (33.97% – 69.66%). In addition to this group, various percentages of heavy minerals such as amphiboles, pyroxenes, mica and garnet, with a few amounts of zircon, tourmaline and rutile were presented in the studied samples.

The light minerals composed of quartz, feldspar, and rock fragments which derived from sedimentary, igneous, and metamorphic rock fragments.

The large amount of unstable heavy minerals compared to ultrastable minerals was referred to immature sediments, arid- semiarid climate, and mechanical weathering in the source area. These immature sediments found to be contain quartz and feldspar together, comparing with mature sediments, that were recognized in south of the study area, were involved only quartz.

The studied samples showed a noticeable amount of amphibole, pyroxenes and micas along the Tigris River at the studied sites, may indicate a continuous transport in spite of being unstable minerals. Furthermore, the results from heavy minerals demonstrated that no evidence of reduction in these minerals diversity downstream.

Studying heavy minerals also can suggest that Diyala River sediments was weathered from igneous- rocks from Iran with minor input from metamorphic rocks, whereas, Tigris River sediments probable came from metamorphic rocks with igneous contributed. Therefore, this study demonstrates that using light minerals in addition to heavy is great benefit in provenance studies

Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

The influence of global warming on channel planform morphology and sediment reworking of the Earth's highest meandering belts

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Keywords: Climate change, Global warming, Yarlung Tsangpo River, Meander, River morphology

Meander planform morphodynamics plays a vital role in rendering planetary surfaces(Seybold Hansjoerg et al.; Willett et al., 2014; Ielpi & Lapôtre, 2019) and regulating climate and carbon cycle (Repasch et al., 2021; Ielpi et al., 2022). The upstream of Yarlung Tsangpo River flowing over the Himalayan highlands develops the Earth's highest meandering belts. Rapid planform changes in the meandering channels within the pristine systems are largely free from human interference. Yet we know little about how the pronounced climate changes in Himalayan regions have impacted the meandering morphology and morphodynamics. Here we show that meander migration and sediment reworking have been accelerated over the past 40 years. Our results are based on the 5200 planform changes of meander bends since the 1980s, integrating geo-referenced high–resolution remote sensing imagery with GIS analysis. Faster migration of frozen outer riverbanks was comparable to the increases in temperature, glacier, and permafrost degradation. Further analysis of controlling factors reveals a consistently positive response between changes in climate and channel planforms. We find that the nearly two-fold increase in meandering channel mobility and sediment reworking was not controlled by autogenic processes or externally imposed noise like active faults. Results indicate that global warming may exert a first control on the upland river morphodynamics and accelerate the fluvial biogeochemical cycle, which further may increase the downstream risk involved with riverbank retreat and planform changes. Our finds improve the understanding of the evolution of upland meandering channels in a warming world and reveal the impacts on sediment reworking of glacier retreat and permafrost thaw.

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Scientific Themes: Theme 5. Continental Siliciclastic Depositional Systems
Session T5-4: Fluvial Sedimentology: Waiting for a New Revolution
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Study on Gas - Water Distribution of Shan 1 - He 8 Member in Su 59 Well Area

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Keywords: Su 59,hydrocarbon generation conditions,sand body,reservoir,air-water distribution

The problem of gas-water co-production has always been the key to limit the stable production and production in the western region of Sulige. Su 59 block is in the area of weak hydrocarbon generation intensity in Sulige area on the plane. The lack of hydrocarbon generation power and the low degree of natural gas filling have led to the widespread water cut of the Shihezi-Shanxi Formation gas reservoir in Su 59 block. Based on core and logging data, this paper mainly analyzes the main control factors of natural gas enrichment in He 8 and Shan 1, the main gas producing horizons. The results show that the regional hydrocarbon generation conditions determine that the gas content of Shan 1 reservoir is relatively high, while the water content of He 8 reservoir far from Shan 2 and Taiyuan Formation source rocks is generally high despite the superposition and development. The gas-water distribution in Block Su59 is affected by the local high point of the structure, sand body distribution, reservoir physical properties and other factors. The gas source in the lower part moves upward, which will be preferentially filled into the channel sand body with high porosity and permeability, and then the gas-water difference will be generated under the control of local structure, namely, the ‘ three-determined ’ gas-water distribution mode of ‘ determining the trend of source rock + determining the pattern of high permeability sand body + determining the gas-water difference in single sand body ’ by micro-structure.

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Theme6

Marine Siliciclastic Depositional Systems

Session T6-2: Sediment gravity flow deposits in marine systems

ID: T6-20098

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-2: Sediment gravity flow deposits in marine systems
Presentation Preference: Oral Preferred

Combining stratigraphic forward modeling and susceptibility mapping to investigate the origin and evolution of submarine canyons

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Keywords: Stratigraphic forward modeling, Susceptibility mapping, Canyon evolution, Upslope model

The debate on the submarine canyon origin between the upslope erosion model dominated by retrogressive mass failures and the downslope erosion model controlled by gravity flows has not been fully settled. However, this debate is critical for explaining submarine canyon evolution. This study combines susceptibility mapping and stratigraphic forward modeling (SFM) to examine the origin and evolution of submarine canyons under various fluvial discharge and morphologies. The SFM work consists of dozens of hypothetical numerical experiments based on typical passive margin bathymetry with half bathymetry occupied by an incipient canyon and associated river mouth topography, and another half bathymetry by steep slopes without canyons. Evolution characteristics in both plan and cross-section views are analyzed, and the impacts of fluvial and morphological features on canyon evolution are tested.

The results indicate that submarine canyons can be divided into four types according to their morphological features, locations, and origins: blind canyons, shelf-incising canyons, step-trigger gullies, and the incipient canyon and its dendritic tributaries. Submarine canyons retreat landward, tributaries develop on the canyon outer banks, and blind canyons grow landward to capture small gullies and form shelf-incising canyons. There are three types of canyon networks: linear canyons with regular spacing, straight main-stem canyons with dendritic tributaries, and sinuous main-stem canyons with tributaries on the canyon outer banks.The upslope pattern is dominant regardless of changes in fluvial discharge and morphologies. The locations of tiny gullies on steep slopes determine the distribution and growth direction of submarine canyons, whereas fluvial conditions and morphology parameters affect the canyon dimensions. High fluvial discharge and high canyon sidewall slope angle promote tributary development and canyon erosion. High canyon sinuosity leads to an asymmetrical distribution of tributaries on canyon outer banks whereas high regional slope angle increases the canyon length and decreases the canyon spacing. There are three critical questions for analyzing canyon evolution: whether canyons are affected by long-term erosive flows, the relative importance of gravity flows and mass movement, and differentiation between main-stem canyons and tributaries. The distance component parallel to the shelf break between rivers and canyon mouths may be more important than the distance component perpendicular to the shelf break.

This study settles the debate between the upslope and downslope erosion models. In addition, it refines the upslope model by highlighting the importance of small-scale gullies and testing the influence of fluvial and morphological conditions on canyon evolution. The conclusions could promote the understanding of submarine canyons and assist in reservoir exploration and hazards prevention.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-2: Sediment gravity flow deposits in marine systems
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Stratigraphic Cycles in Turbidite Sand Sheet Systems----Implications for Progradation/Retrogradation Cycles

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Keywords: sand sheet systems, stratigraphic cycles, turbidite, progradation, retrogradation

Attempts have been made in the past to link stratigraphic cycles in turbidite sequences to progradation (i.e. thickening and coarsening upward) and retrogradation (thinning and fining upward). However, if the sedimentary system is laterally unconfined or shows much compensational stacking, the relationship between stratigraphic cycles and such vertical sequences may be more complex or stochastic. Meanwhile, progradation and retrogradation imply a basinward or landward shift in deposition respectively, but few 2D outcrop sections along depositional dip have been studied sufficiently to establish the longitudinal variations in stratigraphic cycles. In this study, two Cretaceous turbidite sand sheet systems, referred to as Pehoe Member B and Paine Member A (abbreviated here to Pehoe B and Paine A) are compared, to investigate the longitudinal stratigraphic variation and possible implications.

With a logging scale of 1:10, statistical methods such as runs tests, moving average, and correspondence tests are used to detect stratigraphic cycles. Combined with facies and thickness analysis, Pehoe B and Paine A sand sheet systems are both interpreted to be laterally confined with dominantly vertical stacking overall. Along depositional dip, stratigraphic cycles of thickening and coarsening upward then thinning and fining upward, where present, are asymmetrical in proximal areas but appear to be more symmetrical in distal areas. The longitudinal variation of stratigraphic cycles is generally consistent with that of maximum thickness of amalgamated beds and total counts or counts/meter of all bypass features. Turbidite vertical sequences of both Pehoe B and Paine A reflect a general progradation then retrogradation process, with superimposed small scale fluctuations, which may infer allogenic variations in sediment supply (3rd to 4th order sequences).

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-2: Sediment gravity flow deposits in marine systems
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Upper Pliocene deep-water sedimentary system in a block of Rakhine Basin, Bay of Bengal

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Keywords: reservoir, sequence, sedimentary, deep-water, Rakhine Basin

In recent years, gas discoveries have been made in the deep water area of the Rakhine Basin in the northeastern part of the Bay of Bengal Basin. The Pliocene deep-water sediments in this area frequently migrate and overlap, and the unconformity is particularly developed. Reasonable sequence stratigraphic analysis methods can guide the identification of favorable target formations and the interpretation of deep-water sediments. Using logging and seismic data, and the sequence stratigraphic framework was established under the guidance of a reasonable deep-water sedimentary sequence model. The sequence boundary was interpreted in the whole area, by identifying the top boundary of the condensation section and the bottom boundary of mass transport depositions. It is clear that the Upper Pliocene, the main target layer in this study area, is controlled by dual provenances in the north and northeast. The sediments from the north are distributed in a small range, which is distributed in a near-north-south direction, and mainly develops small channel-lobe complexes. The sediments from the wider distribution range and greater thickness of the sediments in the northeast, which are distributed in the northeast-southwest, and are mainly composed of large-scale channel complexes. Drilling revealed that the sediments of the northern provenance are finer in grain size, and the sediments of the eastern provenance are coarser. The eastern part of the study area has more developed reservoirs. Affected by the development of sedimentary inheritance, late sedimentation is more likely to erode the early thin hemipelagic mudstone caprock, which makes the overall preservation conditions in the eastern part relatively poor and the trap effectiveness decreases. Although the northern reservoir is small in scale, under certain structural background conditions, it is easier to form small lithologic hydrocarbon reservoir with sand lens.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-2: Sediment gravity flow deposits in marine systems
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

IDENTIFICATION AND CONTROLLING FACTOR OF CHANNELS IN HUANGLIU FORMATION OF THE LEDONG SAG IN THE QIONGDONGNAN BASIN

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Keywords: the Qiongdongn basin,Huangliu Formation,channel,sedimentary model,controlling factor

The Ledong Sag is located in the western part of the Qiongdongnan Basin in the northern South China Sea. It is connected to the Lingshui Sag, the Lingnan Lower Uplift in the south, the Yinggehai Basin in the west by the F1 fault, and the Yanan Lower Uplift in the north. In recent years, the Miocene lithological traps in the Ledong Sag have become hotspots for exploration in the South China Sea. Many medium and large-scale gas fields have been discovered. The discovered gas fields are all closely related to submarine fans and gravity flow channels. For more oil and gas discoveries to increase the success rate of lithological trap exploration, it is necessary to strengthen the identification of channels and the study of control factor.

On the basis of 3D seismic data, drilled cores, wall cores, logging, FMI logging and analytical tests, the seismic facies, litho-electric facies and sedimentation of the channels are analyzed. The structure and sedimentary characteristics and their controlling factors have been comprehensively studied. The results achieved are as follows: 1)On the basis of the sequence stratigraphic framework, techniques such as heavy minerals, petrology, seismic stratigraphic interpretation, and paleo-geomorphic restoration are used to clarify the provenance and controlling factor of sediments in the channel. 2) The Huangliu Formation in the Ledong Sag developes two phases of channel, which mainly developes five types of sedimentary microfacies: main channels, overflow-natural dike, landslide mud, inter-channel and continental slope mud. 3) The formation and evolution of the two-phase channels and the direction of the main provenance are mainly controlled by sea level changes, paleomorphology and tectonic activities.4) The early channels in the Huangliu Formation are mainly developed in the Yingqiong junction, which are characterized by a large number, small scale, strong branching, and braided features. The late channels are restricted to the central canyon in the Ledong Sag, which are a characteristic of single-branch axial restricted channel and multi-stage development in the longitudinal direction.5)The physical properties of late channels are mainly medium porosity and high permeability, which are mainly distributed in deep water areas, and the reservoirs are buried in shallow depths. It is the key exploration direction in the channel field of the Huangliu Formation. The main channel is the most favorable sedimentary unit of the channel.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-2: Sediment gravity flow deposits in marine systems
Presentation Preference: Oral Preferred

Hybrid event bed characteristics, distribution, and its role in high-frequency change of the Upper Triassic submarine fan succession in the West Qinling Orogen Belt, Northeastern Margin of Tibet Plateau

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Keywords: Submarine fan, Bed type, Hybrid even bed, Mudclast, Allogenic, Autogenic

Hybrid event beds (HEBs) record the disequilibrium of the submarine fan evolution via the mud-forced dampening turbulence, which could be caused by allogenic and autogenic forcings in either proximal or distal segment of the lobe-dominant submarine fan within several timescales. Detailed field investigation (over 550 m in total) together with petrographic and mineralogical analysis of selected outcrop sandstone and mudstone samples show that the Upper Triassic submarine fan succession (mostly the Nalu Formation) is composed mainly of turbidites, HEBs, and mass-transport deposits (MTDs) in the West Qinling Orogen Belt, Northeastern Margin of Tibet Plateau. Five types of HEBs (i.e., HEB-1 to HEB-5) ranging from 0.094 m to 3.40 m are recognized based on their thicknesses, sedimentary structures, and textures. Bed by bed description and measurement (1142 beds in total) show that these HEBs are mainly distributed within various facies associations of the lobe-dominant submarine fan succession, including the dominance of HEB-1 and HEB-2 beds (~71.50%) within distributary channel to lobe off-axis settings (FA1~FA3) and the significant ratio of HEB-3 to HEB-5 beds (~54.22%) within the lobe fringe to lobe distal fringe settings (FA4~FA5). Different petrographic and shapes of mudclasts from their microscopic perspectives, particularly MC-1~MC-3 type, suggest erosional bulking and disaggregation of heterolithic, homogenous mudclasts within H1b and H3 interval of HEBs, which could play different roles in the longitudinal mud-driven flow transformation between turbulent and laminar flow behaviors. By contrast, the MC-4 type of mudclast mainly comprising non-cohesive carbonaceous materials and platy detriatal minerals has less contribution to the flow stratification. The vertical distributions of the HEB-prone succession are characterized by four types of depositional scenarios in the studied localities, which has yielded significant allogenic and autogenic information combined with the recognition of the dominant HEB types and the thickening- or thinning-upward trend of vertically stacked submarine lobes according to the process-based sedimentological interpretation. The study has enhanced our understandings of the HEBs distribution of the submarine fan succession in the east margin of Palaeo-Tethys Ocean based on most undiscovered deep-water outcrops, particularly in the Upper Triassic Nalu Formation, and it also shows that the development of HEBs contribute to the initiation, gradual switching, and avulsion of the high-frequency submarine fan evolution due to the alternation between disequilibrium and equilibrium.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-2: Sediment gravity flow deposits in marine systems
Presentation Preference: Oral Preferred

A turbidite sedimentation is discontinuous due to autogenic flow fluctuations associated with interface instability

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Keywords: Turbidite, deepwater, Kelvin-Helmholtz waves, flow fluctuation, CFD simulation

Turbidite systems are responsible for transporting a significant amount of sediments into deepwater basins and preserving important environmental and sedimentological signals from the shallow water areas. The deposition of turbidite is generally thought to occur during the waning stage of a turbidity current as the flow energy gradually decreases and sediment accretion increases. With a high-resolution CFD (computational fluid dynamics) method and grain-size data from the field, we simulated a natural scale turbidity current releasing from a relatively steep slope to a flat basin. Our results show that the flow accelerated along the steep slope with little deposition but quickly shifted to depositional mode once it arrived at the flat plain. As the flow adjusted itself along the slope, the turbidity current developed Kelvin-Helmholtz (KH) waves between its upper flow boundary and the ambient fluid, with a wavelength of 15 m to 50 m and amplitude of 5–10 m. The KH waves had a direct impact on the sediment concentration and flow velocity profile, effectively causing the flow to fluctuate between supercritical and subcritical status. Consequently, the sedimentary processes within the flow also alternated among deposition, bypassing and erosion. During the simulation, the flow only used 26 % to 33 % of its total running time on depositing sediments and had a similar amount of time for erosion. In the remaining time, the flow was mostly bypassing the observational area. Contrasting to the traditional view that a turbidite is the result of a continuous depositional process forming characteristic Bouma sequences, our study suggests that the flow power and associated sediment transportation in a turbidity current are inherently fluctuating and alternating due to the autogenic KH instability. Our study has important implications for understanding the depositional processes of turbidite sedimentations and interpreting various information contained within such deepwater deposits.

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Session T6-2: Sediment gravity flow deposits in marine systems
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Sedimentary characteristics and genetic significance of Late Triassic deep-water fine-grained gravity flow in Dayugou area, West Qinling

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Keywords: Density current,Fine turbidity current,Sedimentary characteristics, Genetic mechanism

Deep water fine-grained gravity flow deposition has important paleoenvironment and paleoclimate indicators, but the deposition process is more complex than coarse-grained sediment gravity flow. The detailed outcrop anatomy shows that the Upper Triassic Kache Formation in the Dayugou area of the West Qinling was deposited by slope fan and and hemipelagic deposition, and the fine-grained sediment gravity flow deposits (fine-grained hyperpycanal flow, hypopycnal flow and fine-grained turbidite) are widely developed. Among them, the fine-grained densified current deposits are mainly siltstone and argillaceous siltstone with suspended load (individual stage sediment thickness is 0.05-0.60 m). The normal flowing water ripple and transitional argillaceous ripple appear alternately vertically, showing overlapping characteristics of multi stage positive rhythm and composite rhythm. The lithologic combination of the hypopycnal flow deposits is characterized by thin interbedings of centimeter-scale sand and mud, which can be roughly divided into two types (Mutti, 2019). The sediment of hypopycnal flow I develop incomplete sand current ripples and the sedimentof hypopycnal flow II contain deformation and development of soft sediments. Fine-grained turbidites are also developed in the stratigraphy (thickness of individual stage is 0.05-0.2 m), which is characterized by Ta-Tb or Ta-Tc of Bauma sequence as a whole. Bi-directional cross bedding (lenticular bedding and herringbone cross-Bedding) developed in the target strata in the study area, indicating that the fine-grained turbidite may be affected by internal waves and tides. The paleocurrent analysis shows that the study area may be transformed by the underflow perpendicular to the continental slope at the same time, which further complicates the deep-water sedimentary process. Around Carnian period of Late Triassic, multi-stage heavy rainfall provided favorable climatic conditions for the formation of hyperpycanal flow in Qinling residual ocean basin. However, the extensive development of fine-grained sediment gravity flow deposition shows that the supply capacity of river sediments in its source area is relatively low, which provides an opportunity for deep-water underflow reconstruction in the eastern margin of the paleoTethys ocean in the Late Triassic.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-2: Sediment gravity flow deposits in marine systems
Presentation Preference: Oral Preferred

Identification and Geological Significance of Shallow Sea Gravity Flow Sedimentary Microfacies of Dongfang A Area in Yinggehai Basin, Northwest South China Sea

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Keywords: shallow sea gravity flow, sedimentary microfacies, lithofacies, logging facies, seismic facies, depositional model

In recent years, more and more submarine fan reservoirs have been discovered, and the research scope of submarine fan is increasingly broad, but there is no unified conclusion on the division of sedimentary microfacies of submarine fan in the academic circle. In 2011, Cummings et al. studied the Bacchus Basin in northern Spain and divided the sedimentary microfacies into main channel, branch channel, composite lobes and composite lobes edge. In 2012, Li Shengli et al. studied the Zhujiang Formation in Liwan 3-1 area, Baiyun Sag, and divided a complete deep-water fan into four subfacies, mainly composed of gravity flow channel, natural dike and slump body deposits. In 2016, Picot et al. studied the Congo fan in late Quaternary and made it clear that large submarine fan was mainly composed of multiple sub-submarine fan lobes and main channels. The characteristics of sedimentary reservoirs of Dongfang A area in Yinggehai Basin, northwest South China Sea have undergone multiple rounds of studies, including exploration, evaluation, and reserves. Currently, the reservoirs within the gas field are believed to be of shallow sea gravity flow deposits origin. There is still a lot of controversy in the understanding of the composition and characteristics of the sedimentary microfacies, which greatly restricts the research accuracy of the sand body distribution law and the heterogeneity within the reservoir, and affects the process of gas field exploration and development.

Through in-depth and systematic analysis of the comprehensive characteristics of lithofacies, logging facies and seismic facies of Dongfang A area, a division scheme of the sedimentary microfacies of shallow sea gravity flow deposits suitable for area A is established upon the known classifications of submarine fan depositional systems both domestic and abroad in addition to the geological background of the target area.Various sedimentary microfacies such as erosion channel, channel side edge, distributary channel and lobes are identified. Based on the above researches, the author proposed an identification plate for sedimentary microfacies of shallow sea gravity flow deposits. The sedimentary microfacies were finely characterized and the plane distribution of sedimentary microfacies was recognized under the control of shallow sea gravity flow deposits model. The second gas formation is controlled by the erosion - filling- overflow sedimentary model of the restricted gravity flow in pre formed depression, and mainly develops sedimentary microfacies such as erosion channel, erosion channel side edge, distributary channel and lobes. The first gas formation is controlled by the unrestricted overflow sedimentary model in gentle slope, and develops sedimentary microfacies such as distributary channel and channelized lobes. This identification method can be widely used in reservoir evaluation, prediction and fine characterization of the similar oil and gas fields to guide the exploration and development.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-2: Sediment gravity flow deposits in marine systems
Presentation Preference: Oral Preferred

Density-current deposits of the southern Mariana Trench: their role in geochemical variations of subducted sediments

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Keywords: Density-current deposits, Sedimentary sorting processes, Geochemical variations, Southern Mariana Trench

Sediments in the Mariana Trench provide an excellent opportunity to characterize sedimentary processes and their role in determining geographic and stratigraphic variations in the geochemical composition of subducted sediments. Sediments analysed for this study are from the southern slope of the Challenger Deep in the southern Mariana Trench, and were retrieved using box samplers during the 2016TS01 Expedition aboard R/V Tan Suo Yi Hao, led by the Institute of Deep-Sea Science and Engineering, Chinese Academy of Sciences. The box cores were subsampled using a push core with a diameter of 10 cm and a length of 70 cm. Each core consists of ~60 cm of sediment from below the sediment-water interface. Analytical results show that sediments in the cores mainly comprise diatom fragments (e.g., Ethmodiscus rex), clay and silt-grade minerals (e.g., plagioclase, serpentine and volcanic glass). According to grain-size variation, particle composition and sedimentary structures, a number of depositional units can be identified in the cores. Each of the depositional units consist of a lower interval that is coarser-grained and bioclast-rich, and an upper interval that is finer-grained and relatively clay-rich. Within a depositional unit, alternation of structureless and laminated intervals, and subtle grain-size and compositional changes are best interpreted to reflect pulsed variations in current flow velocity and sediment flux, rather than being the products of separate flow events. The combination of overall mud-rich grain size, a lower laminated division with nested graded intervals, and an upper graded, but otherwise structureless division, within each depositional unit resembles the structure of mud densite. Consequently, the depositional units are interpreted to be the products of mud sediment density flows. They are not deep-sea oozes deposited from pelagic settling, which are not characterized by either current-formed laminations or grain-size sorting. The depositional units, which were defined from variations from mineral composition and grain-size, help explain geochemical data. For example. bioclast-rich samples in laminated intervals are typically marked by higher SiO_2 but lower Al_2O_3, MgO, TiO_2 and ΣREE contents compared to those of clay-rich sediments in graded intervals. Particularly, ΣREE contents systematically increase upwards within depositional units, which is clearly caused by sedimentary sorting during density-current deposition that readily disperses finer, clay-rich components to deep water depths in the trench. Overall, along a trench, therefore, what is subducted depends on the proportion of resedimented versus pelagic sediments. A sedimentary pile dominated by clays would have a different geochemical signature to those dominated by diatoms and radiolarians, with the clay component being either arc-derived or of pelagic origin with secondary growth of Fe-Mn minerals. We suggest that sorting process, and thereby a geographic and stratigraphic variation in sedimentary components during transporting to the trench, can further complicate the geochemical composition of subducted sediments, as well as of arc magmas related to sediment-derived components.

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Session T6-2: Sediment gravity flow deposits in marine systems
Presentation Preference: Oral Preferred

A numeric study of turbidity currents bedforms associated with a normal fault topography

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Keywords: turbidity current, numerical modeling, bedforms, deep-water, cyclic step

Seafloor topography is known to have a major influence on deep-water gravity flows by affecting their flow behavior and depositional style. Previous investigations suggest that normal faults can control the hydraulic status of a turbidity current and form characteristic bedforms. However, how a normal fault triggers the flow transition and how such a transition controls the bedforms formation remain poorly quantified. In this study, advanced computational fluids dynamics numerical simulations are used to investigate the behavior of turbidity currents when flowing across the escarpment generated by a normal fault. We systematically assess how variations of fault dip angles, fault displacements, and initial flow velocities control the hydraulics of turbidity currents and associated depositional processes. Results show that the normal fault topography exerts a fundamental control on the flow hydraulic behavior by accelerating the flow. The influences of the initial flow velocity and sediment concentration on a turbidity current are generally secondary but also affect the bedform formation by changing the erosion and depositional styles. Such a complex control mechanism may explain the synchronous existence of antidunes and cyclic steps observed in deep-water fans. This research bears important implications in predicting turbidity current hydraulics and resulting deposits in tectonically active basins where the normal faults reach the seafloor.

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Session T6-2: Sediment gravity flow deposits in marine systems
Presentation Preference: Oral Preferred

Response of unconfined turbidity current to segmented folds

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Keywords: turbidity current, numerical modeling, deep-water, fold and thrust belt

Deep-water fold and thrust belts are generally composed of networks of folds that have a major influence on the pathways and deposition of turbidite systems. However, the detailed hydraulic responses and associated depositional patterns of a turbidity current within such fold networks, particularly segmented fold topography have not been well understood. This study combines structural modelling of fault-related folds and computational fluid dynamic simulations of turbidity currents, to reveal the hydraulic and sedimentological behaviours of an unconfined turbidity current interacting with two en echelon fold segments. A natural scale turbidity current is released upslope of a variety of two-segment-fold scenarios, in which the strike of the structures is orthogonal to the dip direction of the slope and the front of the flow. The results show that the lateral growth and linkage of individual fold segments, as well as the separation and overlap distance of fold segments strongly influence the style of turbidite sedimentation. For two unlinked folds, the turbidity current flows across the overlapping area of the folds while also diverting sideways along the upslope fold limbs. In contrast, where the two-fold segments are structurally linked to form an elevated overlapping zone, the main body of the turbidity current is diverted around the folds to spread downslope. The separation distance between the two folds has a critical influence on the amount of flow diverted sideways. The overlapping distance of the fold segments determines the relative thickness of sediment accumulated in the front of the downslope fold limbs. The results of the study have implications for turbiditic slope-fan models and the prediction of sand distribution in deep-water fold and thrust belts.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-2: Sediment gravity flow deposits in marine systems
Presentation Preference: Oral Preferred

A new insight into the genetic mechanism of the Miocene sediment mounds in the Qiongdongnan Basin, northern South China Sea

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Keywords: Qiongdongnan basin, Meishan Formation, Mounds, Gravitational gliding, Detachment faults, Genetic mechanism

The mounded stratigraphy at the top of the Miocene Meishan Formation (Fm.) in the southern slope zone of Qiongdongnan Basin attracted extensive attention. The mounds were interpreted to result from various controversial geneses such as reefs, contourite mounds, sediment waves, and incised canyons. In this study, the newly collected seismic data were used to characterize the mounds, and a relatively reasonable genetic mechanism was proposed. The seismic profiles revealed that the mounds alternated with “V”-shaped troughs, forming a mounded topography at the top of the Meishan Fm., which showed regular sinusoidal fluctuations in the cross-sections. The lateral distribution of the mounds and troughs is characterized by the alternating distribution of E-W trending narrow ridges and gullies. The current mainstream interpretations of the origin of the mounds in this area can be divided into two categories: reefs and channel erosion. However, the latest drilling revealed that the mounds were mainly composed of bathyal mudstones instead of reefs. On the other hand, it is doubtful whether the seafloor could be sculptured by erosion to form a mounded topography that showed regular sinusoidal fluctuations. Many previous studies show that the formation of topographic relief in deep water probably originated from one kind of soft-sediment deformation caused by slope instability, which provides enlightenment for this study. The analysis of tectonic evolution showed that the southern slope became steeper abruptly resulting from accelerated subsidence since the late period of the Meishan Fm. deposition (10.5Ma). Meanwhile, frequent earthquakes induced by the re-activated faulting and intense magmatism caused strong vibration. These factors were highly likely to cause slope instability and gravitational gliding. In this case, the unconsolidated plastic layer near the sea-bed slipped along a detachment surface the detachment surface presents as a strong reflecting surface on seismic sections, which drove the formation of a series of small N-dipping listric detachment faults above the detachment surface. The plastic layer was cut into multiple tilted fault blocks. Since then, the troughs between fault blocks controlled the distribution of the submarine channels and were finally filled by sandstones and bathyal mudstones. The erosion capacity of the submarine channels was limited, otherwise, most of the mounds in the whole area would be likely to be destroyed beyond recognition. The fault blocks and the infillings in troughs were eventually compacted to form a typical phenomenon of regular topographic relief. The genetic model of the mounds proposed here is novel and can provide a reference for the interpretation of similar phenomena in other regions.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-2: Sediment gravity flow deposits in marine systems
Presentation Preference: Oral Preferred

Sedimentation across structurally complex deep-water slopes: Neogene to Recent stratigraphic evolution of the Hikurangi subduction margin, New Zealand

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Keywords: Deep-water, slope, seismic, subduction, turbidite

Deep-water sedimentation on active margins involves complex sediment pathways through interaction with structures. Descriptions of sediment distribution in such settings are often and necessarily simplified into models, such as‘fill and spill’or‘tortuous corridors’. Understanding the distribution of sediment across slopes has implications for resource exploration, understanding geohazard likelihood, and predicting the potential fate of pollutants in the deep-sea. Here we document Neogene to recent sedimentation patterns of the Hikurangi subduction margin, offshore eastern New Zealand to characterise depositional systems across a deep-water fold-and-thrust belt.

A series of thrust-bound structures bound intra-slope basins, each tens of kilometres long by kilometres wide, have been diachronously forming, filling, and deforming over the past 25 Ma. In the offshore, actively building portion of the subduction wedge bathymetric, 2D and 3D seismic, and well data analysis constrain large scale sedimentation patterns. 15,344 km^2 of 3D seismic across this margin allow structural and reflector sequence interpretation, with mapping of sedimentary systems describing the evolving sediment-structure interaction. Deep-marine sediments include (hemi-) pelagites, turbidites, mass-transport deposits (MTDs) and contourites. Five sedimentary systems delivered sediment across nine slope basins, with channels variably running axially and transverse to the slope along their profile. The run-out lengths of the channels vary spatially and temporally. Coarse grained sediment was captured across a range of slope accommodation zones, whose fill varies along strike of individual depocentres. At times sediment was trapped in upper-slope basins, but at other times was ducted to base-of-slope basins or even bypassed the slope entirely. Cannibalisation of previously filled basins via mass wasting is common. Variably-active sediment inputs, bypass conditions and structure development resulted in the development of complex depositional systems, often with similar styles of sedimentation occurring contemporaneously in proximal and distal basins, contrary to simple fill and spill models.

Fundamentally, sediment supply and distribution is governed by external controls, e.g., tectonic evolution of the margin, sediment flux, and climate. However, at basin scale local forcing such as growth of bounding structures, emplacement of MTDs, or breach of structures by sediment conduits dictates sedimentary system style. At the smallest scale, autogenic regulation of the sedimentary system, e.g., flow stripping at sills and channel avulsions contribute to the spatiotemporal variation in sediment distribution. Constraining the interaction of this hierarchy of controls helps determine if basins were filling, spilling or a combination of these end members at any point in their evolution.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-2: Sediment gravity flow deposits in marine systems
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Characteristics of deep-water gravity-flow deposits under the background of salt tectonic activities: A case study of the Miocene in block A, Lower Congo-Congo Fan Basin

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Keywords: salt structures, gravity flow deposition, interactions, Miocene, Lower Congo-Congo Fan basin

The Lower Congo-Congo Fan Basin is a typical saline passive continental margin basin located on the east coast of the South Atlantic Ocean. Its complex salt tectonic activities have an important impact on the spatial distribution of the slope channel-lobe system, which controls the hydrocarbon accumulations. Understanding the relationship between salt structures and deep-water gravity-flow deposition is the key to making breakthroughs in deep-water petroleum exploration in the study area, and has important research significance. Based on the seismic - logging curves interpretation and seismic attribute analysis, the process and characteristics of gravity-flow deposition under the background of salt tectonic activity of the Miocene in block A of the Lower Congo-Congo fan basin are revealed. The results show that the deposition center and sand-rich position during the early filling-overflow stage and the late passing-erosion stage in the minibasins are different. The angle between gravity flow direction and axial direction of minibasin is inversely proportional to the size of lobe in the minibasin. The interaction relationships between salt structures and channels include seven types: redirection, restriction, blocking, migration, erosion, uplift and truncation. When the salt tectonics activity is weak and the capacity of provenance supply is strong, the sediments tend to be transported to a distant place to form lobes; otherwise, most of the sediments are blocked by salt tectonics and develop lobes.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-2: Sediment gravity flow deposits in marine systems
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Turbidite system dominated by normal faults growth and linkage on a slope belt of rift basin: Bonan Sag, Bohai Bay Basin, China

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Keywords: Fault linkage and growth, Turbidite system, Paleo-geomorphology restoration, Lacustrine rift basin, Bohai bay basin

The complex fault system has great influence on the deposition pathways and filling process of sediment in the slope belt of rift basin. We use 3D seismic data and drilling cores to study the influence of faults growth and linkage on turbidity current flow process and dispersal pattern in the kenxi gentle slope belt in the south of Bonan Subsag, Bohai Bay Basin. Two typical palaeo-geomorphologys of the fault growth process were identified, including fault-terraced type and slope type, and 5 faults linkage styles controlling the direction of turbidity current. 13 lithofacies , including two pebbly sandstone facies, 9 sandstone facies and one mudstone facies are identified, which were interpreted as turbidity current deposition. According to the degree of erosion and deposition, and the types of lithofacies associations, it can be divided into 6 deep-water depositional artchitecture units: erosional channel, transitional channel, depsitional channel, channelized lobe, depositional lobe and sheet-like sandbody. Two types of turbidity flow process under the control of fault activity were elucidated, including weakly confined gentle slope type flow process and confined fault-terraced type flow process. In addition, five types of sediment dispersal patterns under the control of faults linkage were established. Tectonic movements are considered to be the major factor controlling the generation and deposition of turbidity current in slope belt of rift basin. Fault activity controls the confinement degree of palaeo-geomorphology, and then affects the difference of flow types and depositional artchitecture units. Channel-lobe system is more likely to develop in weakly confined palaeo-geomorphology formed by weak tectonic activity, and channel system is more likely to develop in confined palaeo-geomorphology by strong tectonic activity. For another, the faults linkage types will lead to the diversity of turbidity dispersal patterns, turbidity current dispersal patterns of the complex slope belts of the faults system are controlled by the geometric characteristics and the evolution degree of the relay rampes.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-2: Sediment gravity flow deposits in marine systems
Presentation Preference: Oral Preferred

Sedimentary evolution of the transitional sequence of the 5th Member of Zhujiang Formation in Baiyun deep-water area, Pearl River Mouth Basin

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Keywords: the shelf slope break belt,gravity flow sedimentary system,system tract,sequence

The 5th Member of Zhujiang Formation (23.03Ma to 21Ma) is one of the main target strata in Baiyun deep-water area of Pearl River Mouth Basin, but the origin and evolution model of its sand bodies are not clear. As a result, in this study we make a comprehensive analysis of the dynamic coupling relationship during the period of 23.03 Ma to 21 Ma, between the shelf slope break belt and gravity flow sedimentary system. Seismic and drilling data from Baiyun sag and Liwan sag are used, as well as published papers on the tectonic evolution of the Pearl River Mouth Basin and the slope break belt. Results show that the transitional sequence of the 5th Member of Zhujiang Formation in Baiyun deep-water area is characterized by forced regressive systems tract, and the transition of the shelf slope break zone during this period controlled the development of the gravity flow depositional system. A sequence evolution model was built for the 5th-4th member of Zhujiang Formation in Baiyun sag and Liwan Sag which suggests the formation mechanisms of LW13-3 sand bodies and BY5-3 sand bodies. Generally, this evolution model may help determine favorable natural gas targets in the 5th member of Zhujiang Formation in this area, guiding future exploration and exploitation activities.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-2: Sediment gravity flow deposits in marine systems
Presentation Preference: Oral Preferred

New insight of sedimentary facies of Miocene to Pliocene Agbada Formation , offshore Niger Delta Basin

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Keywords: Gravity flow, Sedimentary facies, Agbada Formation, Offshore, Niger Delta Basin

OML 123 block is located in the shallow water (2m-45m water depth) of the south-eastern Niger Delta Basin. The Agbada Formation is the main oil productive reservoir in the study area. Predecessors did a lot of research on sedimentary facies and believed that the area belongs to deltaic facies. This paper, based on comprehensive analysis of rock core, well-logging and seismic data, suggested that the Agbada Formation in the study area developed not only deltaic facies , but also gravity-flow deposits. Sedimentary background analysis proved that the study area has the basic conditions for forming gravity flow deposit. A large number of sediments generated under strong hydrodynamic conditions, such as pebbly sandstones and massive sandstones, were observed through the examination of nearly 800m of conventional core. Furthermore, some sedimentary features that would only formed in the case of gravity flow were identified, such as deformation structure, convolute bedding, sluicing structure, Bouma sequence, and the graded bedding, which is the best representative of gravity flow. Alternatively, the detailed well-logging analysis recognised GR logging shapes associated with gravity-flow depositional facies. In wireline logs, gravity flow sand bodies exhibited cylindrical, coarsening-up, fining-up, and serrated motifs. Moreover, seismic facies showed both sheet-like and mounded external forms (geometries), and parallel/continuous as well as chaotic/hummocky internal reflections. Furthermore, well profile analysis determined the distribution of gravity flow in lowstand systems tracts of sequences, and the delta-gravity flow deposition model suitable for Agbada Formation in the study area was established. The discovery of gravity flow may be of great significance for further lithologic exploration.

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Session T6-2: Sediment gravity flow deposits in marine systems
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Genesis of gravity flow channel in Ledong area, Yinggehai Basin, South China Sea

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Keywords: Gravity flow channel,Yinggehai Basin, Ledong area,sedimentary characteristics,genetic analysis

The Huangliu Formation (11.6Ma5.7 Ma) in the Yinggehai Basin develops large-scale gravity flow channels(reach to 140 Km in length) in the Yingdong slope belt , which is the key target of oil and gas exploration. This study comprehensively analyzes the sedimentary characteristics and control factors of the gravity flow channel in the Ledong district using 3D seismic, cores, drilling, and logging data. The gravity flow channel is mainly developed in the lowstand system tract of the second member of the Huangliu Formation. The typical gravity flow sedimentary characteristics include deformation structure and scouring surface identified from the core; The particle size curves reveal that the sorting of sediments is poor. And the projection analysis of the C-M diagram shows the characteristics parallel to the baseline, which is in line with the transition type of high-density turbidity current to low-density turbidity current. Based on the core facies and logging facies, the gravity flow channel deposition can be divided into five depositional elements: erosional channel, main channel, secondary channel, channel edge, and marine mud. The erosional channel is marked by a high amplitude box-shape curve; the main channel is marked by a high amplitude straight box curve and high amplitude weakly toothed box; and the channel edge is dominated by finger type, micro amplitude finger type, and interbedded bell type. Based on the seismic facies and superposition model in the seismic section, the spatial and temporal analysis of gravity channel deposition is carried out. The results can be divided into three stage. In the initial stages, the furcate area shows weak amplitude and chaotic reflectors in seismic data; weak to moderate amplitude and discontinuous reflectors dominate the edom channel during development stage; the extinction stage is characterized by medium-high amplitude and continuous reflection.The gravity flow channel during the deposition of Huangliu formation in the Yinggehai basin was formed under the coupling action of five factors: the sharp decline of relative sea-level (max decline is more than 150m), the short distance from provenance, large-scale sediment supply for the delta, the inherited incised valley that provides sand transport pathway for channel infilling, and the influence of underlying fault weak zone, within which, the weak fault zone is the main controlling factor.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-2: Sediment gravity flow deposits in marine systems
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Sedimentary characteristics of gravity flow in Well NK-1 in South China Sea and its influence on reef-buliding

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Keywords: Well NK-1,Gravity flow deposition, Reef-building, MJ island reef,South China Sea

MJ island reef is an atoll build on the base of volcanic eruption. The drilling of well NK-1 showed that the deposition of thick gravity flow during 25.8-25.1Ma caused the water to become shallow rapidly, which laid an important environmental foundation for the growth and development of reefs. The gravity flow deposition thickness of this section is 127.6 m, which can be divided into two sections from bottom to top. The lower section is 30.3 m thick, which is a clastic flow deposition. The rock types of gravel include dacite, basalt, tuff, coral reef block, etc; The gravels psephicity are fine, poorly sorted (10-350mm), and the content is 50-65%. Gravels are mixed and piled up, and are distributed in various forms such as horizontal, inclined and upright, Intergravels are filled with plaster and fine reef debris. The high roundness of gravel indicates that it may be transported from coastal sediments to slope sediments by gravity flow.The upper section is 84.6m thick, deposited by granular flow, and the particles type is mainly bivalve shells, a few coral reef blocks and small volcanic gravels. The particles have a certain sorting property, are stacked at medium high angles, have a certain orientation, and the upward particle size becomes coarser. The volcanic gravel is significantly thinner than that in the lower section, and is mainly distributed in the lower part of the section, and gradually disappears upward, which may be related to the decrease or disappearance of volcanic rock provenance caused by the growth of reefs in the provenance area. The water above the gravity flow deposition in this section became shallower, and the reef began to be builded, eventually forming the atoll landform of MJ island.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-2: Sediment gravity flow deposits in marine systems
Presentation Preference: Oral Preferred

How do old submarine landslides influence future mass failure processes?

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Keywords: Submarine landslides, Exmouth Plateau, Geohazard prevention

Submarine landslides represent a potential geohazard as they can generate tsunamis, and damage subsea cables and coastline infrastructure. Previous studies have revealed that old landslides can modify and affect the morphology and routing directions of subsequent turbidite systems. However, the role of submarine landslides in dictating where and why subsequent landslides deposition will occur is still an important problem to address. This work aims to reveal how old landslides influence the younger landslides by interpreting five landslides in Exmouth Plateau, NW Australia. We indicate that the location, nature, geometry, and hazard potential of future mass failure events are profoundly affected by the presence of old buried landslides. We show that previous failures can : i) provide the lithological control for the future landslide's basal failure zone; ii) provide bathymetric constraints to the subsequent landslide; iii) switch the direction of the subsequent failure, which is key for understanding tsunami hazard; iv) and enhance the erosive ability of the future failure events. More importantly, we indicate that the thickness distribution pattern of old landslides can provide a mechanism for predicting future landslide's location and depocentre. Therefore, our study could provide a useful case study in offshore geohazard study (e.g. tsunami prediction) as our results can be used to predict future landslides transport direction, depocentre and location.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-2: Sediment gravity flow deposits in marine systems
Presentation Preference: Oral Preferred

Seismic recognition of supercritical turbidity-current bedforms

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Keywords: supercritical flow bedforms, turbidity currents, seismic recognition, antidunes, chutes-and-pools, cyclic steps

Compared with open channel flow, turbidity current is more easily transformed into supercritical flow due to its lower reduced density. Submarine investigations have shown that upslope-migrating sediment waves and/or supercritical-flow bottoms are ubiquitous in modern turbidity-current environments, including shallow delta front slopes, submarine canyons and channels, levee backslopes, channel-lobe transition zones, fan lobes, and even abyssal plains. Recognized supercritical turbidity-current bedforms include antidunes, chutes-and-pools, and cyclic steps. Most of these bedforms are identified by their morphological characteristics revealed by bathymetric measurements, together with seismic profiles and bottom samples. Nevertheless, the relevant seismic evidence has not increased much, aside from the well-known upslope/upstream migration, backsets, and undulations with backsets and/or foresets. It remains unclear how to distinguish various supercritical-flow bedforms by seismic data. On the other hand, recent discoveries in flume experiments and numerical simulations have greatly improved our understanding of the formation and evolution of various supercritical-flow bedforms. Here we attempt to combine these findings with the practice of seismic identification of various types of supercritical-flow bedforms. Our seismic recognition and interpretation are largely built on the analysis of external morphology and internal architecture of different bedforms.

Morphological analysis reveals the size (wavelength and wave height), aspect ratio (wavelength to wave height ratio), symmetry (symmetrical, upslope asymmetrical, and downslope asymmetrical), and upslope migration of the waveforms. In general, antidunes present symmetrical to weakly asymmetrical sinusoidal streamwise profiles, with relatively small wavelength and aspect ratio, while cyclic steps are mostly upslope or downslope asymmetrical, with large wavelength and aspect ratio. All supercritical-flow bedforms migrate upslope.

The analysis of internal architecture reflects the types and characteristics of stratification observed in seismic profiles. Four general types of seismic-based beddings are defined, which are undulations with backsets and foresets, planar upslope-dipping backsets, concave-upward backsets, concave- to convex-upward backsets, and alternating concave- and convex-upward backsets, respectively. The first type of seismic beddings can correspond to antidunes or fully depositional cyclic steps depending on their symmetry; the second and third types may reflect the partially depositional to partially erosional cyclic steps, or fully depositional cyclic steps with different degrees of late erosion at their downstream end, and the last one may represent antidunes superimposed on the chutes-and-pools bedforms.

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Session T6-2: Sediment gravity flow deposits in marine systems
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Calciclastic and siliciclastic gravity flow deposits in a tectonically active setting, West Qinling, central China

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Keywords: turbidity current, debris flow, gravity flow transformation, hydrocarbon exploration

Siliciclastic gravity flow deposits have been well documented in outcrop, in the subsurface, and from modern systems. In contrast, mixed siliciclastic and calciclastic (carbonate) gravity flows deposits have been relatively understudied. Here, we report such an outcropping system from the Lower Triassic of the northern West Qinling (Qinghai province, central China) - an active continental margin during that period, with a focus on deep-water carbonate breccia-rich beds and associated deposits. Based on grain size, fabric, bed thickness and vertical sequence, two basic types of breccia-rich beds are recognized in the study area. Type I beds are characterized by very large (pebble to boulder size), subangular to subrounded carbonate (ooid grainstones/packstones), igneous and intraformational rip-up clasts that are disorganized, matrix-supported or clast-supported. Type I beds form the thickest beds (3 to 15 m) in the area, one of which shows an irregular, sharp top surface with protruding megaclasts and ponding sediments. In contrast, Type II beds comprise two-layer units, with the lower division resembling type I beds except for overall finer-grained (sand to cobble) clasts and thinner bed thickness (typically <3 m), and the upper division showing Bouma-like (Ta-Te) sequences. The boundary between the lower and upper parts of type II beds is typically gradational.

The above characteristics suggest that a type I bed was deposited by a subaqueous debris flow alone, whereas a type II bed was deposited by a subaqueous debris flow (the lower debrite division) and a co-genetic turbidity current (the upper turbidite division) due to transformation of debris flow during a single flow event. The thicker and coarser-grained type I beds (debrites) lack linked turbidites at the outcrop, probably due to limited mixing of these larger debris flows with ambient waters or more likely bypassing of co-genetic turbidity currents down-slope. Transport of large lithoclasts of ooid grainstones/packstones and other non-carbonate clasts/blocks, and a tectonically active setting with inferred significant faulting, indicate that these breccia-rich beds were probably caused by the catastrophic collapse of a shallow-water clastic shelf and carbonate platform margin due to fault-related earthquakes. Taken together, the investigated calciclastic and siliciclastic gravity flow deposits suggest a down-slope flow transformation trend from slumps/slides to debris flow and then to turbidity currents, as suggested from other siliciclastic systems. From a hydrocarbon exploration perspective, type II breccia-rich beds themselves tend to show a higher reservoir potential (especially at its upper turbidite division) than type I breccia-rich beds. However, the presence of the latter might suggest significant volumes of reservoir sands bypassed downstream by co-genetic turbidity currents.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-2: Sediment gravity flow deposits in marine systems
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Ponded turbidites: field and textural expression of flow ponding processes of mud-rich turbidity currents (Szczawa, Oligocene, Polish Outer Carpathians)

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Keywords: ponded turbidites, ponded flow evolution, banded sandstone, combined-flow bedforms, normal grading, mineralogical sorting

Sedimentary succession at Szczawa, Fore-Magura Tectonic Unit of the Polish Outer Carpathian Orogen, is composed of deep-water turbidites. The studied section is mud-predominated, with several thick to very thick turbidite beds comprising well-developed basal laminated sandstones. The sedimentary features show widespread evidence for confinement and ponding of the depositing turbidity currents, probably in structurally-controlled intraslope mini-basin. The vertical sequence of bed-forming sedimentary structures can be interpreted according to the results of an experimental study of flow ponding conducted by Patacci *et al.* (2015). Several sequences begin with cross-laminated divisions which show paleocurrent direction opposite to the upper part of the bed. This can express the first flow reflection off a confining slope. Lower parts of sandstone beds show heterolithic light-dark (sand-sandy mud) parallel lamination and banding. This type of mud-rich tractional structures was probably formed under decelerating basal transitional mud-laden flows (*sensu* Baas *et al.*, 2009). The banded division is often followed by cleaner sandstone with well-developed combined-flow structures, e.g. hummocky cross-stratification-like structures, sigmoidal-cross lamination, biconvex ripplemarks and inclined synsedimentary folds. These structures are evidence of interactions of oscillatory and unidirectional flow components. The former is provided by the propagation of internal waves, generated at the internal concentration interface in stratified ponded suspension. At the boundary between co-genetic sandstone and mudstone, some centimetre thick silty division occurs frequently. This was deposited probably when the input flow started to decline. Graded, abnormally thick mudstone caps terminate such beds suggesting the collapse of static and presumably inflated muddy clouds after basal flow decline.

Basal sandy-to-silty divisions show normal grain-size grading typical of turbidite beds. Normal distribution grading applies to sand-sized and coarse silt grains. Different depositional intervals vary in terms of matrix content and degree of grain-size and compositional segregation at the scale of laminae. Banded divisions are composed of alternating matrix-rich and/or matrix-supported sandstones/coarse siltstones, or sandy mudstones with sand laminae. The process of mud-fractionation seems to be hindered, and mud-rich tractional structures were probably formed under transitional flows with near-base turbulence at least partly damped. In contrast to mud-rich banded divisions, combined-flow structures are composed of cleaner sandstone. This may testify to better fractionation of cohesive fraction to muddy cloud at the subsequent stage of basal flow evolution, as a consequence of an increase in flow velocity and flow turbulence. Laminae-scale compositional and grain-size sorting is best visible in siliciclastic-bioclastic sandstones. Namely, there is a tendency of these two grain populations to separate into lower siliciclastic and upper bioclastic layers. Grading in mudstone caps is associated with mineral sorting. Lower parts of mudstone divisions are enriched in quartz, feldspars and clay minerals, at the expense of carbonate micrite. This regularity can be the evidence of preferential fallout of silt-sized quartz grains and flocculated clay particles. It would also prove that the muddy suspended cloud was of density low enough to enable gravitational segregation of particles that differ in size and mineral composition.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-2: Sediment gravity flow deposits in marine systems
Presentation Preference: Oral Preferred

Sediment dynamics of submarine landslides by grain-resolving simulations

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Keywords: Granular Collapse, Runout Distance, Cohesive force

Many turbidity and debris currents are associated with large-scale submarine landslides, which are important transporting agents for oceanic sediments. We investigate the sediment dynamics of submarine landslides via grain-resolving direct numerical simulations. The landslide process is simplified as the submerged collapse of weakly polydisperse, loosely packed cohesive granular columns. The cohesive forces act to prevent the detachment of individual particles from the main body of the collapsing column, reduce its front velocity, and yield a shorter and thicker final deposit. The cohesive forces significantly reduce the amount of available potential energy released by the particles. Computational particle tracking indicates that the cohesive forces reduce the mixing of particles within the collapsing column, and it identifies the regions of origin of those particles that travel the farthest. The simulations demonstrate that cohesion promotes aggregation and the formation of aggregates. They furthermore provide complete information on the temporally and spatially evolving network of cohesive and direct contact force bonds. While the normal contact forces are primarily aligned in the vertical direction, the cohesive bonds adjust their preferred spatial orientation throughout the collapse. They result in a net macroscopic stress that counteracts deformation and slows the spreading of the advancing particle front.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-2: Sediment gravity flow deposits in marine systems
Presentation Preference: Oral Preferred

RESEARCH ON SEQUENCE STRATIGRAPHIC FRAMEWORK AND SEDIMENTARY MODE OF LOWER CONGO BASIN

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Keywords: Lower Congo Basin,sequence stratigraphic framework, sedimentary facies mode

The Lower Congo Basin is a passive continental margin salt-bearing basin developed since the Oligocene. It has multiple sets of oil and gas systems and superior oil and gas accumulation conditions. However, there are insufficient studies on the basin-scale sequence stratigraphy and the development and evolution of gravity flow in the sequence framework. In this paper, the sequence stratigraphic framework and sedimentary facies mode of key strata in the basin were systematically studied using a large number of drilling, logging and seismic data. The research results show that 12 large-scale sequence interfaces have been identified in the target interval, including 7 sequences in the Tertiary and 4 sequences in the Cretaceous. They are named SSQ1-SSQ11 from top to bottom. The deposition of the submarine fan in the Lower Congo Basin can be divided into two stages: Oligocene-Miocene and Pliocene-present. The Oligocene-Miocene developed two deposition centers in southeast and northwest areas, with large deposition thickness; the Pliocene-present day has only one deposition center, and the stratum is relatively thin, which is located on the side of the salt boundary basin. Four types of sedimentary facies were identified, including gravity flow channels, embankments, flowering bodies, and deep-semi-deep muddy sediments. Finally, the gravity flow deposition mode of the slope-deep sea plain was established. The gravity flow deposition type is greatly influenced by the terrain slope, and the slope part is mainly developed by canyon channels. As the slope of the terrain becomes slower, restrictive waterways, weakly restricted waterways-natural embankment systems, flowering bodies and deep-semi-deep sea muddy deposits are developed in sequence.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-2: Sediment gravity flow deposits in marine systems
Presentation Preference: Oral Preferred

Soft-sediment deformation structures in the Numidian Formation (Oligo-Miocene) of the Ouarsenis Mountains, NW Algeria

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Keywords: Numidian Formation, turbidities, deep-sea sediments, SSDS, Algeria

The Numidian Formation (upper Oligocene – lower Miocene) in the Ouarsenis Mountains (NW Algeria) is well exposed in the areas around the towns of Theniet El Haad and Ouled Ben Abdelkader; Four well-exposed sections are described in detail, including three sections and one section respectively from the mentioned areas. The Numidian Formation here consists mainly of siliciclastic turbidites and other sediment gravity flow deposits intercalated between hemipelagic mudstones. The sediments show numerous types of sedimentary structures, including a wide range of soft-sediment deformation structures (SSDS). These are not distributed in a more or less haphazard way but are related to the lithofacies of the sediments. The four sections comprise eight lithofacies (F1-F8). Lithofacies F1 (concentrated density flows) consists of massive sandstones with SSDS caused by liquefaction (load casts) and fluidization (fluid-escape structures: pillars and dish structures). Lithofacies F2 (concentrated density flows) consists of normally-graded, medium- to very coarse-grained sandstones with primary depositional structures such as parallel lamination, ripple cross-lamination, and abundant erosional structures such as gutter casts, flute casts, mud ripples, groove casts and scour structures around obstacles, and still more or less enigmatic structures such as longitudinal ridges and furrows, and frondescent marks. SSDS due to liquefaction (convolute lamination) and fluidization (fluid-escape structures) are rare. Lithofacies F3 (hyper-concentrated density flows) is represented by inversely-graded pebbly sandstones to parallel stratified sandstones with some climbing ripples, and groove casts Lithofacies F4 (low-concentration turbidity current) consists of medium- to fine-grained parallel-laminated sandstones with abundant convolute lamination and rare load casts. Lithofacies F5 (debris-flows and mudflow) occur as conglomerates with mudstone clasts and as folded sandstones; both convolute lamination and ball-and-pillow structures are fairly common. Lithofacies F6 (slumps) consist of sandstones and siltstones that were strongly deformed while still in an unlithified state; the beds show centimeter-scale convolute lamination, as well as slump folding, commonly as isolated masses within F8. Lithofacies F7 (low-concentration turbidity current with hemipelagites) consists of alternations of mudstones, siltstones, and sandstones which do not show specific structures apart from parallel lamination. The last lithofacies, F8 (autochthonous sediment), contains only marly mudstones without sedimentary structures that are visible in the field.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-2: Sediment gravity flow deposits in marine systems
Presentation Preference: Oral Preferred

Gravity-driven Sediment Flows on the Shallow Sea Floor of a Muddy Open Coast

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Keywords: Gravity-driven sediment flows, High concentration layer, Sediment transport, Muddy open coast, Coastal erosion, Jiangsu coast

Wave and/or current supported gravity-driven sediment flows (GDSFs) cause substantial sediment movement across the continental shelf, contributing to morphological evolution in many regions worldwide. However, they appear to occur episodically and ephemerally and, therefore, it remains a challenge to document them in detail with *in situ* measurements. Here we present solid evidence of frequent generation of such flows over the shallow sea floor of a muddy open coast. They were triggered by wave resuspension and/or sediment settling from the overlying water column, maintained by wave- and/or current-induced bed stress, and terminated due to upward spreading of bottom sediment within the high concentration layer. Randomly selected GDSF events were analyzed to realize parameterization with a buoyancy-friction model; the resultant bed drag coefficient for two of the cases is higher than the value of 0.003, which is attributed to the additional drag at the interface between the overlying flow and the moving GDSFs. Although short-lived, the observed GDSF events in the three different seasons indicate that they occur more frequently than previously thought.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-2: Sediment gravity flow deposits in marine systems
Presentation Preference: Oral Preferred

Holocene shallow-marine hybrid event beds from the East China Sea

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Keywords: Sediment gravity flow, Hybrid event bed, Turbidite, Debrite, Shallow-marine deposit

Many sediment gravity flow deposits that developed in deep marine settings fit into neither the typical Bouma nor the matrix-supported debrite classification schemes and instead show hybrid character (comprising both turbidite and debrite features). Our studies of shallow-marine deposits have documented the presence of such mixed flow deposits in the river-dominated deltas and wide shelves. AMS 14C dating, grain size analysis and measurements of stable isotopic composition of organic matter were conducted to delineate the depositional process of the recognized hybrid beds. The internal subdivisions of the hybrid event beds, including H1, H3a, H3b and H5 divisions, were differentiated mainly based on sedimentary textures, including cohesive mud content, sand content and sorting. The data indicate that hybrid sediment gravity flow deposits were sourced from intra-shelf failures and/or hyperpycnal flows, and subsequently transformed and deposited as hybrid event beds. The occurrence of hybrid event beds in modern shallow delta front/shelf settings is an important novelty, implying that flow transformations are perhaps widespread and not only limited to deep marine systems.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-2: Sediment gravity flow deposits in marine systems
Presentation Preference: Oral Preferred

Patterns of sediment accumulation and erosion rates in turbidite deposits: Insights from a decade of time-lapse bathymetry and flow monitoring

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Keywords: turbidites, sedimentation rates, repeat bathymetry, erosion rates, turbidity currents

Turbidites form some of the largest sedimentary deposits on earth. These deposits often form the final sink of a sediment routing system and hence the sedimentation rates control their long-term storage of sediments, nutrients, carbon and pollutants. Measurements of short term ($<10^3$ yrs) sedimentation rates in turbidite systems are rare, especially below 100 years due to dating limitations. Yet these short-term rates have a strong control on depositional patterns as they record high-frequency palaeo-climate changes and control the fine-scale sedimentary heterogeneities in the stratigraphic record. Here we use decadal bathymetric difference maps, cores and flow monitoring data to show how sedimentation rates vary from source to sink in two distinct modern turbidite systems (Bute Inlet and Congo Fan). We quantify the sedimentation rates in different fan regions (e.g., canyon, mid-fan, lower-fan), turbidite environments (e.g., channel, channel-lobe transition, lobes) and sub-environments (e.g., channel-axis, channel-margin, proximal-lobe). Additionally, we provide the first systematic measurements of erosion rates in turbidite systems. The results show the expected Sadler's effect (i.e., negative power-law relationship) between sedimentation rates against time span. We found sedimentation rate variability shows distinct signatures depending on the turbidite environments and sub-environments. From proximal to distal, we identified two sedimentation rate regimes that appear in the fan region, environment and sub-environment scales: (i) regressive downstream erosion, and (ii) progressive downstream erosion. These regimes correspond to a transition from regular low-magnitude events to infrequent high-magnitude events. Our results are compared with direct flow monitoring data to show changes in the process-product relationship at different timescales are related to contrasting turbidity current characteristics/frequencies. Furthermore, the use of time-lapse maps enables us to also highlight the important role of erosion rates on the dynamics of turbidite deposits, which provide an important guide to interpreting short-term turbidite depositional cycles in the rock record.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-2: Sediment gravity flow deposits in marine systems
Presentation Preference: Oral Preferred

Can mica play a role in forming hybrid beds of submarine lobe systems?

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Keywords: submarine lobes, hybrid beds, flow transformation, mica

Hybrid beds deposited by transitional flows are found to be more and more common in submarine lobe systems, and various ways of promoting flow transformation have been proposed. Clay concentration, especially clay flocculation has been regarded as the main reason for the increase of flow cohesiveness, and in recent years, microbial bioforms has also been revealed to play an important role. Mica is a phyllosilicate mineral which is structurally similar to clay mineral, its widely electrostatic force at mica surface has been widely used in medical area, but seems to be overlooked in geoscience area to have played a role in promoting flow transformation. In this study, a well-exposed submarine lobe complex with hybrid beds developed at its frontal fringed which are exceptionally mica rich are introduced to discuss the possible role of mica in promoting flow transformation. The lobe complex is composed of twelve lobe elements, the first three lobe elements are aggradational stacked, preserving axis to the frontal fringe deposits; the rest eight lobe elements are compensational stacked, preserving axis to lateral fringe deposits. Only frontal fringe of the first three lobe elements are hybrid beds prevalent, occupying 80% of the interval. Mineralogy and grain size analysis have been undertaken to compare the mineralogical difference between the axis to lateral turbidite beds and frontal fringe hybrid beds. The results show that the samples are all composed of quartz, mica and feldspar, and frontal fringe contains three times as much mica than the lateral fringe, with an average of 60%. Mica in the hybrid beds range from silt to medium sand in size and the um scale biotite and muscovite flocculate to form flocs, which are common in hybrid beds. The clay mineral and organic matter is very little in the sampled beds and clay mineral flocculation is hardly detected. This study reveals that mica may play an important role in the flow transformation process.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-2: Sediment gravity flow deposits in marine systems
Presentation Preference: Oral Preferred

Effect of submarine sediment landslides on the redistribution of manganese nodules

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Keywords: Manganese nodules,three-dimensional DNS-DEM coupling,Lagrangian particle tracking model,The cohesive forces

Manganese nodules, also known as polymetallic nodules, are widely distributed in the deep-sea plains of the global oceans and are a potential source of key metals such as copper, nickel and cobalt. The nodule distribution has both spatial aggregation and heterogeneity, which may be related to the inundation and collapse process of the surrounding sediments.In this study, sediments are abstracted as weakly polydispersed and loosely packed viscous particle cones. Through a three-dimensional DNS-DEM coupling model based on immersion boundary method and considering cohesion, the effects of cone shape, particle size and cohesion on the flooding and collapse process of accumulated sediments in stratified environment are studied, and the dynamic characteristics of sediment flooding and collapse are analyzed. The movement model of manganese nodule particles under the condition of sediment landslide is constructed by using Lagrangian particle tracking model.The simulation results show that the larger the slope is, the longer the transport distance of sediment particles is, the more manganese nodules are covered; the smaller the particle size is, the more uniform the distribution is, which leads to the cover of manganese nodules; cohesion significantly reduces the available potential energy released by particles, promotes the formation of aggregates and aggregates, slows the diffusion of advancing particles, and reduces the farthest movement distance of particles, which often leads to manganese nodules being covered.

Session T6-3: Deep-water channels: Morphology, architecture, flowdynamics

ID: T6-10780

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
Presentation Preference: Oral Preferred

How do paleovalleys in low-accommodation foreland basin respond to long-term transgression? Insights from the McMurray-Wabiskaw interval in the Western Canada Foreland Basin

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Keywords: Paleovalley, low-accommodation foreland basin, meandering channel-belt deposit, delta, tidal channel and bar, strandplain/shoreface

The McMurray Formation and Wabiskaw Member in Alberta, Canada record a paleovalley system developed under the influence of a continental-scale river that longitudinally transported and debouched sediment into the southward-transgressing Boreal Sea in the distal, low-accommodation Western Canada Foreland Basin (WCFB). In this study, we present a high-resolution stratigraphic framework for the paleovalley fill in the McMurray-Wabiskaw interval, which was deposited during a long-term transgression. Using wireline logs from >20,000 wells and more than 500 cores, regional mapping focused on resolving stratigraphic relationships and the distribution of depositional environments across approximately 60,000 km^2 in the Athabasca Oil Sands Region of northeastern Alberta. The studied stratigraphic interval is part of a third-order sequence: the McMurray Formation developed during a period of relative sea-level fall, lowstand, and early transgression, while the overlying Wabiskaw Member was deposited during late transgression. Within the McMurray Formation, superimposed fourth-order sea-level fluctuations in this low accommodation setting created a complex amalgam of deltaic strata vertically and laterally juxtaposed with valley-fill deposits. Relative sea-level rises resulted in rapid transgressions in which the shorelines migrated >400 km landward. Thin (5-15 m thick), widespread deltaic parasequence sets were deposited during subsequent sea-level highstands. During relative sea-level falls, fluvial meandering channel belts developed in downcutting paleovalleys, with associated shorelines dramatically prograding basinward. In the Wabiskaw Member, continued sea-level rise coupled with potentially decreasing sediment supply resulted in the development of tide-influenced/dominated channels and bars in estuaries. The final phase of the third-order transgression was marked by a regional transgressive ravinement event and several southwestward backstepping wave-dominated shorefaces/strandplains. This paleovalley fill in the low-accommodation foreland basin demonstrates a transition from deposition in continental fluvial and marginal-marine settings subject to high-frequency eustatic changes, to open-marine conditions over a long-term transgression.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Morphology of river channels and surface runoff of the northern Campania Plain (Italy) during LGM

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Keywords: LGM, Campania Grey Tuff, Incised Valley, palaeomorphology

The Campania Plain, southern Italy, formed as a large graben or half-graben filled with thousands of meters of Quaternary sediments. Of particular interest is the recognition of an important stratigraphic marker, the Campania Grey Tuff (CGT) deposits (39 ka B.P.) during one of the last explosive eruptions of the Campi Flegrei, a complex volcanic system along the Tyrrhenian margin of the plain. The CGT blanketed the whole area and filled morphological depressions, dipping gently towards the central region of the plain, giving origin to a thick, laterally continuous, volcaniclastic unit that covered previous marine-transitional settings, whose landforms controlled the facies distribution and post-depositional settings of the CGT deposits. Since 39 ky, most of the Campania Plain became a land area. Following the eustatic regression associated with the LGM sea-level drop, a seaward shift of the shoreline and the forced regression of paralic-shallow marine depositional systems concurrently occurred, while the rivers flowing in the inner plain likely started fluvial downcutting with formation of a major incised valley. The surface underlying the regressive phase associated to the sea level drop is clearly recognizable across the plain as it is cut in the ignimbrite deposits. The reconstruction of this surface was based on geological and geophysical data, including stratigraphic well logs and high-resolution single channel reflection profiles to image the stratigraphic pattern of the continental shelf. The 3D representation has shown the morphology of the palaeovalley developed during the LGM. The valley is characterized by a complex structure likely related to channel entrenchment and aggradation. Two main downcuttings occur in correspondence of the modern Volturno River course and the Regi Lagni Channel (formerly Clanio River). The Volturno river likely flowed almost in the present location and received the waters of the Agnena Canal (formerly the Cales River, to north) before the deepest part of the incision located close to the present-day delta area. The Clanio River came from the east, conditioned by an older volcanic dome, and created a wide bend in the plain, entering the deep incision south of the mouth of the current Volturno River. The reconstructed surface actually suggests the occurrence of a complex network of incisions that supports the reconstruction of a channel entrenchment on the plain and especially towards the coastline, which at that time was located ca. 13 km offshore. Above this surface, large remobilization of volcaniclastic material took place during the re-establishment of the fluvial system, witnessed by the abundance of reworked pyroclastic ash and clasts recognized in the alluvial deposits of the medium-upper part of the valley fill. Previous radiocarbon dating indicated that the valley started to form at ca. 37 ka B.P. The onset of the LGM renewed fluvial downcutting leaving the previously formed terraces ca. 10 m above the valley floor. These deposits occur in the subsurface below the present delta plain and have their offshore equivalent in the thick succession of upper Pleistocene prograding units deposited during the Falling Stage of the sea level, bounded at the top by the erosional surface.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
Presentation Preference: Oral Preferred

A millennial-scale record of Late Pleistocene and Holocene glacio-eustatic events: evidence from the Pescara paleovalley system (Central Italy)

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Keywords: Paleovalley system, integrated facies analysis, parasequence architecture, glacio eustasy, melt water pulse, Po-Adriatic basin

A buried paleovalley system, about 50 m deep and 2 km wide, was identified beneath the Pescara coastal plain (Central Adriatic) through combined stratigraphic, sedimentological, paleontological and geotechnical data. Detailed analysis of a 52 m-long-core recovered from the paleovalley depocenter allowed the high-resolution facies architecture reconstruction of the paleovalley fill (PVF) above the incised Early Pleistocene bedrock. Seventeen closely-spaced radiocarbon dates provide a high-resolution chronological framework for the cored succession.

A 13 m-thick fluvial gravel body, which mostly accumulated during the Last Glacial Maximum (30-19 ky BP), forms the lowermost PVF. This deposit is interpreted as the lowstand systems tract (LST) and shows an erosional and time-transgressive basal surface representing the sequence boundary. Above the LST, the cored succession (11.3-8.0 cal ky BP) displays a deepening-upward trend, from poorly-drained/inner-estuarine to lagoonal/outer-estuarine facies associations. These soft, organic-rich silty clays represent the transgressive systems tract (TST) and are linked to the post-glacial sea-level rise that caused the progressively drowning of the Pescara paleovalley and the formation of an estuary. The maximum flooding surface (about 8.0 cal ky BP) marks the onset of coastal progradation, and defines the base of the highstand systems tract (HST). This latter is characterized by a shallowing-upward tendency from paludal clays to fluvial gravels, with transition to coastal sands in the distal sector.

Within the Holocene (TST+HST) strata, seven millennial-scale depositional cycles bounded by flooding surfaces (parasequences or Ps) were recognized. Transgressive parasequences (Ps 1-3) exhibit a distinctive retrogradational stacking pattern that records the drowning of the valley and estuary formation, in response to rapid, stepwise sea-level rise likely driven by Melt Water Pulses (MWPs) 1B and 1C. MWP 1D likely triggered the maximum landward migration of the shoreline at the peak of the Holocene transgression, around 8.0 ky BP. As sea-level stabilized, between 8-7 ky BP, coastal progradation started and the estuary was progressively filled with freshwater organic-rich deposits (Ps 4), which in turn were replaced by more drained coastal-plain facies (Ps 5-7). In the last 5.2 ky BP (Ps 6-7), further coastal progradation took place and a wave-dominated fluvio-deltaic system developed. Hence, highstand parasequences (Ps 4-7) show a particular aggradational to progradational stacking pattern.

Very low accumulation rates assessed for LST (0.7 mm/y) suggest almost complete sediment bypass between 30-11.3 ky BP. On the other hand, TST parasequences testify rapid aggradation with the highest accumulation rates (up to 9.4 mm/y), whereas HST deposits show a mean value of 2.9 mm/y. During the Holocene, the study site evolved from a laterally confined region of sediment storage (the paleovalley, between 11.3-8.0 cal ky BP), to an unconfined sector where sedimentation took place patchily according to complex mechanisms of coastal plain progradation (last 8.0 ky).

This study documents for the first time the onshore development of a paleovalley system in front of the Mid-Adriatic Depression and provides new stratigraphic evidence for MWP 1B and poorly documented MWPs 1C and 1D.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Sedimentary evolution of Miocene gravity flow deposits in block X, Lower Congo Basin, West Africa: response to source supply and continental margin morphology

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Keywords: gravity flow deposits, sedimentary evolution, source supply, continental margin morphology, Miocene, Lower Congo Basin

Research about sedimentary evolution and its response to source supply and continental margin morphology of the gravity flow deposits is the key to hydrocarbon exploration breakthrough in the deep-water. Based on integral analysis of seismic, logging and core samples in block X of the Lower Congo Basin in the West Africa, the Miocene sequence framework is redefined and the sedimentary units of the Miocene gravity flow deposits are fully identified. The sedimentary evolution of the gravity flow deposits is systematically revealed, and its response to source supply and continental margin morphology is discussed. The Miocene in the study area can be divided into four 3rd order sequences, referred to as SQ1 (Lower Miocene), SQ2 (Lower part of Middle Miocene), SQ3 (Upper part of Middle Miocene) and SQ4 (Upper Miocene). Four major types of deep-water sedimentary units are identified, namely MTD, gravity flow channel (including erosional bypassing channel, restricted erosional channel, weakly restricted erosional- aggradational channel and unrestricted aggradational channel), levee and lobe. In SQ1, the gravity flow deposits were mainly developed in the stretching zone of block X with NW-SE extension, and the dominant sedimentary unit was lobes or unrestricted aggradational channels. During SQ2, the gravity flow deposits were widely distributed (NW-SE trending), and weakly restricted erosional-aggradational channels were dominant. In SQ3, the gravity flow deposits developed in the north of the study area with NWW-SEE extension, and restricted erosional channels were widely recognized. In SQ4, the gravity flow deposits developed in the whole study area (E-W trending) with erosional bypassing channels being dominant. SQ1-SQ4, the gravity flow deposits were generally characterized by progradation. That the Congo River delivered abundant source supply to the deep-water caused by tectonic uplift, climate cooling and sea level fall was the overriding factor for the progradation of the gravity flow deposits. The continental margin morphology (tilting shelf and wide slope) and the gradient change of the slope caused by salt structures and faults controlled the sedimentary dispersion process and the sand body distribution.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Morphology of canyon-fan system and its effects on oil reservoir in Crawford Skipper Basin, North Sea

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Keywords: canyon-fan system, gas chimney, offshore oil reservoir

Inspired by exploration wells in Mariner Oil Field (located in Crawford Skipper Basin, North Sea), we find that canyon-fan system is able to play a significant role in the formation of offshore oil reservoir. In the study area, a large canyon-fan system was found through multiple seismic profile analysis, and deep-water system develops a characteristic pattern of depositional architecture from slope canyon and channels to lobes on the basin floor during Palaeocene. The analysis of cores obtained from exploration wells shows that in the deep part of the basin, mudstone is extremely fine grained with irregular fracture surface, while in the upper part, there exists un-bedded mudstone along with moderately fossils and claystone. The canyon is full of chaotic low amplitude reflectors with some discontinuous high amplitude reflectors at the base, which probably indicate slumps and slides. The canyon-fan system formed during the depositional progress exerts enormous influence on the distribution of reservoirs (migration or trap of oil and gas). The branch channels deposited with strong tidal currents benefit for lateral migration of hydrocarbon, while faults beneath basin floor provide vertical migration paths, which is key for canyon-fan system reservoir. According to the volume attribute, there are gas chimneys through sediments, indicating the leakage of hydrocarbon (natural gas and clean oil) during or after the establishment of reservoir. The research results show that the canyon-fan system deposited under specific sedimentary environment is potential to form large oil and gas reservoir.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
Presentation Preference: Oral Preferred

Quaternary Deep-water Sedimentary Characteristics and Their Relationship with the Gas Hydrate Accumulations in the Qiongdongnan Basin, Northwest South China Sea

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Keywords: Channel-levee facies, Mass transport deposits, Qiongdongnan Basin, Gas hydrates

Recent geological investigations and offshore drillings have revealed the great prospects of the gas hydrate resources in the Quaternary sediments of the Qiongdongnan Basin (QDNB). Pore-filling gas hydrates were first discovered in the sand layers during the 2019 gas hydrate drilling expedition (GMGS6) in the QDNB. Logging data, 2D/3D seismic data, recovered cores, and grain size analysis were used to study the sedimentary facies and their relationships with the gas hydrates. It was found that the Quaternary sediments are hemipelagic deposits, mass transport deposits (MTDs), and channel-levee facies. The MTDs are characterized by vertical superposition and transverse migration. Both fracture-filling (in vein, massive, and nodular occurrences) and pore-filling (disseminated) gas hydrates were identified. The fracture-filling gas hydrates mainly occur in the muds. The pore-filling gas hydrates mainly occur in the sand layers of the channel-levee facies, which can provide reservoir spaces for the gas hydrates. It is speculated that the MTDs could be a favorable seal for the accumulation of gas hydrates. Multi-stage gas charging may have caused the multi-layer distribution of the gas hydrates. Under the premise of sufficient gas sources, the combination of channel-levee facies and overlying MTDs is conducive to the enrichment and preservation of pore-filling gas hydrates, which could be an exploration target. This study provides a reference for gas hydrate prediction and exploration in the QDNB and other prospecting areas with similar geological settings around the world.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
Presentation Preference: Oral Preferred

Slope-gully to slope-fan deposits constrained by slope gradient and relative sea level changes; Insights from the Pearl River Mouth Basin,northern South China Sea

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Keywords: slope-gully to slope-fan deposits, slope gradient, relative sea level changes, South China Sea

Submarine canyons, slope channels and gullies have been well known as long strip-shaped negative landforms and long-term conduits for transfer of sediments from continental shelf slope to abyssal plain, and the slope-gully to slope-fan deposits play an important role in revealing the early growth process of continental shelf margins. Up to now, studies on slope gully deposits have mainly focused on the steep slope regions in West Africa, New Zealand, Antarctic continent, North America, Mars and some inland lake basins. Different from submarine canyons and slope channels, the slope gullies have the following universal rules: (1) generally developed in steep slope area; (2) often linear in planform, relatively straight and shallow; (3) mainly confined and erosional; (4) small scale compared with submarine canyons and channels.

In the Pearl River Mouth basin, northern South China Sea, a set of unique slope-gully to slope-fan deposits was developed along the continental slope during the period of Early-Middle Miocene. The slope-gully to slope-fan deposits were obviously zoned constrained by slope gradient: the slope gullies were mainly discovered on the upper slope and didn't cut off the shelf slope break; while the slope fans were developed on the middle to lower slope area, a single slope fan was stripe-shaped and multiple slope fans converged to form a slope fan group. Based on high-resolution 3D seismic data, 23 slope gullies were divided into three types: erosional-depositional, depositional and sediment bypassed. A comprehensive analysis of cores and well logs uncovered that the slope-gully to slope-fan deposits were fine grained turbidite deposits supported by the ancient Pearl River. According to the plane distribution characteristics of the slope-gully to slope-fan deposits revealed by seismic slices of root-mean-square amplitude, the slope-gully to slope-fan deposits were mainly developed in the low systems tract to the early transgressive systems tract, and then were gradually disappeared accompanying the rise of the relative sea level.

In general, the slope-gully to slope-fan deposits were fine grained turbidite deposits, obviously zoned constrained by slope gradient (the gradient of upper slope is from 2° to 3.5°, and the gradient of middle to lower slope is changed from 0.8° to 1.5°) in the plane distribution, and mainly controlled by relative sea level changes in vertical evolution.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
Presentation Preference: Oral Preferred

Geomorphology of a bended submarine canyon in Wanhu Seamount region, northern South China Sea: Insights from manned submersible observation and measurement

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Keywords: Turbidity current, Geomorphological analysis, Submarine canyon, Sediment waves, Manned submersibles

Submarine canyons can transport large volumes of terrigenous material from the continent to the deep-sea environment and are the primary conduits of source-to-sink systems. The large-scale morphologic features of canyons have been well studied using seismic reflection and the bathymetry data. However, detailed analyses of the small-scale elements of canyon morphology are relatively few because of the limited resolution of traditional field investigations. In this paper, the multi-scaled geomorphology of a bended submarine canyon (canyon C4) located in Wanhu Seamount region (northern South China Sea) is described and discussed based on the in-situ high-definition video data, high-precision near-bottom acoustic data, and push-cores obtained using the manned submersible vehicle. The NNW-trending submarine canyon diverted to 122.5° at the foot of Wanhu Seamount, and the fresh erosional surfaces were recorded using the video data at the canyon axis bend. A total of eight sediment waves were generated at the overbank of the bending region. These waves contain wavelengths and wave heights decreasing in an upslope direction from the canyon axis towards the Wanhu Seamount. The C-M pattern (coarsest one percentile grain size versus median grain size values), grain cumulative probability curves, and grain size gradations derived from the sediment cores suggested that these sediment waves were induced by a turbidity current. The bending of the canyon resulted from the deflection and reflection of the turbidity currents, which were constrained by Wanhu Seamount. The abnormal geomorphologies of some sediment waves were related to the back-squeezed underflow of the turbidity currents. The turbidity current behavior was compared and found to be in agreement with the experimental and modeling simulation results mentioned in the literature. However, the morphologic setting in the natural case was more complex than that observed from the experiments, with the flow behaviors being more complicated. Future studies are required for more detailed comparison between the natural case and simulations to better understand the turbidity current behavior in a bended submarine canyon.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
Presentation Preference: Oral Preferred

Variations and controls of asymmetry and stacking pattern for unidirectionally migrating deep-water channels

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Keywords: Unidirectionally downstream-migrating channels, unidirectionally upstream-migrating channels, channel cross-sectional asymmetry, latitudinal variations, Ekman spiral

This study is the first documentation of a global variation in channel morphology and stacking pattern, evident from a global database of 60 channels that are migrating sideways. The chosen channel examples migrated both parallel to and against the dominant contour-current direction (i.e., unidirectionally downstream-migrating versus upstream-migrating channels). Downstream-migrating channels differ from their upstream-migrating counterparts in that they are confined totally by incisions rather than by overbank levees or sediment drifts developed downstream of contour currents. All channels display an asymmetrical cross-section with their steep flank located towards the channel migration direction. An Ekman spiral varying with latitude is proposed to account for the observed (latitudinal) variation in channel asymmetry and stacking pattern. Analogous to wind-driven ocean currents, submarine channel turbidity currents, impacted by the friction force of contour currents, result in Ekman transport. This causes net cross-stream sediment transport, thereby forcing successive channels to migrate unilaterally.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Left-sided asymmetry of Neocomian submarine fans of West-Siberian interior sea (Russia)

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Keywords: Achimov Formation, morphology, asymmetric submarine fan, channels, avulsion, mud/sand turbidite systems

During the Berriasian - Early Valanginian time, an asymmetric submeridional interior deep marine basin existed within the bounds of West Siberia which in the north was connected with boreal seas. As a result of avalanche sedimentation from the east (Siberian Platform) and south-east (Altai-Sayan folded region), partly from the west, clastic material was transported into the deep-sea basin to form Achimov fans. The Achimov Formation has a clinoform structure and is confined to the Neocomian base, overlying the Bazhenov argillaceo-siliceous source-rock, being a promising target for HC resource potential. Most of the discoveries have produced significant oil and gas condensate flows.

The results of sedimentological analysis of cores collected from 50 wells in various West-Siberian fields show that Achimov reservoir are composed mainly of fine-grained to medium-fine-grained sandstones and siltstones with poor reservoir properties. The rock structures are similar to those of the Stow (1) and Bouma (2) sequences described for clayey and sandy turbidites. The deposits also contain hybrid beds represented by debris siltstones with clayey intaclasts and sandstones with massive and fluid structures. The deposits distinctively feature the presence of carbonaceous debris which indicates their being transported by deltaic or river channels (hyperpycnal genesis of turbidites). Architectural elements of submarine fans in the Achimov Formation have been identified based on integrated core, well-logs and seismic data. Turbidite channels and lobes represent main targets to study submarine fans. Slope channels have slightly meandering shape. Distributary channels become more meandering at a longer distance from the bottom of the slope. Achimov submarine fans feature various morphologies, from radial to elongated shapes, and usually have a few feeder channels. The fan morphology depends on submarine slope dip, grain-size distribution and sediment volume. On average, unconfined submarine fans are 20-50 km long, 20-50 m thick, and 15-30 km wide.

Based on the research results, the authors identified morphological similarity between Achimov submarine fans of West Siberia and modern oceanic fans of the Amazon and Congo rivers (3) associated with mud and mud/sand turbidite systems (4) and found out a left-sided asymmetry of Achimov submarine fans. The preferential development of distributary channels and lobes in the left part of the main feeder channel is attributed to radial avulsion and asymmetric growth of levees. This allows to predict predominant development of sand reservoirs (and much higher NTGs) in the left side of asymmetric fans, and vice versa, lower NTGs in its right side.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
Presentation Preference: Oral Preferred

The formation and development of avulsions and splays of submarine channel systems: Insights from 3D seismic data from northeastern Bengal Fan

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Keywords: Submarine channel systems, Avulsions; Splays, Channel evolution, Bengal Fan

Avulsions and splays of submarine channels are important autogenic responses affecting sediment distribution in deep-water areas; however, their formation and development are still not well understood. Using high-resolution 3D seismic data and spectral decomposition red-green-blue (RGB) color blends, two seismically well-imaged submarine channel systems (SCS1 and SCS2) on the northeastern Bengal Fan are used to document the formation and development of avulsions and splays. The results suggest that avulsions occurred mainly during the early evolution stage of submarine channel systems. SCS1 and SCS2 were respectively accompanied by one and four avulsions and accordingly produced two and five independent submarine channels. During this early phase, these channels collectively incised into the underlying stratigraphy but lacked levee deposits. Splays, in contrast, developed consistently during the late evolution stage of the submarine channel systems. Three crevasse splays and three overbank splays developed on the overbank areas of SCS1 and SCS2. During that late stage, channel and levee deposits built over the site of former erosion, thus forming the aggradational phase of channel evolution. Crevasse and overbank splays are two different types of splay observed on this part of the Bengal Fan. The former were created by flow breaching of the adjacent levees, producing large-scale elongated shapes; they were related to relatively stable sediment gravity flows, a high-degree of channel instability, and steep levee topography. Overbank splays, however, were created by flow overtopping adjacent levees and produced small-scale, fan-like shapes; they were related to gradually-weaking sediment gravity flows, a low-degree channel unstability, and gentle levee topography.

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Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
Presentation Preference: Oral Preferred

Evolution of the Pleistocene Aggradational Channels in Offshore Myanmar

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Keywords: Myanmar, Pleistocene, Deep-water, Channel centerline, Channel evolution

Recentlythe proportion of incremental reserves from deep-water increased year by year and exceeded 50% since 2010. Deepwater exploration has become the key area of future oil and gas exploration. As one of the main reservoir for deep-water oil and gas explorationdeep-water channels have attracted more and more attention. Based on high-resolution40 Hz3D seismic datathis study carried out a detailed description of an aggradational channel-levee complex in offshore Myanmar. The centerlines of the different channels in the complex were recognized from bottom to top. The overall width of this channel-levee complex is 25~30 km. The width of the single-channel is about 300 mand the thickness is estimated to be 10 m. The channels' centerlines in this complex show an organized evolution. The channel was relatively straight with low curvature at the beginning of aggradationand the curvature gradually increase over time. During aggradationthe deep-water channels not only swing but also sweep downstream. Predecessors believed that downstream sweep is very rare in deep-water channelshoweverour research shows that this phenomenon does exit in the study area.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
Presentation Preference: Oral Preferred

Morphological and architectural evolution from inception to abandonment of submarine channels: An example from the Pleistocene Bengal Fan

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Keywords: Submarine channels, channel inception, morphological and architectural evolution, end-member types of channel belt, Bengal Fan

3D seismic data from the Bengal Fan along with spectral decomposition and RGB color blending techniques allows the exploration of morphological and architectural evolution of a Pleistocene submarine channel, from its inception to abandonment. Five main architectural elements of the Bengal channels were recognized: feeder and trunk channels, oxbows, levees, channelized and unchannelized crevasse splays, and lobe complexes. Four end-member types of channel-complex sets (CCSs) were identified: (1) straight to low-sinuosity, non-leveed (immature CCS1), (2) moderate-sinuosity, non-leveed (submature CCS2), (3) high-sinuosity, leveed (mature CCS3), and (4) high-sinuosity, leveed CCSs (supermature CCS4-5). Channelization commenced with the erosion of straight to low-sinuosity, non-leveed CCSs from an initially featureless slope, and evolves from immature through supermature CCS stages with a spatiotemporal increase in channel sinuosity (Si). A statistical analysis of channel width (W), thickness (T), and cross-sectional area (Ca) suggests that W, T, and Ca progressively increase from immature CCS1 and submature CCS2, upward to supermature CCS4 and CCS5, and to mature CCS3. Architecturally, mature and supermature CCSs have overbank levees, crevasse splays and oxbows, but immature and submature CCSs don't. Immature, submature, mature CCSs have abrupt lateral offset of channel fairways, but supermature CCSs don't.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
Presentation Preference: Oral Preferred

How do tectonics influence the initiation and evolution of submarine canyons? A case study from the Otway Basin, SE Australia

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Keywords: Submarine buried canyons, Mass wasting processes, Canyon-fill, Tectonic activity

The architecture of canyon-fills can provide a valuable record of the link between tectonics, sedimentation, and depositional processes in submarine settings. In this study, we investigate the role of plate tectonics in the initiation and evolution of submarine canyons. We demonstrate that plate tectonic-scale events (i.e. continental breakup and shortening) have a first-order influence on submarine canyon initiation and development. Initially, the Late Cretaceous (c.65 Ma) separation of Australia and Antarctica resulted in extensional fault systems, which then formed a steep stair-shaped paleo-seabed. Subsequently, the Late Miocene (c.5 Ma) collision of Australia and Eurasia has resulted in substantial uplift and exhumation in the SE Australian continental margin. These tectonic events have resulted in elevated seismicity that ultimately gave rise to the gravity-driven processes (i.e. turbidity currents and mass wasting processes) and formed the canyon base. The inherited stair-shaped topography then facilitated gravity-driven processes which established a mature sediment conduit extending from the shallow marine shelf to the abyssal plain. We indicate that the canyon stratigraphic architecture can be used as an archive to record tectonic movements. Moreover, the factors which preconditioned and triggered gravity-driven processes can also induce canyon initiation and facilitate canyon development.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Morphologic and depositional transformations of deep-water channels in the Rakhine continental margin since late Miocene and their responses to the route-shifting of the Brahmaputra River

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Keywords: Deep water channels, morphological characteristics, sedimentary constitution, sedimentary transformation, Brahmaputra River

The response of the evolution of deep-water depositional system to the shifting of sediment routing is an important topic of the current source-to-sink study. In this paper, three-dimensional seismic data and detrital zircon age spectrum data are used to reveal the transformations of deep-water channels in morphology (W = width, T = depth, C_a = cross-sectional area) and sedimentary constitution (channel development degree (C_d) = ratio of channel cumulative cross-sectional area to coincident profile area) and their responses to the changes of sediment-routing systems of Brahmaputra River. Morphologically, deep-water channels occurred in late Miocene are wide ($1837 < W < 11271$ m) and deep ($180 < T < 936$ m), with relatively larger cross-sectional areas ($0.298 < C_a < 6.252$ km^2). However, channels occurred in Quaternary are narrow ($357 < W < 1629$ m) and shallow ($31 < T < 159$ m), with relatively smaller cross-sectional areas ($0.008 < C_a < 0.167$ km^2). As for Pliocene channels, their values of widths ($858 < W < 4490$ m), depths ($77 < T < 283$ m), and cross-sectional areas ($0.049 < C_a < 0.942$ km^2) are between above-mentioned two end members. For the sedimentary constitution of deep-water channels, late-Miocene ones are absent in levees and thus, are named non-leveed channels, corresponding to high degree of development (C_d = 0.18%). On the contrary, Quaternary channels are flanked by levees and hence named leveed channels, corresponding to low degree of development (C_d = 0.015%). As for channels occurred in Pliocene, they consist of both levee ones and non-leveed ones and correspond to moderate degree of development (C_d = 0.035%). The detrital zircon core density statistics from the 362 cruise of International Ocean Drilling Program (IODP) present that the characteristic age spectrum (0-60 Ma core density age) of the Paleo-brahmaputra river has decreased gradually since the late Miocene (5.35%→4.75%→4.58%). Such fact suggests the influence of sediment-routing systems of paleo-Brahmaputra river on the northwestern margin of Bangladesh was gradually decreasing since late Miocene and accordingly, less and less sediments from Himalaya-Tibet Plateau were accumulated in the study area. Above all, it could be concluded that it was the gradual decreasing in sediment supply of the catchment (paleo-Brahmaputra river) that drived the decreases in widths, depths, and cross-sectional areas, and the degree of development of deep-water channels.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Numerical study on suspended sediment in Dongtou Archipelago areas

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Keywords: Dongtou archipelago, SSC, tides, temporal and spatial variation

Estuaries are key areas of land-sea interaction. Suspended sediment concentration (SSC) and its transportation play an important role in the ecological environment and geomorphology evolution. In this paper, a modeling study with high resolution for the Oujiang Estuary and Dongtou archipelago using a three-dimensional unstructured-grid finite-volume coastal ocean model (FVCOM) has been established and well-calibrated. Combined with the observed data, the spatial and temporal variation of SSC in the estuarine waters around the Dongtou archipelago is analyzed. The hydrodynamic model is validated with observed velocity and direction data over spring and neap tides. The results show that the tides are asymmetric in spatial and temporal distribution. The SSC peaks occur after the peaks of current velocity in the Dongtou archipelago. SSC at the bottom is more than 2 times that at the surface and the SSC during the spring tide is higher than that during the neap tide. There is lateral residual circulation between the channels of Damen Island and Xiaomen Island.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
Presentation Preference: Oral Preferred

LES-DEM numerical investigation on particle suspension mechanism in turbidity currents

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Keywords: turbidity current, particle suspension, coherent vortical structure, force analysis

Turbidity currents are a natural phenomenon that extensively happens in deep-water environment. They are essentially a fluid-particle coupled motion process. Particle suspension mechanism is the key to the evolution of turbidity currents, which affects the shape maintenance and transport distance of the currents during their propagating along the continental shelf. Nowadays, we employed the LES-DEM model to simulate the small-scale lock-exchange turbidity currents over an inclined fixed slope, with the variation of terrain slope and initial particle concentration. The advantage of this method is that it can accurately track the trajectories of individual particles and analyze their force processes while characterizing the hydrodynamics of the current. In our study, the initial particle concentration is set to 1-2%, and the terrain slope angle varies between 1/20 and 1/5. The simulation results indicate that particle suspension in turbidity currents occurs mainly near the current head, and the number of the suspension particles increases first and then decreases, closely related to the fluid vorticity. The uplift of these particles is associated with the presence of a large-scale transverse coherent vortical structure that accompanies the local low-pressure core. By force analysis , it is the bed-normal total force that determines the patterns of particles entering and exiting the suspension state. The increase in particle concentration gives rise to a significant increase in the positive bed-parallel and bed-normal total forces. This implies that not only does the advance speed increase, but also the particle suspension level of the current is enhanced. The increase of the slope angle makes the advance speed of the turbidity current along the slope slightly increase, however, the particle suspension does not depend on the variation of the slope angle under the small slope angle condition.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Deepwater Channel Characteristics and Hydrocarbon Accumulation in xisha Area

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Keywords: Xisha area,deepwater channel,seismic reflection, hydrocarbon accumulation

The xisha area is located in the northern part of the South China Sea . The seabed topography is complex . The water depth reaches 1000-3000m . Since Miocene, the xisha area was in a stable subsidence period, and its tectonic activity was not active. After the Miocene, it entered the deep-water depositional environment of the continental slope. Based on 2D seismic data, a terrigenous deepwater channel was identified in the study area. During the sedimentary period of the Upper Miocene Huangliu Formation, deep-water channel deposits with terrigenous clasts as provenance developed in the west of Huaguang Sag, Qiongdongnan Basin. Controlled by sea level, the Huangliu Formation developed three stages of deepwater channel. In the early stage of the Huangliu Formation, the development of channel was in the low sea level stage, and the developed channel were U/V downward incised channel, which had strong limitations. In the early stage, the upstream part of the channel was composed of several independent branch channels, and the downstream part of the channel converged into a composite channel system and cut each other. In the middle period of the Huangliu Formation, the development of the channel is a period of rapid sea level rise, and the channel is characterized by channel complex, which is highly restrictive. In the middle stage, there are many restricted branch channels upstream, and many independent channels downstream converge to form a channel complex. In the later stage, the early channel is cut and moved in plane. The late stage of channel development is in the high sea level period, which is characterized by channelize-lobe with weak restriction. In this period, the upstream part of the channel is a single swing channel, the middle part is a complex of several swing channels, and the downstream part is a channelize-lobe.

The three-stage Deepwater Channel is controlled by sea level changes. From the early stage to the late stage of the channel , the sea level changes from the low stage to the high stage. The restriction of the developed deepwater channel gradually weakens. The Channel develops from a single channel with strong restriction in the early stage to a channel complex with multiple channel cutting and migrating each other in the middle stage, and then transits to a channel complex and a channelize-lobe in the late stage.

The first deep-water gas field of in China has been found in the deep-water channel of the central canyon. According to the analysis of hydrocarbon source conditions, the study area has a good organic matter generation and preservation system. At the same time, the Deepwater Channel developed in the deep-water sedimentary environment of the continental slope, developed huge thick marine mudstones of Huangliu Formation, and had better sealing conditions. The sediments filled in the deepwater channel are presumed to be clastic rock ; The channel develops in the depression, and the oil and gas generated in the lower part can migrate upward along the faults controlling the depression to form reservoirs in the channel.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
Presentation Preference: Oral Preferred

Geomorphological and sedimentary characteristics of the Pearl River submarine canyon - fan system, northern South China Sea

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Keywords: Submarine canyon, Submarine fan, Turbidity currents, Mass transport deposits, Tectonics, South China Sea

The Pearl River submarine canyon - fan system (PRCF) comprises one of the most important sediment source to sink systems in the northern continental margin of the South China Sea (SCS). The system is of significant implications for understanding the sedimentary evolution of the host continental margin and for deep-water hydrocarbon and gas hydrate exploration in the same margin. Previous research on the PRCF has mainly focused on its morphological characteristics and associated sub-bottom submarine landslides, with little attention paid to the sedimentary infillings. Here we used two-dimensional seismic profiles, combined with multibeam bathymetric and scientific ocean drilling data, to investigate the geomorphological and sedimentary characteristics of the canyon-fan system.

The multibeam bathymetrical data reveal that modern PRCF extends more than 300 km from the shelf break off the paleo-Pearl River Delta in the north, via the continental slope, to the deep sea basin in the south. The system consists of the Pearl River submarine canyon in the continental margin and its connecting submarine fan at the toe of the margin. The canyon can be further subdivided into four segments, which are a head area consisting of about 19 NNW-SSE-trending submarine tributaries, a nearly E-W-oriented upper reach, a NWW-SEE-striking middle reach, and a NW-SE-trending lower reach. Overall, the canyon gradually narrows downstream. Our seismic sequence analysis indicates that the PRCF began in the late Middle Miocene. Thickness of the system is the thickest in the upper reach and the thinnest in the middle reach. Seismic facies analysis reveals that the canyon - fan system has dominantly been filled by coarse-grained turbidites and mass transport deposits, with the mass transport deposits increased upward. Little lateral swinging is observed during the development of the PRCF. Formation and evolution of the canyon - fan system are predominantly controlled by tectonics. Other factors, including sea level changes and sediment supply, may also play an important role.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
Presentation Preference: Oral Preferred

Evolution of cyclic steps and related flow process at canyon mouth on slope of the Rovuma Basin, offshore Mozambique

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Keywords: Cyclic steps, Morphology, Bottom current, Slope break, Flow process, Rovuma Basin

Cyclic steps, as a typical submarine bedform, have been intensively recorded at canyon mouth in submarine environment around world. Previous studies documented the morphology and sedimentary feature of the cyclic step and determine its formation mechanism, flow dynamic features, to reveal its downslope flow process evolution. However, the alongslope flow process under the influence of seafloor topography and ocean circulation was not taken into account fully, leading to a general lack of consensus on the spatial flow process at canyon mouth. 3D seismic data were used to depict the morphology and internal architecture of cyclic steps at the canyon mouth in slope of the Rovuma Basin (offshore Mozambique), to determine the sedimentary features of the cyclic steps and reveal its spatial flow process evolution of and related controls. The result shows that turbidity current interacts with northward flowing bottom current, resulting in northward deflection deposition of turbidity current. Sandy part of turbidity current flows along the axial direction of canyon mouth, forming a linear series of crescent-shape net-erosional cyclic steps. These cyclic steps are characterized by short steep stoss side and long gentle lee side. Muddy part of turbidity currents is deflected towards to north flank of canyon mouth by the bottom current, and deposited as undulating net-depositional cyclic steps, showing long gentle stoss side and short steep lee side, which are orthogonal to axial direction of canyon mouth and thin out away from canyon mouth. However, local slope breaks at seafloor increase the velocity of downslope turbidity current, thus enhance the erosion of flow on cyclic steps, which results in the formation of net-erosion cyclic step, making the stoss side become short and gentle, and lee side become steep.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
Presentation Preference: Oral Preferred

Quantitatively parameterizing slope channel system in Taranaki Basin, New Zealand using seismic geomorphology

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Keywords: Paleo submarine channels, seismic geomorphology, Taranaki Basin

Abstract

Understanding the geometry of paleo submarine channels gives key information about their origin and the nature of deposition within them. Quantitative characterisation of paleo submarine channel systems is seldom undertaken, whereas modern-day submarine channel characteristics are reasonably well known. This study addresses these differences by presenting extensive quantitative data (2336 measurements from 126 channel segments) about the geometry of submarine channels within the Miocene Taranaki Basin succession, using seismic geomorphological analysis. Submarine channels have been analysed from four stratigraphic intervals: lower and upper Moki Formation (16 – 13 Ma), and lower and upper Mount Messenger Formation (13 – 7 Ma). The results show differences in channel cross-sectional and planform morphology, indicating significant changes in channel geometry through time. The maximum channel cross-sectional area increases from 0.15 km2 in the lower Moki Formation to 4 km2 in the lower Mount Messenger Formation, decreasing to 1.6 km2 in the upper Mount Messenger Formation.

Lower Moki Formation channels have average sinuosity, meander length, and amplitude of 2.4, 3.2 km, and 2.4 km, respectively. By comparison, the upper Mount Messenger Formation channels have values for the same parameters of 1.0, 0.9 km, and 0.07 km. There is no relationship between Moki and Mount Messenger formation channel occurrences or characteristics with either the timing or magnitude of Miocene changes in sea level, or with short term variations in sediment flux, as suggested in previous work. Instead, longer term changes in subsidence and, in particular, marked progradation of the shelf-slope system and increasing slope gradient, due to increasing rates of sediment supply to the basin through the Miocene, have controlled the frequency and characteristics of the channels. There are close parallels between Miocene Taranaki channel geometry and modern fluvial channel geometry despite orders of magnitude difference in their dimensions.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
Presentation Preference: Oral Preferred

Hydrothermal plume and particle transport in stratified environment

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Keywords: Hydrothermal plume, Particle transport, Dynamic characteristics, Computational fluid dynamics

Buoyant plume refers to the plume flow form of fluid driven by buoyancy completely or partially in environmental media. It widely exists in nature and human activities, such as near SST drainage, deep-sea hydrothermal plume and so on. At present, there are more than 700 hydrothermal vents in the world, of which nearly 200 have temperature information. There are significant differences among different vents, but the attention to low-temperature vents is still very low. On this basis, based on the fluent simulation results, the influence range and material diffusion law of deep-sea hydrothermal vent plume under different temperatures and different background flow conditions, including high-temperature and low-temperature hydrothermal field, are analyzed, which is of great significance for chemical growth and hydrothermal ecological community reproduction. While exploring the impact of hydrothermal vents at different temperatures on biological communities, based on the coupled simulation of fluent and edem, this paper analyzes the transport mode of different material particles under the hydrothermal source under the condition of transverse flow, which is helpful to guide the exploration and development of mineral and sulfide resources and reveal the origin of early life on the earth. The research shows that the hydrothermal plume at different temperatures has different plume rising height, mass flux, heat flux and influence range. The sedimentation laws between different material particles are summarized, and on this basis, the transport and deposition laws of different particles under the background flow of layered environment are given quantitatively. The research results have supporting value for the tracing of submarine hydrothermal vents, the study of marine material and energy cycle process, the exploration of seabed mineral resources and environmental assessment.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
Presentation Preference: Oral Preferred

Characterization and Exploration Potential of Deep-water Depositional System in the Rakhine Basin, Myanmar

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Keywords: deep-water,depositional system,exploration potential,Myanmar

The current study documents the seismic facies of deep-water elements of Bengal Fan in Rakhine Basin, Myanmar and addresses their exploration potential. Several gas reservoirs have been discovered in different elements of deep-water systems in Myanmar, such as frontal splays, overbanks, channel complexes and mass transport deposits.

Our observations and results suggest that the depositional elements primarily evolve from confined channel complexes during Eocene to Early-Middle Miocene to channel-levee complexes during Late Miocene to Holocene based on integrated subsurface dataset including high-resolution 3D seismic data and various drilling data as long as some Submarine canyon complexes and mass transport complexes are identified, which is controlled by paleogeomorphology and sediments input coupling the regional tectonic movements.

Four dominant kinds of depositional elements were established based on seismic facies and wireline-log interpretation, namely submarine canyon complex, mass transport complex, confined channel complex and aggradational channel-levee complex. The latter two complexes are tended to relative sand rich and be of better exploration potential. Moreover, the two complexes mainly developed as straight and parallel to each other along North-South in the west part of Rakhine Basin, and more sinuous, frequently migrating stack in the east part of Rakhine Basin, which indicate the difference of paleogeomorphology, sediment supply and potential sand reservoir. For confined channel complexes, the erosional fairway elements, are large and prominent incision flanked by wedge-shaped outer levees. Channel-axis deposits are characterized by discontinuous high amplitude reflectors that are formed by lateral and vertical migration of coarse-grained channel thalweg deposits. Inner levees are characterized by chaotic, or transparent low amplitude reflectors with a stepped shape. Seismic reflections within outer levees are almost always continuous, but can range from low to high amplitude. For aggradational channel-levee complexes, levee sediments are characterized by low amplitude, continuous, and/or relatively transparent reflectors with a double-wedge shape that thins away from channel-fill sediments that characterized by high amplitude, discontinuous reflections on seismic. Within the complexes, secondary classifications were defined to feature the migration of the depositional system.

We infer that the complex and its subdivisions are related to the presence of good reservoirs not only the thickness and distribution but also the physical properties. The elements are statistically analyzed by seismic characterization and gas reservoir parameters and the exploration potential are predicted. The trapping potential includes the structural trap related to the compressional anticline strike to NW-SE and the stratigraphic trap draping on the wings of the structures or sand pinch-out. Comprehensive consideration of the match between structure and depositional system, it is possible that more traps are favorable to develop in the east part of Rakhine Basin because of the larger structure relief and richer sands, and more important is the possible better source kitchen near to the continental sediments supply.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
Presentation Preference: Oral Preferred

Evolution, 3D-architecture and Reservoir of the Deepwater Channelized System-Insights from rifted lacustrine and deep marine basins

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Keywords: deepwater channelized system, sequence stratigraphy, reservoir architecture

The deep lacustrine and marine fan are usually composed of channelized system instead of homogeneous sandstone lobe. This study characterizes the depositional evolution and 3D-architecture of the deepwater channelized system using 3D seismic, well logs, outcrops, and core data in the representative Paleogene rifted lacustrine Bohai Bay Basin, Pleistocene deepwater Gulf of Mexico. The results reveal the deepwater channelized system evolves from an unorganized amalgamated pattern by high energy flow to an organized distributary pattern by low energy flow from the bottom to the top in a 3rd order depositional sequence, with an upward increase in sinuosity and decrease in aspect ratio, and aggradation updip and lateral migration downdip.
. The high-density sandstone is deposited in the proximal setting and the low-density sandstone is deposited in the distal setting. The best reservoir is determined by the sediment source, slope gradient, bathymetry, and facies. The amalgamated turbidite sandstone and trunk channel sandstone sourced from the underlying delta front have the best reservoir quality.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
Presentation Preference: Oral Preferred

Sedimentary configuration, evolution and controlling factors of upper Indian fan channel-embankment composite system since Miocene

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Keywords: upper Indus Fan, channel-embankment system, controlling factors

Based on the parameters such as submarine canyon, seismic reflection characteristics, superposition patterns, spatial distribution and time scale, we put forward the identification standards of channel-embankment system of different levels, and established the division methods of channel-embankment composite system. The upper Indus fan channel-embankment composite system is systematically divided. We have selected typical seismic profiles, finely divided the types and characteristics of seismic facies (internal reflection structure and external form) of upper Indus fan channel-embankment composite system, characterized the spatial combination relationship of various seismic facies, and established the sedimentary configuration of different levels of upper Indus fan channel embankment system. Combined with the isochronous stratigraphic framework established by previous studies, we analyzed the differences of the seismic facies characteristics and the sedimentary configuration in the near end, middle end, far end (space) and early-middle-late (time) of channel-embankment system at all levels. Combined with the tectonic background, provenance, paleoclimate, sea-level fluctuations, we analyzed the controlling factors of channel-embankment system evolution at different levels, and finally established a complete spatial-temporal evolution model of upper Indus fan channel-embankment system since Miocene.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
Presentation Preference: Oral Preferred

Channel inception through bottom current erosion of pockmarks: a numerical simulation study based on the geophysical research in western South China Sea

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Keywords: Channel, Pockmark, Bottom currents, Numerical simulation

In deep-marine environments, ocean currents can sculpt the seafloor and control the development of channels by their interaction with rough topography, while the necessary conditions and controlling factors for this process are still unclear. Based on geophysical data analysis, a comprehensive channel system is identified in the western South China Sea, and the alongslope channels in this channel system are proved to be formed by the interaction between bottom currents and pockmark trains (Yu et al., 2022). In order to reveal the process of channel inception through bottom current, a numerical simulation study is conducted based on the morphological, sedimentary and oceanographic settings documented in Yu et al. (2022). The simulation results show that the bottom currents can erode pockmark trains in cohesive sediments, when they are in an appropriate velocity. The action of bottom current will lead to the coalescence of discrete pockmarks and the formation of an “immature channel” with a rough thalweg, as observed in the study of Yu et al. (2022). The interaction of bottom currents with the pockmarks induces a significant seafloor erosion at the streamwise edges of the pockmarks and at the seafloor between pockmarks. Bottom current erosion is strongest at the downstream edges of pockmarks, where the horizontal velocity reaches a maximum and an upwelling forms. The bottom-current erosion also increases as the reduction of pockmark interval distances. There is a maximum distance between pockmarks that can be coalesced by bottom-current erosion into a channel, which is ~6 times the diameter of the pockmark according to the simulation results. This study provides evidence and details of the formation of channels by bottom currents, which helps reconstruct paleoceanographic conditions based on the sediment architecture. It also shows the complex hydrodynamics at these structures that strongly control sedimentary processes and may affect distribution of benthic ecosystems in deep-water environments.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
Presentation Preference: Oral Preferred

Sequential bedform development in mixed turbidite–contourite systems: An example from the Cosmonaut Sea, East Antarctica

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Keywords: Mixed-system bedforms, sediment waves, furrows, Cosmonaut Sea, Antarctica

Mixed turbidite–contourite depositional systems are commonly found on continental margins, but their bedforms and associated sedimentary processes have not been studied in depth. In this work, we used multibeam echo-sounder, sub-bottom profiling, and multichannel seismic data from the continental rise of the Cosmonaut Sea, East Antarctica, to (1) identify primary bedforms in a combined-current (i.e., turbidity current + contour current) channel–levee system and (2) inferbedform-associated sedimentary processes. Within turbidite channels and on adjacent levees and distal overbank deposits, scours, furrows, and sediment waves of varying dimensions and trends were identified. These bedforms are interpreted to have formed in two steps, which have been likely repeated over and over again through time. First, scours and sediment waves within the channels were formed by turbidity currents, while sediment waves on adjacent levees were likely formed by synchronous interactions between overspilled unconfined turbidity currents and the Antarctic Bottom Water (AABW) contour current. Second, after waning of the episodic turbidity currents, AABW flow created a field of erosional furrows on a distal overbank, with these furrows truncating the large field of sediment waves earlier generated by the combined flow of interacting currents. Bedform locations, orientations, and truncating relationships are key for identifying the likely origins of mixed-system bedforms.

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Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
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Characteristics of debrites, turbidites and contourites in the Upper Ordovician Pingliang Formation along southwestern margin of the Ordos Basin, western China

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Keywords: debris flow, turbidity current, contour current

Deep-sea deposit is one important work in sedimentological field, but work on the ancient sedimentation is relatively rare, especially about relationship between sedimentary record and paleo-environment. Using outcrop, petrography, paleocurrent, trace element, δ13C, δ18O, 87Sr/86Sr, etc., deep-sea deposits had been researched in the Ordovician Pingliang formation along southwestern margin of the Ordos Basin. The Pingliang formation could be divided into five typical lithofacies. Lithofacies 1 is horizontal-bedded micritic limestone, mudstone, chert layer and tuff, which is correspongding to deep-water autochthonous deposits. Lithofacies 2 consisting of calcirudite with massive bedding, result from debris flow deposits. Lithofacies 3 is graded bedded calacrenite with imcomplete Bouma sequence indicating calacentie turbidites. Lithofacies 4 consisting of bioturbated and cross-lamination micrite with fine-coarse-fine sequence, it is due to low energy contour current. And cross-lamination lens-shaped calcarenite (lithofacies 5) being various scale of fine-coarse-fine sequence, is higher energy contour current deposits. The δ13C, δ18O, 87Sr/86Sr and trace elements of these lithofacies show distinctly different features. They are helpful to reconstruct paleo-environment including relative sea-level, paleosalinity, and paleoclimate. The relative sea-level showed rising feature consisting of 3 rising-falling cycles, paleosalinity also display 3 high-low cycles, and the paleoclimate conclude 4 dry-moist cycles. Contour current usually active dramatically when relative sea-level is rising, salinity changes obviously and environment is relatively moist, but turbidity current and debris flow are inverse.

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Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
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An integrated approach using electrical logs, petrography, and sequence stratigraphy for the determination of depositional environment of Cambrian Khewra Sandstone in Potwar Plateau, Northwest Himalayas: Deltaic Vs Coastal (Beach-Aeolian) with present day analogues

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Keywords: Khewra Sandstone, Potwar, Deltaic, Coastal Plain , GR Facies

Khewra Sandstone of Early Cambrian age is proven reservoir rock of Potwar Plateau, Upper Indus Basin, Pakistan. The Khewra Sandstone is largely considered as deposit of deltaic environment. Whereas few geologists are of the view that Khewra Sandstone is part of coastal plain. The distinction between the deposits of above two environments is often very difficult in the absence of regional seismic data.This paper is based on comparative studies of GR facies of Khewra Sandstone and its relative interpretation in Adhi Field. The study shows that over all lithology of Khewra sandstone is same in Potwar and Salt Range & is interpreted as part of coastal plain deposit with mixed Beach-aeolian environment.

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Session T6-3: Deep-water channels: Morphology, architecture, flow dynamics
Presentation Preference: Oral Preferred

Seismic expression, distribution, and paleo-oceanographic implications of contourite deposits in the Browse Basin, offshore NW Australia

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Keywords: Contourites, NW Australia, Deep marine deposits, Sedimentology, Facies

Contourites are marine sediments deposited by thermohaline-induced bottom currents. The distribution, geometry, and size of these deposits are controlled by the presence, direction, and strength of their causal currents, thus they can be sensitive indicators of changes basin geometry, sea-level change, tectonics, and (paleo)oceanography. In this study we use 2D seismic reflection datasets (covering an area of c. 75,000 km) from the Browse Basin, offshore NW Australia to study the interaction between marine currents and tectonics. This is a key location to study, given the abundance of geophysical imaging, and the past and present occurrence of several major thermohaline currents that swept a tectonically active margin. Using 2D seismic data has an advantage since they image large areas of the Earth's subsurface; however, the spacing between individual 2D lines (i.e., 10 km by 10 km) mean it can be difficult to map the distribution and orientation of the contourite deposits smaller than that spacing. We show that the basin contains five main Palaeocene-to-Miocene and Recent seismic-sequences (S1 to S5), which in this area and for the purpose of this work were divided into two main groups. Group 1 comprises seismic sequences (S1-S2) and each of them are 800-1000 ms TWT thick, containing continuous to semi-continuous, low-to-moderate amplitude reflections. It is important to note that S2 can be split into two sub-sequences; the lower sub-sequence has a similar seismic expression to S1, whereas the upper one contains discontinuous, low-amplitude reflections, maybe suggesting slight changes in the energy conditions. The seismic character of Group 1 (and the lower part of S2) is not strongly indicative of deposition under the influence of contour currents, thus we infer they reflect deposition under pelagic to hemipelagic conditions. The second group comprises the middle to upper seismic sequences (S3 to S5) and has a very different seismic expression to Group 1, recording different depositional conditions. The internal reflections found in the sequences of Group 2 define constructional contourite bodies that are locally scoured by channels. S3 contains large (400 ms TWT high by 10 km long wide by 5 km long) clinoforms that are intensely gullied. These clinoforms may document progradation of the carbonate-dominated basin margin or the development of giant bedforms under the influence of bottom currents. Sequence S4 also contains large (up to 300 ms TWT high), steeply dipping clinoforms, whereas the shallowest and youngest sequence, S5 extends up to the seabed and contains abundant evidence for locally deep (up to 200 - 300 ms TWT by a few hundred metres wide) erosion, and the formation of contourite bedforms and related scours found in Group 2, maybe controlled by the Antarctic Intermediate Water and the NW Indian Intermediate Water or their ancient predecessors. Thus, sequences S3 to S5 record a contourite-bearing depositional system strongly affected by the action of bottom currents. The distribution and scale of the described geo-bodies permitted us to interpret potential directions of the bottom currents affecting the deposits, showing how they may have changed as the basin evolved.

Session T6-5: Asian continental margin sedimentation: Processes and records

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Session T6-5: Asian continental margin sedimentation: Processes and records
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Depositional patterns and potential analysis of the 2nd member of the Shahejie Formationin J oilfield of the Liaodong Uplift , Bohai Sea

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Keywords: J oilfield, The 2nd member of the Shahejie, reservoir, Depositional patterns, potential analysis

The clastic rocks, dolomite and their mixed deposits were drilled in the Es2 of the Paleogene in the J Oilfield. The rapid lateral variation and unclear distribution of the above three types of rock reservoirs have affected the exploration of J Oilfield. Based on logging data, core description, conventional sheet and cast sheet, combined with palaeotopography, paleoclimatic, and paleo-salinity, the study shows that braided channel delta deposits, carbonate platform deposits, deep lake deposits and semi-deep lake deposits are mainly developed in the Es2, and the above three show the characteristics of the wax and wane. The potential for development of dolomite reservoir is small through the study of the main controlling factors of the reservoir physical properties on the basis of sedimentary model, thin section observation and correspondence physical properties analysis, combined with the reservoir distribution characteristics. The sand body on the west side with larger potential is widely distributed on the early age of Es2 Formation according to the seismic phase and attribute characteristics, which is the next major area of adjustment. This method can be used for reference to research similar reservoirs and tap potential in Bohai Bay basin.

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Session T6-5: Asian continental margin sedimentation: Processes and records
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Response of marine terrigenous sediment to source-sink processes and weathering intensity in the northern South China Sea since the past 244 kyr

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Keywords: South China Sea, continental margin, Kuroshio intrusion, sea-level change, chemical weathering

The Asian continental margin has been an ideal natural laboratory to catch a glimpse of paleo-climate and source-to-sink processes. However, exploring the past environment information documented in marine siliciclastic records requires a comprehensive knowledge of the influence of sea-level fluctuations, chemical weathering, sediment provenance, and particulate transport on proxies' interpretation. The northern South China Sea (SCS) margin has attracted plenty of investigations due to huge sediment discharges and continuous deposition since the late Cenozoic. Here, based on a 35 m-long sedimentary core (MD12-3429) retrieved from the northern SCS continental slope, we present the results of mass accumulation rates (MAR), grain-size end-member modeling, elemental compositions, and Sr-Nd isotopes in siliciclastic sediments, in order to extract the chemical weathering and Kuroshio intrusion signals stored in marine terrigenous sediment over the past 244 kyrs. On the basis of major and rare earth elements and Sr-Nd isotopic data, Taiwan rivers were identified as the primary source for terrigenous particles in the core, while the sediment from the Pearl River increased during the glacial period. According to grain-size end-member modeling and MARs results, two different hydrodynamic modes, the sea level changes and the Kuroshio intrusion, govern the sediment source-to-sink processes on the continental slope. On the one hand, the dropped sea level promoted the progradation of paleo-Pearl River mouth, which lead to its contribution increased during low-stand intervals. On the other hand, enhanced Kuroshio intrusion into the northern SCS during the prevailing winter monsoon period and El Niño-like conditions might have played an important role in transporting Taiwan sediment during glacial-interglacial cycles. Most major elements and weathering indices (such as CIA, CIW) show great correlation with Al_2O_3/SiO_2, indicating significant hydrodynamic effects. The K/Al ratio and the stacked chemical weathering index (SCWI) were applied to reconstruct the history of chemical weathering. For the past 244 kyr, our chemical weathering indexes generally exhibited high weathering intensity in the interglacial period that in the glacial period and can correlate well with Younger Dryas (YD), Heinrich 1 (H1) events, indicating climate-depend of chemical weathering intensity. Nevertheless, strengthening chemical weathering intensity periods were also observed during two glacial intervals (MIS5 and MIS3). We propose that subaerially exposed and chemically weathering of Taiwan sediment on the continental shelf may account for this phenomenon.

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Session T6-5: Asian continental margin sedimentation: Processes and records
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Shelf-margin architecture and deposition variability across the mid-Pleistocene climate transition, northeastern South China Sea

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Keywords: Sequence stratigraphy, glacio-eustasy, shelf-margin growth, mid-Pleistocene climate transition, Pearl River Mouth Basin

The shelf-margin prism of the Upper Pliocene to Pleistocene in the northeastern South China Sea has recorded significant signatures of glacio-eustatic cycles and paleo-climatic conditions. Integrated analysis of 3D seismic, well-logging, and borehole dating data in the study area provided a detailed depiction of the high-resolution sequence architecture and depositional evolution as they responded to the glacio-eustatic cycles and climate changes. The shelf-margin section of the Upper Pliocene to Pleistocene is comprised of a composite sequence bounded by a regional unconformity, which can be further divided into five sequences confined by subordinate unconformities. The two lower sequences (S1-S2) with similar and simple internal structures, are displayed as having roughly equal thicknesses (ca. 50 m) and gently seaward-dipping foresets. In contrast, the upper three sequences (S3-S5) are characterized by the development of high (200–600 m) and steep (2–5◦) shelf-margin clinoforms, which can be further divided into fifteen clinothems. The sequences generally embody four systems tracts, showing different stratal stacking patterns, and the linking contemporaneous depositional systems including fluvial channels, deltaic and slope fan systems are documented. Based on the chronostratigraphic framework, comparisons have been made between the sequence cycles and the global oxygen isotopic records. The results suggest that the formation of different order sequences may have been in response to the glacioeustatic cycles paced by the Milankovitch orbital cyclicity. The abrupt changes in the sequence and depositional architectures between S1-S2 and S3-S5 are assumed to be related to the significant increases in the amplitudes and durations of the glacio-eustatic fluctuations across the mid-Pleistocene climate transition (MPT). Intensively variable climatic conditions with strengthened monsoons during and after the MPT could have potentially led to an abundant sediment supply, which may have enhanced the development of shelf to shelf-edge delta systems with the large-scale prograding clinoforms.

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Session T6-5: Asian continental margin sedimentation: Processes and records
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OSL and radiocarbon dating of a core from the Bohai Sea in China and implication for Late Quaternary transgression pattern

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Keywords: Bohai Sea, Transgressions, Late Quaternary, Quartz OSL dating, Radiocarbon dating, Sea-level changes

The Bohai Sea is a semi-enclosed continental shelf sea in northern China. Three transgression layers have been identified from the Late Quaternary strata in the western Bohai Sea and the coastal regions, which provide critical information on Late Quaternary sea-level fluctuations and landscape development. The three transgression layers were previously assigned to Marine Isotope Stage (MIS) 1 (transgression 1, T1), MIS 3 (T2) and MIS 5 (T3), respectively, mainly based on 14C dating. However, this chronological framework aroused an enigma that the regional sea level in MIS 3 was even higher than that of MIS 5, conflicting with the context of global sea-level pattern. In order to clarify this issue, here quartz optically stimulated luminescence (OSL) dating (four samples) was used to constrain the T2 chronology of borehole TJC-1 from the western Bohai Sea. Radiocarbon samples (eight) of peaty sediments were also measured for reference and comparison. All the four OSL samples showed saturation ages of >80 ka, suggesting that the T2 layer should have formed at least in MIS 5, instead of in MIS 3. Radiocarbon ages in T2 should have been severely underestimated, with a saturation age range of 22-30 cal. ka BP, similar to all the previous published radiocarbon ages. The renewed OSL chronological framework for Late Quaternary transgressions in the western Bohai Sea is in better compliance with the history of global sea-level change.

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Session T6-5: Asian continental margin sedimentation: Processes and records
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Suspended sediment transport in Minjiang River Estuary and northern Taiwan Strait-TS system

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Keywords: sediment transport, river plume,. muddy sediment area, Taiwan Strait, Minjiang River Estuary, bottom tripod observation

The muddy sediment area in the north of the Taiwan Strait is the end of the mud belt along the coast of Zhejiang and Fujian. Its material source is affected by the substances entering the sea not only from the Yangtze River, but also a from nearby Minjiang rivers and rivers on the west coast of Taiwan. Therefore, the study of material transport in the mud sediment area in the north of the Taiwan Strait is of great significance to understand the material source and sedimentary environment evolution at the end of the Zhejiang Fujian mud belt. The observation results show that the salinity of the surface water in the Minjiang Estuary and northern Taiwan Strait gradually increases from the Minjiang Estuary to the south, the lowest salinity occurs in the southern Minjiang Estuary, the highest chlorophyll value appears, and the water turbidity is relatively high, indicating that the water body in this area is obviously affected by the Minjiang River. The salinity of the bottom water is the lowest in Xinghua Bay, and gradually increases towards the mid-Taiwan Strait. The areas east of Pingtan Island is covered by high salinity water, while the chlorophyll value is very low, indicating that this horizon is no longer affected by the substances delivered by Minjiang River. The high value area of water turbidity mainly occurs from the coastal waters around Pingtan Island to the Xinghua Bay estuary.

The bottom tripod observation results show that the salinity of the water on the north side of Pingtan Island changes greatly during the tidal cycle. During the low tide, it is obviously affected by the river plume from the Minjiang estuary, and the sediment transport is carried to the southeast, indicating that the sediment from the Minjiang River into the sea makes a great contribution to the muddy sediment area in the north of the Taiwan Strait.

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Session T6-5: Asian continental margin sedimentation: Processes and records
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Linking source and sink: geochemistry and zircon U-Pb ages provenance record of drainage systems in potential provenance area and Yinggehai-Qiongdongnan Basin, South China Sea

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Keywords: Yinggehai Basin, Qiongdongnan Basin, Provenance, Geochemistry, Zircon U-Pb age

The Yinggehai Basin (YGHB) and Qiongdongnan Basin (QDNB) has received a large amount of terrigenous sediment from different continental blocks since the Paleogene, preserving Cenozoic sedimentary records of the Tibetan Plateau uplift, the tectonic activity of the adjacent plate, and climate change in Southeast Asia. Large scale of oil and gas reservoirs have been discovered in the YGHB and QDNB recently, but the provenance of the marine sediments in this area are poorly understood. In this study, sandstone samples were taken from drilling cores in the joint area of YGHB and QDNB, and cover all Oligocene, Miocene and Pliocene formations. The trace element, rare earth element (REE) and detrital zircon U-Pb geochronology of sedimentary rocks from the Oligocene to Pliocene is examined in this study to investigate the temporal and spatial variations in provenance since the early Oligocene. The Red River has been supplying sediments with positive Eu anomalies from basic-ultrabasic metamorphic and volcanic parent rocks to most parts of two basins, while Hainan Island has delivered sediments with negative Eu anomalies from granitic and sedimentary parent rocks to the eastern slope area of YGHB. The U-Pb ages of detrital zircon range from 3000 to 30 Ma, suggesting that sediment input is derived from multiple sources. Importantly, the Upper Oligocene Formation contained exclusively Cenozoic, Mesozoic, Palaeozoic, and Proterozoic zircon ages, and the age spectrum showed two major peaks at ca. 245 and 423 Ma, indicates that Upper Oligocene sediments in the northwestern area of the QDNB may have originated from the Red River, which had four major peaks at 254, 418, 751, and 1848 Ma, suggesting that sediments from the Red River entered the QDNB as early as the Late Oligocene. Detailed analyses of these components indicate that both the Red River and Hainan are likely the major sources of the sediments in the two basins, with additional minor contributions from Central Vietnam. The reconstructed provenance evolution model reveals that the Red River Provenance (RRP) provided the sedimentary materials for the Central Depression in the YGHB and western QDNB from the Oligocene to the Pliocene, and it was also one of the sources of the sediments deposited on the Yingdong Slope during the Miocene. Most of the sediments preserved in the Yingdong Slope and QDNB areas were derived from the Hainan Island Provenance (HIP) from the Oligocene to the Pliocene, and sediments deposited in the Central Depression in the YGHB were also derived from the HIP during the Miocene. The joint area of two basins had a mixed sediment source area, including the RRP and HIP, during the Cenozoic.

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Sediment provenance and drainage evolution of small mountainous rivers in Taiwan since the last glaciation

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Keywords: provenance analysis, climate change, source-to-sink, Late Quaternary, East Asia, clay minerals

As an important component in East Asia sediment source-to-sink systems, small mountainous rivers in Taiwan deliver disproportionately large amounts of sediments to oceans. Although the modern fluvial sediment transport processes, discharge fluxes and sediment compositions have been well investigated, the drainage evolution of these mountainous rivers remains understudied and sediment fluxes are expected to vary greatly in glacial-interglacial cycles due to the tremendous climatic fluctuations. To define how the drainage of Taiwan mountainous rivers has evolved since the last glaciation, we target a sediment core (98 m in length) from the Zhuoshui River delta, western Taiwan and use sediment petrography, heavy mineral analysis, detrital zircon U-Pb geochronology and clay mineralogy to investigate provenance variations and river basin evolution since 60 ka. Sediments of the last glaciation show comparatively high illite crystallinity index values, low metasedimentary lithic fragment and stable heavy mineral contents and similar detrital zircon U-Pb ages with downstream signatures, indicating prominent sediment contributions from the Coastal Plain and Western Foothills regions (elevation < 1 km) during the glaciation. However, characteristics of the deglacial and Holocene sediments indicate high contributions from the higher Hsueshan Range and Central Range regions (elevation > 1 km). We suggest that headward extension and drainage capture since the deglaciation, which was most likely due to the increasing monsoon rainfall, account for the provenance variations in the discharged sediments. This implies a climate-driven drainage reorganization of the small mountainous rivers in Taiwan since the last glaciation. Our findings highlight the previously-overlooked, variable provenance information from Taiwan in glacial-interglacial cycles, and the dynamic source signatures are important to East Asia sediment source-to-sink studies.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
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Origin and Paleodepositional Environment of the Early Cretaceous Chert in Taolin area, Riqingwei Basin, Eastern China: Evidence from Geochemical Study

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Keywords: The continental margin of East Asia, Riqingwei Basin, siliceous rock, orgin, paleodepositional environment

In this study, we performed an inorganic geochemical study of cherts from the Lower Cretaceous Laiyang Formation in Taolin area, Riqingwei Basin, located along the continental margin of East Asia. The study about cherts in Taolin area is relatively weak, so far, the origins of it include exhalative sedimentation, sedimentary-hydrothermal alteration, etc. The goal of this study is to determine the origin and paleodepositional environment of the chert and to establish a depositional model for the Laiyang Formation. An integrated study, involving outcrop investigation, optical observation, X-ray diffraction (XRD) and major, trace and rare element analysis, has been performed on eight chert samples from the Laiyang Formation. These samples contain highly abundant exhalative textures and structures, such as laminae and banded textures, mesh-vein structures and contemporaneous deformations. Thin sections and XRD analyses show that in addition to terrigenous clastics, chert samples are mainly composed of cryptocrystalline to microcrystalline quartz. Based on the petrographic analysis, SiO_2 (58.48%~70.11%; average 63.55%) , Ba/Sr (1.86~6.45; average 3.63) , ΣREE (201.25~247.99; average 221.10) results, $SiO_2/(K_2O+Na_2O)$-MnO/TiO_2 diagram and Fe-Mn-(Cu+Ni+Co)×10 ternary diagram, the chert samples are primarily hydrothermal in orgin, however, portions of samples exhibit effect of terrigenous detrital material. Additionally, $100MgO/Al_2O_3$ (14.11~25.61; average 19.39) , Cu/Zn (0.05~0.44; average 0.24) , MnO/TiO_2 (0.05~0.42; average 0.16) , Al/(Al+Fe+Mn) (0.69~0.85; average 0.75) , δCe (0.86~0.96; average 0.91) and $(La/Ce)_N$ (1.36~1.59; average 1.47) results indicate that the chert samples were deposited on a continental margin in an anoxic environment with strong hydrodynamic conditions. In combination with previous research results, we could conclude that the siliceous rock formed in a continental margin extensional environment.This environment was characterized by well developed hydrothermal activity and anaerobic condition, which was conducive to enrichment of Si and such increased influx of silica to seawater may have been related to the early rifting induced by volcanism. Si-rich hydrothermal fluids were ejected through submarine vents and mixed with seawater to crystallize and precipitate fine siliceous particles, which then underwent diagenetic transformation to form siliceous rocks.

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Session T6-5: Asian continental margin sedimentation: Processes and records
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Evolution of Asian large rivers recorded in the East and South China Seas

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Keywords: Provenance analysis, Source-to-sink, Large river, Drainage reconstruction, China Seas, Tibetan Plateau

Large rivers are bloodlines of continents. Those originating from the Tibetan Plateau and traversing continental East Asia play a critical role in shaping surficial landscape and discharging sediment and nutrient. Although the history of these rivers is relatively short due to continuous Cenozoic perturbations, it has been a long journey to reconstruct their birth and dynamic evolution in which many puzzles and challenges remain. In addition to drainage basin morphometry and thermochronometry and paleoaltimetry of source terranes, the river history is documented in provenance information of ultimate sediment sinks in the China Seas but a regional-scale correlation of provenance data is still developing. In this study, we explore the promise of this holistic perspective in restoring the evolution of three arteries of China (the Yangtze, Pearl, and Red rivers), by compiling and reevaluating a large volume of published provenance data (zircon U-Pb geochronology, K-feldspar Pb isotopes, and whole-rock Nd isotopes) from Cenozoic strata of the East and South China Seas and records of the large river basins. We go beyond the classical averaged paradigm of provenance signatures by carefully investigating intersample variability to provide a basis for grouping comparable samples and detecting outliers. The general inheritance of zircon age spectral patterns and small fluctuation of Nd isotopes in the Neogene strata suggest provenance stabilization in the China Seas and establishment of near-modern drainage configurations. The paleo-drainage basins before the Miocene are interpreted to be smaller than their modern sizes and drainage expansion likely occurred over the Oligocene. Our analysis suggests that the widely accepted model of drainage capture between the Yangtze and Red rivers and its variants may be unlikely. Provenance signatures and paleocurrent measurements of the Paleogene strata distributed in the southeastern Tibetan Plateau margin show inclination to source supply from local terranes instead of through-flowing river systems.

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Session T6-5: Asian continental margin sedimentation: Processes and records
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Orbital- and millennial-scale sea ice variations in the Northern Okhotsk Sea shelf since the Last Glacial Maximum

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Keywords: sea ice, ice-rafted debris, endmembers analyses, the Okhotsk Sea

Sea ice plays a crucial role in Earth's climate system and its past reconstruction is important to investigate the connections and feedbacks with other climatic components. The sea-ice conditions in the Okhotsk Sea are critical variables for assessing the evolution and response of the surface hydrography and the Okhotsk Sea Intermediate Water to the global climate change. Previous researchers have focused on the south-central part of the sea, however, the history and mechanism of the sea-ice conditions, especially in the source area of the sea-ice formation, are still controversial. Here we examine the history of sea ice activity recorded in core LV87-54-1 recovered from the northern Okhotsk Sea shelf using high-resolution grain-size analyses. We extracted 4 endmembers and use EM4 as the sea-ice proxy, useing AnalySize, a program developed by Matlab platform, to conduct endmembers analyses on the data. According to the ice-rafted debris (IRD) results, seasonal sea ice was persistently predominant in the northern shelf of the Okhotsk Sea since the last glacial. The EM4 content was high and the sea ice activity was intense during the Last Glacial Maximum and Heinrich Stadial 1, while the extreme cold climate condition and weakened moisture transport would allow more sea ice formation. Meanwhile due to relative amplification of the Siberian High with its influence on the northern and eastern Asia, and weakening of the Aleutian Low and location of its center in the northeastern Pacific, strong northern geostrophic winds predominate over the Okhotsk Sea, leading to the active sea ice formation. Sea ice formation decreased at the onset of the Bølling-Allerød warm period. EM4 and IRD levels remained low stably since 11.4ka due to: the Amur River injected more warm fresh water into the Okhotsk Sea, which suppresses subsequent sea ice formation during periods of enhanced East Asian; owing to weakening of Siberian High situated distantly from northeastern coast of Asia, and amplification of Aleutian Low situated in northwestern Pacific near the eastern coast of Kamchatka, eastern geostrophic winds with both northeastern and southeastern components are dominated in the Okhotsk Sea during winters, which occurs a decrease in the sea ice coverage.

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Session T6-5: Asian continental margin sedimentation: Processes and records
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Source-sink processes at different scales in the Bay of Bengal since the Last Glaciation and their climate control mechanisms

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Keywords: Source-sink, sedimentary pattern, Indian summer monsoon, sea level, Bay of Bengal

Based on the surface and core sediment samples collected from the Bay of Bengal (BoB), source-sink processes at different scales since the Last Glaciation were investigated. We set up a modern sedimentary model with currently highest spatial resolution in the BoB; established age model with high temporal resolution since the Last Glaciation; clarified provenance mixing models and quantified their contributions; made it clear the periodic variation characteristics of terrestrial input and their relationship with the Indian summer monsoon (ISM) and sea-level changes. A “2-3-2” provenance mixing pattern was suggested in the central BoB: Himalaya + Indian Peninsula in the west, Himalaya + Myanmar in the east, Himalaya + Indian Peninsula + Myanmar in the central. Sea level and ISM play controlling roles in the terrestrial supplement from different provenances. The sea level mainly controls the sedimentary pattern through the transfer of the depositional center in the glacial-interglacial scale, while the ISM controls the sediment generation, transport, and deposition process through the control of erosion production, precipitation, runoff, and monsoon circulation. Materials from Indian Peninsula and Myanmar were mainly carried through the surface monsoon circulation. Compared with period before the Holocene, the intensity of the ISM and thus, the southwest monsoon circulation strengthened, which enhanced the transport of Indian Peninsula material to the study area, while the materials from the Indo-Burman Range and Irrawaddy River were limited since they were mainly transported through the northeast monsoon circulation. The estimation results of the quantitative inversion model support the general understanding that the Himalayan source has been dominant since the Last Glaciation, with an average contribution of 70%. However, sediments from the Indian Peninsula and Myanmar have also contributed significant mass to the central Bay of Bengal since 25 ka, especially since 7.5 ka, which has been neglected in previous studies. The percentage of provenance end-member contribution in the Last Glacial Maximum, Heinrich 1, early Holocene climatic optimum, and middle-late Holocene was significantly different, which was closely related to the evolution of the ISM at the millennium scale. The periodicity analysis shows that the percentages of end-member contributions of the three provenances have obvious quarter precession and millennium scale cycles, which provides indirect evidence for the climate control mechanism of regional source-sink processes. These studies provide a basic source-sink connection foundation for regional sedimentology and provide a paradigm for global deep-sea deposition, especially the deep-sea fan deposition pattern.

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A model for predicting the distribution of turbidity of suspended solidas based on remote sensing water color data

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Keywords: Ocean color remote sensing, Turbidity of suspended solids, Multivariate elements, Multivariate statistics

The distribution of turbidity of suspended solidas at the same time cannot be obtained due to the limitation of the survey conditions and the weather environment in the estuary area. To solve this problem on the basis of turbidity of suspended solidas surveying data and remote sensing data in Bohai Sea, the remote sensing water color data closest to the surveying time of each station was extracted, and then the correlation between the measured data of suspended solids data and the ocean color data of the same time in an area near the Yellow River estuary and the central region of the Bohai Sea are calculated in this paper. The results show that the ocean color data obtained from the MODIS 551, 481, 443, and 667 nm bands are highly correlated with the measured turbidity of suspended solids. In the same band, the correlation between the ocean color data and the turbidity data of suspended solids varies in different regions. With the increase in distance from the shore and water depth, the correlation coefficient between the ocean color remote sensing data and the measured turbidity of suspended solids initially ascends. The correlation coefficient between the ocean color remote sensing data and the measured turbidity of suspended solids at the surface is relatively high in the area around the Yellow River estuary with a water depth of approximately 14–16 m compared with that in other areas near the Yellow River estuary. In the central region of the Bohai Sea with a water depth of approximately 16 m, the ocean color remote sensing data show a significantly positive correlation with the measured turbidity data of suspended solids. Based on the above analysis, the model data is selected from the area with good correlation. And then,we established a model to express the relationships between turbidity of suspended solids data at the surface and the ocean color, sediment, water depth, estuary distance, coastal distance, and other factors,which is verified to be effective, and then the model is applied to estimate of turbidity of suspended solids which in the Yellow River estuary.

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Detrital zircon records of the deep-time source-to-sink system in northern South China Sea: From orogenic event to provenance transition

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Keywords: Source-to-sink system, detrital zircon, Pearl River Mouth Basin, provenance transition, rain shadow effect

The deep-time source-to-sink (S2S) system focusing on the sedimentary records of pre-Quaternary geological events and paleoclimates is of great significance to reconstruct regional paleogeographic patterns. As a Cenozoic sedimentary basin in northern South China Sea, the Pearl River Mouth Basin (PRMB) experienced complex tectonic evolutionary history, and was characterized by the provenance transition as well as depositional environment change. The intrabasinal low uplifts, coupled to the extrabasinal Pearl River drainage systems, supplied sediments to the basin, forming the deep-time S2S system in PRMB. However, the timing of extrabasinal sediments starting transporting into PRMB remains controversial. Furthermore, the driving mechanism of the transition from intrabasinal provenance to extrabasinal provenance is poorly understood.

Paleogene sandstones from Zhu 1 depression in the northern PRMB provided valuable detrital zircon records for U-Pb geochronology and Eu/Eu* anomaly analysis. The detrital zircon U-Pb ages were used to reconstruct the sediment routing system, and the Eu/Eu* anomalies in detrital zircons were employed to reconstruct the crustal thickness of South China margin. The result shows that there is a single detrital zircon U-Pb age peak in the early Eocene strata, and that the late Eocene strata exhibits multiple detrital zircon U-Pb age peaks. The zircon U-Pb ages comparison between potential source regions and sedimentary basin shows different sediment routing systems during Eocene, indicating the transition from intrabasinal provenance to extrabasinal provenance in PRMB. Meanwhile, Eu/Eu* anomalies in detrital zircons suggest that the crustal thickness increased from ca 30 km to 70 km in South China margin during Cretaceous. This supports the Cretaceous orogenic event in which the Okhotomorsk Block moved with the Izanagi Plate in the direction transition and collided with the South China Block along the east Asian margin. As the response to the Cretaceous orogenic event, the extensive Cathaysian Coastal Mountains developed along the South China margin.

A model is established to explain the relationship between the Cretaceous orogenic event and the late Eocene provenance transition, although there is an obvious span. The Cathaysian Coastal Mountains prevented the humid Pacific air from reaching into the inland of South China, which is known as the rain shadow effect. Therefore, the northwestern side of the Cathaysian Coastal Mountains was arid, whereas its southeastern side was humid. The drainage system developed in humid climate and transported sediments to PRMB along the Cenozoic extensional rift, forming the buffered deep-time S2S system from Cathaysian Coastal Mountains to PRMB.

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Response of paleoredox evolution to deepwater ventilation since the last deglaciation in the Okinawa Trough

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Keywords: paleoredox evolution, deepwater ventilation, the last deglaciation, the Okinawa Trough

Variability of deepwater circulation during the LGM in the Okinawa Trough (OT) has long been the focus of numerous paleoceanographic studies. However, variations of paleo-redox evolution and initiating mechanism related to deepwater circulation remain unclear. We present molybdenum isotope compositions, redox sensitive elements, and productivity proxies from Core OKT-3 to reconstruct pro-redox conditions and its response to deepwater circulation in the OT since the last deglaciation. Relatively positive value of $\delta^{98/95}$Mo, relatively enrichment of Mo and Cr and low Mn/Al ratio suggested suboxic condition in the OT prior to 11.5 ka. It might be caused by a combination of weak deepwater ventilation in the OT and large amounts of terrestrial freshwater discharge during low sea level period. Negative excursion of $\delta^{98/95}$Mo and slightly enrichment of Mn suggest that deepwater conditions gradually switched from suboxic to oxic during 11.5-7 ka caused by strengthening of the North Pacific Intermediate Water (NPIW) and the South China Sea Intermediate Water (SCSIW) in the OT. The obvious peak of TOC/Al, U/Al and Ni/Al, synchronous with widespread enhanced primary productivity in North Pacific and its marginal sea during 11.5-9.5 ka (PB period) suggested the influence of NPIW within the OT was gradually increasing. Abrupt changes occurred at 7 ka for $\delta^{98/95}$Mo, Mn/Al and Mo_{EF}, Cr_{EF} in OKT-3 suggested oxic bottom water condition. The strengthening Kuroshio Current (KC) induced enhanced advection of NPIW and/SCSIW into the OT facilitated appearance of oxic depositional environment. It's worth noting that strong upwelling triggered high productivity had little influence on deepwater redox condition since 7 ka. Our study suggested better deepwater ventilation and poor organic matter preservation condition likely switched OT from a regional source of venting CO_2 to atmosphere during sea level highstand.

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Session T6-5: Asian continental margin sedimentation: Processes and records
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Provenance, Sedimentation and Formation of the Holocene Yangtze Delta: A Multi-approach Investigation

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Keywords: Yangtze Delta, Provenance, Sedimentation of delta process, Zircon U-Pb chronology

Detrital records preserved in the stratigraphy of the delta system provide abundant information related to the Holocene climate change and land-sea evolution. The Yangtze River drainage basin spans longitudinal gradients, links the high Tibetan Plateau and the marginal seas in the western Pacific Ocean, has been mainly affected by Asia Monsoon climate, and under significant anthropogenic modifications recently. The Yangtze Delta (YD), as the main sink of the Yangtze River, its formation process during the Holocene has long been a research subject. In this study, we investigated three sedimentary cores across the YD. By an integrated combination of multiple approaches, including the end-member unmix modelling on grain size data, bulk sediment magnetic properties analysis and detrital zircon U-Pb chronology for sediment source constraints, we aim to decipher a panoramic view of the transport and sedimentation processes and formation history of the Holocene YD. Our unmix modelling shows that although the three cores display distinctive sedimentary compositions, the same sedimentary facies on each core have been under uniform depositional process. The detrital zircon U-Pb provenance records indicate that in the early Holocene, sediment source signature of the upper reaches of the Yangtze basins dominates the Yangtze Estuary sediments. Since the middle Holocene, the YD sediment source shifted to the middle catchments which may be owing to both strong monsoon climate and intensified erosion caused by active human interventions. Marine sourced sediment has likely provided an additional supply for the building of the YD during the last 2 ka.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
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Uncoupled water and sediment transport on the inner shelf of East China Sea during Typhoon Chan-Hom (2015)

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Keywords: water and sediment transport, Changjiang Diluted Water, cross-shore, Typhoon Chan-Hom

Typhoon Chan-Hom swung by the coast near the Changjiang Estuary on July 11-12, 2015. Post-typhoon surveys, one conducted 3-4 days after Chan-Hom and another exactly one month later, were carried out to investigate her impact on the hydrodynamics, sediment transport and biogeochemical processes of the shelf off Oujiang, nearly 430 km southwest of the Changjiang Estuary. Measured salinity and $\delta^{18}O$ during the first survey showed the presence of a large volume of freshwater, up to 20 m thick, in the upper water column where the Chlorophyll-a concentration was also elevated, indicating additional supply of external nutrients. However, low concentration of suspended particulate matter and particulate organic carbon (POC), and the positive-biased isotopic composition ($\delta^{13}C$) clearly suggest that Chan-Hom caused significant southward transport of freshwater from the Changjiang Diluted Water, but insignificant amounts of terrestrial particulate matter. Measurements of the ^{210}Pb activity of seabed sediments showed post-typhoon freshness of offshore sediment and exposure of “old” sediment inshore, indicating a cross-shore transport of bed sediment during Typhoon Chan-Hom. It has been reported that extremely high resuspension of bed sediment by the typhoon could trigger gravity flows that result in downslope (cross-shore) sediment transport.

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Nitrogen fixation changes regulated by EAM system in the northern South China Sea since the last deglaciation

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Keywords: last deglaciation, East Asian monsoon system, organic nitrogen isotope, South China Sea

Reconstruction of the nitrogen cycle history is crucial to understand climate changes in the past, present and future, as the marine carbon and nitrogen cycles are tightly coupled. However, the reconstruction of nitrogen cycles and its regulation mechanism in the SCS remain highly uncertain due to the terrestrial inorganic nitrogen (IN) contamination (obscure δ15Nbulk) and the scarcity of high-quality sedimentary records. Here, we present a high resolution δ15N records of organic nitrogen (δ15Norg) since the last deglaciation (16.5 ka) obtained from a well-dated marine sediment core (NH07) in the northern SCS. Unlike most δ15Nbulk records in the SCS, the δ15Norg records show clear response to the typical climatic periods like early Holocene (EH), Younger Dryas (YD), Bølling-Allerød (BA) and Heinrich event 1 (H1). Two possible causes of the observed variations in δ15Norg records are as follows: (1) North Pacific-wide spreading of Eastern Tropical North Pacific denitrification signals through Kuroshio branch and North Pacific Intermediate Water, as δ15Norg show two peaks during the deglaciation, BA and the EH periods, which were identical to the global mean pattern due to the acceleration of global denitrification. (2) Local nitrogen fixation (NF) changes regulated by East Asian monsoon (EAM) system. After careful comparisons of δ15N and climate records from adjacent and global, the latter mechanism shows the most potential to cause the variations in δ15Norg records, and has been further validated by synchronously varying productivity indexs (Opal and ON contents) records in the NH07. Both NF rates and productivity in the SCS were constrained by nutrient supply, which was regulated by the EAM system. Stronger mixing during YD and H1, strong winter moon and weak summer moon, enhances the supply of excess phosphorous (low N:P) from the subsurface waters, thus increased the NF and productivity. This mechanism is consistent with modern observations and glacial/interglacial records in the SCS and the North Atlantic.

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Sediment weathering records and "Source-to-Sink" process in the Sunda shelf since the Last Glacial Maximum

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Keywords: Sunda shelf, sediment transfer, provenance, weathering regime

The continental margin is a key area for the study of the combination of sea and land, mainly because the information of climate and sea level change is well preserved in this sedimentary area. The study of terrigenous sediment fluxes in marginal seas is of great importance to the study of global climate change and biogeochemical cycles. The process of terrigenous sediments being weathered and eroded from the source area and sedimentary basin and transported to the marginal sea for deposition plays an important role in the study of "Source-to- Sink" process. The Sunda shelf is the largest shelf in tropical region and the emergence of the broad shelf during glacial period may induce significant change of sedimentary environment. One of the major debate and critical issue for palaeoenvironmental study on the Sunda shelf is how to distinguish the sediment sources and the mechanism of signal transmission, while the key is the impact of shelf emergence on sediment “Source-to-Sink” processes. This study on base of sediment cores drilled by SONNE RV in the continental slop in southwest South China Sea and based on K/Al Rb/Sr CIA WIP and other weathering indexes, the chemical weathering history recorded by 17964-3 cores since 23 ka BP was reconstructed by analyzing the elemental composition of the sediments at the 17964-3 station. It was revealed that the chemical weathering intensity in the glacial period was significantly higher than that in the Holocene. During the last ice age, sea level fell by at most about 120 m compared with the present, and the shelf was widely exposed, we propose that the shelf has played different roles in the glacial-interglacial cycle. In interglacial, the shelf is the Sink of sediments from adjacent rivers in the islands, while it turns to be a Source for sediment deposited in the continental slope during the glacial period. Combined with end-member characteristics of seaborne river sediments around the modern Sunda shelf, we aim to trace the sediment provenance using 234U/238U isotopes and reveal the impact of shelf emergence on sediment transport. Furthermore, we compare chemical weathering intensity and sediment residence time in terms of “comminution age”, in order to find more robust evidences to interpret the enhance of weathering intensity during glacial period.

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Fluid inclusion characteristics and material sources analysis of MIS6 stage sediments in the South Yellow Sea

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Keywords: South Yellow Sea, Yangtze River, fluid inclusion, material sources

Based on the study of quartz in the Late Pleistocene sediments of core YZ05 from the Yangtze Shoal, the South Yellow Sea, we analyzed the petrographic characteristics of quartz-hosted fluid inclusions, including the number, size and gas percentage, and compared them with the surface fluvial sediments in the upstream, midstream, and estuary of the Yangtze River. It was found that there is a great deal of inclusions in the sediments, in terms of the number and size, most quartz-hosted fluid inclusions are concentrated in the range of 2–5 μm in diameters and 17–47 in number per 10-3 mm3. In addition, quartz-hosted fluid inclusions have different forms, most of which are regular circular, oval or quadrilateral, and the distribution mode of inclusions is mainly banded distribution. The inclusions are mainly secondary, accounting for about 90% of the total. At room temperature, most of the inclusions are liquid-rich and the gas percentage is between 10% and 30%. The characteristics of quartz-hosted fluid inclusions in the sediments of the study area are similar to those of the modern Yangtze River estuary. And there are necking inclusions in the sediments, which indicates that the source rocks of the sediments were formed under high temperature conditions, and the sediments in Shigu in the upstream of the Yangtze River also show the same characteristics. Therefore, our research shows that the sediments in the study area came from the ancient Yangtze River during the Late Pleistocene, and the sediments in the upstream of the Yangtze River reached the South Yellow Sea area at that time.

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Study on borehole magnetic strata in northern Liaodong Bay

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Keywords: Liaodong Bay, magnetic strata, sedimentation rate and thickness

Liaodong Bay, located in the north of Bohai Sea, is the largest bay in the Bohai Sea. Its sedimentary history is an important window to reveal the tectonic evolution and geographical pattern formation of Bohai sea since late Quaternary. JXC-1 and YKC-2 boreholes are long sequence research boreholes with precise chronological control in the Liaodong Bay.

The continuous low-field magnetic susceptibility measurement and paleomagnetic alternating field demagnetization measurement were carried out, the measurement interval was 2 cm, and the chronostratigraphic framework of the two boreholes was established. The results show that the bottom boundary age of JXC-1 borehole is 1.2 Ma. MBB is located at a depth of 45.18 m, which is quite different from other boreholes in Bohai Sea and its surrounding areas. The bottom boundary age of YKC-2 borehole is about 0.7 Ma, and the deposition of positive polarity of Burong was recorded. No MBB was found. Polarity events such as Gothenburg and Blake are mainly recorded.

The Cenozoic geological structure of Liaodong Bay Depression is mainly characterized by "three depressions intercalated with two convexes", that is, from west to east, Liaoxi depression, Liaoxi uplift, Liaozhong sag, Liaodong uplift and Liaodong depression successively. Based on regional stratigraphic correlation, it is found that the sedimentary thickness of the northern Liaodong Bay has been "thick in the east and thin in the west" since late Pleistocene. Both JXC-1 and YKC-2 boreholes are located in Liaodong Bay Depression. The sedimentation rate and thickness of the two are different, mainly due to the influence of neotectonic movement, namely the Quaternary activity of TanLu Faults. During the past 1 Ma, the Liaozhong sag has been in a state of rapid subsidence compared with the Liaoxi sag, but the subsidence depth cannot be predicted because no marker layer has been detected in YKC-2 borehole.

According to the sedimentary thickness since the Middle Pleistocene, the Bohai Sea and its surrounding areas can be divided into four regions: Bozhong Area, Liaodong Bay Area, Bohai Bay Area and Laizhou Bay Area. Among them, Bozhong area is the subsidence center, and MBB has the deepest burial depth in the whole area. The main tectonic units in Bohai Bay area and Laizhou Bay Area are Huanghua depression and Jiyang Depression respectively, and the burial depth of MBB gradually deepens from south to north. MBB buried depth in Liaodong Bay Area is the shallowest among the four regions. The deposition of the whole Bohai Sea and its surrounding area is relatively continuous, and the deposition thickness decreases from the center to the periphery of the Bozhong depression. These results indicate that, based on the control of neogene tectonic basement, the influence of Tanlu faults activity since the late Pleistocene has been superimposed to control the variation of sedimentary thickness in the region. This study deepens the understanding of tectonic and sedimentary evolution models in this area.

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Evolution of sedimentary environment during syn-rifting stage in the deep water area of Pearl River Mouth Basin

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Keywords: South China Sea,paleogeographic evolution,sedimentary environment

For a long time, it has been widely believed that the sedimentary environment of the Pearl River Mouth Basin is mainly continental environment during the syn-rifting period. With the deployment of IODP scientific drilling as well as high resolution seismic survey in the deep water area of Pearl River Mouth Basin, the previous argument has met challenge and some studies show that marine transgression may have occurred in the deep water area during the syn-rifting period, especially the marine strata initially developed in mid Eocene. However, there is poorly understanding on how the sea-land environments progressively changed. Therefore, it is very important to detailed analyze the evolution of the sedimentary environment and characteristics of the sedimentary systems during the syn-rifting period in the deep water area. This research is of great significance to understand the formation, evolution of the South China Sea and petroleum exploration in the deep water area.

This study focuses on the deep and ultra-deep water area (ZhuIV Depression) in the Pearl River Mouth Basin. Through the comprehensive correlation of the sedimentary environment between neighbor sedimentary basins and paleogeomorphology reconstruction, it is believed that the transgression of sea water from east to west controlled the change of the paleogeographic transitional patterns during the syn-rifting period. According to the evolution of provenance area, combined with seismic facies-sedimentary facies analysis, the distribution and evolution of sedimentary systems during the syn-rifting period in the study area were clarified. During the lower member of Wenchang Formation development (early mid-Eocene), the eastern margin of the study area was generally open proto-SCS, small sags are characterized by diffuse extension and isolated lacustrine basins in response to high angle faults activities. During the upper member of Wenchang Formation deposition (late mid-Eocene), the Heshan and Xingning sags were mainly dominated by lacustrine deposits due to the local uplift barriers, though the basin was expanded. Some straits were formed and connected with proto-SCS in the southern Liwan sag and the eastern margin of Jieyang and Jinghai sags due to strong detachment fault activities. The sedimentary environment was transferred to marine-continental transitional facies or restricted bay. During the Enping Formation deposition (late Eocene), the range of transgression gradually expanded, coastal-neritic environment appeared throughout the study area.

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Early diagenesis of trace metals (Ni, Cu, Zn, Cd, Mo, and U) in sediments from the Changjiang River estuary and implications for the marine element cycles

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Keywords: estuary, porewater, element cycle, early diagenesis

Estuaries play an important role in the transfer of terrestrial trace metals from continent to ocean. Most terrestrial dissolved trace metals are known to be particle-reactive and largely scavenged in the estuarine mixing zone. The immobilization of trace metals at these depositional settings can have significant impact on the global cycles of these metals. In this study, porewater and solid phase data for redox-sensitive, bio-active trace metals (Ni, Cu, Zn, Cd, Mo, and U) were collected on a transect across the Changjiang River estuary at different water depths with varying bottom water oxygen concentrations. We evaluate the respective mechanisms of trace metal accumulation, retention and remobilization during early diagenesis across the physical and chemical gradients. We demonstrate that porewater exchange processes are the predominant mechanism for solute transport between sediments and overlying waters. Sediments are characterized by authigenic fixation of these trace metals through either diffusive uptake or transfer via a particulate phase from water columns. The studied trace metals show differential behavior during early diagenesis: (1) Cu, Zn, and Cd are intimately associated with organic matter; (2) Ni, Mo, and U are closely linked to diagenetic reactions of Mn-Fe oxides. Transient redox conditions, due to the dynamics of the mobile layers, strongly influence the trace metal distributions in both sediment and porewaters. Zinc and other trace metals such as Cd and Mo mainly form authigenic accumulate as solid sulfide precipitates or co-precipitation with Fe-sulfides under conditions of anoxia where sulfide is present, while authigenic U accumulation is mediated by microbially-produced Fe(III) and sulfate reduction at depth. Instead temporarily more oxygenated conditions could have resulted in transient re-oxidation and recycling of trace metals through diffusion across the benthic boundary. These findings thus suggest that elements and nutrients have undergone significant biogeochemical transformations under dynamic environments in the estuary before reaching the open ocean, which have important implications for the global marine element cycles.

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Sources and transport processes of sediments on shelf and deep-sea basin: Constraints from quartz particles characteristics

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Keywords: Quartz surface microtextures, Source to sink, South Yellow Sea, Parece Vela Basin

Abstract: Quartz has high hardness, excellent chemical stability, and outstanding weathering-resistance capability, so that the surface microtextures of quartz particles can provide abundant information and details about the sedimentary environment. Due to different geological processes, its surface will form different morphological features, the surface microstructure of quartz particles is closely related to the transport history of sediments and sedimentary environment, and can be used as an indicator of sedimentary environment (Vos et al., 2014), and is of great significance to reveal the provenance, hydrodynamic, and source-to-sink process from inland to deep-sea basin. Scanning electron microscopy observation, geometric parameters analyses, surface microstextures statistics, crystallinity index, and oxygen isotope analyses were performed on the quartz grains extracted from the three core sediments. Two of them from the shelf of the South Yellow Sea (cores H07 and B02) and one from the Parece Vela Basin of the western Pacific Ocean (core C-P19). By comparing the different microstextures and chemical features of quartz from desert, estuary, coastal zone, shelf to deep-sea basin, we can understand the quartz particles sources-to-sink and transport processes. The main findings are as follows, some quartz particles which is able to reach the shelf and deep-sea basin are generally come from Mu us, Badain Juran, and Tengger desert, however, most of quartz on shelf and deep-sea basin come from the nearby sources, only small part comes from aeolian sources. The quartz particles on the shelf mainly come from the fluvial sediment of Yellow River, Yangtze River, and erosive materials along the Shandong Peninsula. Although the cores in shelf are located on the transport path of the East Asian winter monsoon, there are little aeolian dust quartz particles input founded, which may be due to the sufficient supply of near source materials, covering up the small amount of aeolian dust input signals. The features of quartz particles in the muddy area of the continental shelf are different from those outside the muddy area. The properties in the muddy area are similar to those in the deep-sea basin, both with the small particle size, worse IPP roundness (Powers et al., 1953; 1982), and the surface microtextures is mainly mechanical, accompanied by a certain degree of chemical dissolution. The quartz particles on continental shelf but outside the muddy area has larger particle size, better IPP roundness, and the surface microstextures is mainly mechanical with little chemical dissolution. The above results show that the source of quartz particles and local hydrodynamic force jointly determined the properties of quartz particles in the region, but hydrodynamics seem play the more important role in the distribution of quartz in shelf and deep-sea basin.

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Deep-time source-to-sink process in eastern China margin

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Keywords: East Asia, Source to sink, landscape evolution, large river system

Source-to-sink philosophy is a geological approach that provides an integrated framework with which to observe geological processes as a continuous and causal system. During the Cenozoic, pronounced landscape changes occurred in the east China margin, companied by reorganizations of large river systems. However, details about these processes remain poorly understood and are hotly debated. In this research, a large number of detrital zircon ages from potential source areas and Cenozoic sediment from the eastern margin of China are systematically compiled. Furthermore, the landscape significance of rift basins in eastern China is also discussed based on the sedimentation patterns. The zircon age spectra in the South Yellow Sea Basin vary significantly in space and time, indicating that the sediment was mainly supplied by local rivers and that the region lacked a dominant large river. In contrast to the South Yellow Sea Basin, three phases of zircon age features were observed in the East China Sea Basin (ECB). Palaeocene-early Eocene sediment exhibiting overwhelmingly late Mesozoic ages was sourced from transversal rivers located around the subsidence centre. This scenario, together with isolated rift basins in eastern China, suggests basin-and-swell physiography. Most of the mid-Eocene to mid-Miocene samples in the ECB show complex zircon age spectra, which are typified by a high proportion of Palaeoproterozoic ages with North China Block and Korea affinities. The dominance of fluvial sediment in the northern part of the ECB means that a large river formed and flowed along the ECB. Since this study represents the first documentation of this river, we name it the East Asia River (EAR). The branch along the South Yellow Sea is named the Sino-Korea River, and the branch that flowed over the Yangtze Block is named the paleo-Yangtze River. The paleo-Yangtze River might have reached the Jianghan Basin starting in the Miocene. ECB samples from the late Miocene to Quaternary are characterized by a high content of Neoproterozoic ages showing present-day Yangtze River features. The evolution of the EAR and deposition in rift basins indicate that the early Cenozoic basin-and-swell physiography terminated in the middle Eocene and was replaced by a southward-tilting landscape across the Korea-South Yellow Sea Basin-ECB region. Resulting from the eastward migration trend of the extension centre in the ECB, the EAR migrated from the western depression zone of the ECB to the eastern depression zone in the late Eocene. The detrital sediment delivered by the EAR became prevalent in the Taiwan region starting in the early Miocene. Our work provides shed new light on the landscape evolution and reorganizations of large river systems in east Asia.

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Evolution of sedimentary environment in the eastern shelf of China since ~ 1 Ma and its relation to sea level and climate change

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Keywords: Sea level, continental shelf, sedimentary environment, glacial-interglacial

The sedimentary environment on the shallow continental shelf provides information on sea level, climate change, and local tectonic changes at the orbital scale. We have performed high-resolution chronological and sedimentological analyses of cores in the Bohai Sea and the Yellow Sea. Through astronomical orbital tuning methods, we established high-resolution age models on orbital time scales for the past ~1 My. Sedimentological analyses and environmental indicators suggest that the sedimentary environment is characterized by alternating shallow marine and coastal/alluvial sedimentary cycles controlled by glacial-interglacial sea-level changes. This result confirms the previous hypothesis that sea-level fluctuations play a dominant role in the sedimentary sequence in this region. In addition, only low-frequency sea-level fluctuations (~100 kyr) are preserved in the South Yellow Sea sedimentary sequence; however, high frequency (~40 kyr) sea-level variations are also preserved in the shallower Bohai Sea sediments, in addition to the 100 kyr cycle. Despite the large spatial variation, this finding suggests that the sedimentary environment of the eastern China margin has been influenced by sea-level changes uniformly over the last million years.

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Tectonic Subsidence of the southeast China coast: new evidences from Late Pleistocene transgression in Ningde bay

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Keywords: Sedimentary geochemistry, Late Quaternary transgression, regional subsidence, land-sea interaction, ancient Zhejiang-Fujian Uplift (ZFU)

Subsidence of the ancient Zhejiang-Fujian Uplift (ZFU) is important to understand opening of the Chinese marginal seas and geomorphology of the east China coast. However, little was known about its subsidence history during the Quaternary. In this study we clarify three marine sedimenty layers constrained by luminescence (OSL) chronology in Ningde area of the southeast China coast, to reveal the regional subsidence process related to the ancient ZFU. The results show that three marine sedimentary layers above bedrock in Ningde area are formed during global sea-level highstands of MIS1, MIS3 and MIS5e, constrained by OSL datings of the three representative cores. Limited marine influence of MIS5e highstand indicated both by microfacies of the representative core and by the paleo-shorline outlined from 120 cores, implies that tectonic subsidence occurs here during the Late Quaternary. The offsets between the peak global sea level and the corrected paleo-shoreline elevations of MIS5e and MIS3 reveal that the average subsidence rate is ~0.5 m/kyr since MIS5e and ~0.8 m/kyr between MIS5e and MIS3 in Ningde area. These evidences suggest that the ancient ZFU possibly subsided rapidly since MIS5e and stabilized since MIS3. This study provides new insights to subsidence history of the ancient ZFU and land-sea interaction in the tectonic subsidence region.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-5: Asian continental margin sedimentation: Processes and records
Presentation Preference: Oral Preferred

Detrital zircon size and U-Pb geochronology in the Mud Belt of the East China Sea: Implications for provenance analysis

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Keywords: detrital U-Pb geochronology, provenance analysis, the Mud Belt of the East China Sea, zircon grain size, residual deposits

With the rapid developments of in-situ analytical instruments and techniques, especially, the laser ablation inductively coupled plasma (LA-ICP-MS), detrital zircon U-Pb geochronology has become the most popular toolkit for provenance analysis over the past two decades. Although numerous studies exist and a myriad of dates have been generated in this community, little attention has been paid to recent sediment deposited on continental margins. Some critical questions have been raised from the literature on the feasibility of zircon U-Pb geochronology in provenance analysis due to the issues of fertility, size effects and the nature of recycling, which urgently appeal us to examine sediments deposited in recent history of Earth thoroughly due to relative abundant information on sources, transport and deposition is available. In this contribution, we examine spatial distributions of zircon grain sizes and U-Pb ages in the Mud Belt of the East China Sea (ECS), aiming to 1) address whether changes in grain size of zircon grains have discernible effects on U-Pb ages and 2) to discuss how provenance signals of zircons can be preserved, modified, and propagated from river point sources to the sinks of the sediments.

The most pronounced feature of zircon grains in the ECS is a fining trend along the Mud Belt from the Yangtze Estuary, sub-aqueous delta in north to the distal end in south, with average equivalent spherical diameters (ESD) decreasing from a range of 100-150 μm to that less than 50 μm. We propose two competing interpretations for this fining trend. The first is due to the loss of mineral abrasion during the transport and the second is as the results of hydrological sorting. The latter is favored because the mean grain sizes between zircon grains and the host sediments are in good agreements with the prediction of the impact law that describes size shifts among different minerals of different densities from a theoretical perspective. Moreover, although there are significant contrasts in zircon grain sizes, most samples in the Mud Belt, except for those located in the distal south end and those close to the coastline, have very similar or identical kennel density estimates (KDE) of U-Pb ages. In addition, as evidenced by high values (>0.9) of Bayesian Population Correlation (BPC) of U-Pb ages and short distances to the modern Yangtze U-Pb ages in a 3D multi-dimensional scaling (MDS) diagram, provenance signals inherited from various fluvial sources could be considered as the most important factor that has determined the U-Pb geochronology in the sediment. At last, we quantitatively estimate the relative contributions from different rivers and residual deposits on the continental shelf using a forward mixing model. Interestingly, our preliminary results suggest that, on average, ca. 20 to 45 % of zircon grains in the Mud Belt have been derived from the the residual deposits formed on the continental shelf during low sea-level stages in the late Quaternary.

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Climatic and environmental impacts on the sedimentation of the Southwest Taiwan margin since last glaciation: Clay mineralogical and geochemical investigations

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Keywords: Clay Minerals, Major Elements, Sedimentology, Weathering, East Asian Monsoon, South China Sea

Scientific studies have focused on the understanding of present and past source to sink processes and their controlling factors over the last decades. In a context of global climatic and anthropic environmental change and sea level rise trends, it is necessary to recognize the impacts of past climatic and environmental changes on sediment production, transport, and deposition. This study focuses on the influence of East Asian summer monsoon (EASM) and El Niño Southern Oscillation (ENSO) driven typhoon precipitation variations and sea level changes on source to sink processes in Southwest Taiwan and the South China Sea. Clay mineralogy and major element geochemistry combined with Nd and Sr isotopic compositions from the sediment core MD18-3569 located on the Penghu Canyon bank off Southwest Taiwan were analyzed in order to identify the origin of sediments and the weathering variation of provenance area since the last glaciation. The results indicate Taiwan as the predominant source of sediments on the Southwest Taiwan margin, with few inputs from Luzon and South China. Clay mineralogy and Nd-Sr isotopes show controls of the EASM precipitation and the sea level change on source to sink processes, respectively. Nevertheless, the comparison between variations of smectite/illite+chlorite, kaolinite/illite+chlorite versus clay fraction Nd isotope, illite chemistry, and crystallinity suggests that the sediment provenance variation might be more related to the draining basin change than the Luzon-Taiwan-South China input change. Bulk chemical index of alteration (CIA) variations displays an EASM driven increase of weathering in Taiwan from the Last Glacial Maximum to the early Holocene and an EASM and ENSO driven weakening of weathering during the middle Holocene. Our multi-proxy study indicates the strong link between paleoclimatic and paleoenvironmental changes and Southwest Taiwan and South China Sea source-to-sink processes.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-5: Asian continental margin sedimentation: Processes and records
Presentation Preference: Oral Preferred

Miocene sedimentary process simulation and sedimentary evolution in EP-B Oilfield, Yangjiang Sag, Pearl River Mouth Basin

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Keywords: Yangjiang sag, delta, forward modeling, sedimentary evolution

The Miocene Zhujiang Formation to Hanjiang Formation in the EP-B Oilfield of Yangjiang Sag, Pearl River Mouth Basin has problems such as unclear sedimentary geometry, development process, sedimentary model and sand body distribution. Based on the delta sedimentary model, combined with logging and seismic data, the sedimentary forward modeling method of Fick's second law (unsteady diffusion) was used to restore the sedimentary evolution process of each interval of the target layer in the study area, and analyze the key interface characteristics. The simulation results show that: (1) The sedimentary evolution of the Zhujiang Formation and the Hanjiang Formation delta can be divided into four sedimentary cycles. During the period of sea level rise, the delta sand bodies of each stage are characterized by vertical accumulation and gradually thicken toward both ends. During the period of sea level decline, the delta sand bodies of each stage are characterized by horizontal accumulation, and the sand body distribution is relatively thin. (2) In the multi-proven delta sedimentary simulation, as the grain size of the sandstone from the Zhujiang Formation to the Hanjiang Formation gradually becomes coarser, the delta gradually transitions from a silt-rich delta to a argillaceous delta, and the adjacent delta lobes are formed by sand bodies. The connected transition is inter-bay development, and the connectivity becomes poor. Based on the 3D geological model obtained by the fusion of multi-information, it can quantitatively reproduce the structural-sedimentary evolution process of the target layer, and explore the depositional process and the controlling factors and formation mechanism of favorable sand body development, providing a reliable prediction model for oil and gas exploration and development in the study area.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-5: Asian continental margin sedimentation: Processes and records
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Fine Description of Sedimentary Microfacies Based on Waveform Cluster Analysis——Taking EP-A and EP-B Oilfields in Yangjiang Sag as an Example

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Keywords: self-organizing neural networ, waveform clustering, seismic facies, sedimentary microfacies, seismic sedimentology

The sedimentary facies of the EP-A and EP-B oilfields in the Yangjiang sag change rapidly in the lateral and vertical directions, and the heterogeneity is strong. The traditional sedimentary microfacies research based on seismic sedimentology analysis mainly extracts the mean square by the stratigraphic slice technology. Root amplitude properties, accuracy and reliability are easily compromised for thinner intervals. Using the self-organizing neural network method, the waveform clustering analysis is carried out, the seismic facies is divided, and the sedimentary microfacies distribution of each interval in the study area is finally determined by combining the existing well data, sedimentary microfacies data and seismic sedimentology analysis. The results show that the waveform clustering analysis based on the self-organizing neural network method can better divide the seismic facies, so as to determine the boundary of each sedimentary microfacies on the plane, combined with the existing sedimentary microfacies research, can more accurately reflect the sedimentary microfacies. The vertical evolution law of facies can provide a basis for further oil and gas development.

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Session T6-5: Asian continental margin sedimentation: Processes and records
Presentation Preference: Oral Preferred

Sediment routing system in Asian continental margin: source to sink process and controlling mechanism

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Keywords: Asian continental margin, source to sink, sediment, controlling mechanism

The Asian continental margin is located at the convergence and collision boundary of the Eurasian, Pacific and Indo-Australian plates, and is subjected to the strongest land-sea interactions and the most frequent exchanges of material and energy. The rivers in the Asian continental margin contributes about two-thirds of the global sediments from rivers to the ocean, which has a great impact on the sedimentation, biogeochemical processes and marine ecology of the marginal seas and the global oceans. Through international cooperation, we have systematically obtained sediment samples and data in the Asian continental margin from the East Siberian shelf in the north to the Bay of Bengal in the south. Based on these data, we compiled the first 1:3000000 sediment type map of the Asian continental margin, and elaborated the distribution pattern of the sediments; We established a set of effective provenance tracing indexes to elucidate the properties of fluvial sediments, identified the sediments provenance in the Gulf of Thailand, Andaman Sea, Bay of Bengal, South China Sea, Sea of Japan, Sea of Okhotsk and East Siberian Sea, described the transport and deposition processes of the fluvial sediment in the sea, and established the sedimentation model for the key areas; The source, input mode and burial of organic carbon on the shelf at different latitudes and their response to natural processes and human activities have been quantitatively evaluated; The controlling mechanism of sediment source-sink process impacted by the Asian monsoon, sea level change, uplift of Tibetan Plateau, sea current and sea ice variations has been revealed.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-5: Asian continental margin sedimentation: Processes and records
Presentation Preference: Oral Preferred

Silicate weathering and river sediment routing processes in East Asian continental margins

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Keywords: Silicate weathering, sediment source-to-sink process, Asian rivers, continental margin

East Asia is featured by two major types of fluvial sediment routing systems: the mega-rivers in Eurasian continent, e.g. the Changjiang (Yangtze) River, and the small mountainous rivers in Taiwan Island and SE China, e.g. the Zhuoshui River and Mulanxi River. Among which, the small mountainous rivers are relatively less investigated although they play a disproportionate role in sediment discharge and greatly influence the terrestrial material cycle in the West Pacific. Here, we use multiple isotopic proxies (radiogenic and stable Be, Sr, Nd, Li and Si) to trace the silicate weathering and sediment source-to-sink processes in the large river systems and small mountainous catchments (Zhuoshui and Mulanxi Rivers) in the East Asian continental margin, and particularly the weathering mechanisms and environmental signal propagation in the catchments will be discussed.

The systematic observations from a granodiorite weathering profile and Mulanxi River sediments suggest strong fractionations in Li, Si and radiogenic and stable Sr isotopes during weathering and sediment recycling processes. The small dynamic mountains rivers in Taiwan exhibit large sedimentary geochemical and provenance heterogeneity despite their fast sediment transfer from land to sea. The Si and Sr isotopes clearly indicate the quick response of sediment weathering to typhoon impact. Our study will provide more constraints on the earth surface processes in East Asia continental margin.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-5: Asian continental margin sedimentation: Processes and records
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Provenance and paleoclimate significance of eastern Hainan Island shelf since Holocene

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Keywords: marine geology,paleoclimate,Hainan Island,provenance analysis,paleoenvironment,Holocene

This research based on the sediment of QZ4,locateing in the eastern shelf of Hainan Island.Through the methods of particle size, clay minerals and geochemistry, the sedimentary environment and material source of eastern Hainan Island are analyzed, and the conclusions are followed:1) Eastern Hainan island shelf sedimentary environment is influenced by various factors, including sea level, climate, ocean current system and human activities, etc., and it can be divided into two phases:Before 8KA, the stage of sea level control was followed by the stage of climate control. And the influence of human activities intensified since 2KA. 2) The materials in the study area were mainly derived from small rivers in Hainan Island, and partly influenced by foreign materials. 3) Two cold events, 8.2KA and 9.7KA, were observed.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-5: Asian continental margin sedimentation: Processes and records
Presentation Preference: Oral Preferred

Sequence stratigraphy and sedimentary processes since the Last Glacial Maximum in Nha Phu Bay and adjacent shelf, central Vietnam

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Keywords: Acoustic facies type, sedimentary processes, Last Glacial Maximum (LGM), systems tract, sequence stratigraphy

Twelve acoustic facies types and three sedimentary systems tracts (LST, TST, and HST) were determined by interpretation of high-resolution acoustic data in Nha Phu Bay and the adjacent shelf since the Last Glacial Maximum (LGM). The acoustic facies types combining with collected sediment samples revealed a range of sedimentary and geomorphological expressions. These expressions can be tied to hydrodynamic processes of deposition and erosion. The lowstand systems tract (LST) comprises sandy sediments exposed on the outer shelf as sand-ridges and underlies the transgressive systems tract (TST) on the middle shelf. LST was developed under shallow-marine settings during the sea-level lowstand 21.0-14.6 cal kyr BP. TST comprises mainly fine sediments deposited during the transgression 14.6-8.0 cal kyr BP in an incised trough of the outer shelf, on the middle shelf, and in the incised valley of the bay. An erosion of the seaward TST portion on the middle shelf occurred during the late transgression. The highstand systems tract (HST) comprises sediments deposited during the sea-level highstand 8.0-0.0 cal kyr BP and is distributed widely in the bay, on the inner-middle shelf, and partially on the outer shelf. A paleo-coast zone around 100-120 m in water depth is recognized through the appearance of sand-ridges and sandy sediments. The coarse-grained sediment distribution and a thin sediment thickness on the inner shelf indicate an erosion-dominated seabed under strong hydrodynamic impactions. The seabed morphology, muddy distribution, and deglacial sediment thickness reveal a dominant sediment-transport pathway out of the bay occurring along the northern bay coast

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-5: Asian continental margin sedimentation: Processes and records
Presentation Preference: Oral Preferred

Distribution, sources and burial of sedimentary organic carbon in the east China seas

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Keywords: east China seas, sedimentary organic carbon, source, burial flux, age

Sources and burial of sedimentary carbon in marginal seas are an important part of the global carbon cycle and budget. The east China seas includes the Bohai Sea, Yellow Sea and East China Sea and are characterized by broad shelves. They receives enormous amount of fluvial sediment from the Huanghe and Changjiang rivers and bury abundant sedimentary carbon. Transport and burial of the sedimentary carbon affect marine biogeochemical processes and marine carbon cycle on different time scales, and even have an important impact on the global climate change.

Based on the investigated data of China over the past 30 years and collected information, including 17596 stations of sediment grain size, 567 stations of 210Pb-derived sediment accumulation rates, 6000 stations of organic carbon, 1024 stations of organic carbon isotope, and 447 stations of organic carbon age, we preliminarily compiled a 1:3000000 distribution map of sedimentary organic carbon of the east China seas, elaborated the distribution characteristics, sources and buried flux of sedimentary organic carbon, and discussed the influence of hydrodynamic forces, sediment composition and human activities on it. The results show: (1) TOC contents in the sediments ranges from 0.01 to 2.12% in the east China seas. And there are high values in the mud areas such as the central Bohai, Sea, eastern coast of the Shandong Peninsula, central Yellow Sea, southwest of Jeju Island, old Huanghe River estuary, southeastern of the Yellow Sea, and Zhejiang-Fujian coast. (2) δ13C values are from -25.80~-20.00‰ and ~70% of sedimentary organic carbon is marine source. (3) range of Δ14C in sedimentary organic carbon is -871 ~ -137‰. The age of sedimentary organic carbon is older in the areas near the old Huanghe River estuary, Jiangsu radiating sand ridges, middle and outer shelf of the East China Sea and northeast Taiwan. (4) The burial rates of organic carbon in the mud areas are higher in the east China seas, which reaches maximum value of 68.8 g/m2/yr in the Bohai Sea mud area and is generally low near the old Huanghe River estuary (15.2 g/m2/yr). The burial amount of sedimentary organic carbon is about 8.2 Mt/yr.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-5: Asian continental margin sedimentation: Processes and records
Presentation Preference: Oral Preferred

Formation of authigenic siderite and pyrite in mud sediments of the Yellow Sea

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Keywords: Early diagenesis, Pyrite, Siderite, Yellow Sea, Sedimentary environment

The formation of authigenic minerals is accompanied by the early diagenetic process of sediments, so authigenic minerals can carry the information of their formation environment (Liu et al., 2019; 2020; 2021). Our preliminary analysis results show that in the lower part of the core, siderite iron content is high, indicating a more oxic sedimentary environment and possibly a continental freshwater environment. In the upper part of the core, the iron content of pyrite increases, which can indicate the beginning of marine transgression. The content of pyrite is also related to the depth of sulfate reduction in this area according to porewater data. The location of the sulfate reduction zone in the study is about 6 m. According to the grain-size results, the core penetrated the mud layer and recorded the evolution of the sedimentary environment since the last glacial period.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-5: Asian continental margin sedimentation: Processes and records
Presentation Preference: Oral Preferred

The impact of dam constructions on sedimentary records along the mud belt in the inner East China Sea shelf

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Keywords: Source-to-sink, Three Gorges Dam, Mud belt

The Anthropocene is a new concept but not yet well constraint geological epoch, and this thinking indicates that humans are gradually having a significant impact on Earth's geology and ecosystems. From the perspective of Anthropocene, human activities in the watershed, such as urbanization, deforestation, damming, etc., have significantly altered the sediment supply. We wanted to know whether such anthropogenic processes could affect the sedimentary record on the continental shelf in a watershed-shelf continuum. In this study, box cores and surface sediments taken at six stations along the Zhejiang-Fujian Zhe-Min) mud belt system were used to investigate the changes in sediment characteristics before and after the construction of dams on rivers along the southeastern coast of China. For example, the Three Gorges Dam (TGD) on the Changjiang River (CJR) around A.D. 2000, the Shuikou Dam (SKD) on the Minjiang River (MJR) around A.D. 1993.
Sample analyses included Multi-sensor Core Logger (MSCL), clay mineralogy, grain-size compositions, and radioisotope measurements. Results in $^{7}Be/^{210}Pb_{ex}$ activity ratio of surface sediment showed that the freshness of terrestrial sediment along the mud belt decreased away from the CJR mouth along the mud belt. The magnetic susceptibility (MSI) has a similar decreasing trend from the Oujang River to the northern Taiwan Strait (TS). The above results indicate that terrestrial signals gradually decreased along the transport pathway. Sedimentation rates calculated from the $^{210}Pb_{ex}$ activity profiles of the box cores also consistently decreased from the CJR to northern TS. Later, the sedimentation rate was used to establish the time span of each box core to show the temporal variability of core sedimentation characteristics. Results showed that the MSI of each box core decreased simultaneously after A.D. 2000. This time point coincided with the operation of the TGD. Kaolinite, which can represent the source of the MJR in the results of clay minerals, has also decreased in stations south of the MJR mouth with the completion of the construction of the SKD. This finding points to the impact of anthropogenic activity in the watershed on the distal marine sediment record.

Reference

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-5: Asian continental margin sedimentation: Processes and records
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

A novel machine learning fingerprinting method using Sparse Representation for delta sediment provenance analysis

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Keywords: Machine learning, Sediment fingerprinting, Sparse representation, Sediment provenance detecting,

Fingerprinting technique is a critical tool for sediment source detection. How to assess more authentic source contributions, based on very limited measured data, is a key scientific question. Sparse representation, a machine learning method, was found to be a good regularizer for natural signals and has the potential to provide answers. Here, we presented a Sparse Representation based Sediment Fingerprinting (SRSF) method and have applied it to analysing the data of sediment cores from the Yangtze River Delta (YRD), where the Yellow River sediment had also contributed to its formation in the last 400–600 years. We quantified the provenance of three cores sediments from the northern YRD using size-specific magnetic and geochemical characterizations. Our results showed that the Paleo-channels of the Yellow River contributed 19.3±5.8% in <16 μm fraction sediment and 23.5±9.2% in 16–32 μm fraction sediment, which was consistent with the previously published results. This study optimized the fingerprinting technique in feature extraction and selection. SRSF method had great potential applications in provenance detection with very limited measured data, the prevention of delta erosion, and land resource management.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-5: Asian continental margin sedimentation: Processes and records
Presentation Preference: Oral Preferred

Sea ice and iceberg discharge events in the far northwest Pacific over the last 190 ka

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Keywords: Northwestern Pacific, Sea ice, iceberg, Pleistocene

Marine isotopic stages 6.5–1 were established in the Tenji Seamount sediment core LV 76-18 based on accelerator mass spectrometry (AMS) 14C data, benthic foraminifera δ18O stratigraphy, and relative paleointensity excursions. Records of planktic foraminifera δ18O and ice rafted debris (IRD) in sediment cores from the Detroit and Tenji Seamounts were used to outline several periods of surface water freshening and increased IRD accumulation induced by icebergs supply and its melting in the northwest Pacific during the last 190 ka. Iceberg discharge events (IDEs) were as well reconstructed over the last and penultimate glacial periods in the central and eastern parts of the Okhotsk Sea and southwestern part of the Bering Sea. Synthesis of planktic foraminifera δ18O and IRD records along with other related proxies from the studied areas concordantly revealed five IDEs in the northwest Pacific and its marginal seas during the last 190 ka: IDE 1 (42–29 ka), IDE 2 (76–57 ka), IDE 3 (118–110 ka), IDE 4 (152–141 ka), and IDE 5 (179–160 ka). Data showed that IDEs 4–1 occurred at low values of Earth obliquity and under a weak Aleutian Low, facilitating snowfall precipitation and enhancing glacier formation at Kamchatka, which is a priority area for capturing atmospheric moisture transferred into northeast Asia. It is likely that IDEs 2 and 1 occurred during phases I (more extensive) and II (less extensive) of the published Kamchatka glaciations during the Late Pleistocene. According to records of several sediment cores from the Tenji Seamount, the IDE 2 was also characterised by a huge and short IRD peaks that was probably forced by the catastrophic influx of lake water from the Central Kamchatka Depression. An analysis of the mineral composition of sediments in fractions more than 63 microns showed that the sediments of the Detroit Seamount has the feeding provinces of the Koryakia and the Kamchatka Peninsula, and the sediments of the Tenji Seamount, mainly of KamchatkaHigh resolution records from the Detroit Seamount core LV 76-21 show, that IDE 1 was characterized by several short periods of icebergs discharging synchronously with Greenland/Chinese interstadials and decrease of sea ice extension in the Bering Sea and the far northwestern Pacific. During the cold MIS 2 there was increase in the sea ice formation in the Bering and Okhotsk seas and its spreading in the northwestern Pacific.

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Session T6-5: Asian continental margin sedimentation: Processes and records
Presentation Preference: Oral Preferred

Changes in sedimentary environment in the subtropical NW Pacific during the Late Quaternary

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Keywords: sedimentary environment, Late Quaternary, Subtropical NW Pacific, Kuroshio Current, North Pacific Intermediate Water;

The sedimentary environment in the subtropical NW Pacific is shaped by a range of crucial factors, including the Kuroshio Current (KC), the East Asian Summer Monsoon (EASM) and the North Pacific Intermediate Water (NPIW). The KC is an important western boundary current in the subtropical NW Pacific Ocean, which brings amounts of warm and high-salinity water from the tropical ocean to the middle-high-latitude areas. The NPIW is characterized by low salinity and mainly occupies the water depth of 300-800 m in the subtropical North Pacific, which is mainly derived from the Okhotsk Sea with little contributions from the Gulf of Alaska. The EASM brings freshwater to the continental margin of the NW Pacific and exerts significant influences on its surface hydrography. These changes themselves and their interactions greatly affect the sedimentary environment of the subtropical NW Pacific during the Late Quaternary. However, the changes of sedimentary environment during the Late Quaternary and processes responsible for these changes still need further exploration. In this study, we present the results from sediment cores retrieved from the Okinawa Trough of the subtropical NW Pacific. This study highlights the important roles of these three factors (KC, EASM and NPIW) in shaping the sedimentary environment during the Late Quaternary in the context of eustatic sea level changes during the late Quaternary.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-5: Asian continental margin sedimentation: Processes and records
Presentation Preference: Oral Preferred

Modern and Holocence Sediment Texture of Sunda Shelf Southern South China Sea

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Keywords: Sand, Silt, Clay, Marine Sediment, Peninsular Malaysia

Sediment texture is an important characteristic that can be used as an indicator of changes that occur in an environment, especially in the continental shelf environment. This is due to the significant changes in this environment throughout the Holocene period. The purpose of this study is to determine the classification of modern and Holocene sediment texture and to identify the changes in sediment texture that may occur during the Holocene period. In this study, we analyzed 30 surface sediment samples and three cores (TRC3, TER16GC13C, and KELC17) from the east coast of Peninsular Malaysia, Southern South China Sea. Radiocarbon analysis of the shell fragments indicated that the studied cores covered the Holocene period. Most modern sediments on the east coast of Peninsular Malaysia fall into the categories of silty clay, silty clay loam, and silty loam. The same applies to the Holecene's sediment texture which was also dominated by a similar type of sediment texture. In comparison, there was a significant difference in terms of the vertical distribution of sediment texture for core TER16GC13C than core KELC17 and TRC3. The highest percentage of sand was recorded for core TER16GC13C which is up to more than 60%. This condition suggests that the environmental changes at the location of core TER16GC13C are more dynamic than TRC3 and KELC17. The increasing current intensity at core TER16GC13C is one of the potential factors that may affect the high percentage of sand. Therefore, this may suggest that the modern and Holocene sediment of the southern part of the South China Sea falls into the moderately fine sediment textural group.

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Session T6-5: Asian continental margin sedimentation: Processes and records
Presentation Preference: Oral Preferred

The controls of the incised valley filling process on the preservation of organic carbon, the East China Sea Shelf

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Keywords: Incised valley fill, Organic carbon preservation, East China Sea Shelf

Incised valleys are generated during river incisions due to a relative sea-level fall. Afterward, as the sea level rose, accommodation was created in the incised valley, allowing sediment and organic carbon to fill. The core MZ03 and seismic profile collected on the southern East China Sea Shelf suggest that the deposits filled the incised valley occurred during Marine Isotope Stage 3 (MIS3). MIS 3 (60-25 ka) is a warm period in the last glacial period, characterized by the frequent occurrence of millennium-scale climatic events and high-frequency sea-level oscillation. Our study aims to investigate the impact of the incised valley filling process on preserving organic carbon in the setting of rapidly changing sea levels.

The deposits that filled the incised valley were not eroded during the LGM and subsequent transgression, allowing the particulate organic carbon (POC) to be preserved for almost 30 ka. During infilling of the valley, the incised valleys are controlled by fluvial, estuarine, and marine processes. The basal fill of the valley is composed of the Minjing bayhead delta-plain and delta-front. The mud exported from the Changjiang constitutes to middle-top of the valley fill. With the total organic carbon, nitrogen, and carbon isotope analysis, the flood event beds of the delta-plain deposits contained the highest organic carbon content (3.4 %). In comparison, the mud from Changjiang coastal mud wedge (middle-top valley fill) yielded TOC that ranges from 0.2 % to 0.7 %. The C/N and the carbon isotope showed that the organic carbon source in the flood event beds was predominantly from C3 plants. The contribution of marine organic carbon dominated the middle-top of the valley fill. The Sr/Ba and Mo/Al were used to indicate the paleosalinity and redox condition. The flood deposits have the lowest Sr/Ba (0.12) and greatest Mo/Al ratios in the core, ranging from 0.3 to 0.63 ($\times 10^{-4}$). The low Sr/Ba indicates that the sediments were less influenced by seawater. The Mo-rich layers could result from a combination of rapid sediment settling and O_2 consumption through the decomposition of organic-rich layers. Due to rapid sedimentation, the fluvial flood beds of the delta plain deposits contain the most enriched organic matter. In contrast, the Changjiang coastal mud has much less organic matter content because post-depositional bioturbation in mud increases short-term redox oscillations, promoting organic carbon degradation. Furthermore, the identification of fluid mud beds (remobilized mud) tends to expose organic matter to oxygen and allows for efficient metabolite exchange with little organic carbon storage. The lower valley fill is characterized by the highest organic carbon fed by the small mountainous river probably due to intense terrestrial flooding caused by monsoon intensification. The middle to top valley fill (coastal mud) has less organic matter content, implying fluvial-dominated delta is perhaps the most favorable place to receive and store the largest amounts of organic matter. These findings have crucial implications for understanding how incised valley filling process affects organic carbon preservation on the shelf.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-5: Asian continental margin sedimentation: Processes and records
Presentation Preference: Oral Preferred

PLEISTOCENE PALAEOCEANOGRAPHIC VARIABILITY IN THE NORTH-WESTERN PACIFIC OVER THE LAST 255 ka: EVIDENCES FROM DIATOM RECORDS

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Keywords: Diatoms, Late Pleistocene, Holocene, Ice Conditions, Environmental Changes

The results of a detailed study of diatom complexes of Pleistocene and Holocene sediments from Pacific Ocean and ecostratigraphic subdivision of sediments showed that changes in assemblages reflect, first of all, a change in hydrological conditions determined by changes in the circulation of water masses and related processes - paleoproductivity of surface waters, development certain species and their migration.

Several periods of changing hydrological conditions were identified, which were reflected in the composition of diatoms associated with significant paleoclimatic events - periods of cooling, with an increase in the duration of ice standing, periods of warming with a strong freshening of the surface water layer, a change in oceanological circulation, leading to an increase and decrease in supply nutrients. Periods were also identified when large volumes of ice were brought into the study area, probably associated with the supply of large masses of ice by currents, most likely coming down from the glaciers of Korjakija and the surrounding areas.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-5: Asian continental margin sedimentation: Processes and records
Presentation Preference: Oral Preferred

Erosion history of the Indus River Basin recorded by Arabian sea deposits since the Oligocene

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Keywords: Himalaya-Karakoram, South Asian monsoon, detrital zircon U-Pb dating, Nd-Sr isotope, heavy minerals, detrital apatite fission track dating

South Asia, especially the Indus River Basin, is one of the regions with the most intense surface erosion, the most active tectonic movement and the most significant influence of monsoon climate in the world. The coupling of erosion, tectonics and monsoon in this region plays a very important role in global climate change and environmental evolution. Although the Neogene (< 23 Ma) history of the Indus River Basin erosion, the Himalaya-Karakoram tectonic activities and the South Asian monsoon changes are relatively clear, the Paleogene (> 23 Ma) records are still lacking. Also, it is not clear whether the Cenozoic erosion process in the Indus River Basin was controlled by tectonic activity or monsoon climate. In this study, we conduct detrital zircon U-Pb dating, Nd-Sr isotopic composition, heavy mineral assemblages and the detrital apatite fission track (AFT) dating on the Indus Fan sediments from the Arabian Sea since ~30 Ma, to reconstruct the erosion history of the Indus River Basin since the Oligocene. Detrital zircon U-Pb age spectrum, Nd-Sr isotopic compositions and heavy mineral assemblages of the Indus Fan sediments demonstrate that, the Himalaya and the Eurasian plate are the main sources of the Indus Fan deposits since the Oligocene. During ~26-16 Ma, the Himalayan source contributed the most to the sediments, which may reflect the extrusion and rapid uplift of the high-grade metamorphic Great Himalayan sequence. The Karakoram strike-slip fault (KF), which activated at ~16 Ma, may be the main reason for the increased contribution of Eurasian plate source during ~16-6 Ma, even though the development of the Lesser Himalaya duplex started at ~12 Ma. The Lesser Himalaya was finally brought up to the surface at ~6 Ma and began to supply erosive material to the Indus Fan, increasing the contribution of the Himalayan source region. The detrital apatite fission track age distributions of the Indus fan sediments show relatively stable and rapid erosion (from 0.6 mm/yr to 1.2 mm/yr) during ~30-16 Ma. This suggests that at least ~30 Ma, a rapid erosion in the Himalaya and Karakoram had begun, and that a geomorphological pattern similar to the present one had been established in the Indus River Basin. The change of provenance or tectonic movements was not consistent with the history of erosion in the Indus River Basin. This suggests that the South Asian monsoon may be the dominant factor that controlling the erosion rate in the Indus River Basin. Tectonics, as the main factor affecting sediment provenance, has a minor effect on the erosion rate of the basin. The increase of ~8-7 Ma erosion rate and subsequent unstable fluctuations may be related to the enhancement of glacial erosion caused by global cooling and the disturbance of high-frequency/high-amplitude climate change to the erosion process.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-5: Asian continental margin sedimentation: Processes and records
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Variations in paleoproductivity during the Holocene Climatic Optimum in the Bering Sea Green Belt and its paleoclimatic implications

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Keywords: Paleoclimate , Paleoproductivity, Holocene Climatic Optimum , Bering Sea

The high north latitude climate has undergone significant changes during the Holocene Climatic Optimum (HCO), but the response of high-latitude marine environment to the HCO remains unclear, particularly in the Bering Sea. In this study, a suite of multiply proxies including sediment grain size, biogenic components (TOC, $CaCO_3$ and Opal) and organic matter stable isotopes ($\delta^{15}N$ and $\delta^{13}C$) of core LV63-19 retrieved from the Bering Sea Green Belt during the China-Russia joint expedition in 2013. The sediment core LV63-19 has an average sedimentation rate of 102cm/ka, which provides high-quality material to examine the response of the Bering Sea marine environment to the HCO. Our results show a pronounced increase in paleoproductivity in the Green Belt during the HCO period (11.5 ~ 9.0 ka). The enhanced paleoproductivity of the Bering Sea is mainly attributed to the dampened sea ice cover, increased duration of phytoplankton growth, and increased nutrient supply. The increases in nutrient supply are not only sourced from the terrestrial contribution but also an increased upwelling of nutrient and carbon-rich deepwater .It is an important reason for the formation of dark laminated sedimentary layers that the productivity blooms in the Bering Sea Green Belt during the HCO , but it is still constrained by multiple factors.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-5: Asian continental margin sedimentation: Processes and records
Presentation Preference: Oral Preferred

Sedimentation conditions of the southern slope of Lomonosov Ridge (Siberian area) during the Late Pleistocene and Holocene

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Keywords: Lithostratigraphy, sedimentation, Upper Quaternary sediments, Lomonosov Ridge, Arctic.

We studied 18 sediment cores taken from the southern the submarine Lomonosov Ridge (Siberian area) during the marine expedition of the R/V Akademik M.A. Lavrentiev" in 2020. We analyzed lithological description, magnetic susceptibility, density, moisture and colorimetric characteristics. The elemental composition was analyzed by the X-ray fluorescence method for 16 cores.

We compared our magnetic susceptibility, density, Mn content and lithology data with ones for sediment cores PS2757-8 and SWERUS-C3-29-GC1 (Jakobsson et al., 2016; West et al., 2021). In result, we set boundaries for MIS1 – MIS5 and established the position of five stratigraphically significant levels (Jakobsson et al., 2016; West et al., 2021). We also identified 6 additional stratigraphic levels. Based on this, we estimate the sedimentation rates. There is a clear trend towards an increase in sedimentation rates from east to west in the study area. In addition, we found that the accumulation of distinct gray layers occurred very quickly at the end of glacial stages at the beginning of interglacial stages. Possibly, the rate of accumulation of these layers was determined by the disintegration of continental and shelf glaciers during periods of deglaciation.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-5: Asian continental margin sedimentation: Processes and records
Presentation Preference: Oral Preferred

High resolution East Asian monsoon changes recorded in Sea of Japan sediments

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Keywords: color stratigraphy, Dansgaard-Oeschger cycles, climate changes

Here, we present a high-resolution record of the East Asian monsoon (EAM) obtained from a new mid-latitude archive of climate variability in the Northern Hemisphere during 30-125 ka. For this purpose, the sediments of the semi-enclosed Sea of Japan, which is a unique region of interaction between oceanic, land, and atmospheric circulation, were used. Using an original photocolorimeter, records of the color brightness (CL) of the Sea of Japan sediment core were obtained with a resolution comparable to the EAM curves of Chinese caves. The age mogel was established by identifying Heinrich events and then by detailed correlation of Dansgaard-Oeschger (DO) interstadials on the CL curve with those recorded in Greenland ice cores and Chinese caves. Comparison of DO cycles recorded in Greenland, Chinese caves, and the Sea of Japan makes it possible to better understand the mechanisms of formation and teleconnection of DO cycles in the Northern Hemisphere. During MIS 3, DO cycles 17-5, recorded in three archives, show the general millennial climate changes characteristic of the cores of Greenland. During MIS 5.2 and 5.3, Greenland ice core indicates gradual cooling after the start of the DO 23 interstadial period, while both EAM records show progressive warming followed by a sharp cooling, indicating differences in environmental evolution between the North Atlantic and the tropical Pacific. .

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-5: Asian continental margin sedimentation: Processes and records
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Provenance discrimination of siliciclastic sediments in the western Sea of Japan over the past 30 kyr: Evidence from major, trace elements and Pb isotopes

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Keywords: major and trace elements, Pb isotopes, provenance, IRD; Liman Cold Current, Sea of Japan

The Sea of Japan (JS), a unique marginal sea without any large river influxes in the western Pacific, provides ample information about the evolution of sea-level, East Asian Monsoons (EAM), sea ice activity, and ocean currents in geological time. However, insufficient investigation in the western JS limits our knowledge of East Asian climate change. This study utilizes major and trace elements and Pb isotopes of fine siliciclastic components (<63 μm) of core LV53-18-2 and determines the provenances using statistical methods and discrimination diagrams. The results show that the terrigenous debris of LV53-18-2 was mainly composed of aeolian dust from northeast China, ice-rafted debris (IRD), and volcanic materials from the Far East coast over the last 30 kyr. During the late last glacial period, sea ice activity carried weakly weathered IRD to the study area. Meanwhile, the strengthened East Asian Winter Monsoon (EAWM) brought dust from northeast China to the study site owing to the cold climate and enlarged sandy land. During the late last deglacial period to early Holocene (15-8 kyr), ascending boreal summer insolation drove the intense melting of sea ice. This led to the deposition of large amounts of weakly weathered IRD and remarkably influenced the chemical composition of the core. After 8 kyr, the global sea level rose to -15 m below the modern sea level and opened the Tatar Strait. Consequently, freshwater supplied by the Amur River entered the JS and gave birth to the Liman Cold Current (LCC), which transported more mafic materials from the Kema Terrane upstream.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-5: Asian continental margin sedimentation: Processes and records
Presentation Preference: Oral Preferred

Grain size variation of Asian dust in the silt and clay fractions of Japan Sea sediment revealing the variability of westerly and East Asian winter monsoon (EAWM) changes in the past 10 million years

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Keywords: Asian dust, PARAFAC endmember modelling, Taklimakan dust, Gobi dust, Ordos dust

Japan sea sediments consist of various detrital materials of eolian and riverine origin. Understanding the provenance of eolian dust is vital for reconstructing the variability of wind patterns and monsoons in the past. A complete aeolian accumulation rates in silt and clay fractions from the Late Miocene to Pleistocene were reconstructed at the Integrated Ocean Drilling Program (IODP) Site U1425 in the Japan Sea.

A total of 180 samples were collected from the Hole 1425D, which had 370 m in length and covered the last 9.69 m.y. Grain size separation was conducted to evaluate the mineral composition in silt (>4 μm) and clay (<4 μm) fractions by X-ray diffractometer (XRD). Mineral composition suggests the source variabilities in silt and clay fractions, which could be interpreted as provenance shifts occurring in 8 and 2.7 Ma.

Parallel factor analysis (PARAFAC) was applied to decompose X-ray diffractograms into individual subcomponents to identify the sources and quantify their contributions. Six-components PARAFAC model was established and 3 Asian dust sources (Taklimakan Desert, Gobi Desert and Ordos Plateau), a riverine source of Japan Island Arc, and 2 biogenic sources of diatomaceous and Opal-CT were identified.

The results show that Taklimakan dust is dominated by the silt fraction, while Gobi dust is dominated by the clay fraction, and they are controlled by the relative contributions of different pathways of dust transport, such as the westerly winds and East Asian winter monsoon (EAWM).

Clay-size dust from Gobi increased during three periods, late Miocene global cooling (LMGC), intensification of Northern Hemisphere Glaciation (iNHG), and mid-Pleistocene Transition (MPT), which reflected increased EAWM winds associated with global cooling and glaciation. Taklimakan became the major dust contributor to the Japan Sea sediments during the warmer climate periods in the latest Miocene to early Pliocene and the Late Pleistocene, where westerly wind activity dominated eolian transport. Dust from Ordos increased greatly 0.95-0.85 Ma due to enhanced Asian aridification since 2 Ma in Northwest China.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-5: Asian continental margin sedimentation: Processes and records
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Long eccentricity forcing Asian dust input into the northwestern Pacific during the early Pleistocene

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Keywords: Asian dust, 405-kyr cycles, ENSO-like state, Western Pacific, Early Pleistocene

Asian dust deposition in the northwestern Pacific is generally linked to high-latitude paleoclimate evolution during the Quaternary. However, whether low-latitude tropical Pacific processes, such as El Niño-Southern Oscillation (ENSO), influence Asian dust input into the northwestern Pacific remains uncertain. Here, we present clear periodic variations in potassium content (K (wt.%)) and gamma-ray attenuation (GRA) bulk density, which are closely linked to the variations in Asian dust, in a sediment core recovered at Site U1438 in the Amami Sankaku Basin (ASB), northwestern Philippine Sea. Based on the shipboard age-depth model, we tuned the GRA to the mass accumulation rate curves on the Chinese Loess Plateau and the 8-kyr-lagged obliquity curve and established the astronomical timescale.

The K (wt.%) content and GRA were higher during glacials and lower during interglacials, as driven by the variability in the Northern Hemisphere ice sheet (NHIS) during the Quaternary. In addition, strong long eccentricity 405-kyr cycles were observed in the dust records (K (wt.%) content and GRA) during the early Pleistocene. The 405-kyr filter results showed that increased (decreased) Asian dust corresponded to the La Niña-like (El Niño-like) state, suggesting that Asian dust input into the northwestern Pacific was modulated by ENSO on 405-kyr cycles in the early Pleistocene. Our study illustrated the possible link between long eccentricity 405-kyr cycles in the Asian interior and low-latitude forcing, including potential modulation by ENSO.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-5: Asian continental margin sedimentation: Processes and records
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

How Did Sediments Disperse and Accumulate in the Oceanic Basin, South China Sea

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Keywords: Sedimentary budget; Sedimentary provenance; Controlling factors; IODP; Oceanic basin of South China Sea

Quantification of the sedimentary accumulation and dispersion process of the South China Sea (SCS) not only establishes an important part on the “source-to-sink” process in East Asia, but also shed lights on the submarine slope failure and associated submarine canyon/channels formation. Based on geological interpretations of more than 30 multichannel seismic profiles covering the whole oceanic basin with constraints from IODP Expedition drilling results, we calculated the sedimentary budget of the oceanic basin since the Oligocene on a million-year geological scale. Sediment isopach maps in different geological time were reconstructed to understand the controlling factors dominating the Cenozoic sedimentary accumulation and dispersion process, as well as the possible sedimentary provenances. Results show that the sedimentary budget of the whole oceanic basin increased gradually with time, although the rate has not been consistent over time. It was complicated by regional tectonics, including the spreading of the SCS, the uplift of the Tibet Plateau and the Taiwan, the Asian monsoon, the onland river systems, as well as the sea level changes. Submarine channel/canyon systems developed in the continental margin acted as the major conduits for terrestrial sediments discharging into the oceanic basin. Opposite trend occurred in the Southwest Sub-basin (SWSB) during the Late Miocene, and in the Northwest Sub-basin (NWSB) during the Pliocene. The former might be related with the local rifting event in the Mekong Shelf, which trapped most of the terrestrial input. While the later was due to the retreat of the Central Canyon and Pearl River Canyon in the Late Pliocene. Sediment isopach maps indicate that the sediments accumulation mainly focused on the NWSB and the northern flank of the East Sub-basin (ESB) before the Late Miocene, with the depocenters generally distributed at the mouth of the channel/canyon systems and slope foot area near basement highs; but gradually migrated to the SWSB and the southern flank of the ESB since Pliocene due to the high sea level and increase of the Mekong River runoff. An exception is the depocenter in the northeast part related with the Taiwan orogeny. Either the thickness or the range increased and spread to the central basin caused by the huge amounts of terrestrial sediment accumulation due to the continuous uplifting and denudation since the Late Miocene. The primary sediment provenances include the South China, Tibet Plateau, Indo-China Peninsula, and Taiwan Island, with minor contributions from the Hainan Island, Palawan, Luzon Islands, as well as local basement highs developed on the continental margin.

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Session T6-7: Mixed depositional processes in coastal to shelf environments

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-7: Mixed depositional processes in coastal to shelf environments
Presentation Preference: Oral Preferred

Outer-shelf conduit within growth-fault compartment Pliocene Orinoco Delta

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Keywords: Orinoco Delta, Mayaro Formation, shelf conduit, collapse scar, tidal distributary channels

Prominent outcrops of the Pliocene Orinoco Delta along the southeast coast of Trinidad Island display a well-known, very thick Icehouse succession of storm-wave dominated delta lobes, as part of a 10-12 km thick Neogene continental-margin prism. There is a previously discovered, steep incision or conduit (400 m wide) with south and north-bounding erosion surfaces, cutting deeply into the Mayaro Formation shelf-edge delta deposits. The ca. 100 m-thick infill of the conduit shows an initial muddy succession passing upwards to very coarse-grained debrites, rotated and slumped blocks, and structureless sandstones that pass upward to a stacked series of sandy to muddy channel fills. The channels show spectacular tidal rhythmites, probably developed on the point bars of subaqueous tidal channels. As one piece of the topset of the shelf-edge delta clinoform, this conduit displays features of the linkage hub between the landward on-shelf delta systems and the basinward slope deposits.

New fieldwork and a re-examination of the incision-infill reveal new details and suggest three possible origins of the conduit: the first is a no river feeder, shelf-edge collapse scar, extending onto the upper slope and infilled by deeper to shallower deposits. This shelf-edge cutting canyon interpretation is supported by the presence of hardground ichnology on the steep walls of the incision and the abundance of chaotic blocks and debrites in the lower two-thirds of the incision infill. The second is a shelf channel or valley linking fluvial channels to on-shelf and outer shelf deltas. This river-connected, subaqueous shelf valley origin, is supported by the upward-coarsening nature of the infill succession and especially the occurrence of shallow-water tidal channels in the upper third of the infill. The third is a canyon developed mainly during transgression or highstand with a collapsed canyon-head infill and an overlying muddy tidal-channel system that had only limited sediment bypass to the deepwater slope and basin floor. This case represents both the shallow-water and the deeper water features of the infill succession, and is supported by similar large shelf-edge collapse features seen elsewhere in the Cruse and Moruga Formations of the paleo-Orinoco margin. This case, unrelated to river supply, also benefits from slight rotational shelf-edge uplift to trigger collapse.

The known Cedar Grove growth fault was active and located some 4 km to the west from the present coast on the southeast corner of Trinidad Island. The growth-fault trapped thickened outer shelf to shelf-edge delta-front and delta-plain sediments within the hanging-wall compartment as the fault stretched about 20 km along strike. All the shelf-edge aggradation and its partial collapse were likely triggered by growth-faulting. After some muddy backfilling and coarse-grained block collapse into the invaginated shelf-edge, this scalloped area attracted a belt of subaqueous tidal channels, thus healing the eroded topography.

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Session T6-7: Mixed depositional processes in coastal to shelf environments
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Ordovician-Silurian and Devonian sedimentary complexes of Mendeleev Rise, Wrangel Island and Chukotka and their correlation

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Keywords: arctic region, paleozoic deposits, carbonate-terrigeneous

There are great similarities in the structure of Paleozoic (O3-S and D2-3) units of Chukotka, Wrangel Island and Mendeleev Rise: synchronous intervals without sedimentation, similar composition of sandstones and general facies patterns. During the studied stratigraphic intervals, shallow water environments are established – carbonate sedimentation for Ordovician-Silurian and terrigenous for Devonian. In Silurian stage, shallower facies were located in the East both for the Mendeleev rise and for Wrangel Island, which is also confirmed by the transport direction. In the Devonian, there is a terrigenous type of sedimentation with a similar composition of sandstone both on the Mendeleev uplift and on Wrangel Island and Chukotka. Transport direction has been established from North to South for the Chukchi region.

The stage of the Ellesmere deformations in the Early Devonian is recorded by absence of deposition on the Mendeleev rise and the accumulation of quartzite sandstones in shallow water environments on Wrangel Island and more deeper ones in Chukotka, which indicates a peneplenization and the weathering crust forming on the adjacent land.

For the Upper Devonian, a parent source probably represented by a series of islands composed of granitoids and meta-sedimentary rocks, because the synchronous sandstone’s composition varies in different sections of Wrangel Island and Chukotka.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-7: Mixed depositional processes in coastal to shelf environments
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Temporal and Spatial Differences in Sediment Dynamics and Processes on the muddy deposit off the Shandong Peninsula: An Observational Study

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Keywords: coastal sediment dynamics, suspended sediment transport, strong wind events, muddy deposit

Sediment from the Yellow River, one of the largest rivers in the world in terms of sediment discharge, is known to be responsible for the elongated distal mud deposit off the Shandong Peninsula. The hydrodynamic and sedimentary mechanisms that maintaining the unique 'Ω'-shape topography and sedimentary structure have always been intriguing to the research community. Instruments including bottom-mounted tripods and moorings were deployed at three stations across the deposit (at water depth of 40, 26 and 55 m respectively) to record the synoptic and seasonal (summer vs winter) variations of oceanographic forcing and sediment dynamic responses. Empirical Orthogonal Function (EOF) analysis was performed to examine the covariability of suspended sediment concentration (SSC) on various forcing factors including waves, winds, currents etc. It shows that tidal flows were the most important physical forcing for SSC variation in summer. Large waves in winter could significantly enhance sediment resuspension at the top of the deposit (the shallowest site) but not as much at either side of the deposit where water is deeper. It is the residual currents (first mode which explained about 40% of the standardized covariability) driven by along-shelf winds that overpowered the winter waves at the 40 m site. In general, advections dominate the southward sediment transport pattern in summer. In winter, however, resuspension due to frequent strong winds dominates the southward sediment transport on the top of the deposit, whereas advection due to residual currents is mainly responsible for the sediment transport in the further nearshore.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-7: Mixed depositional processes in coastal to shelf environments
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Submerged beach rocks from the continental shelf of southern Brazil

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Keywords: Beach rocks, continental shelf, southern Brazil

The continental shelf of southern Brazil presents three alignments of beach rocks, submerged, between Chuí and Torres. For this study, we used on-board maps, seismic profiles and dive data information. A GPS was used for the location of the beach rocks. The depth was obtained by echo sounding and precision aneroid. The first beach rock, located to the south, is made up of two blocks, Hermenegildo South and Hermenegildo North, 0.70 and 14 km from the coast and with their peaks at ±9 m and ±13 m from the depths. Then there is the beach rock Fronteira Aberta, 19 km from the coast and its summit at ±13 m depth. The next is formed by two blocks, Albardão South and Albardão North, with their peaks at ±7 m and ±8 m and ±23 km and ±12 km from the coast. It is followed by the Capela beach rock which is at a depth of ±7 m and 0.50 km from the coast. The fifth beach rock, Minuano, is also divided into south and north, with their peaks at ±19 m and ±17 m depth and 26 km and 35 km from the coast. The next beach rock, called Carpinteiro is located 30 km from the coast and divided into South and North, with their peaks at ±14 m and ±15 m depth. The next is the Barra Falsa beach rock, divided into south and north. Their summits are between ±13 m and ±15 m deep and with a distance of 15 km and 20 km from the coast. The eighth beach rock is also divided into two sectors, South and North, with its peaks at ±15 m and ±13 m depth and 0.50 km and 1 km from the coast. The next beach rock, Solidão, has its summit at ±21 m depth and is 1.5 km from the coast. The tenth beachrock, Capão da Canoa, is divided into South and North, with their peaks at ±25 m and ±27 m depth, and 2.6 km and 4 km from the coast. The last beach rock, Torres, is divided into South and North and their peaks are at ±24 m and ±20 m in depth and 1.3 km and 1.8 km from the coastline. In general, we can say that the internal continental platform of southern Brazil, presents three alignments of beach rocks: the first located between 7-10 m, the second between 13-19 m and the last between 20-30 m, corroborating with the terraces described by several authors. According to the sea level variation curve, the beach rocks located between 7 and 10 m deep have an age of ±7,100 years AP, those located between 13 and 19 have an age of ±7,500 years AP while the sandstones of beach that is in the depth between 20-30 have an age of ±8.000 years AP.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-7: Mixed depositional processes in coastal to shelf environments
Presentation Preference: Oral Preferred

Estimating paleotidal constituents from well-preserved tidal rhythmites: Review and new data from Pliocene "tidal gauges" in the paleo-Orinoco Delta, Trinidad

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Keywords: paleo-Orinoco Delta, tidal cycles, tidal bundles, rhythmites, tidal constituents

The Orinoco Delta is one of the few river deltas where both modern and ancient tidal processes records can be studied. The ca. 5 My succession on the island of Trinidad contains remnants of paleo-Orinoco deltaic deposition preserving both tide- and wave-influenced delta lobes within the same time intervals, just like its modern Orinoco Delta that has both wave-dominated and tidal-dominated lobes. The tide-influenced delta lobes and estuaries preserve some spectacular tidal bedding signals including tidal rhythmites. The tidal record encoded within the tidal rhythmites is preserved well enough that the primary tidal constituents responsible for the tidal currents that deposited the rhythmic facies can be inferred.

Lower to upper Pliocene tidal rhythmites have been examined in two main paleo-Orinoco sub-environments: (1) estuary and delta lobe deposits of Morne L'Enfer Fm. at Erin Bay and (2) abandoned tidal channels associated with tide-influenced delta-front deposits from Telemaque sandstone Member of Manzanilla Formation at Matura Bay. Both wave- and river-current signals are also present in most of the study areas.

Tidal constituent analysis of unusually well-preserved paleo-Orinoco tidal rhythmites reveals a hierarchy of tidal signals that include semi-diurnal, diurnal, fortnightly (neap-spring), monthly (perigee-apogee), semi-yearly, and possibly seasonal and yearly cycles that span thickness intervals ranging from mm to meters.

The tidal constituents were dominated by, in decreasing importance, M_2, S_2, and likely K_1 rather than O_1. The modern data clearly show that K_1 is more important in terms of tide-generating potential than O_1, as was likely so in the Pliocene. In both the rock and modern records N_2 is more significant than O_1, P_1, and K_2 are in terms of tide-generating potential. The comparison between the constituent analysis of the ancient tidal record and the modern tide measurements reveals their similarities in tidal patterns and constituent types and from this we deduce that the tidal constituents responsible for the Pliocene Orinoco Delta tides were mixed semidiurnal tidal cycles similar to those found today in Trinidad (Atlantic type-synodically dominated) rather than Caribbean (tropically-dominated) type.

Furthermore, the thickness of the tidal rhythmites, accumulated either by ponding in near-abandoned channels or by lateral accretion in dunes within channel bars, allows sediment accumulation rates to be estimated. In the alternating sand- and mud-dominated rhythmites the preserved laminae thickness is positively related to tidal current strength, sediment discharge, and seasonal changes, and also reflects environmental processes.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-7: Mixed depositional processes in coastal to shelf environments
Presentation Preference: Oral Preferred

EVIDENCE OF FLUVIAL DOMINANCE IN THE MOST FAMOUS ANCIENT TIDE-DOMINATED DELTA: A REINTERPRETATION OF THE UPPER CRETACEOUS SEGO SANDSTONE AND BUCK TONGUE, BOOK CLIFFS, UTAH

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Keywords: varying river discharge, river flood, interflood, fluvial-dominated delta, deltaic deposits, Western Interior Seaway

Interpreting nearshore systems and rocks is particularly challenging given the presence of multiple processes varying in space and time. In this study, we provide a reassessment of the relative roles of fluvial, tidal, and wave processes in the deposits of the Sego Sandstone and Buck Tongue, which probably represent the best studied and most widely interpreted ancient tide- (or mixed tide-wave-) dominated delta. Detailed sedimentological analysis at selected localities confirmed that potentially tide- and wave-generated sedimentary structures (e.g., bidirectionality, heterolithic bedding, hummocky cross stratification) or evidence for brackish water (e.g., trace fossils) are common; however, in most of the cases, a dominant fluvial signature that has been so far unrecognized can be interpreted. This signature consists of a cm- to dm-scale alternation of sandstone and heterolithic beds representing flood-interflood periods of a varying river discharge. Evidence for marine incursions is often present only in the interflood beds and subordinately to the dominant river-derived interbedding. Recognition of widespread fluvial processes across the studied units would highlight a historical and persistent overinterpretation of tidal (and wave) processes. We suggest that the widely used approach for interpreting nearshore deposits applied to the Book Cliffs but also elsewhere is inappropriate to decipher the complexity of these systems.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-7: Mixed depositional processes in coastal to shelf environments
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Study on division of sequence stratigraphy and its petroleum geological meaning of the Silurian marine siliciclastic depositional systems in the Tarim Basin, China

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Keywords: Division of sequence stratigraphy, sedimentary facies, source-reservoir-caprock assemblage, favorable exploratory targets, Silurian, Tarim Basin

The Silurian has a residual area of about 24.9 × 104 km2 (96,139 mi2), and many hydrocarbon shows have been encountered in the Kepingtage sandstones in the Tarim Basin. Based on the cores, logging, seismic, and analysis data, division of sequence stratigraphy, characteristics of sedimentary facies, and its petroleum geological meaning of the Silurian in the basin were studied. The Wenlock Yimugantawu Formation and the Llandovery Tataaiertage and Kepingtage formations are Silurian in age. The Silurian can be divided into three second-order sequences, and ten third-order sequences. The Kepingtage Formation consists of Lower, Middle, and Upper Members, and the Lower Member is divided into three third-order sequences (Sq1, Sq2, Sq3), and the Middle Member is Sq4, and the Upper Member is divided into two third-order sequences (Sq5, Sq6). The Tataaiertage Formation consists of Lower and Upper Members, and is divided into two third-order sequences (Sq7, Sq8). The Yimugantawu Formation is divided into two third-order sequences (Sq9, Sq10). The third-order sequences of Sq1, Sq5, and Sq7 belong to the type - I sequence, while the others are the type - II sequence. Four types of depositional systems were identified in the Silurian, including shore-neritic-deep water shelf, tidal flat, tidal flat-shore composite, and braded delta systems. The sandstones of Sq1, Sq2, Sq3, and Sq5 at the depths of 4200 – 6230 m have porosity of 0.73% - 20.62%, averaging 8.25%, and permeability of 0.01-1855 mD, averaging 12.22 mD, indicating that the Kepingtage sandstones have good reservoir quality and are the potential exploration layers.

Deep water shelf of Sq 4 is developed in the depositional center of the Manjiaer and Awati Depressions. Organic carbon content of the deep-water shelf black shales ranges from 0.47% to 0.92%, their chloroform bitumen ‘A’ ranges from 177.5 to 417 PPm, and their vitrinite reflectance ranges from 0.74% to 1.34%. The thermal simulation results from Shun 1 well show that the source rocks of Sq4 were in early maturation in 290 Ma (Ro>0.5%), in middle maturation in 230 Ma (Ro>0.7%), and in late maturation in 40 Ma (Ro>1.0%). Sandstones of fluvial, braided delta, upper foreshore in Sq 1, Sq 2, Sq 3 are widely distributed across the basin. The neritic-deep water shelf mudstones of Sq4 form regional caprock, and the tidal red mudstones of Sq 7 form local caprock. Combinations between Sq1-Sq3 and Sq4, having syngenetic source-reservoir-caprock assemblage and favorable accumulation conditions of hydrocarbons generating from the Cambrian - Ordovician source rocks, are the potential oil-bearing layers. The sandstones from Sq1 to Sq3 and Sq5 around the margins of the Manjiaer and Awati Depressions, and in the Shuntuoguole Low uplift are the favorable exploratory targets.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-7: Mixed depositional processes in coastal to shelf environments
Presentation Preference: Oral Preferred

Facies Associations, Stacking Patterns and Conceptual Depositional Model of Early Devonian Strata in Eastern Saudi Arabia

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Keywords: Shoreface, estuarine, fluvial, sequence stratigraphy

The Arabian Plate witnessed several transgressive and regressive episodes during the Early Devonian. During the Pragian-Emsian, two regressive events separated by a transgression are characterized by specific facies associations, stacking patterns, and gamma ray signature.

This study is based on subsurface core data. Lithofacies at sub-foot scale, interpretive sedimentary processes and depositional environments, combined with wireline and image logs. Palynological analysis was found crucial for localized stratigraphy.

Overall, the Formation of study is representing paralic depositional environments subdivided into a lower, middle, and an upper unit. The lower unit is dominated by shoreface successions that are cut by prograding tidal channels. The middle unit displays a variety of facies associations indicating estuarine channels, barriers, washover sediments, tidal sand and mud flats, central basin, flood-/ebb-tidal deltas. Different elements of these facies coexist to form stacked bayhead deltas. The upper unit is dominated by prograding tidal channels, marshes, and floodplain deposits.

Cross sections across depositional strike and down depositional dip show the lateral variation of facies associations and a sequence stratigraphic framework. Image logs are used to establish an overall depositional dip direction and better predict lateral facies change. Stacking patterns in the cross sections are classed as: 1) lower unit representing a forced regressive system, 2) transgressive middle unit, and 3) an upper normal regressive system.

The overall lithofacies characteristics and associations aided in identifying sedimentary processes and depositional environments. Further analysis on the stacking patterns resulted in interpreting two regressive events separated by a transgression. This dataset along with cross sections were used to classify the regressive successions as a forced regressive system and a normal regressive system.

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Session T6-7: Mixed depositional processes in coastal to shelf environments
Presentation Preference: Oral Preferred

Delineation of 3rd order depositional sequences and sea level changes during Bathonian-Oxfordian, Kachchh basin, Gujarat, India

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Keywords: Microfacies, 3rd order depositional sequences, Bathonian-Oxfordian succession, Kachchh basin

Kachchh sedimentary basin is a peri-continental basin in the extreme west of Indian Peninsula.
The Mesozoic rocks ranging in age from Middle Jurassic to Upper Cretaceous occur conspicuously in the various major uplifts, and are exposed extensively in the Kachchh Mainland, Wagad, the 'Islands' of Pachcham, Bela and Khadir, and the Chorar hills. The Mainland outcrops expose a continuous succession from Bathonian to Santonian and consists of most prominent ridge extending for about 193 km from Habo in the east to Lakhpat in the west. On the basis of detailed field studies in Jhura dome, Kachchh Mainland and laboratory investigation of 60 rock samples, the 370m succession of rocks is stacked in to three 3rd order depositional sequences. The stacking pattern of microfacies assemblage refers to the architecture of vertical succession of depositional sequences. Transgressive sequence-I, Regressive sequence and Transgressive sequence-II have been recognised. The 84m Transgressive sequence-I consisting of four microfacies assemblages: (i) Oolitic fossiliferous grainstone - Sandy fossiliferous grainsone, (ii) Oolitic fossiliferous grainstone - Calcareous mudstone, (iii) Pebbly fossiliferous grainstone - Calcareous mudstone, (iv) Fossiliferous intraclastic grainstone - Calcareous mudstone representing upward deepening facies succession. The 130 m Regressive sequence composed of five microfacies assemblages: (i) Fine grained sandstone - Siltstone, (ii) Pebbly fossiliferous packstone - Siltstone, (iii) Pebbly cherty calclithite microfacies, (iv) Gypsiferous mudstone - fine grained sandstone, (v) Medium to coarse grained sandstone microfacies showing upward shoaling facies succession and the 155m Transgressive II consists of five microfacies assemblages: (i) Gypsiferous mudstone-Medium to course grained sandstone, (ii) Sandy fossiliferous packstone - Gypsiferous mudstone, (iii) Sandy oolitic packstone - Siltstone, (iv) Conglomeratic fossiliferous oolitic packstone microfacies, (v) Conglomeratic fossiliferous ironstone microfacies showing upward deepening facies succession.
From the present study It is inferred that there is marked deepening of sea during Bathonian as indicated by microfacies assemblages of transgressive sequence -I. Shallowing of basin during Callovian is suggested by microfacies assemblages of Regressive sequence that deposited during gradual increase in sediment supply and maximum deepening of basin in Early Oxfordian is marked by microfacies assemblages of Transgressive sequence- II that deposited during rapid sea level rise. The relative sea level curves indicate several sea level fluctuations during whole sequence prior to major sea level drop at the end of the transgressive sequence-II. The microfacies study reveals that the relative sea level cycles might have been controlled due to active tectonic mechanism (Cloetingh,1986; Kauffman,1984).

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-7: Mixed depositional processes in coastal to shelf environments
Presentation Preference: Oral Preferred

Analysis of the sedimentary reservoir architecture in a tide-dominated estuary: The study of the Athabasca block in Canada McMurray Formation Oil Sands Reservoir

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Keywords: tide-dominated estuary, McMurray Formation, architecture elements, tidal bar, lateral accretion

Tidal-dominated estuary is a system with complex hydrodynamic characteristics and sedimentary processes, influenced by bidirectional currents and sea-level fluctuations. Based on high-resolution seismic data, 168 well coring datas and logging data, a detailed description of the sedimentary characteristics, architecture model and evolution of the tidal-dominated estuary reservoir in the Lower Cretaceous McMurray formation is presented. The results are as follows: 1) The lithofacies associations are divided into 9 types of architecture elements. The nine architecture elements are channel, salt marsh, fluvial point bar, tidal point bar, mud flat, mixed flat, sand flat, tidal bar and offshore. The boundary surfaces of each architecture elements are depicted and the logging characteristics is concluded. 2) The plane and vertical distribution of architectural elements are revealed, and the sedimentary model is constructed. In the longitudinal section of estuary, the architecture elements is fluvial deposits (channel, fluvial point bar, salt marsh), tidal flat (mud flat, mixed flat and sand flat), tidal sand bar, tidal flat, and offshore from land to sea. In the cross section, tidal sand bar, sand flat, mixed flat, mud flat, tidal point bar and salt marsh are distributed successively from the center to the sides. 3) The main reservoirs such as sand flat and tidal sand bar are distributed in the incised valley formed during mid-short-term regression, and the frequently incised sedimentary landform controls the distribution range and plane morphology of the main reservoirs (sand flat and tidal bar). Tidal bars are mainly distributed in the incised valley with larger water depth. The sand flat is primarily distributed in the flat area of the lateral edge of tidal sand bars or in the incised valley. The sand flat and the mixed flat occured the erosion and filling phenomenon inside. Tidal bar has a wide band shape with a typical high-angle continuous lateral deposits.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-7: Mixed depositional processes in coastal to shelf environments
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Diagenesis of shale oil reservoir in Lucaogou Formation, Junggar Basin

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Keywords: mixed rocks, diagenesis, Jimusar Sag

Hydrocarbon exploration has been increasingly concentrated in mixed rocks its large quantities. Mixed rocks are always heavily cemented, while high quality reservoirs have large numbers of pores created by dissolution and/or dolomitization. Thus, one of the major challenges for characterization of mixed rocks are to understand the distribution of diagenesis, associated products and controlling factors responsible for determining the quality and overall heterogeneity of the reservoirs. This study takes the Lucaogou Formation in Jimusar Sag as an example to study the diagenetic evolution of the reservoirs. Through comprehensive core analysis, the control factors of reservoirs development under different burial depths were identified, and the differential genesis was revealed.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-7: Mixed depositional processes in coastal to shelf environments
Presentation Preference: Oral Preferred

Source-to-sink analysis for the late-Quaternary Qiantang River incised-valley fill and its implications for delta-shelf-estuary dispersal systems globally

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Keywords: Changjiang, delta-shelf-estuary system, elementary geochemistry, mixing model, sediment budget, zircon U-Pb geochronology

The Changjiang (i.e. the Yangtze River) debouches a huge amount of sediment to the East China Sea and exerts a significant effect on the evolution of the down-drift Qiantang River system. This study quantitatively documents the temporal change in the import of Changjiang sand and mud to the late Quaternary Qiantang River incised valley by establishing separate mixing models based on zircon U-Pb ages for the sand and trace-element compositions of the mud fraction. Results indicate that the Qiantang River provided all of the sediment to its valley before ca 8.0 cal. kyr BP. However, its sediment proportion decreases upward due to the onset of export of sediment from the Changjiang after its delta had prograded sufficiently. Changjiang mud, a major component (ca 87%) of the Changjiang-derived sediment, is considered to be primarily supplied through the resuspension and landward transportation of sediment from the inner-shelf mud wedge in the East China Sea by flood-tidal currents and waves. Changjiang sand, which arrived in the Qiantang River valley later than the mud, is interpreted to be derived from the reworking of older deposits on the East China Sea shelf and along the northern margin of the Qiantang River estuary. In the later part of the valley fill, Qiantang River sediment is only ca 9% of the Changjiang contribution, although Qiantang River mud has begun to be exported recently. The Changjiang contribution to the Qiantang River system constitutes ca 50% of the total sediment load discharged by the Changjiang during the 8–6 cal. kyr BP period, but <4% since 6 cal. kyr BP. This study illustrates the need to exercise caution when interpreting compositional data from linked coastal-shelf sediment-dispersal systems with significant along-coast transport, and is expected to be applicable in a general way to other linked river-coastal-shelf systems.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-7: Mixed depositional processes in coastal to shelf environments
Presentation Preference: Oral Preferred

Rapid accumulation of early Holocene tidal rhythmites in the paleo-Han River estuary, Korea: Evidence of intensified summer monsoon

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Keywords: tidal rhythmite, early Holocene, summer monsoon, Han River delta, sediment discharge

Rapid transgression occurred globally during the early Holocene, leading to estuarine deposits in the incised valleys with typically insignificant fluvial sediment loads except for major rivers. High monsoon-related sediment discharge in the early Holocene has been documented from the major rivers, but little is known about the fluviosedimentary response of the small to moderate rivers. Facies and stratigraphic analysis of long (~ 50 m) borehole cores, obtained in the northern Gyeonggi Bay, west coast of Korea, revealed that up to 35-m-thick Holocene deposits consist of two units, i.e., Lower and Upper units. Lower unit is 15–20 m thick and is characterized by interlaminated sands and muds and a slightly fining-upward textural trend. Upper unit is less than 10 m thick and displays a slightly coarsening-upward textural trend. Parallel to ripple cross-laminated and cross-bedded sands constitute the major facies of Upper unit. Lower unit hosts 15-m-thick tidal rhythmites, displaying hierarchical tidal rhythmicities in the laminae thicknesses, including diurnal inequality, neap-spring tidal cycles, fortnightly inequalities, and semiannual tidal cycles. AMS radiocarbon dating indicates the rhythmites succession formed between 9–8 ka B.P. (14C dates) when the summer monsoon intensified to result in high sediment discharge like many tropical to temperate regions. Despite the moderate discharge of the Han River (1/45 of the Yangtze River and 1/30 of the Brahmaputra River), such rapid accumulation (~15 mm/yr) indicates that the sediment loads of the paleo-Han River are comparable to those of the large rivers in the early Holocene. The enhanced sediment discharge of the paleo-Han River is further aided by the geology and morphology of the catchment area, which is composed mostly of impermeable granitic bedrocks with a steep slope gradient, promoting surface runoff. The tide-dominated paleo-Han River estuary was fed by fluvial muddy sediments in the early Holocene transgression and became a deltaic setting with a relatively sediment-starved condition in the late Holocene sea-level highstand when the summer-monsoon intensity has decreased notably. The absence of well-developed tidal rhythmites in Upper unit is ascribed to the mixed-energy condition in the late Holocene when the northern Gyeonggi Bay was subject to offshore waves. The present study showcases that relative sea-level changes under shifting climate regimes played a crucial role in the stratigraphic evolution of the Han River delta.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-7: Mixed depositional processes in coastal to shelf environments
Presentation Preference: Oral Preferred

Multi-stage Miocene forced regressive deposits on the northern South China Sea shelf: Responses to a southwesterly flowing paleocurrent

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Keywords: Pearl River Mouth Basin, Sequence stratigraphy,Forced regressive deposits, SW-oriented paleocurrent

In this study, high-resolution 3D seismic, log and core data were used to identify multiple stripe sand deposits in Miocene strata in the Huizhou Sag, Pearl River Mouth Basin, northern South China Sea.

Analysis of stripe sand deposits includes seismic facies analysis and seismic geomorphology analysis: (1) Seismic facies analysis: Three main types of seismic facies can be recognized within stripe sand deposits : Seismic facies1 located in front of the stripe sand deposits has a wedge shape and pinching out seaward with very high amplitude reflections; Seismic facies 2 located in central part of stripe sands has moderate-high amplitude and high angle reflections with clinoforms characteristic; Seismic facies 3 located in tail of stripe sand deposits has parallel to sub-parallel and low-amplitude reflections with wedge shape, numerous scour gutters can be found here. (2) Seismic geomorphology analysis: By means of RMS amplitude and color-blended (RGB) spectral decomposition extractions from top to base of stripe sand deposits, we found that entire stripe sand deposits have a NE-SW orientation with characteristic of NE-narrow and SE-wide, its interior develop striate structure in the middle part especially.

After analysis above, we consider stripe sand deposits to be beach ridge sedimentary facies. Identified beach ridges in study area may form in stage of sea level fall, the presence of forced regressive beach ridge deposits can be evidenced by: (1) In the seismic section, the interior of forced regressive deposits is typical of upward and toplap characteristics, with the presence of a basinward-dipping upper bounding surface as a whole.; (2) In logging, it shows the Coarsening-upward sandstone with abrupt change of top and bottom, and the thickness of forced regressive sand body in the same period changes from thin to thick in sedimentary tendency, but in general, the thickness of the youngest forced regression wedge is the largest; (3) The bottom interface of the sharp-based sandstone can be observed on the core, and below the RSME are fine-grained silty sand or mudstone, in which a large number of bioturbation can be found;

In identified beach ridges deposits, one of the oldest period (developed after 23.8 Ma) appeared with the NE to SW divergence characteristics, so we speculated that the dominant SW-oriented paleocurrent was already exists since 23.8 Ma. Carbonate platform and uplift in the southeast region gradually developed landward, the strike of beach ridge deposits gradually changed from the whole nearly parallel to paleoshoreline to the northern half nearly parallel to the platform edge and the southern half nearly parallel to the paleoshoreline. Subsequently, the carbonate platform gradually retreated seaward, and the strike of beach ridge deposits formed gradually parallel to the paleo-shoreline, which may indicate that the flow direction of the NE-SW paleocurrent had some changes in the narrow area between the carbonate platform and paleoshoreline.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-7: Mixed depositional processes in coastal to shelf environments
Presentation Preference: Oral Preferred

How to orientate a shallow-marine silicilastic platform in 3D? A stratigraphic study from the Ktawa Group in Morocco (Late Ordovician, Gondwana)

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Keywords: Stratigraphy, HCS, siliciclastic, Gondwana, Ordovician, Morocco

The Southern Anti-Atlas of Morocco contains shallow-marine siliciclastic sediments from Late Ordovician time. These were deposited on the northern platform of Gondwana and are part of a large-scale flooding, which started in the Latest Precambrian. Here, a set of 42 stratigraphic profiles were logged in the field in order to constrain the Ktawa Group (Sandbian to Katian). Drone-based 3D photogrammetric reconstructions allowed to calibrate the logs thicknesses. The profiles were correlated through satellite and drone-based images along a ca. 175 km long continuous transect. The transect contains sections with orientations pointing from NE to SE, allowing to discuss semi-3D interpretations.

The Lower Ktawa Group is dominated by shales, punctuated by fine to coarse sandstones units forming successive cuestas. Six different sand cuestas outcrop in different zones of the transect. A general model can be hypothesized, whereby each cuesta includes a low-energy upper offshore parasequence at its base, which is subsequently truncated by high-energy storm-dominated (reworked) HCS beds during the ensuing transgression. Two cuestas, however, differ from this model and call for additional refinements. They include bioturbated, coarse-grained and cross-bedded deposits with a sharp base (i.e. tidal?).

Although the general stratigraphic framework is relatively well understood, the orientation of the system remains challenging. Two main hypotheses are drawn, and seem to explain equally well the data. One possibility is a system with a dominant W to E proximal-to-distal trend. Clinoforms would be organized as prograding sequences towards the E. The alternative model is a system oriented S to N, where each cuesta represents a laterally restricted “megalobe”. A switch in feeders and/or differential subsidence could explain the lateral shift in emplacement of the cuestas. In both models, the two cuestas containing coarse-grained units would represent major regressive excursions. Furthermore, both models require syn-sedimentary differential subsidence to account for the measured sediment thicknesses.

On the larger scale, the study region (Foum-Zguid region) is transiting eastward into a time equivalent shale-dominated area (Tagounite region), until reaching another sandy area approx. 300 km further NE (Erfoud region). Hence, in a W to E clinoform interpretation, the basin would have a conjugated coastline to the NE with another depositional system orientated S to N. In a S to N "megalobe” interpretation, two parallel depositional systems would fill a globally S to N oriented basin, thus forming a single and coherent trend for all formations.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-7: Mixed depositional processes in coastal to shelf environments
Presentation Preference: Oral Preferred

Clay coated grain distribution and formation process in tidally influenced systems; case study from a modern analogue, Ravenglass Estuary, UK

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Keywords: clay coating, reservoir quality, tidal systems

Understanding the reservoir properties (texture, architecture and chemistry) is crucial for successful extraction and injection of fluids and gases from/to subsurface reservoirs. Mineral composition, storage capacity and pore connectivity of reservoirs are typically controlled by combination of depositional and diagenetic factors. Depositional properties such as mineralogy, grain size, sorting and fluid chemistry provide a template for burial diagenetic pathway

There is a strong link between (depositional) detrital clay content and their distribution on pore scale attributes. Excess detrital clay typically fills pores and bridges pore throats resulting in reduced permeability. However, the presence of limited amount of grain coating detrital clay has a positive influence on reservoir attributes by inhibiting burial cementation and hence retaining porosity and permeability. Therefore, understanding the detrital clay type and distribution is crucial for prediction of subsurface reservoir attributes.

This study examines the distribution of detrital clay coated grains and clay coat forming processes on and around bar formations in a modern estuary (Ravenglass Estuary, UK). Material covers surface sediments from a range of facies and up to 5m long cores representing deposits since the last glacial maximum. The preliminary results suggest that, almost all facies associations host clay coated sands, however, thickness, continuity and distribution of clay coats vary. Tidally influenced sands display wide range of grain sizes and typically contain less than 2% total detrital clay. The majority of the clay fraction occurs as clay coats. Discontinuous clay coats with heterogeneous distribution is typical in this facies. Bar associated salt marshes are typically finer grained and typically richer in total detrital clay (reaching up to 9.5%). In this facies association, clay coats are more common and coats are typically continuous. However, with increasing detrital clay content, the habit of detrital clay evolves from grain coating to pore filling, decreasing the depositional porosity and permeability. These findings are valid for both surface and shallow subsurface sediments of the Ravenglass estuary.

We suggest that high energy environments with limited detrital clay content (c. 2%) are likely to be characterised by discontinuous clay coats and hence more prone to quartz cementation during mesodiagenesis. Relatively finer sediments (fine sand), deposited by lower energy processes, typically display more continuous clay coats. These deposits are more likely to retain higher porosity and permeability due to inhibited quartz cementation during mesodiagenesis. However, a further increase in detrital clay content would result in pore filling clay which would have a detrimental effect on reservoir quality in buried sandstones.

These preliminary results and numerical cut-offs, of 2 and 9.5% grain coating clay,, will be further refined by additional systematic data collected both from surface and subsurface sediments. Understanding of grain size, clay content and clay coat attributes will be discussed in this presentation.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-7: Mixed depositional processes in coastal to shelf environments
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

The mixed sedimentary characteristics and genetic mechanism of Canglangpu Formation of the Lower Cambrian in the eastern Sichuan basinSW China

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Keywords: eastern Sichuan basin,Canglangpu Formation,mixed sedimentation,distribution law,genetic mechanism

The mixed sediments of the Canglangpu Formation in the eastern Sichuan basin are widely developed and have good exploration prospects, but the relevant research and understanding are still weak. Deepening the research on the mixed sediments of the Canglangpu Formation is of great significance to the exploration of mixed reservoirs in this area. During the depositional period of the Canglangpu Formation, the study area experienced two complete transgression-regression cycles, with obvious stratigraphic differentiation between the upper and lower members. The lower part is mainly composed of sedimentary carbonate diamictite, and the upper part is mainly composed of sedimentary clastic diamictite, which are mainly distributed in the coastal-neritic shelf sedimentary environment. On the basis of previous research, combined with the observation of typical outcrop profile, the identification of thin rock section, and the study of drilling and logging geological data, a model for identifying the electrical response of the melange in the study area was established. Combining lithofacies features with logging facies features, a diagram for the classification of diamates suitable for this area is proposed. The study area is dominated by facies-change mixed sedimentation, and the sedimentary environment is a complete mixed coastal-detrital mixed shelf-carbonate mixed shelf sequence. Two mixed sedimentary facies and five Subphases and 12 microphases. The mixed sediments of the Canglangpu Formation, under the special background of alternating uplifts and depressions, have obvious characteristics of ring-like development around underwater paleohighs. The main factors controlling the formation of mixed layers are vertical tectonic movements and sea level changes. The dominant reservoir facies belts in the area are concentrated in the oolitic shoals and sand shoals developed in a ring-like shape around the paleohigh.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-7: Mixed depositional processes in coastal to shelf environments
Presentation Preference: Oral Preferred

Geomorphology and sediment dynamics of the Liyashan oyster reefs, Jiangsu coast, China

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Keywords: oyster reefs, suspended sediment concentration, hydrodynamics, drag coefficient, spatial patterns

Oyster reefs and their spatial patterns are deemed to change the local hydrodynamic condition and exert profound impacts on the grain size, concentration and transportation of suspended sediments. Meanwhile, high suspended sediment concentration often results in excess mortality among oysters. Oyster reefs are rare and vital ecosystem in Liyashan national marine park, Jiangsu Coast, China, however, urgent conservation efforts should be made on account of the drastic reduction in reef areas. To investigate the sediment dynamics and the geomorphology, we employed two tripod observation systems and carried out UAV aerial surveys, alongside elevation measurement with RTK. High mud content (60%) was found in the bed sediment at the reef ridge, causing much lower drag coefficient than other recorded values of living oyster reefs, indicating the death of oysters and the degradation of reefs in Liyashan. Ridgelines of the string reefs at 45 degrees to the current direction and high suspended sediment concentration in the water body (50–370 mg/L) that exceeds the threshold (200 mg/L), which will affect nutrient uptake efficiency and further result in gill saturation, decrease of clearance rate and associated deposition, were probably crucial causes of the death of oysters. Our findings are useful for restoring natural oyster reefs and designing artificial reefs for nature-based coastal defense.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-7: Mixed depositional processes in coastal to shelf environments
Presentation Preference: Oral Preferred

Morphodynamics of multiple intertidal sand bars along the sandy coast of Lianyungang, China

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Keywords: sand beach, intertidal sand bars, UAV aerial survey, satellite imagery, bedform analysis

Multiple intertidal sand bars are sedimentary landforms commonly found on low-gradient sandy coasts with a significant tidal range exposed to low-moderate wave energy. They play an important role in the context of environmental, ecological, and functional coastal protection strategies. Nevertheless, the understanding of their morphodynamics is hampered due to the lack of high-resolution field data and convenient tools for bedform analysis. Here, the morphodynamics of intertidal sand bars was investigated at two adjacent tidal beaches on the north and south coasts of a small estuary on the Lianyungang coast of China by repetitive RTK-GPS leveling, UAV aerial surveys, surface sediment sampling, satellite remote sensing analysis, and automatic bedform analysis. Two distinct types of intertidal sand bars are found to the north and south of the Longwang River mouth (Lianyungang, Jiangsu, China), namely, low-amplitude ridges (or called ridges and runnels) and sand waves. The northern area is characterized by 2-5 oblique, asymmetrical, and dynamic bars that appear at the seaward end of the intertidal zone from where they migrate landward, to finally attach to the steep beach on the landward end of the intertidal zone, presenting a life cycle of ~14 years. The southern area, by contrast, is characterized by 6-9 parallel, complete, continuous, symmetrical, and stable sand bars that occupy the lower part of the intertidal zone. The different morphodynamic behavior of the two bar systems is attributed to sediment supply in each case. The combination of UAV aerial surveys, satellite imagery, and quantitative bedform analysis has demonstrated their great potential in documenting the response of intertidal sand bars to human activities and global change effects.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-7: Mixed depositional processes in coastal to shelf environments
Presentation Preference: Oral Preferred

The impacts of compaction-influenced accommodation and erosion resistance on the morphology of fluvial-dominated deltas: a modelling study

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Keywords: Process-based forward models, compaction, accommodation, erosion resistance, channel dynamics, delta morphology

The first-order impact of compaction, which reduces bed thickness, has been shown to influence delta morphology by increasing sediment retention upstream of the delta through additional accommodation. However, compaction also impacts the erosion resistance of sediments. This study uses a numerical approach to understand how the combined volume reduction and increase in erosion resistance of compacted sediments affects delta morphology. For this purpose, a new erosion resistance formula for cohesive sediment was derived and integrated with the compaction module of Delft3D, which was previously developed to quantify only compaction-induced volume reduction. The updated code was then used to generate a series of seaward prograding and vertically stacking deltas. For each delta, a compaction rate between 0 to 10 mm year-1 was assigned. The simulated deltas are analyzed by first classifying the delta into depositional environments: delta top, delta front, and pro delta. Then, for the delta top and delta front depositional environments, the accommodation and erosion resistance encountered by new sediments depositing in these regions are calculated. Finally, the impact of compaction on morphological changes in the simulated deltas due is quantified using the planform aspect ratio, which is related back to the channel bifurcation and avulsion behaviour. The simulated deltas experience two stages of development, starting with a progradation stage through rapid basin infilling, followed by an aggradation stage as the deltas encounter a deeper water depth. In lower compaction scenarios (0 – 0.1 mm year-1), the impact of erosion resistance is more dominant, stabilizing the channel, leading to more frequent bifurcation, which mainly occurs during the delta progradation stage. As the compaction scenario increases to 10 mm year-1, more accommodation is created in the delta top, destabilizing the channel. This leads to more frequent avulsion, characterized by regional avulsion closer to the channel mouth during the delta progradation stage and nodal avulsion that splits the channel around the delta apex during the aggradation stage. Avulsions mainly carry the sediment load parallel to the initial shoreline, transitioning from an elongated delta top shape to a semi-circular shape. For the first time, the presented modelling results unravel the interaction between the compaction-driven volume reduction and the associated increase in erosion resistance on delta morphology. This new insight can be applied to comprehend the controlling process in ancient delta deposits and predict the evolution of modern deltas under a changing climate.

Session T6-8: Characteristics of mixed sediments and their seismic sedimentologic response

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-8: Characteristics of mixed sediments and their seismic sedimentologic response
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Seismic geomorphology of shoal-water deltaic and mixed carbonate-siliciclastic beach-bar systems in hanging wall of rift basins

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Keywords: Shoal water delta, mixed carbonate-siliciclastic beach bars, seismic geomorphology, rift basin

Recent studies of ancient rift basins focus on the tectono-sedimentary models, which emphasize the control of tectonics on the distribution and evolution of depositional systems in rift basins, whereas these studies seldom address stratigraphic dominated depositional models. Compared to footwall depositional systems, hanging wall depositional systems are especially underexplored due to their fine-grained, thin-layered, and widely distributed features. We integrated seismic data, cores, and well logs to define the dispersal of hanging wall depositional systems that are related to the fluctuation of lacustrine level in the late syn-rift and post-rift stages. We identified one third-order sequence (SQ1) on the seismic reflection data and subdivided five fourth-order sequences (SSQ1–SSQ5) based on the features of parasequence sets. The strata in SQ1 record a complete regressive and progressive lacustrine process. We interpreted shoal-water deltaic systems and mixed carbonate-siliciclastic beach-bar systems in the SQ1. Within SSQ1 and SSQ2, sediments fed from the northwest, west, and southwest, and developed shoal-water deltaic systems with an average width range of the distributary channel belts within 680–1220 m. In SSQ3, beach-bar systems gradually changed from clastic beach bars to mixed carbonate-siliciclastic beach bars in a basinward direction. Clastic beach-bar systems and mixed carbonate-siliciclastic beach-bar systems were extending north–northeast with an average length of approximately 8–3.5 km and a width of 4–1 km. For those in SSQ4 and SSQ5, shoal-water deltaic systems prograded into the lacustrine, and distributary channel belts occur with an average width range within 520–880 m. We developed a spatial and temporal quantitative evaluation of deltaic and beach-bar reservoirs within a third-order sequence on the hanging wall dip slope, and it has potential worldwide implications for other hanging wall dip slopes in rift basins.

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Session T6-8: Characteristics of mixed sediments and their seismic sedimentologic response
Presentation Preference: Oral Preferred

Lithofacies characteristics and shale oil significance of the mixed rock of Fengcheng Formation in the Hashan area, northern Junggar Basin

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Keywords: shale lithofacies, reservoir characteristic, oil-bearing property,Fengcheng Formation,Junggar Basin

Compared with the conventional lacustrine shale, the Permian Fengcheng Formation in the Junggar Basin is a complex sedimentary construction deposited under the background of an alkaline limited lake basin and controlled by terrigenous supply, volcanic activity and endogenous chemical deposition. Aiming at the problem that it is difficult to determine the dominant lithofacies of the alkaline lacustrine shale in the Fengcheng Formation of the Hashan piedmont in the Junggar Basin, Starting from the drilling test data, through macroscopic core observation, microscopic identification, X-ray diffraction mineral analysis and total organic carbon test, and comprehensively considering sedimentary structure, mineral type and organic matter content, five types of shale lithofacies were classified. By means of field emission scanning electron microscopy, high-pressure mercury intrusion, casting thin sections, micro-CT scanning, two-dimensional nuclear magnetic resonance and other testing methods, the classification evaluation of reservoir characteristics and oil-bearing properties of different shale lithofacies was carried out. It is clarified that the organic-rich laminar endogenous chemical deposits are characterized by high TOC, medium S1 and mesopores, and shale oil is mainly in a bound state, and occurs in nano-scale matrix dissolved pores, micro-scale dolomite and feldspar secondary pores, which is the dominant lithofacies in the source rock layer. Laminar terrigenous clastic sediments containing organic matter and layered pyroclastic sediments containing organic matter are characterized by medium TOC, high S1 and high porosity, and shale oil is mainly free, and occurs in micron-scale fractures and secondary dissolved pores, which is the dominant lithofacies of the reservoir.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-8: Characteristics of mixed sediments and their seismic sedimentologic response
Presentation Preference: Oral Preferred

Mixed sedimentary characteristics of the first member of Shahejie Formation and its control on reservoir quality, Bohai Sea

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Keywords: Diacite, salt water lake, high-quality reservoir, the first member of Shahejie Formation, Bohai Sea

The mixed sedimentary facies belt, lithology and physical properties change rapidly in the first member of the Shahejie Formation in the Bohai Sea, and the mixed sedimentary characteristics and the origin of the high-quality reservoirs are not clear.

Aiming at the above problems, the facies belts and rock types and their distribution of mixed sediments were divided by drilling and seismic. The relationship between different facies, different rock types and porosity and permeability is analyzed by rock types, cast thin sections and physical properties. Use carbon-oxygen isotopes, trace elements and other geochemical data. The formation environment of bioclasts, micrite dolomite crust and calcite and dolomite between skeleton particles in mixed sediments was analyzed. The characteristics of mixed sediments and their control on reservoir quality are discussed.

The results show that: (1) There are three types of sedimentary facies, namely, nearshore mixed fan, nearshore mixed shoal, and far-shore mixed shoal in the first member of Shahejie Formation in the Bohai Sea, which are further divided into mixed channel, mixed clastic shoal, and mixed facies. Debris beach, mixed micrite and other microphases. And the formation of bioclast-dominated, terrigenous debris-dominated and chemical precipitation carbonate-dominated diamictite. (2) The analysis of carbon and oxygen isotopes, thin sections and geomorphology of the diamictite in the first member of Shahejie shows that the lake basin was a closed-semi-closed saline and shallow lake basin in this period. The diamictite is relatively developed on the local uplift belt. The local uplift zone is mainly composed of harder rocks. The local uplift zone is close to the water surface and has sufficient sunlight for a long time, which provides a development location for the development of diamictite. Under the condition of intermittent supply of terrigenous debris, the intermittent supply of terrigenous debris provides sufficient time for the mud in the near-source fan/braided river delta to be washed away by waves. And it provides clear water conditions for the growth of snails and other organisms. (3) The volcanic rock base provides a large amount of nutrients such as nitrogen, phosphorus and potassium for the prosperity of snails and other organisms in the diamictite. Intermittent supply of terrigenous clasts provides feldspar, quartz, and lithic particles for the development of diamictite. (4) Volcanic rock bases, local uplifts, and intermittent sources in saline environments are the depositional conditions for the formation of diamictite in large-scale mixed sediments. (5) Enclosed by dolomite cladding and early dolomite cement, the cavity pores and intergranular primary pores of the mixed water channel, mixed clastic shoal, and snails in the mixed bioclastic shoal are largely preserved. . The bioclastic-dominated mixed bioclastic shoal reservoirs have the best physical properties. The water channels and mixed detrital beaches dominated by terrigenous detritus are followed. Mixed micrite shoals and near-source fan/braided river delta reservoirs dominated by chemical precipitation with minimal bioclastic content are the worst. The results provide effective guidance for the exploration of diamictite oil and gas reservoirs in the first member of the Shahejie Formation in the Bohai Sea.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
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Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Substrate erosional features beneath mass transport deposits and their implications for sand-hosted gas hydrate in the Qiongdognan Slope, north South China Sea

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Keywords: Linear substrate erosion, Mass Transport Deposits, Late-Quaternary slope, South China Sea

Substrate erosional features beneath mass transport deposits (MTDs) are becoming increasingly apparent and important in understanding of the erosional mechanisms of the seafloor and long distance transport of deep-water deposits in shelf margin. Based on the high-quality seismic dataset, five thin MTDs associated with concave incision were identified in the late-Quaternary lower slope regions of Qiongdongnan basin, north South China Sea. Compared to 'background' hemipelagic sediments, such thin MTDs at the seismic scale are characterised by higher gamma ray, resistivity, velocity, bulk density and lower neutron porosity on logging-while-drilling (LWD) data, as well as high dip and random azimuth in high-resolution resistivity image. Four linear erosional features with different geometry and scale, such as from large to small megascour and cat-claw scours, grooves, peel-back scours and striations in turn, were characterized by seismic topography, horizon dip slice and horizon amplitude attribute. An undeformed block and a deformed block at the bottom of MTDs were recognized by higher gamma ray, bulk density, velocity and resistivity as well as lower porosity and permeability than these of MTD's matrix. Such blocks were semi-consolidated in the core photograph and may be resulted from strong dewatering and shear compaction at the base of MTD. Megascour is interpreted as a consequence of substrate tooling of large and rigid blocks when they over-run the loose and unconsolidated sandy substrate. Cat-claw scours, radially distributed grooves, peel-back scours and divergent striations are also related to the further fragmentation of large blocks due to the friction with the substrate or variations in flow dynamics. Like the meandering channel incision, such erosional features can also be as an auxiliary indicator for the presence of turbidite sands in seismic profile, assisting to find the sand-hosted gas hydrate in the deepwater area of passive continental margin.

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Session T6-8: Characteristics of mixed sediments and their seismic sedimentologic response
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Features and Model of Mixed Sediments in Continental Rift Basins: A Case Study on the Lower Section of the 1st Member of Shahejie Formation in Lixian Slope, Raoyang Sag

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Keywords: continental rift basin, Raoyang Sag, 1st Member of Shahejie Formation, beach-bar, mixed rock, paleoenvironment

Not only do mixed rocks distribute in marine basins, but they also distribute in a large number of hanging wall slope areas in rift sags. In the lower section of the First Member of Shahejie Formation, the Raoyang Sag experienced rapid flooding, resulting in a great increase in the lake basin area and accommodation space. The siliciclastic influx from the river-delta systems was transferred in the lake basin by waves and coastal currents and deposited with carbonate sediments to form a set of coastal shallow-lake and beach-bar facies, which was distributed throughout the area. In order to clarify the characteristics and sedimentary model of the mixed rocks in the hanging wall slope areas of the rift sags, this work is mainly based on the core data and logging data of the Lixian slope. Through the core and slice observation, grain size analysis, log facies analysis, we studied the sedimentary characteristics and distribution of mixed beach-bars in the work area. Seismic data, pollen data, and trace element data were analyzed to restore the depositional environment controlling factors such as paleoclimate, paleo-provenance, paleogeomorphology, and paleo-water characteristics in the First Member of Shahejie Formation. On these bases, the sedimentary model of the mixed beach-bar in the rift sags was systematically summarized. The results showed that the beach-bar facies developed in the hanging wall slope area of Raoyang Sag can be divided into siliciclastic beach-bars, carbonate beach-bars, and mixed beach-bars according to petrologic characteristics. Moreover, mixed beach-bars can be divided into component-mixed beach-bars and stratified-mixed beach-bars. The lithology of component-mixed beach-bar was mainly calcareous sandstone, sandy oolitic limestone, and bioclastic limestone; Stratified-mixed beach-bars were mainly composed of biological limestone or dolomite interbed with thin layers of sandstone and siltstone. The distribution of mixed beach-bar was controlled by factors such as paleoclimate, paleo-provenance, paleogeomorphology, and paleo-water characteristics. Therefore, different sedimentary patterns developed in different positions and different sedimentary stages on the slope. Based on the differences of the paleo-sedimentary environment in different areas of the slope, the hanging wall slope of the rift sag can be further divided into a near-shore ramp, a far-shore ramp, and a far-shore low uplift. In the early stage of flooding, the water depth of the lake basin was large. Stratified-mixed beach-bars and carbonate beach-bars were deposited in the near-shore ramp, and component-mixed beach-bars were deposited in the far-shore ramp. Carbonate beach-bars were mainly distributed on the far-shore low uplift; For the late flooding stage, the water gradually became shallower. Consequently, siliciclastic beach-bars were mainly developed in the near-shore ramp. Component-mixed beach-bars and stratified-mixed beach-bars were formed in the far-shore ramp. This research can provide new ideas for not only the study of mixed rock sedimentary systems but also oilfield exploration.

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Session T6-8: Characteristics of mixed sediments and their seismic sedimentologic response
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Relationship between rapid lacustrine transgression and formation of hybrid siliciclastic-carbonate beach bar in a rift basin: A Case study based on the Bohai Bay Basin

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Keywords: Rapid lacustrine transgression, beach bar, Depositional system modal, Rift lacustrine basin, Palaeogene, Bohai Bay Basin

The early stage of each rifting episode in the lacustrine rift basin is conducive to the formation of large-scale beach bar. However, negligible research has been conducted on the beach bar types of hybrid sedimentation in lacustrine rift basin, especially for the hybrid siliciclastic-carbonate deposit (material) types, temporal and spatial distribution, and hybrid deposit causes, which indicate the distribution state of sediments in the early stage of rifting episode. In this study, the first member of Shahejie formation in Baxian sag, Bohai Bay Basin, was considered as an example for the first time, and abundant geological and geophysical data, including drilling data, well log curves, and high-quality full-coverage 3D seismic volume survey data, were obtained. Lithologic results indicate that the beach bar can be divided into four types: clastic beach bar, carbonate beach bar, hybrid siliciclastic-carbonate beach bar, and storm beach bar. The (hybrid siliciclastic-carbonate) beach bar is the result of the differential accumulation of terrigenous clastic and endogenous carbonate in the basin under the rapid lake transgression. The distribution of beach bars is inherited on the plane, and the syn-palaeogeomorphology controls the distribution of beach bars. The fault tilt plate and local palaeotopographic uplift are important development components of beach bars. The distribution of beach bars has a good correlation with the change of lake level vertically and a mirror symmetrical relationship with the maximum lake flooding surface. This study demonstrates that climate and provenance determine the type of beach bar, while palaeogeomorphology determines its shape and spatial distribution. The initial stage of rifting often corresponds to the process of rapid lake transgression, and the supply signal of terrigenous clasts experiences the characteristics of hysteretic response, which is conducive to the precipitation of carbonate rocks in the basin under the dry climate background. This study not only defines the types and spatial distribution characteristics of sediment in the initial stage of episodic rifting in lacustrine rift basin, but also provides guidance for the search of lithologic oil and gas reservoirs (traps).

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Session T6-8: Characteristics of mixed sediments and their seismic sedimentologic response
Presentation Preference: Oral Preferred

Depositional characteristics of a lacustrine mixed sediment system: A case study from the eastern Shijiutuo Uplift, offshore Bohai Bay Basin, eastern China

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Keywords: Lacustrine mixed sediments, Compositional mixing, Nearshore biota, Depositional evolution, Bohai Bay Basin

Mixed siliciclastic-carbonate sediments have been widely studied, especially those of marine origins. However, it is rarely investigated in continental settings. Boreholes from the Qinhuangdao-A (QHD-A) block in central Bohai Bay Basin sampled lacustrine mixed sediments during the Eocene period (32-38 Ma), providing an opportunity to facilitate this aspect of research. Here, an integrated facies analysis combined microscopic and core data reveals a siliciclastic fan-delta system that mixed with nearshore bioclastic shoals, forming the major “compositional mixing” and subordinate “strata mixing”. Moreover, seismic data, well-logs, and lithofacies logs divided mixed sediments into three evolutional units (U1-U3). The U1 and U2 were dominated by compositional mixing, showing that volcaniclastic sands and gravels mixed with bioclastic debris that are composed of shallow-depth biota assemblages. Within the U1, it occurred locally due to high siliciclastic input during the low-level period. Peak, however, took place in the U2 because lake level rise led to increasing accommodation and decreasing siliciclastic influx. With further deepening of water depth in the U3, shallow-depended biota was not well developed and carbonates increased. The change results in a distinct depositional sequence of strata mixing that centimeter-scale carbonates interbedded with siliciclastic beds in the highstand. In this study, the relatively warm climate and low tectonic activity may result in prevailing occurrences of nearshore biota, which offers a vital foundation for the formation of mixed sediments approaching to a fault-controlled steep hanging-wall margin. Furthermore, lake-level change is a key gauge in regulating evolutions of the mixed sediment type. These findings are clear that under certain conditions, mixed sediments can take place with amounts of siliciclastics, which bring new insights into mixed deposits, especially in continental settings.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
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Presentation Preference: Oral Preferred

The characteristics and origin mechanism of clay minerals of saline lacustrine mixed sediments-a case study of the Northwest Qaidam Basin

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Keywords: Clay minerals, mixed sediments, Saline lacustrine basin, Diagenesis, Qaidam

Previous scholars have studied clay mineral distribution and its effects on reservoir properties of sandstones, but it is not clear how clay minerals origin, evolve and influence reservoir properties of saline lacustrine mixed sediments. Aiming at clay mineral development mechanism of saline lacustrine mixed sediments, and taking the Neogene in the northwestern Qaidam Basin (NWQ) as the target layer, this research described the drilled cores of five key wells and 30-40 wells, used X-ray diffraction, rock analysis, pyrolysis and other methods, analyzed the characteristics of lithologies, clay mineral types, contents, assemblages and distribution of the Shangyoushashan (N22), Xiayoushashan (N21) and Shangganchaigou (N1) formations, and discussed clay minerals' origin and diagenetic evolution. Mixed fine sediments including fine sandstones, siltstones, mudstones, and carbonate rocks are developed in the Neogene of NWQ, where shale kerogens mainly belong to type III with a small amount of type II2. Diagenesis types include compaction, cementation, disolution and others, the N22 is in the early diagenetic stage B, the N21 at the early diagenetic stage B-middle diagenetic stage A, and the N1 in the middle diagenetic stage A-B. Clay minerals are mainly composed of montmorillonite mixed layer (I/S), illite (I) and chlorite (Ch), with sporadic smectite in the shallow layer. The contents of montmorillonite mixed layer decrease while those of illite and chlorite increase vertically with the increase of depth. The contents of montmorillonite mixed layer, illite and chlorite in the N21 and N1 increase from NW to SE along the source direction. The contents of illite and chlorite increase while those of montmorillonite mixed layer decrease gradually from SW to NE perpendicular to the source direction. On the whole, the total contents of clay minerals in these three formations are relatively stable in the study. The clay mineral types and contents are affected by climate, sedimentary facies and diagenesis. Saline lakes under alkaline conditions are developed in NWQ during the Neogene. Smectite and montmorillonite mixed layer are relatively rich in shore and delta front subfacies while illite and chlorite relatively rich in semi deep lake. The Neogene are rich in potassium ion (K+) under the influence of the parent rock. With the deepening of the water body, the contents of K+ increases, the EH decreases and the PH increases, which is conducive to the existence and enrichment of divalent iron ion (Fe2+) and magnesium ion (Mg2+). In the water body with alkaline conditions rich in K+, aluminum ion (Al3+) and K+ are replaced by Fe2+ and Mg2+ from smectite and transformed into illite. At the same time, Fe2+ and Mg2+ are relatively enriched, which provides a material basis for the formation and of chlorite. Clay minerals have effects on fine grained reservoirs and their oil and gas distribution, so the research results are meaningful to shale oil and gas exploration of saline lacustrine mixed sediments.

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Lacustrine Mixed Siliciclastic-Carbonate Sediments in Paleogene Funing Formation of The Subei Basin, Eastern China: Characteristics and Origin

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Keywords: Subei Basin, Gaoyou sag, Jinhu sag, Funing Formation, mixed sediments, lacustrine basin

The study of sedimentary characteristics and genetic mechanism of mixed siliciclastic-carbonate sediments (MSCSs) is not only the focus of sedimentary geology, but it is also an important issue in petroleum exploration and development. We have discovered the lacustrine MSCSs, the interstratified siliciclastic-carbonate sediments and the textural mixture of siliciclastic and carbonate materials (s-MSCSs) in the second member of the Paleogene Funing Formation (E_1f_2) in the Gaoyou and Jinhu sags, Subei Basin, eastern China. We use core, mud-log and thin-section data to clarify the E_1f_2 s-MSCSs into five types, and we also use geochemical data of the E_1f_2 mudstone including X-ray diffraction (XRD) whole rock, XRD clay, and trace elements to quantitatively analyze lake paleosalinity. The E_1f_2 s-MSCSs mainly consist of siliciclasts, ooids, intraclasts, and mud, and they could be siliciclast-dominated, allochem-dominated, or without dominant components. We analyze that mixed sediments occur under either traction flow or gravity flow. The s-MSCSs of the traction flow origin develop small-scale, wavy cross-bedding and consist of siliciclasts and ooids of similar size; the s-MSCSs of the gravity flow origin develop massive bedding and graded bedding with complex lithology, and they mainly consist of siliciclasts and allochems of different size. We hypothesize that the increase of lake paleosalinity controlled by the climate and the moderate siliciclast influx under stable tectonic setting provide the material source for s-MSCSs in the lacustrine basin. Multidirectional flow is common during the deposition of s-MSCSs of traction flow origin, and seasonal flooding produces s-MSCSs of the gravity flow origin. Lacustrine s-MSCSs in the Gaoyou and Jinhu sags have significantly smaller scale and quantity, and ooids rather than bioclasts occupy most of the carbonate components.

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Application of Machine Learning Method in Palaeogeomorphology Restoration of Backfill Strata

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Keywords: Paleogeomorphic Recovery,Seismic Attributes,Machine Learning,Filling Geological body,Image Filters

Palaeogeomorphology is usually an important factor controlling the development of regional sedimentary facies and reservoir distribution. After the formation of palaeogeomorphology, it will be affected by multiple factors such as tectonic deformation, sedimentary filling, differential compaction, weathering and denudation, so that it is difficult to restore to the original form in the study. Filling type palaeogeomorphology refers to the depression or low part of palaeogeomorphology is filled by different lithology during the sedimentary process. Due to the thin and uneven distribution of the later filling geological body, the response characteristics of the seismic profile are not obvious, so it is difficult to use seismic information to identify the lithology and restore the paleogeomorphology of the stratum containing filling. In view of the above geological problems, this study adopts machine learning method to restore the palaeogeomorphology of filling strata. The core of this study is as follows: Firstly, selecting the sensitive seismic attribute of protruding filled geological body anomaly; Secondly, image filtering is carried out on the optimized sensitive seismic attributes to highlight the edge of filling geological body; Thirdly, clustering analysis of filtered attributes is carried out to magnify the difference between geological bodies and palaeostratigraphy, and classifying the filled geological bodies and sediments of the same period. After clustering, the distribution of geological bodies can be calculated and paleogeomorphology can be restored. This method can be used to identify and characterize filled geological bodies, and on this basis, the influence of filled geological bodies on palaeogeomorphology can be eliminated. Compared with the traditional method of palaeogeomorphology restoration of stratum thickness, it can more closely approximate the original palaeogeomorphology and reflect the palaeoenvironment at that time, which is of great significance to the interpretation of sedimentary facies and reservoir prediction.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-8: Characteristics of mixed sediments and their seismic sedimentologic response
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Oceanographic controls on mixed sediments on continental slope

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Keywords: Oceanographic processes, Mixed sedimentary processes, Mixed sediments

Oceanographic processes play an important role in submarine morphology, sedimentary processes and the associated deposits. Based on the integration of 3D seismic data and piston cores from the northern South China Sea (SCS) margin, this study identifies mixed deposition that composes of foraminiferal sands, clastic silts and less quartz sands, which were deposited by mixed sedimentary processes dominated by gravity flows and contour currents. The silt-free mixture of foraminiferal and quartz sands are featured with sandy contourites and observed in the piston cores that are located in the thalweg of slope channels. Meanwhile, they are displayed within the interval of turbidites, indicating the sandy sediments were initially sourced from shelf and delivered into the deep-sea slope through gravity flows. The dating results suggest the gravity flows occurred during and after last glacial maximum, when the paleo-shoreline was far from shelf edge. Combined with the morphological features and seismic-reflection features, this study suggests that terrigenous coarse-grained sediments were difficult to reach to shelf edge and be delivered into deep slope finally. Instead, the foraminiferal sands around shelf edge have a great potential to get into the slope channel through the gravity flows triggered by oceanographic processes (i.e., intense slope current and internal waves). Silty sediments are mostly featured with contourites. This study sheds light on how oceanographic processes influence mixed deposition occurred on continental slope, which is meaningful for the understanding the origins of mixed sediments elsewhere.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
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Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Sedimentary characteristics and genetic mechanisms of a mixed sediment system in shallow lake area:An example from Wenan Slope,Baxian Sag,Bohai Bay Basin,Eastern China

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Keywords: Wenan Slope, the first member of Shahejie Formatin, mixed sediments, genetic mechanisms, mixed models

Mixed siliciclastic-carbonate sediments were widely distributed in Bohai Bay Basin. To determine the sedimentary background and characteristics of the first member of Shahejie Formation in Wenan Slope, core, logging, seismic and analytical test data were collected for sedimentology research. Then, genetic mechanisms of mixed sediments were specific and models of mixed siliciclastic-carbonate sediments in shallow lake were built.

Beach-bar systems with mixed sediments were widely developed in shallow lake environments during the large scale lake transgression of first member of Shahejie Formation (Es_1). The sedimentary background was as follows: 1)Wenan Slope during Es_1 interval was gentle, which the palaeoslope angle was between 0.9-1.5°; 2)the spore and pollen spectra were particularly characterized by a high abundance of Quercoidites, which indicated varied warm and arid conditions; 3)the lithology, paleontology and sedimentary structures of the Wenan Slope showed that the lake basin's body of water was relatively shallow(less than 10m).

Beach-bar systems deposits were characterized by complex lithology. The classification of mixed rocks in this study was considered by siliciclastic components and carbonate components. The study showed that lithology included sandstone, siltstone, oolitic limestone, biostromal limestone, oolitic sandstone and oolitic siltstone. An identification of lithology was established, which used core, photomicrographs and logging. Based on their depositional arrangementwe recognized two kinds of mixed sediments, called “compositional mixing” and “strata mixing” respectively. The compositional mixing was characterized by oolitic sandstone and oolitic siltstone, which refers to two different components accumulated in space and time and were observable at bed scale. The later referred to clastic rocks, carbonate rocks and mixed rocked organized in meter-scale interbedded beds (Chiarella et al., 2017). The compositional mixing deposited limitedly in the near-shore ramp. The distribution of strata mixing was widely. In the early stage of transgression, the compositional mixing deposited. When the lake level was suitable, the strata mixing deposited.

The gentle-slope paleogeomorphology and warm paleoclimate were the important preconditions for the development of mixed sediments in continental lacustrine basins. The mixed sediments were mainly controlled by changes of the relative lake level and supply of siliciclastic. In this study, there are three types of genetic mechanisms, called facies mixing, punctuated mixing and in suit mixing (Mount,1984). In suit mixing and punctuated mixing were characterized by compositional mixing. Facies mixing was characterized by strata mixing. During the large scale transgression of Es_1, siliciclastic input was restricted and carbonate increased. In the far-shore ramp, siliciclastic influx by fluvial discharge were limited to develop, and bioclastic cemented siliciclastic, which called in suit mixing. In the near-shore ramp, facies mixing deposited. Both compositional mixing and strata mixing are distributed. When the lake level was suitable, supply of siliciclastic was increased, facies mixing developed widely. In the near-shore ramp, the siliciclastic carried by the delta front mixed with the carbonate deposits and then formed a small range of mixed deposits, which genetic mechanism was punctuated mixing.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-8: Characteristics of mixed sediments and their seismic sedimentologic response
Presentation Preference: Oral Preferred

Sedimentary characteristics, geomorphology and seismic response of mixed sediments in K6 Oilfield, Bohai bay, China

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Keywords: Mixed sediments, Sedimentary characteristics, Seismic response, Bohai bay

The lower Shahejie Formation of K6 oilfield are characterized by thin interbedded mixed sediments, with complex sedimentary facies, lithologic types and distributions, which restrict further exploration and development.

In order to study the sedimentary, seismic response and distribution characteristics of the reservoir in K6 oilfield, an isochronous stratigraphic framework was firstly established, and the paleogeomorphology of each oil group in the lower Shahejie Formation was restored. Secondly, combined with the core, 3D seismic data, geomorphology and DST data of the study area, different sedimentary facies characteristics and their seismic responses are studied.

The result shows that there are mainly three sedimentary types developed in the area, mixed deposition, braided-delta, and valley (fan-delta filling). (1) mixed deposition are developed around the higher platform in the middle of Kenli16 area. The lithology is dominated by terrigenous clastic carbonate diamictite and carbonate terrigenous clastic diamictite, and the reservoirs are characterized by thin interbeds (mostly less than 2 meters). The seismic response is a set of parallel phase axis with high amplitudes and low frequencies. (2) The braided delta from the west provenance is overlapped at the platform. And the delta front develops alternately with the diamictite. The seismic response is a set of progradation reflection with high-frequency and weak-amplitude. (3) The valley is in the shape of an incised channel in the seismic section, and develops on the east side of the study area. The thickness of reservoir is large (mostly more than 5 meters), and the core slices show that coarse-grained sandstone develops. The DST data shows oil production of the valley reservoir can reach to 400 tons per day, which is significantly higher than other types of sedimentary facies. Analysis indicates that the structure, paleomorphology and sedimentary structure are the main factors affecting the seismic response and sedimentary characteristics.

According to the seismic response characteristics of different sedimentary facies, the reservoir distribution was finely described. The actual drilling confirmed that the sedimentary facies was accurately described, with reservoir prediction accuracy reaches to 80 %. Under the guidance of reservoir research, the daily oil production reaches 2,000 tons, which effectively guides development of the mixed-sediment oilfield.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
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Presentation Preference: Oral Preferred

Dolomitization and Lithology Basement Influence on the High Quality Reservoir of Siliciclastic and Carbonate Mixed Deposition in Paleogene System of Bohai Sea Area

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Keywords: Dolomitization, Lithology Basement, Siliciclastic and Carbonate Mixed Deposition, Forming Mechanism, Shahejie Formation

This study investigates factors controlling high quality mixed reservoir forming in Shahejie formation in Bohai Sea area.

On macro level, the scales of mixed reservoir were influence by basement lithology, sedimentary environment and paleogeomorphy feature. Petrographic combined with petrophysical analysis, four types of reservoirs are summarized.
Type I reservoir (represented by Q29 structure): beach bar bioclastic dolomite and fan delta dolomitic conglomerate mixed deposition, which is of volcanic basement uplift tectonic background in the near-shore steep slope zone, is of large reservoir scale.
Type II reservoir (represented by B36 structure): mixed deposition of oolitic dolomite and dolomitic conglomerate reservoir in the background of the superposition of delta sandstone in the near-shore gentle slope belt and the uplift of volcanic basement, is of large reservoir scale. Type III reservoir (represented by B13 and J9 structure): bioclastic dolomite reservoir of the off-shore volcanic basement uplift background, is of medium scale.
Type IV reservoir (represented by C2 structure): dolomitic conglomerate, oolitic dolomite, calcareous conglomerate and clastic dolomite reservoir with the off-shore marine carbonate basement is of small reservoir scale.

On micro level, microfabric and genesis of microbial dolomitization is analyzed by advanced technologies. Spherical dolomite and cyanobacteria were characterized by Scanning Electron Microscopy, Cathode Luminescence and Electron Probe. Organic matter components were identified by Laser Raman and Infrared Spectroscopy, and 3D characterization of organic matter was performed by Laser Confocal Focus. The formation stage and genetic mechanism of microbial dolomite were determined by Laser Microanalysis of C\O isotopes. Fabric characteristics of microbial dolomite were established through Maps and Focused Ion Beam.
Dolomitization sequence is obtained based of the origin, occurrences and its forming temperature from low to high: micrite dolomite<spherulite dolomite<syntaxial dolomite<gravitational dolomite<microcrystalline envelope domite<isopachous rim or dog-tooth dolomite< blocky cements (syntaxial and mosaic dolomies) < microcrystalline saddle dolomite.
Type I reservoir is mainly developed with gravitational dolomite and dog tooth dolomite, which will significantly increase compaction resistance of rocks and further preserve favorable reservoir physical property. The forming of microcrystalline saddle dolomite is related to mantle-derived CO2 and hydrothermal activity in deep strata.
Type II reservoir is featured with spherulite dolomite, dog tooth and associated with micritic envelopes, both of which are related to biological activities. In both type I and II reservoir, the volcanic basement and microbial dolomitization process are influenced with each other. The basement lithology influence carbonates by providing rich Mg2+ in volcanic material which will result in the bio-organism flourishment, and further favored micritization and dolomitization. Carbonates impact siliciclastics by providing rich Ca2+ minerals for early carbonate cement precipitation. The isopachous cement will enhance rock compression strength, and

early syntaxial calcite cements are followed by ubiquitous dissolution with the effect of acid fluids in deep layers.

Type III and IV reservoir is composed of micritic dolomite, intergranular syntaxial dolomite and mosaic dolomites whose physical properties are poor. Favorable reservoir properties only occurred as a result of selective dissolution by meteoric water leaching, non-selective dissolution of carbonate syntaxial cements and intercrystalline pore generation during dolomitization process.

Reference

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-8: Characteristics of mixed sediments and their seismic sedimentologic response
Presentation Preference: Oral Preferred

Sequence architecture and depositional evolution in the north-eastern shelf (33.9-10.5 Ma) of the Pearl River Mouth basin, South China Sea

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Keywords: Sequence architecture, depositional evolution, paleo-Hanjiang River deltaic system, shelf, South China Sea

Based on integrated analyses of seismic, well-logging, core data and paleontological data, we systematically document the sequence architecture and depositional evolution of north-eastern shelf of the Pearl River Mouth Basin (PRMB) in the northern South China Sea (SCS). The depositional pattern of the Hanjiang River and Dongsha Uplift related deposits is firstly established in the study. The infill of the Late Oligocene to Middle Miocene successions on the north-eastern continental shelf part of the PRMB can be divided into three composite sequences (CS3-CS5) that are bounded by regional unconformities and comparable conformities. These composite sequences could be further divided into nine sequences that are defined by local unconformities or transgressive-regressive boundaries. Depositional-geomorphological systems represented on the shelf mainly include inner-middle shelf deltas, shoreface deposits, reefal platforms, shelf sand-ridges and fine-grained deposits.

Large-scale shelf-deltaic deposits are prominent in CS3 driven by very high sediment input from a strongly uplifted and possibly enlarged catchment area after immediate lithospheric breakup of the SCS. The rapid Early Miocene transgression, apparently enhanced by tectonic subsidence, caused a great retreat of Hanjiang River-related systems in CS4; shoreface (CS4-1) to reefal deposits (TST of CS4-2) and finally shelf muddy deposits (CS4-3) are recorded around the Dongsha Uplift. A muddy-prone deposition of CS5 is related to the enhanced tectonic subsidence but less sediment supply. The NE-striking geomorphic pattern of sand-ridge related systems possibly caused by the intensification of the south-westerly flowing paleocurrent likely related to the Dongsha Movement after ca. 13.8 Ma.

The north-eastern shelf of the Oligocene to Middle Miocene SCS records the interactive responses to tectonism, sea-level change, sediment supply and oceanic hydraulics. It indicates that reefal platform deposits in the TST of CS4-2 and shoreface deposits in CS4-1 are present around the Dongsha Uplift in the north-eastern shelf of the SCS. This study has potential implications for the sedimentology architecture as well as further reservoirs and hydrocarbon evaluations in shelf area of the SCS.

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Session T6-8: Characteristics of mixed sediments and their seismic sedimentologic response
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Identification and evolution model establishment of braided - meander sedimentary system in east China Sea

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Keywords: braided-meander transition, Seismic sedimentology, Depositional system, Evolutionary model, Xihu depression

Huagang Formation in Xihu Sag in the East China Sea is a river delta interactive transitional deposit. It is one of the important oil and gas bearing strata and one of the important development strata in Xihu sag. Due to the rapid vertical and horizontal changes of channel sediments and the lack of offshore well data, reservoir prediction has always been the focus of attention. Using seismic sedimentology method, combined with core and logging data, this paper identifies the river type, constructs the plane distribution form of rivers in Huagang Formation, and establishes the vertical evolution law.

Based on the application of seismic sedimentology method, it is considered that during the period of Huagang Formation, delta plain and front sedimentation are mainly developed, and three types of distributary channel deposits such as braided flow type, meandering type and serpentine type are developed.

In the low stand stage, the terrain is gentle, the material source is sufficient, and a / s > 1. The sediments are mainly vertical accretion, which is in the form of braided flow distributary channel. The river channel is relatively large, with a width of about 2.0km. The river channel boundary is mainly low curvature and straight. In this period, the river channel is mainly vertical accretion, so the lateral pinch out points are clear. Three to five box shaped single sand bodies are developed vertically. The thickness of single sand varies from 20 to 40m. Along the river channel Narrow and long strip-shaped core beach sand body, with an average length of 2.28km, a width of 0.82km and an area of 1.88km2; During the transgression period, the sea level dropped to the low point and gradually increased, the material source supply gradually decreased, and the lithologic particle size became finer. It is mainly argillaceous siltstone, with the development of meandering distributary channel deposition, the curvature of the channel increased significantly, and large-scale edge beach deposits were developed locally. The channel width is 0.5 ~ 1.2km, and the sandstone thickness is 8 ~ 30m; During the highstand period, the sea level rises to the maximum flooding surface, and the material source supply is scarce. The stratum mainly develops mudstone, and locally develops small-scale river channels, which is characterized by a set of mud wrapped sand. The stratum as a whole is a set of anti rhythmic deposition. The thickness of sandstone is generally less than 10m, generally 1 ~ 5m. Small meandering river channel deposits are developed, the river channel width is less than 100m, flowing from northwest to Southeast, with large curvature, frequent diversion and mutual cutting and overlapping.

This achievement enriches the understanding of the sedimentary model of Huagang Formation in Xihu Sag, explores the application of seismic sedimentology method, and is of great significance to the identification, characterization, evolution, exploration and development of channel sand bodies in the study area.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
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Presentation Preference: Oral Preferred

Improved seismic sedimentology in the study of fluvial-delta facies reservoir

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Keywords: East China Sea Shelf Basin, Huagang Formation,Fluvial delta facies, Seismic sedimentology

The delta-fluvial deposit of the Oligocene Huagang Formation in the Xihu Sag of the East China Sea Shelf Basin is characterized by rapid change in sedimentary facies.And the conventional slice attributes have poor morphology, making it difficult to predict the reservior and satisfy the subsequent exploration and development of lithologic reservoirs. The traditional seismic sedimentology technology is optimized by applying the characteristic technologies such as frequency-boosting interpretation, inversion-conventional -90° phase shift joint construction of seismic lithologic bodies, nonlinear slices, paleogeomorphology restoration, and multi-attribute fusion, and obtains slice-attribute geological forms. Typical, conducive to sedimentary interpretation.

The study found that the Huagang Formation developed three types of sedimentary bodies: braided rivers(Fig. 1) , meandering rivers(Fig. 2) and shallow water deltas(Fig. 3), and the vertical sedimentary evolution was controlled by the mid-term base-level cycle and paleogeomorphology(Fig. 4). In the early to mid-term base-level cycle ascent, vertical superimposed sand bodies developed, mainly braided channel deposits; in the late ascending cycle and the early descending semi-cycle, isolated sand bodies developed, mainly meandering river deposits; In the middle-late period of the mid-term base level decline, migratory medium-thick sand bodies developed, mainly composed of shallow-water delta deposits. Restricted paleo-geomorphology controls sand body distribution, while non-restricted paleo-geomorphology has little effect on sand body distribution. Based on reservoir characterization, it is proposed that the fault sealing type and the reservoir updip pinch-out type structural lithological traps are the main directions for the next rolling potential in this area. The relevant seismic sedimentological characteristic methods have certain reference significance for the fine characterization of fluvial-delta facies reservoirs in other regions.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-8: Characteristics of mixed sediments and their seismic sedimentologic response
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

The seismic sedimentology of tidal systems of the Pinghu Formation in Xihu Sag, Eastern China

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Keywords: Tidal flat,Tidal channel,Seismic sedimentology,Transgressive System,Pinghu Formation,Xihu sag.

The exploration of Pinghu Formation in Xihu sag has achieved great success in recent years. The sedimentary system, sedimentary facies and sand body types of Pinghu Formation have attracted wide attention but still stay controversy for its depositional background of transitional marine and continental settings. In this paper, the types and distribution characteristics of sand bodies in Pinghu Formation are described in detail by seismic sedimentology combined with core and logging data.

Based on the core, logging and analysis data, this paper defines the typical transgressive system tract (TST) of Pinghu Formation as a tidal flat system. On the seismic stratal slices, the sandstone of tidal channels is 2-5 m thick.

During the transgression period, the sea level in the study area was relatively high, and the sediment supply is less in a very low-gradient slope terrain setting. Thus, the hydrodynamic tidal current are relatively strong. Widespread core observations include double clay layers, reaction surface, rhythmic bedding, tidal bundles and bioturbation. The lithologic assemblage of core observations is dominated by mudstone and coal deposits, which are summarized as tidal flat deposits in the TST period. The sandstones are linear-like but relatively isolated.

Coal seams are widely developed in TST with a content up to 4%. It is formed in the tidal flat facies where the sea level continues to rise and is widespread. It represents the maximum flooding and shows a high-continuous and strong amplitude on the seismic section.

Strata slicing of the transgressive zone (Fig. 1) show that a series of narrow stripes of inverted dendritic tidal channels, similar to modern tidal channel deposits developed in the low zone in the east of the study area. It is characterized by wider roots, gradually branching off landward, and gradually narrowing in its width. The width of the tidal channel sand body in the work area is between 80 m and 320 m. The wells penetrated the end position of the tidal channel, with a thickness of only 2m~5m and a width-to-thickness ratio of about 30:1.

This study enriches the cognition of sedimentary model of Pinghu Formation in Xihu sag (Fig. 2), and explores seismic sedimentology of thin tidal channel sandstones constrained by isochronous coal seam framework, which has potential significance for sedimentology architecture and further reservoir and oil and gas evaluation in Xihu sag.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
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Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Lithological characteristics of lacustrine mixed rock in the Paleogene and its influence on reservoir physical properties in lower Ganchaigou Formation in Yuejin area, Qaidam Basin, China

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Keywords: mixed rocks, lacustrine carbonate rock, physical control factors, Qaidam Basin, Paleogene

The mixed rocks of the paleogene lacustrine are widely distributed in the Yuejin area of the Qaidam Basin, China, and the carbonate mineral content is obviously dominant. In-depth discussion of lacustrine carbonate rocks is beneficial for the further exploration and development of mixed-rock oil and gas reservoirs. With the help of cores, well logging, analytical laboratory data and regional seismic data from multiple wells in the study area, the lithology, physical properties and diagenesis characteristics of the mixed rock reservoirs dominated by lacustrine carbonate rocks in the upper part of lower Ganchaigou Formation were analyzed. Discuss the formation environment of different lithology, reservoir space type characteristics, and the influence of different lithology and evolution on the reservoir physical properties of lacustrine carbonate rocks. The Paleogene in the Yuejin area has developed carbonate-dominated mixed rock lithological assemblages. Several major rock assemblages can be seen, including lacustrine limestone(lacustrine dolomitic), mudstone, siltstone and mixed rock assemblages.Grain limestone(grain dolomite), micrite limestone(micrite dolomicrite), muddy-marl stone (muddy-dolomite stone), algal limestone (Algal dolomite), limy mudstone (dolomite mudstone), mudstone, limy siltstone (dolomite siltstone), lime-bearing argillaceous siltstone, all of them are mixed rocks with no more than 50% carbonate mineral composition, clay mineral composition and silt composition. Different rock types and lithological combinations reflect the multiple effects of changes in the lake depositional environment, the alternation and evolution of clear water deposition and mixed water deposition, and the mixing of terrigenous materials during the upper part of lower Ganchaigou Formation depositional period. Lithology has obvious control effect on the storage space, algal limestone, grain limestone, limy siltstone(dolomitic siltstone) have high porosity and good reservoir properties, while the porosity of the micritic limestone, argillaceous siltstone and mixed rock is relatively low, and the reservoir properties are poor. Regional geological data can be used to evaluate the reservoir properties of different types of mixed rocks and predict favorable oil and gas exploration targets.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-8: Characteristics of mixed sediments and their seismic sedimentologic response
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Sedimentary sequence and main control factors of mixed siliciclastic-carbonatesA case study from the First Member of Paleogene Shahejie Formation, Huanghekou Sag, Bohai Bay Basin

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Keywords: mixed siliciclastic-carbonates,mixed sediments,control factors, Huanghekou Sag

It has been confirmed by exploration practice that mixed siliciclastic-carbonates can serve as favorable reservoirs for oil and gas, which is a hot research topic nowadays. The Bohai bay basin is one of the most developed areas of mixed siliciclastic-carbonates in continental lacustrine basin, with a diverse range of types. Base on the core observation, thin section identification, cathodoluminescence, seismic data, and trace elements analysis, the development characteristics, main control factors and vertical sequence of mixed siliciclastic-carbonate in the First Member of Paleogene Shahejie Formation in Huanghekou sag of Bohai Bay Basin were studied systematically. The results show that the bottom-up mixed siliciclastic-carbonates development is composed of section I-granular dolomitic glutenite, section II-granular dolomitic sandstone, section III-granular dolomitic (gray) rock, section IV-mud dolomitic (gray) rock, and section V-mud shale. Among them, Section III is a high-quality section for reservoir development because it contains a large number of gastropods and ostracods. However, complete sequences are relatively rare due to a variety of conditions, and often have some sections missing. The development of mixed siliciclastic-carbonates is controlled by multiple factors (e.g., paleostructure, paleogeomorphology, sediment supply, climate, and lake level change). Near the source area, the development of carbonate rocks is inhibited by the large supply of land-derived clastic, and the overall expression is a mixed siliciclastic-carbonates clastic (section I and II). Away from the source area, the terrestrial clastic supply is weaken and its influence on carbonate sedimentation is limited. Section III -granular dolomitic (gray) rock and section IV -mud dolomitic (gray) rock are developed. The depositional environment stabilizes and mud shales form as the lake level rises and the water column deepens. This study can promote the deepening of mixed sedimentation research and provide a scientific basis for mixed siliciclastic-carbonates reservoir prediction and hydrocarbon exploration.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-8: Characteristics of mixed sediments and their seismic sedimentologic response
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Characteristics and formation mechanism of mixed siliciclastic-carbonate fine-grained deposits in the saline lacustrine basin: A case study of the Lower Youshashan Formation in the northwestern Qaidam Basin

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Keywords: mixed deposits, diagenesis, reservoir quality, saline lacustrine basin, Qaidam Basin

With the breakthrough of unconventional resource exploration, mixed fine-grained reservoirs are also a crucial tight reservoir with massive hydrocarbon occurrence. However, despite having made significant contributions to hydrocarbon occurrences, mixed fine-grained rocks in saline lacustrine basins show great mineralogical and petrophysical properties heterogeneity in petroleum exploration activities. The controlling factors and formation mechanism of high-quality reservoirs remain enigmatic, bringing significant challenges to hydrocarbon prediction. The Lower Youshashan formation with the characteristics of fine grain size and complex lithology in the northwestern Qaidam Basin constitutes important oil reservoirs. Here, core and thin section observation, scanning electron microscope, X-ray diffraction, porosity and permeability test, carbon and chlorine analysis, and high-pressure mercury intrusion were carried out on different lithofacies of mixed fine-grained rocks to clarify the characteristics and formation mechanism of high-quality reservoir. The reservoir lithology of Lower Youshashan formation is mainly composed of fine-grained sedimentary rocks such as mudstone, marl, siltstone, argillaceous siltstone and silty mudstone, and fine sandstone, Oolitic Limestone and algal limestone are developed in some areas. In the freshwater environment, it is dominated by mechanical sedimentary differentiation, and the lithology is mainly clastic rocks such as siltstone. In brackish water and saline water sedimentary environment, chemical sedimentary differentiation increases, and mixed siliciclastic-carbonate and carbonate rocks and mixed rocks are relatively developed. With the increase of water salinity, the siltstone decreases, which is mainly mixed rocks containing evaporite minerals.Typically, the mixed siliciclastic-carbonate deposits contains high content of carbonate minerals. The content of carbonate minerals is generally greater than 30%, while the content of quartz, feldspar and clay minerals is similar, mainly between 20% - 50%, reflecting the strong mixing phenomenon of siliciclastic and carbonate minerals. Evaporite minerals (content < 10%) are also common in reservoir samples. The porosity and permeability of the Lower Youshashan formation are generally low with average porosity and permeability of 7.81% and 5.73 md respectively. The pore type of the mixed siliciclastic-carbonate reservoirs is mainly the residual intergranular pores, secondary dissolution pores and fractures. Fractures and carbonate dissolution pores greatly improve the reservoir space and are the key factors for the formation of high-quality reservoirs. The reservoir quality of mixed fine-grained rocks in the study area are mainly controlled by sedimentary environment, water salinity, diagenesis, tectonic stress and thermal evolution of organic matter. The sedimentary environment and water salinity control the rock type and mineral composition of the reservoir. Mixed siliciclastic-carbonate fine-grained rocks with high clastic content or carbonate mineral content have relative high reservoir quality. This research will provide new insights into reservoir quality evaluation and sweet spot prediction in mixed siliciclastic-carbonate fine-grained reservoirs.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
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Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Characteristics and a depositional model of mixed siliciclastic-carbonate rocks of the upper Lower Jurassic Da'anzhai Member Ziliujing Formation (Huilong area, Sichuan Basin, SE China)

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Keywords: Mixed sedimentary rocks, Depositional model, Da'anzhai Member, Ziliujing Formation, Jurassic; Sichuan Basin

The term "mixed sediments" is used to describe a mixture of terrigenous clastic and carbonate rocks. There is a comprehensive understanding of mixed deposition in the marine environment, deposition in continental environments is relatively poorly understood. Here, we report the results of a study of the Da'anzhai Member of the Ziliujing Formation in the Huilong area of the Sichuan Basin, southwest China. The geological context provides the opportunity to characterize the various sedimentary microfacies and to propose a model of the development of sedimentary lithologies in a continental lake succession. Our approach includes a comprehensive microfabric analysis of field outcrops, and studies of drill-cores, and well-logs, and it enables us to reconstruct the evolution of sedimentary processes and sedimentary microfacies in the study area. The study of petrofabric characteristics such as combination of rock types, bedding structures and fossil content, revealed that the Da'anzhai Member in the study area comprises lacustrine mixed carbonate-siliciclastic strata, which formed in shallow littoral and deep lacustrine sedimentary environments. The studied facies were subdivided into five mixed-sediment facies-types, representing the following depositional environments: high-energy shelly beach, low-energy shelly beach, sandy shoal, shallow lacustrine and deep lacustrine. The observed characteristics of the mixed-sediment facies of the upper Lower Jurassic (Lower Toarcian) Da'anzhai Member in the Huilong area, combined with a previous study of the provenance of the siliciclastic (terrigenous supply), and carbonate rocks (mainly from deposition of shell material), we concluded that the deposition of lacustrine mixed sedimentary successions in the study area was predominantly controlled by changes in lake level, siliciclastic and biogenic sediment supply, and hydrodynamic conditions.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-8: Characteristics of mixed sediments and their seismic sedimentologic response
Presentation Preference: Oral Preferred

Genesis of dolostones under weakly mixed siliciclastic-carbonate sedimentation as the response to the late carboniferous icehouse climate: a case study of the Xiaohaizi Formation in the Tarim Basin

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Keywords: Tarim Basin,Xiaohaizi Formation,Weakly mixed dolomite,Terrigenous quartz

Mixed siliciclastic-carbonate sedimentation is commonly developed in the environment of frequent sea level fluctuations caused by the Glacial-interglacial cycles of the Carboniferous-Permian Gondwana continent, which are widely distributed in Tarim, Upper and Lower Yangtze regions of China, North America and Western Europe. In this paper, the origin of weakly mixed dolomite containing terrigenous clasts in carboniferous in Bamai area, Tarim Basin is studied by means of petrography and isotope study. The dolomite is an important oil and gas reservoir in the study area. This set of dolomites has a residual grain structure and contains 1-8 wt. % terrigenous debris, including quartz, feldspar, kaolinite and illite. Based on the paleo-environmental proxies such as Ti/Al, Mg/Sr and Vi/(Vi+Ni), the mixed deposits of Carboniferous in the study area were developed under intermittent humid climate, and most of them were related to sea level decline. Increased chemical weathering caused by humid climate can provide more terrigenous debris for offshore shelf areas [1]. The $\delta^{18}O$ of the weakly mixed dolomite is heavier than that of the unmixed limestone, which may be related to the glacial climate. As the lighter ^{16}O entered the ice sheet preferentially, ^{18}O was relatively enriched in seawater during this stage [2]. The Mg/Sr ratio of weakly mixed dolomite is lower than that of limestone, which reflects the cold paleo-environment in the stage of sea level decline. In addition, $^{87}Sr/^{86}Sr$ of weakly mixed dolomite is slightly heavier than that of limestone without obvious mixed dolomite, which is close to or slightly higher than that of Carboniferous seawater, indicating that seawater is mainly derived from fresh water. The cathodoluminescence of the dolomite is very poor, which is related to the low Mn content in seawater at the same period. In the stage of glacial sea-level decline, downflow was formed due to the increase of seawater volume from the coastal zone carrying terrigenous detritus to the vicinity of carbonate shoal, and the supply of Mg^{2+} in seawater and the enhancement of seawater circulation led to peneogenetic dolomitization of dissimilar grains such as bioclasts and sand. The fall in sea level also led to the exposure of carbonate flats, resulting in weak cementation and retention of intergranular pores, resulting in the formation of weakly mixed dolomites with good reservoir properties.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-8: Characteristics of mixed sediments and their seismic sedimentologic response
Presentation Preference: Oral Preferred

Model and genetic mechanism of mixed siliciclastic and carbonate sediments in continental rift basin: a review of Bohai Sea area

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Keywords: mixed sediment, sedimentary model, genetic mechanism, reservoir characteristic

Lacustrine mixed reservoirs, which possess large thickness, favourable reservoir quality and high productivity, are generally distributed in the Palaeogene of the Bohai Sea area. It becomes a research focus in Bohai continental rift basin by considering complex geological conditions and various types of mixed deposition.

Based on numerous exploration practices, this paper summarizes the genetic mechanism and model of Palaeogene mixed sediments in Bohai Sea area. The mixing processes are macroscopically controlled by regionally stable tectonic setting and locally intense fault activity, arid climate and saline water, unstable siliciclastic supply of local uplift inside basin and positive palaeo-geomorphologic unit. In consideration of the relationship with siliciclastic supply, two genetic types of mixed sediments are identified as proximally mixing and distally mixing. Based on further analysis of different slilicic lastic sedimentary system, palaeo-geomorphologic setting and characteristic of basement rock, the above two models could be divided into 6 specific mixed types: 1) proximal mixing with fan delta; 2) proximal mixing on the flank of fan delta; 3) proximal mixing on the flank of braided river delta; 4) proximal mixing on the abandon braided river delta; 5) distal high-energy mixing; and 6) distal low-energy mixing. An independent facies system of continental mixed sedimentation has been first established in the Bohai Sea area which consist of three types of facies, seven types of subfacies and twelve types of microfacies.

Comprehensive analysis shows that types of proximal mixing with fan delta, mixing on the flank of fan delta, mixing on the flank of braided river delta and distal high-energy mixing tend to form excellent reservoirs on account of large thickness, coarse grained, low content of matrix, rich in bioclasts or carbonate particles and general dolomitization.

We propose several issues should be emphatically discussed in current genetic mechanism researches on mixed sediments: 1) growth habit of calcareous shell paleobiology and microbial dolomitization; 2) relationship between fine-grained mixed sediments and shale reservoirs; and 3) seismic prediction technology for mixed sediment reservoirs.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
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Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Carbonate fabric diversity and preservation influenced by clastic deposition archived in Neoproterozoic mixed successions

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Keywords: Mixed carbonate - siliciclastic sequences, Neoproteorozoic, Death Valley, Carbonate factory, Microfacies

The sedimentary record of the Pahrump Group in Death Valley comprises well-exposed successions of mixed carbonate and siliciclastic deposits. Despite the abundance of studies focussing on the depositional dynamics of mixed carbonate – siliciclastic deposition in the Phanerozoic, the record of similar Proterozoic examples is comparatively sparse. Using high-resolution stratigraphy and microfacies analyses, this study investigates the Tonian Horse Thief Springs Formation within the Pahrump Group of Death Valley, California, in order to propose first-order constraints on the interplay between carbonate and siliciclastic deposition in the early Neoproterozoic. The mixed successions are unlike many previously studied examples interpreted as being caused by glacio-eustatic sea-level changes, thus arguing for a more relevant tectonic influence on siliciclastic deposition. This interpretation is supported by detailed microfacies analyses of siliciclastic-rich dolostones, which show abundant soft-sediment deformation features suggesting sudden pulses of sandstone deposition onto a shallow marine carbonate shelf. The Tonian carbonate factory recovered quickly after being smothered by siliciclastics, particularly due to abundant stromatolite growth. A new relationship between siliciclastic input, carbonate fabric diversity, and carbonate preservation is established based on microfacies analyses, putting forward that siliciclastic deposition had a significant impact on the formation and preservation of later-stage diagenetic dolomite cements, as well as on stromatolite morphology and carbonate fabric diversity within the microbialites. Repeated siliciclastic incursions had a significant impact on the Proterozoic carbonate factory of the Horse Thief Springs Formation, as well as on diagenetic modification and preservation of shallow marine carbonates, and we establish previously unexplored relationships between carbonate and siliciclastic strata in the Proterozoic.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
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Presentation Preference: Oral Preferred

Identification, distribution and evolution of mixed siliciclastic-dolomitic deposits in Jeribe/Upper Kirkuk reservoir, southeast Iraq

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Keywords: Identification, distribution ,mixed siliciclastic-dolomitic

There are several important transformations of carbonate to clastic in the evolution history of Middle East. The Ghar/Kirkuk sand transformed to Asmair carbonate is the typical mixed deposit in southeast Iraq, the Jeirbe/Upper Kirkuk reservoir in H oilfield is the represent of this process. Identification, distribution and evolution of this mixed deposits is great useful for the development of this reservoir, and can shed light on the mechanism of mixed deposits.

The seismic data, logging data and core analysis data were used to recognize and describe mixed siliciclastic-dolomitic deposits in different scale: stratigraphic/seismic scale, lithofacies/well log scale and core/plug scale. In the seismic scale, the surfaces between dolomite and sand are well identified due to the different wave impedance, the mixed deposit is mostly developed above and below the wave impedance transformation interface. In well log scale, based on the lifhofacies correlation of diferent wells, the mixed deposit is distributed in layers as a whole, with good stability, and its thickness varies with different locations in sequence. In core/ plug scale, four types of mixed lithology (dolomite bearing sandstone, dolomitic sandstone, sandy dolomite and sand bearing dolomite) were identified. The evolution of mixed siliciclastic-dolomitic deposits in Jeribe/Upper Kirkuk reservoir is controlled by facies: form bottom to top, the faices changed from alluvial to transitional facie and finalized evolved to carbonate platform. The mixed lifthofacied changed from sand dominate deposit to dolomitic dominate deposit.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
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Presentation Preference: Oral Preferred

Carboniferous mixed deposition characteristics of marine-continental transitional facies in Bayanhot Basin

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Keywords: Mixed deposition, Marine-continental transitional facies, Carboniferous, Bayanhot Basin

Bayanhot Basin is structurally located in the southeast of Alxa Block, Inner Mongolia Autonomous Region, and its general strike is NE-SW. At present, it is in the early stage of exploration and development, and oil and gas have been shown by drilling, but the exploration work has not made a great breakthrough. Therefore, it is of great significance to clarify the sedimentary facies types, and depict the distribution characteristics of sedimentary systems, so as to provide evidence for optimizing favorable zones for oil and gas exploration.

Considering the characteristics of tectonic evolution, provenance system, logging facies and seismic facies, sequence stratigraphy and depositional system study of the Carboniferous in Bayanhot Basin were carried out by core, drilling, logging and seismic data, as well as grain-size, heavy mineral, thin section and paleontological analysis data. The results show that three third-order sequences, namely SC1c, SC2j and SC2y, were developed in the Bayanhot Basin from bottom to top, roughly corresponding to the lower Carboniferous Chouniugou Formation, the upper Carboniferous Jingyuan Formation and the Upper Carboniferous Yanghugou Formation.

And the lithology of Lower Carboniferous Chouniugou Formation is limestone, dolomite, argillaceous limestone and calcareous mudstone interbedded with pebbled sandstone. The lithology of Upper Carboniferous Jingyuan Formation is dark gray and grayish green mudstone, silty mudstone interbedded with light gray siltstone-fine sandstone in different thickness, interbedded with thin coal. The lithology of Upper Carboniferous Yanghugou Formation is dark gray fine sandstone, pebbly sandstone, sandy conglomerate interbedded with silty mudstone and coal.

The Carboniferous in the study area is mainly composed of tide-dominated delta, gravity flow, shoreland and mixed shelf. Tide-dominated delta is mainly developed in the west and east, shoreland is developed in the central and mixed shelf in the south of the work area. It was found that underwater distributary channel and mouth bar in tidal-dominated delta front, coastal sand bar in shoreface and sandy shoal in mixed shelf are favorable exploration zones.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
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Sedimentary architeture and seismic response of the Huangniuling Formation in the Maoming Basin

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Keywords: Maoming Basin, Fan Delta,Seismic response

Recently, fan delta research is mainly focused on paleomorphology, sedimentary features, reservoir evaluation, etc., with less research on fan delta seismic architeture. This paper integrates Tectonics, Sedimentology, and Seismic Numerical Simulation as a guide to study the fan delta outcrops of the Huangniuling Formation in the Maoming Basin, to delineate the geological configuration of the fan delta braided channels through observation and measurement of the field outcrops, and to carry out seismic orthogonal simulations of the fan delta braided channels of different overlapping types using the high-order interlaced grid finite difference method based on acoustic equations. At the same time, the seismic response characteristics of the Huangniuling Formation were analyzed to summarize the stacking pattern of the fan delta braided channels, which provides a basis for the seismic interpretation of the fan delta.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-8: Characteristics of mixed sediments and their seismic sedimentologic response
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Study on Sedimentary facies of the middle sub-member of Shahejie Foemation in Qingshui area, Liaohe Depression, Bohai Bay Basin,China

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Keywords: sublacustrine fans, deep lake-semi-deep lake facies, sandstone, natural gas

Sedimentary facies is a combination of depositional environment and sediments formed in this environment, and a depositional system which be constituted by the combination of different types of sedimentary facies of organically connected under certain natural conditions constitutes. The oil and gas source rocks in the middle sub-member of Es_3 in Qingshui area are widely developed, with large thickness, and the organic matter of good type, high abundance and high degree of thermal evolution. The conducting research on the types of sedimentary facies in the study area by using the research methods of sedimentary geology, combined with information about drilling, logging, seismic, core, etc, and previous research results. The results show that the sublacustrine fans facies are mainly developed in the middle sub-member of Es3 of the study area, and followed by deep lake-semi-deep lake facies. The sublacustrine fans facies are distributed in the north and south of the study area, and can be divide into two subfacies such as in middle fans and outer fans. Among them, the middle fans subfacies can be further divided into several microfacies including discriminating channel, inter-discriminatory channel, front edge and side edge of discriminative channel. In addition, the deep lake-semi-deep lake facies are mainly developed in the east of the study area. The sedimentary facies as the mirror about different depositional environments during sedimentary period, obviously controlling the distribution of reservoirs. Sandstones are extremely developed and distributed of continuous flake surrounding the middle fans subfacies. The sediments of areas on the south of Well Shuang 102 and the north of Well Shuangshen 3 what the percentage of sandstone can exceed 80%, and the thickness of sandstone is more than 200m, is a high-quality natural gas reservoir, and can be used as the main target area for natural gas evaluation and development in the study area. The muddy sediments are massive developed but sandstones are scarcely developed near the deep lake-semi-deep lake facies. The sediments of areas on the east of Well Manan 3 what the percentage content of sandstone is less than 20% and the thickness is less than 20m, is the most important hydrocarbon source rock in the study area. The practice of oil and gas exploration shows that the formation and distribution of oil and gas are strictly controlled by the temporal and spatial distribution of sedimentary systems and sedimentary microfacies and their diagenesis history. It is possible to further expand and deepen the understanding of the strata in the study area, and to screen the natural gas enrichment areas more accurately through the analysis and study of sedimentary facies, there are great significance to the exploration and development of natural gas.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-8: Characteristics of mixed sediments and their seismic sedimentologic response
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Study on the Sediment Geochemical Data Unmixing Methods

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Keywords: sediment mixing, unmixing model, sediment geochemical data, K-means

Sediment mixing in Source-to-Sink system can interfere with the analysis of source signals, thus affecting the deeper understanding of tectonism and climate change on the Earth's surface. At present, in order to analyze the geological information preserved in the sedimentary record, two models of unmixing sediment geochemical data have been proposed, namely the "top-down" mixing model and the "bottom-up" unmixing model. The "top-down" mixing model is to imitate the mixing process artificially in accordance with the law of conservation of matter, so as to obtain the contribution rate of each source region to the sediment in the sink region. This model is suitable for the watershed system with well-preserved situation in the whole area, where the researchers is familiar. The "bottom-up" unmixing model is to use only geochemical data of sediment in sink area to obtain original rock data of source area. This model is suitable for circumstances when the source areas are not well constrained and/or when a sufficient number of sediment geochemical data in sink areas are available. So far, the "top-down" mixing model has achieved good feedback, while the feedback of the "bottom-up" unmixing model is not ideal. The purpose of this study is to achieve the goal of provenance analysis and/or paleogeographic reconstruction, by modifying the existing "bottom-up" unmixing model of sediment geochemical data and/or using a new method to explore the model. We initially used K-means cluster algorithm to unmix a collected fluvial detrital geochronologic data set in northeast China, which included 13 samples and 1759 data, covering 7 rivers. The results show that the clustering algorithm is better for simple watershed, and the clustering effect of complex watershed depends on the setting of cluster number K. We expect to improve the K-means clustering algorithm to promote the development of sediment geochemical data unmixing methods.

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Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Oral Preferred

Turbidite Fan classification of the Meishan Formation in the Qiongdongnan Basin and Their Exploration Significance

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Keywords: Northern South China SeaMeishan Formation, Submarine Fan, Types of turbidite fans, High-quality reservoir

The turbidite fans of Miocene Meishan Formation in the Qiongdongnan Basin are important targets for natural gas exploration in the northern South China Sea. The type of turbidite fans is closely related to the degree of reservoir development. During the deposition of the Meishan Formation, sea level continued to rise and sea area continued to expand. In the early stage of the lowstand system tract, affected by regional tectonic-sedimentary background and fault activity, six types of turbidite fans were developed: fault controlling intra-slope fan, terminal basin- floor fan, sag-controlling syn-depositional fault root basin floor fan, integral basin floor fan, canyon cutting basin floor fan and passive filling basin floor fan. In the late stage of the lowstand system tract, slope fans were mainly deposited in the continental slope area. During highstand system tract, shelf fans were mainly deposited on the shelf or at the shelf edge. Among them, fault controlling intra-slope fan, canyon-cutting basin floor fan and integral basin floor fan are important exploration targets with developed reservoirs. In comparison, sag-controlling syn-depositional fault root basin floor fan, shelf fan, slope fan has relatively higher risk of exploration due to poor sedimentary differentiation and high shale content. The terminal basin- floor fan and passive filling basin floor fan have fine grain sands with high shale content, thus need to be avoided in the hydrocarbon exploration. The development of different turbidite fan reservoirs follow certain patterns spatially in the northern South China Sea. In the western part of the basin, various types of fan reservoirs are developed due to sufficient provenance supply. However, the accretive continental slope in the middle section and the regressive continental slope in the eastern section are short of good quality reservoirs due to the long distance from the provenance area. Insufficient sediment supply leads to deposition of fine-grained debris with high shale content. The classification of turbidite fans and the understanding of reservoir development provide important theoretical guidance and are practically significant for the exploration of turbidite fan related reservoirs in the Meishan Formation, Qiongdongnan Basin.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Oral Preferred

Main controlling factors and effectiveness of turbidite fan reservoir of the Meishan Formation, Qiongdongnan Basin

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Keywords: Turbidite fan Reservoir, Main controlling factors, Reservoir effectiveness, Meishan Formation, Qiongdongnan Basin

The turbidite fan of the Miocene Meishan Formation in Qiongdongnan basin is a major contributor to natural gas in this area. The sedimentary mechanism, analysis of main reservoir controlling factors and advances in reservoir prediction techniques directly affect the increase of natural gas reserves and production in this area. Based on a large number of data from DST, formation fluid test, coring and rotary sidewall coring, referring to relevant enterprises standards, the turbidite fan reservoir of the Meishan Formation in Qiongdongnan basin is divided into four classes: high-quality, good, effective and tight. Those four types are corresponded to high-production capacity, commercial-production capacity, merely-production capacity and dry layer respectively. The research shows that the type and internal composition of turbidite fans , bottom current reworking and accumulation effectiveness are key factors affecting and restricting the success rate of reservoir prediction. Step fault basin-floor fan, incised valley basin- floor fan and integral basin-floor fan are three turbidite fan types with relatively developed reservoirs. Bottom current reworking is highly important to improve the reservoir quality of mid fan and distal fan in open flow environment. For the incised valley basin-floor fan, the lithologic lateral seal needs to be taken into account. For the integral basin-floor fan, the reservoir pinch-out needs to be mainly considered. At present, the accordance rate of reservoir prediction of Meishan turbidite fans in this area is very low. The methods proposed in this study will be of great value to improve the success rate of reservoir prediction.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Reservoir types and its petroleum significance of the Lower Cretaceous lacustrine carbonates in the eastern of Brazil

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Keywords: lacustrine carbonates, silicification, dolomitization, reservoir, Lower Cretaceous

Giant commercial oilfield has been discovered in the Lower Cretaceous lacustrine carbonates in Great Campos Basin in the eastern of Brazil. However, huge amounts of silicon have been discovered in core samples, and some carbonates have altered to siliceous rock completely. Some studies have shown that these lacustrine carbonates developed on the central paleouplift of the lake basin. Algal reefs and particle shores have developed on the paleouplift, which was similar to the distally steepened carbonate ramp. These carbonates have experienced dolomitization, siliceous cementation and displacement during diagenetic process. Many scholars thought that silicon appeared in the carbonates could destroy the reservoir properties undoubtedly, which affect the reserve evaluation and development plan design. While some scholars also found that siliceous rocks could be reservoirs and could discover hydrocarbons. Reservoir types, relationship between silicon and carbonates, and hydrocarbon potential of the silicified carbonates in the Lower Cretaceous lacustrine carbonates in the eastern of Brazil require systematic studies. Based on the lithological analysis, integrating with the geochemical analysis, diagenetic evolution, reservoir types, and reservoir evolution of lacustrine carbonates have been studied.

Through the microscope observation, it found that giant quartz crystals filled the fractures in limestone, part of pores in framework limestone, and replaced part of the limestone framework. Grainstone debris stayed in the almost silicified rocks. Pores formed by the dissolution of silicous rocks have been discovered. Stomatal amygdaloid basalts developed below the carbonate strata, and carbonate xenolith has been found in basalts. Adularia was found in the baslt almond. Dumbbell shaped dolomite and saddle dolomite was discovered in the local basalt strata. The phenomenon observed above demonstrated that strata fluid with silicon entry the carbonate strata and then silicon precipitated in carbonates fractures and pores. In the local area, silicon displaced carbonate matrix. The strata fluid with silicon may have relationship with deep hydrothermal. During the diagenesis process, carbonates could be completely altered to siliceous rocks which could be dissolved by hydrothermal. Then the siliceous rock reservoirs formed. Primary porosity in the lacustrine carbonates was dominated by intergranular pores and residual intergranular pores. Secondary porosity includes mold pore and intercrystalline pore. Inter quartz crystalline pore and dissolved pore also developed in siliceous rocks. In the local area, expanded pores formed by fracture dissolution can be discovered. The main reservoir type is fracture-porosity reservoir. Through geochemical analysis, carbonates fractures filled with quartz developed inclusions. The peak homogenization temperature of inclusions distributed from 120-140 ℃. Part of limestone was dolomitizd. Integrated with the carbon and oxygen isotopes analysis of dolomites, oxygen isotope shift to negative direction.

It suggests that the underlying volcano uplifted and sprayed at the early deposition period of carbonates. After the deposition of carbonates, deep hydrothermal with silicon and magnesian reformed carbonates, which formed silicon cementation, replaced siliceous rocks, and dissolved siliceous rocks. Fracture-porosity reservoirs developed in carbonates and siliceous rocks in the Lower Cretaceous lacustrine carbonates in Campos Basin, indicating that siliceous rocks could be hydrocarbon reservoirs. Silicified carbonate strata also has hydrocarbon exploration potential.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Sequence stratigraphy and depositional model of shale in the lower section of Wufeng Formation and Longmaxi Formation in southern Sichuan Basin

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Keywords: Wufeng formation, Longmaxi formation, sequence stratigraphy, depositional model

Cores, rock slices, paleontological fossils, well logging and geochemical data were used to analyze the Upper Ordovician (Katian) to the Lower Silurian (Rhuddanian) in order to explore the temporal and spatial evolution characteristics of the Wufeng-Longmaxi Formation in the southern Sichuan area. The sequence boundary identification and sequence division were carried out in the uplift stage, the sequence stratigraphic framework of the marine shale in this area was established, and the sedimentary evolution history of the Wufeng Formation-Longmaxi Formation was analyzed. A method for identifying the sequence boundary and dividing the fourth-order sequence of marine shale is established, which uses the graptolite sequence as the time scale, the logging response feature to reflect the formation layer stacking model, and the lithological changes, sedimentary structure and geochemical parameters to reflect the depositional environment. . The single-well vertical sequence and the well-connected profile show that the Wufeng Formation-Lower Longmaxi Formation experienced three transgression-regression cycles, with 3 largest marine flooding surfaces and 7 system tracts; regional tectonic subsidence and global sea level were discussed. The control effect of the rise and fall on the relative sea level rise and fall. The regional tectonic subsidence played a leading role in the depositional period of the Wufeng Formation, and the relative sea level rise and fall of the lower Longmaxi Formation was mainly controlled by the global sea level rise and fall. A marine shale sedimentary model with fourth-order sequence as unit was established under the influence of multiple factors such as compression structure, paleo-uplift, glacial climate, and terrigenous input.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Characteristics and Geological Significance of Organic-rich Dolomites from Upper Ordovician Wufeng -Lower Silurian Longmaxi Formations on The Eastern Side of Kangdian Ancient Land

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Keywords: Wufeng -Longmaxi Formations, Dolomite characteristics, shale

This paper focuses on the characteristics and geological significance of Marine organic-rich dolomite, which has received less attention at present. Based on the full collection of previous achievements and data, the Hanyuan section of Ya 'an in the southern margin of Sichuan Basin was selected for detailed observation, measurement and description, and field samples were collected for geochemistry, paleontology, mineralogy and other tests. The organic-rich dolomitic shale and argillaceous dolomite in the lower part of Hanyuan section in Ya 'an were identified through the measurement and analysis of shale outcrop samples from Wufeng Formation-Longmaxi Formations. According to the petrological composition, microscopic feature recognition and petrogeochemical analysis, the depositional environment of dolomite in the upper section of the profile is shallow shelf, oxidization-suboxidation environment, high palaeo-productivity but abundant terrigenous detrital supply. The sedimentary environment of the dolomite in the lower member is a shallower water body than the deep water shelf, a subreduction sulfide environment, a high palaeo-productivity and a lack of terrigenous debris supply hypoxia environment. By discussing the relationship between the origin of organic dolomite and the enrichment of organic matter in Wufeng and Longmaxi formations, it is proposed that the existence of rich organic matter dolomite is closely related to the prosperity of microorganisms, its distribution may be beneficial for the favorable environment for the formation of organic shale in the basin edge zone, and provide more abundant geological basis for the expanded shale gas exploration in Yangtze region.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Oral Preferred

Sedimentary Characteristics of Enping Formation in Huizhou 14 Sub-sag of Zhu I Depression and Its Indicative Significance to Source Rocks

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Keywords: sedimentary facies, source rock, Huizhou 14 Sub-sag, Zhu I Depression

The middle-deep lacustrine source rocks of Wenchang Formation have always been the focus of exploration in Zhu I Depression, while the source rocks of Enping Formation have made weak contribution. However, Huizhou 14 Sub-sag is special. The thickness of Wenchang Formation in Huizhou 14 Sub-sag is small. But the Enping Formation develops thick sediments with large buried depth, which seems to have more favorable conditions for the development of source rocks. However, due to the unclear understanding of the sedimentary characteristics of Enping Formation and the development characteristics of source rocks, the petroleum exploration in Huizhou 14 Sub-sag has not achieved commercial success. In view of this, the sedimentary characteristics and source rock development of Enping Formation in Huizhou 14 Sub-sag are comprehensively studied using the data of drilling, logging, core and laboratory analysis, and the conclusions are as follows.

For the lower member of Enping Formation, the deposition occurred in the fault-subsidence period. The lithology is composed of sandstone interbedded with mudstone, without coal seam. Its sedimentary facies include braided river delta faces and shore shallow lake faces. The middle-shallow lacustrine source rocks are developed. By contrast, the deposition of the upper member of Enping Formation occurred in the depression period. The lithology is characterized by gray sandstone and mudstone intercalated with coal, mostly in the form of interbedding. The deposition model of shallow braided river delta facies and shore shallow lake facies is developed. The analysis shows that the source rock assemblage of swamp and shore shallow lake facies is developed in the upper member.

The development of source rocks are affected by sedimentary environment and closely related to sedimentary facies. The biomarker characteristics of Enping Formation indicate that the sedimentary environment was weak oxidation, and the source of organic matter is mainly higher plants, supplemented by aquatic algae. The content of planktonic algae is low, which proves that the water body was shallow during its deposition. Meanwhile, the content of planktonic algae in the lower member of Enping Formation is slightly higher than that in the upper member, which proves that the water body in the lower member was deeper than that in the upper member. The development of coal measure source rocks in the upper member shows that the sedimentation rate and deposition rate were relatively high, and the hydrostatic environment of mutual balance was achieved.

Based on these understanding, the distribution of source rocks of Enping Formation is predicted by using multi-attribute neural network method. The calculated hydrocarbon expulsion is 5.31×10^{8} tons, which proves that Huizhou 14 Sub-sag has a good exploration prospect.

The research is of great significance to the exploration of sub-sags dominated by Enping Formation source rocks in Zhu I Depression.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Discussion on typical deep water depositional model under the background of passive continental margin

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Keywords: passive continental margin,deep water,depositional model,shelf,slope.

With the deepening of global exploration activitiesdeep water deposition has become the focus of attention.Based on the statistics of 1196 discovered oil and gas fields in the world193 oil and gas fields related to deep water sedimentary reservoirsof which nearly 60 are related to passive continental margin basins.Passive continental margin basinalso known as Atlantic continental margin basinis usually referred to as stable continental marginwhich has long been relatively stable in structure.Most of the deep water sedimentation develop under passive continental marginand their depositional patterns are different due to factors such as provenance supplyshelf-slope characteristics and so on.Based on the analysis of regional tectonic and depositional settingthis paper selects typical examples under the background of passive continental marginanalyzes the wide-narrow evolution of basin shelf and the geomorphic features of continental slope areacarries out the study of provenance supply and transport processand discusses the sedimentary development characteristics under the background of passive continental margin.As a resultfour typical deepwater depositional models under the background of passive continental margin are establishedand their sedimentary process are controlled by multiple factors and have their own characteristicsnarrow shelf-restrictive slope model with direct provenance feed and mainly channel systemnarrow shelf-unrestrictive slope model with direct provenance feed and mainly lobechannelized lobesystemsand richwide shelf-restriction slope model with shelf provenance feed and mainly channel systemandwide shelf-unrestricted slope model with shelf provenance feed and mainly lobechannelized lobesystemsand lack.At presentthe discovery of oil and gas in deep-water sedimentary reservoirs under the background of passive continental margin is very considerableand commercial oil and gas with great value has been obtainedwhich shows broad exploration prospects and deserves our attention and research.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Oral Preferred

Fine-grained sedimentary investigation and shale lithofacies mapping Take Wufeng-Longmaxi sequences in the Sichuan Basin and its surrounding areas as an example

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Keywords: Fine grain deposition, Longmaxi formation, Shale facies, Terrigenous clast

Taking the Wufeng-Longmaxi Shale in the Sichuan Basin and its surrounding areas, the earliest commercial shale gas in China, as an example, this paper performs a series of investigations based on considerable drilling and outcrops, e.g., stratigraphic division and correlation, lithofacies classification and identification, deposition environment analysis, deposition model establishment, sedimentary microfacies-lithofacies mapping and favorable lithofacies prediction.

The study focuses on three key issues of sequence stratigraphy and sedimentology of fine-grained sedimentation, establishes lithofacies mapping technology based on inorganic and organic components and carries out systematic sedimentary microfacies-lithofacies mapping with well-divided third-order sequences as units, which aims to describe distribution and evolution of sedimentary microfacies-lithofacies as well as predict and evaluate high-quality shale distribution. Specific workflows are described as followings. Firstly, geology, log and geochemistry are combined to develop stratigraphic division methods for fine-grained deposits based on detailed sequence and system tract divisions using multiple parameters and to establish chronostratigraphic frameworks for refining sequences and system tracts. In this way, sequence stratigraphy of thin layers at fine-grained system can be interpreted. The sequence evolution of fine-grained deposits at the Wufeng Formation to Long-1 Member in Sichuan Basin and its surrounding area is characterized by cyclicity and periodicity, which can be divided into three third-order sequences, corresponding to three transgressive-regressive cycles, which are further subdivided into seven system tracts, i.e., seven sedimentary environment evolution stages. Secondary, a lithofacies division method for fine-grained deposits integrated inorganic and organic components is developed to identify and divide fine-grained sedimentary facies. Lithofacies classification criteria based on three terminal diagram of inorganic minerals is determined, where both inorganic mineral and organic matter contents as considered as classification parameters. The inorganic lithofacies are divided into 4 categories with 8 subclasses, while organic facies is divided into five levels based on organic matter content. Consequently, fine-grained sedimentary facies are comprehensively classified and named based on the principle “organic matter content determining quality and inorganic component content determining lithology”. Seven key lithofacies are combined and classified based on the comprehensive lithofacies classification. One good lithofacies and three fair lithofacies are determined to meet the needs of shale gas exploration and development. Thirdly, sequence stratigraphy and lithofacies in two directions, e.g., cutting and parallel to deep-water shelf, are compared to understand deep-water deposition model and lithofacies distribution. The deposition model of Wufeng-Longmaxi shale is established, suggesting that the shelf was deposited at the platform in Sichuan Basin and its surrounding areas during Wufeng-Longmaxi period. Primary mineral contents from palaeocontinent to shallow water shelf and then to deep water shelf is determined in an order: terrigenous clasts and clay, carbonate mineral, and quartz.

A lithofacies mapping technology based on inorganic components and organic components is established based on these three theoretical understanding of fine-grained sedimentation. Systematic sedimentary microfacies-lithofacies mapping is carried out for seven system tracts under the guidance of the established deposition model, which is based on quantitatively-mapped three principal mineral contents and organic matter content, reducing environment distribution mapped by environmental geochemical parameters as well as determined paleowater depth.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Tidal currents transporting terrestrial organic matter to the sea, evidence from the Eocene Pinghu Formation in the Xihu Depression, East China Sea Shelf Basin, China

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Keywords: tidal currents, terrestrial organic matter, neritic source rocks, biomarkers, palynofacies

Carbonaceous fragments and stripes were discovered in the Eocene Pinghu Formation neritic clastic rocks in the Xihu Depression, East China Sea Shelf Basin. The dark striated layers interspersed in the fine sandstones have an abnormally high total organic carbon content of 7.16%. The kerogen in the neritic mudstones is type II2, indicating that the organic source was dominated by terrestrial species with a limited contribution of aquatic organisms. Rivers are thought to transfer the terrestrial-derived organic matter debris into the sea (Saller et al., 2006; Deniau et al., 2010; Abbassi et al., 2014; Deng et al., 2019; Zhang et al., 2020), although other researchers have suggested that tidal currents can also transport organic matter into seas by disrupting marshes (Li et al., 2015). However, in the Xihu depression, these theories were under debate.

In this study, source rock samples of neritic, tidal flat (or lagoon), and delta front from the Pinghu Formation in the study area were collected and analyzed. Biomarkers and sedimentary organic matters in the neritic mudstones were compared to those in the tidal flat (or lagoon) and the delta front mudstones. The results confirm that the organic matter composition of the neritic mudstones is similar to the tidal flat (or lagoon) mudstones, indicating the supply of plant materials in tidal flat (or lagoon) is the primary organic matter source in the marine environment.

Trace element indexes confirm that the climate was warm and humid and plants flourished during the deposition period of the Pinghu Formation. In addition, the western slope of the Xihu Depression is flat with sags on it, which are favorable to the formation of marshes. The high gammacerane, high sulfur, and framboidal pyrite associated with the coal seam together reveal that the water is quiet and saline, which is favorable for organic matter preservation. The lithology assemblages of the tidal flat (or lagoon) sedimentary facies show frequent interbedding of coal, mudstone, and sandstone strata, indicating that hydrodynamic power increased suddenly and marshes were easily eliminated. These findings suggest that the tidal currents are the dominant mechanisms driving organic matter from the tidal to the neritic environment.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Oral Preferred

Source-to-Sink System Analysis of the Meishan Formation Turbidite Fans in the Northwest of the Central Depression of the Qiongdongnan Basin, Southern China Sea

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Keywords: Source to sink system, Rock-mineral analysis, Meishan Formation, Central depression, Isotope test, Turbidite

Large and medium-sized gas fields such as Lingshui 17-2 have been discovered in the Miocene Huangliu Formation-Pliocene Yinggehai Formation in the central depression of the Qiongdongnan Basin. The exploration of the mid-deep Meishan Formation has not yet been made a major breakthrough, due to the fact that the sand body distribution and the sand-controlling mechanism of the Meishan Formation are not well understood. This paper focuses on the turbidite fan sandstone of the Meishan Formation in the northwest of the central depression of the Qiongdongnan Basin. Microscopic thin section observation, rock and mineral composition statistics, and isotope test, were applied to analyze the elements of the "source sink" system and sand-controlling mechanism, combined with macro structural evolution and river channel development characterization. The result reveals that the turbidite fans of YC35-X well was transported and deposited from NW to SE along the No.1 fault, the No.13 fault and multi-stage channels of the Honghe fault zone with multi-provenance supply from the Hainan Island, the central Vietnam and the Honghe River. The turbidite fans of YC24-X and LS13-X well was transported and deposited from NNW to SSE along the No.5 fault, the No.3 fault, the No.2 fault and multi-stage channels with provenance supply from the Hainan Island. The turbidite fans of ST36-X well was transported and deposited from NE to SW along the No.5 fault, the No.6 fault, the No.2 fault and multi-stage channels with different branches of provenance supply from the Hainan Island. The source-to-sink system of the Meishan Formation in the northwestern of the central depression of the Qiongdongnan Basin is absolutely controlled by the provenance of the Hainan Island, which is manifested by multi-provenance supply from the Hainan Island, the Honghe River and the central Vietnam, converging along the inherited active-faults and multi-stage channels, and being deposited at the bottom of submarine fans. The northeast of the YC35-X and ST36-X turbidite fan is a favorable zone for the development of turbidite sand bodies of the Meishan Formation in the northwest of the central depression of the basin.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Provenance and sedimentary facies of Upper Triassic Mungaroo Formation in North Carnarvon Basin

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Keywords: Provenance, sedimentary facies, Mungaroo Formation, North Carnarvon Basin

Based on the regional tectonics, seismic sedimentology and petrology, it is considered that there is no northern provenance in the Mugaroo Formation in the study area. The provenance mainly comes from the Australian craton, including the Ross highland and its basin in the southern Australian craton, and the Pilbara highland adjacent to the study area. The comprehensive analysis of drilling and logging, paleontological, core, thin sections, seismic and other data showed that the study area developed three types of sedimentary facies : fluvial, delta, and shore-shallow sea; sedimentary facies is generally northeast-southwest banded distribution, from south to north in turn developed fluvial face, delta face, shore and shallow sea face. Sequence stratigraphic study suggested that the Mungaroo Formation in the study area included 3 third-order sequences, such as SQ1, SQ2 and SQ3 from bottom to top. The reservoir mainly developed in the late stage of lowstand system tract and highstand system tract of third-order sequence. Among them, in the late stage of low-stand system tract and high-stand system tract, medium-thick layers rivers, medium-fine sandstones of delta facies and a small amount of thin coal seams are developed ; the transgressive system tract is dominated by thick-layer mud intercalated with thin-layer powder and fine sandstone, and local layers are frequently interbedded with thin limestone and coal seam. Comprehensive study showed that the provenance and relative sea level controlled the development of tidal-controlled delta in the study area (Fig. 1). With the relative sea level decline, from SQ1 to SQ3, the main body of tidal-controlled delta continues to move northward.

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Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
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Seismic and Stratigraphic Correlation of Miocene Turbiditic Sandstone Reservoir in the Gharb Basin, Onshore Morocco

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Keywords: Gharb basin, Seismic and Stratigraphic Correlation, Sandstone Reservoir, Turbiditic sand, Biogenic gas

The Gharb basin is a westerly dipping foreland basin located in the external zone of the Rif fold belt, Morocco. Nappe migration in the Miocene formed the original foreland basin in which the sands were deposited. The Nappe continued to develop after the deposition of the Miocene marine turbiditic sandstones, developing one primary normal fault and several minor antithetic and synthetic normal faults that act as the traps for commercial biogenic gas.

In the study area, 21 wells have been drilled to produce biogenic gas, 10 of them were drilled during the 1960's and 70's. Since 2009, Circle Oil and SDX Energy Company drilled 12 wells in the area. The study has access to all the well data, plus a large 3D dataset provided by SDX. The study aims to assess the distribution of the main sandstone reservoirs, correlate the packages from the wells to the seismic data using structural mapping and amplitude analysis, and assess the depositional environment and controls on reservoir development.

The wells penetrate 5 sandstone intervals, 4 of them producing commercial gas flows. The sand intervals are named the Hoot Sandstone, Guebbas Sandstone, Gaddari Sandstone, Lower N'Zala Sandstone and Upper N'Zala Sandstone. Among these intervals, the Hoot Sandstone is the most prospective, with the main reservoir interval being a 10 metres thick sand, which has resulted in the largest discoveries.

The Hoot, Guebbas and Gaddari sandstones are heavily faulted by the later movement of Nappe, and interpretation of the 3D seismic data reveals a complicated structural compartmentalization of the reservoir. The operator, SDX, has drilled seven wells to produce the gas in the Hoot reservoir. However, the latest well drilled on a larger structure where other wells had previously been drilled, encountered a depleted reservoir. This study was also tasked to ascertain possible reasons why the well, KSR-16, was depleted, by undertaking a detailed interpretation of Hoot sandstone reservoir. Results suggest the well KSR-16 was within a reservoir segment connected to well KSR-8.

A correlation of the sandstone units has been made between the well data and seismic. Based on this correlation, the sandstone distribution has been mapped and deep-water paleoenvironmental models constructed. Many of the sandstone intervals show a distribution and thickness relationship to the syn-depositional structural pattern. This work provides useful information for sandstone distribution prediction and its relationship to faulting for further exploration in Gharb Basin.

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Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
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Key Factors Affecting Reservoir Properties of Submarine Fans in the Meishan Formation of Lingshui Depression , western Qiongdongnan Basin

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Keywords: Qiongdongnan Basin,Lingshui depression, Meishan Formation, Submarine, Deepwater sandstone,Reservoir properties

Several giant deep-water gas field s (e.g., LS17-2, LS25-1) resoundingly discovered in the last decade confirm the superiority of gas accumulation in the deep-water sandstones of the Lingshui Depression, western Qiongdongnan Basin. Although the deep-water sandstones in the Lingshui Depression are generally large in body size, the reservoir properties vary distinctly with sandstone bodies. To better understand the mechanisms and critical factors that affect the reservoir properties of deep-water sandstones in the Lingshui Depression, an investigation based on the 3D seismic data, geophysical logs, and core samples that were recently collected from the submarine fans of the Meishan Formation was conducted. The seismic characterizations and the rare earth elements and heavy mineral assemblages of cores indicated that submarine fans of the Meishan Formation can be classified into two categories: 1) channel-lobe complex with sediments primarily sourced from the Hainan Island; 2) channel-levee complex with depositions mainly supplied from the Kunsong Uplift. The casting slice and scanning electron microscope observations suggested that both compositional and textural maturities of channel sandstones were generally higher than those of lobe or levee sandstones. Meanwhile, the porosity and permeability of channel sandstones were commonly higher relative to the lobe or levee sandstones, implying that hydrodynamic conditions during sediments transport were the primary factor affecting the reservoir properties. Diagenesis including the mechanical and geochemical compactions were also identified in the submarine fans. Mechanical compaction was inhibited by overpressure, particularly for sandstones spatially located in the depression center, contributing to the porosity of channel sandstones being >15% at a burial depth of ~4800m. Chemical compaction was dominated by carbonate cementation. Carbon and oxygen isotopes of carbonate cement suggested that carbonates were primarily sourced from the bioclastic limestone supplied by shelf collapse and partly from the deep pore fluids rich in calcium. Summarily, the hydrodynamic conditions during deposition and mechanical compaction during burial were the key factors that should be considered for the formation of high-quality reservoirs in the Submarine fans of the Lingshui Depression.

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Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
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Temporal transformation trend of submarine-fan morphology and its allogenic/autogenic controlling factors

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Keywords: submarine-fan morphology, sandy radial fan, channel-levee system, controlling factor

After the late 1980's, variation on submarine-fan morphology has been discussed, and sandy radial fan and channel-levee systems have been recognized as morphological end members. Questions are whether submarine-fan morphology changes temporary within the long-term submarine-fan system development or not, and if so, what is the controlling factor on it. This study examined total eight examples of submarine-fan systems, developed in forearc and backarc basins of the NE and SW Japan arcs, in terms of morphological change trend, duration and its possible causes. As a result, in most cases, the morphological type of submarine-fan systems transformed from the sandy radial fan type to the channel-levee system type during their 2- to 10-million-year development life, except for a trough-fill turbidite setting. This temporal transformation trend might be caused by gradual decrease in coarser material supply due to tectonic waning in hinterlands, and by the increase of depositional surface gradient due to sediment wedge formation during sedimentation, resulting in the downstream-ward shift of the transition point between a channel and a depositional lobe, producing a channel-levee system-dominated condition.

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Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
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Tectonic evolution and depositional response from rift through drift to foreland periods in the Lile basin, South China Sea

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Keywords: Continental marginal basin, Lile basin, South China Sea

The Lile Basin is a Cenozoic passive continental basin in the south-central South China Sea, and its formation and evolution record the geological process from rifting to spreading in the South China Sea. The results show that the tectonic evolution of the Lile Basin has undergone three distinct stages, namely the Paleocene-Early Oligocene rift stage, the Late Oligocene-Early Miocene drift stage, and the Middle Miocene-Quaternary foreland stage. The tectonic evolution and sedimentary influx control the development of large reservoirs. During the Paleocene-Early Oligocene period, rifting forms along the NNW-SSE extension, the basin receives mainly sediment supplies from the north and west, and a series of fan-delta systems are developed, but in other sides a smaller fan-delta system develops. During the Late Oligocene-Early Miocene stage, with the South China Sea spreading and the Nansha Block away from the margin of South China, the Lile basin enter a drifting stage, marine carbonate deposits were widely developed due to far from the continental clastic sediment supply. Since the Middle Miocene, the South China Sea spreading has terminated and the Proto-South China Sea has completely disappeared, the basin moves into the foreland stage. The basin underwent a rapid subsidence due to the subduction and collision of the Philippine Sea Plate. The carbonate platforms in the northern part gradually submerge, and the muddy abyssal deposits with turbidite sandstones occur in the southern part. Hence, the tectonic evolution of the Lile Basin shows obvious differences in depositional infilling, and also records a wealth of information on the evolution of the South China Sea extension.

Reference

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Research of delta characteristic of Source-to-Sink and sedimentary reservoirs in Northeastern Bozhong Sag dongying group II

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Keywords: Northeastern Bozhong Sag, delta, Source-to-Sink system, sedimentary reservoirs

A large and Mega-thick delta is existing in Northeastern Bozhong Sag Dongying formation II. It has a low exploration degree and a large exploration potential. Research of the delta is of great significance in expanding the field of exploration. Main Reasons for Drilling Failure is the poor reservoir condition in the area, because of the thin reservoir thickness and low porosity and permeability, so a research of searching favorable reservoir development area is essential. The research is to prove the reservoir potential of the delta by the study of provenance, structural, sequence and sedimentary model characteristic. In the research, the research idea from source to sink is used. The sandstone distribution of the delta is characterized by the high resolution seismic attribute analysis and the horizoncube technique. In the research, seismic multi-attribute clustering analysis technology and neural network pattern recognition technology are widely used, which greatly improves the accuracy of the research The research proves that the granitic metamorphic rock area in northwest Bohai Bay Basin is the favorable provenancethe Dashihe delta is a more sand-rich sedimentary facies belt in the lower dongying group IIthe phase IV of Dashihe delta has the better reservoir condition in the area.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Occurrence forms and composite genesis mechanism of glauconites: A case study from the Neoproterozoic rocks in North China

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Keywords: Glauconite, occurrence form, maturity, genesis mechanism, Neoproterozoic, North China

In recent years, more and more studies have found that the occurrence forms of glauconite are complex, and the single genesis proposed by the previous has been unable to explain the different occurrence forms of glauconites. The Neoproterozoic in North China has developed several sets of glauconite, but the occurrence forms and their genesis are still unclear.Taking the Neoproterozoic glauconite-bearing rocks in North China as an example, the occurrence forms, forming conditions and genesis of glauconite have been systematically studied through outcrops, thin sections, X-diffraction, SEM, electron probe and trace element experiments. The study shows that the glauconites have complex forms, including granular, colloidal, detrital pseudomorphic, pigment-infested and halo - rimmed. The glauconites were classified into five types based on the different color, morphology and chemical composition, namely green granular glauconite, yellow-green granular glauconite, yellow-brown granular glauconite, yellow colloidal form and dark brown detrital glauconite. The formation of glauconite is controlled by material sources and redox conditions. The iron components and glauconite developed in the underlying Xiamaling Formation provided the material source for the glauconites in the Changlongshan Formation. Green and yellow-green granular glauconites were formed in two different pseudomorphic replacement stages, and yellow-brown granular glauconites were formed by early pseudomorphic replacement or layer lattice genesis and later alteration. The colloidal glauconites were formed under the condition of authigenic cementation in the early stage, and most of them were oxidized and altered in the later stage. Dark brown detrital glauconites were formed by later re-transportation and allochthonous re-deposition of autochthonous authigenic glauconite or mica pseudomorphic glauconite by origin of layered lattice. A systematic classification of glauconites in the Neoproterozoic and the establishment of the evolution pattern of different glauconites can provide scientific basis for the restoration of paleogeographic environment and diagenetic sequences in North China or similar areas worldwide.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Oral Preferred

Tectonic control on turbidite sedimentation of Upper Jurassic sandstones in Western Central Graben, North Sea

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Keywords: Western Central Graben, Upper Jurassic, turbidite, shoreface

In the UK Western Central Graben, due to high pressure and undercompaction, Upper Jurassic Feshney Member turbidite sandstones shows good reservoir quality when its buried depth is more than 4500m. However poor seismic imaging, it is difficult to predict the variation of Freshney Member sandstones, which leads to many wells' failure for hydrocarbon exploration.

Rifting created a faulted sag with thick marine claystone and turbidite sandstones, and uplifted margins with shoreface sandstones in the Late Jurassic. Based on the analysis of heavy minerals, composition of grains, and grain size, turbidite clastic sediments from re-deposition of shoreface sandstones in Multi-point source around uplifted margin. It has been found that thicker shoreface sandstones conversely resulted into thinner turbidite sandstones by several wells.

Based on thickness variation of Freshney Member, paleotopographic restoration shows southwest part is deepest with steep slope and northern part is shallowest with gentle slope in the sag. Salt movement and faulting action make shoreface deposition is unstable in the southwest margin, as a result, more sands slumped into deepwater area with thicker turbidite sandstones by steep slope. On the contrary, there is thinner northern part turbidite sandstones. Therefore tectonic mechanism controls turbidite fans development. According to this new cognition, the distribution of Freshney sandstone successfully predicted was from western margin in G Field which located the center of Western Central Graben.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Oral Preferred

Source of the sand-rich gas hydrate reservoir in the northern South China Sea: Insights from detrital zircon U-Pb geochronology and seismic geomorphology

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Keywords: Gas hydrates, Sand-rich reservoirs, Detrital zircon U-Pb dating, Provenance, South China Sea

Gas hydrates that occurred in coarse-grained sediments were drilled in the Qiongdongnan Basin for the first time, and this was also the first time sand-rich gas hydrate reservoirs were discovered in the northern South China Sea. To determine where the sands come from of the Quaternary gas hydrate reservoirs in the Qiongdongnan Basin, we integrate core-log-seismic data, major elements, and rare earth elements geochemistry as well as detrital zircon U–Pb geochronology to characterize the sand-rich gas hydrate reservoirs in detail.

It is clear that the gas hydrate saturation and physical properties of coarse-grained sand-rich gas hydrate reservoirs are better than those of fine-grained reservoirs. In addition, the gas hydrate saturation has an obvious positive correlation with the grain size of its host sediments, indicating that the newly discovered sand-rich gas hydrate reservoirs in the South China Sea have high resource potential. Furthermore, fine sand or even medium sand with some typical sedimentary structures of turbidity currents can be observed in the cores.

Geochemistry shows that sands are sourced from mature continental sedimentary rock provenances, and the detrital zircon U–Pb ages also indicate that the Quaternary sediments in the Qiongdongnan Basin were mainly influenced by the provenances of the Red River, the Truong Son Belt, and the Hainan Island. Combined with seismic geomorphology, it can be determined that the sediments from the northern Truong Son Belt and the Red River could be transported into the Qiongdongnan Basin, and then are deposited as submarine fan systems, forming sand-rich gas hydrate reservoirs.

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Evaluation and exploration practice of Paleogene high quality reservoir in Panyu 4 Sag, Pearl River Mouth Basin

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Keywords: Panyu 4 Sag, Paleogene, reservoir evaluation

Panyu 4 Sag is a proven hydrocarbon rich Sag with high exploration degree and few and small remaining medium and shallow structures. Oil and gas exploration is facing the transformation from medium and shallow Neogene structural reservoir to deep Paleogene. After 15 years of three rounds of exploration, five Paleogene drilling wells have achieved poor results. Although sand shows abundant, the physical properties of the reservoir are poor and the distribution range of high-quality reservoirs is unclear, which restricts the exploration process of Paleogene Wenchang Formation. Aiming at this problem, the Paleogene reservoir conditions are systematically studied. Starting from the source-to-sink system, the differences of parent rocks in the three provenance areas around Panyu 4 Sag are analyzed, and the differential evolution model of deep reservoirs under different provenance systems is established. It is considered that the granite in Xijiang low uplift has the characteristics of high silica, high potassium oxide, small ratio of light rare earth to heavy rare earth, less dark minerals and high maturity of parent rock composition provided by Xijiang low uplift, It is a high-quality material source supply area with low rock debris content and strong anti compaction ability. Combined with the characteristics of regional tectonic activities, based on the restoration of the original basin, a structural sedimentary response model of "early fault control and late slope control" is proposed in the high-quality provenance supply area. It is considered that the early activity of Wenchang is strong and the late activity of Wenchang is weak, which is characterized by episodic activities. At the same time, episodic tectonic activities control the sedimentary characteristics of the area. The early stage of Wenchang is dominated by fan delta deposition and the late stage of Wenchang is dominated by braided river delta deposition. This understanding has promoted the exploration process of Paleogene in the gentle slope belt of Panyu 4 Sag, obtained multi-layer oil layers by drilling, and obtained oil samples in Wenchang Formation, opened a new situation of Paleogene exploration, and has certain guiding significance for the next Paleogene exploration of Panyu 4 Sag.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
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Characteristics of deep tight clastic rock reservoirs and genesis of relatively high-quality reservoirs: A case study of Paleogene in Panyu 4 Sag, Pearl River Mouth Basin

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Keywords: Pearl River Mouth Basin, Panyu 4 depression, paleogene wenchang formation, reservoir characteristic, genesis of relatively high-quality reservoirs

The clastic rock reservoirs of the deep Paleogene Wenchang Formation in the Panyu 4 sag in the Pearl River Mouth Basin are generally more than 3100 m deep, with strong heterogeneity and generally poor physical properties, with medium to ultra-low porosity and ultra-low permeability. Aiming at the problems in the study of the characteristics and genesis of deep tight and low permeability reservoirs , the characteristics of clastic rock reservoirs and the genesis of relatively high-quality reservoirs in Panyu4 sag were studied through core observation, casting thin section identification, scanning electron microscopy, physical property analysis, X-diffraction analysis, etc. with basin structure and provenance system as a constraint condition The research results show that: 1) The petrological characteristics, physical properties, pore throat structure, diagenesis and evolution of different provenance systems and sedimentary facies types of reservoirs are significantly different; 2) Compaction is the main controlling effect on the decrease of reservoir physical properties , dissolution improves the physical properties of the reservoir to a certain extent, and under these comprehensive controls, five types of low-permeability reservoirs are developed. 3) The northern steep slope zone of Panyu 4 sag mainly develops relatively high-quality reservoirs dominated by sedimentation, the southwestern gentle slope zone mainly develops high-quality reservoirs of feldspar dissolution and pore-increasing type dominated by diagenesis, and the northwest gentle slope zone mainly develops a relatively high-quality reservoir of quartz-rich and compaction-resistant reservoir dominated by the parent rock type.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
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Depositional characteristics and sedimentary sequences of Late Jurassic deep-water gravity flows in Eastern Moray Firth Basin, North Sea

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Keywords: Moray Firth Basin, Late Jurassic, debris flow deposits, turbidity current deposits, sedimentary sequence, depositional mode of gravity flow

Through a large number of core observations, drilling/logging data analysis, and combined with gravity flow deposition theory, a systematic analysis was carried out on aspects of depositional characteristics, depositional processes, and sedimentary modes of Late Jurassic deep-water gravity flows in the northeastern Moray Firth Basin, North Sea. Research shows that the gravity flow deposits in the study area can be divided into gravel debris flow deposits, sandy debris flow deposits, argillaceous debris flow deposits, turbidity current and secondary slumping deposits. Among them, massive sandy debris flow deposits is most developed one. According to the vertical superposition mode of different or identical flow regimes in different stages during the gravity flow deposition, three vertical sequences have been established, and different deposition sequences correspond to their unique depositional environments. Sedimentary sequences dominated by debris flow deposits are usually found in restricted channels, sedimentary sequences dominated by debris flow deposits interbedded with turbidity current deposits are mostly developed in weakly restricted channels, and sedimentary sequences composed of debris flow and turbidity current interbeds are common in lobe complex.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
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Application of SVR attribute fusion constrained by geological model in reservoir description of shallow water delta: a case study of X gas field in Xihu Sag

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Keywords: Xihu Sag, Distributary Channel,Support Vector Regression,Reservoir Prediction.

X gas field is located in the central inversion structural belt of Xihu Sag, East China Sea basin. The main target layer H4 is in shallow water delta sedimentary environment. The dominant frequency of seismic data of the gas field is low (25Hz), while the buried depth of H4 layer is large (3300m ~ 3400m). The reservoir has low porosity and low permeability, and the consistency of sand body thickness predicted by conventional seismic inversion is low.

Aiming at the characteristics of full coverage of 3D seismic data and less drilling in X gas field, this paper makes up for the lack of sample points in SVR algorithm through forward and inverse modeling under the guidance of geological model and setting up virtual wells. Then, by extracting seismic attributes and optimizing sensitive attributes characterizing sand body thickness, SVR algorithm is used for multi-attribute fusion to complete the quantitative prediction of H4 sand body.

Based on the reservoir prediction results, it is proposed that H4 layer is a distributary channel deposit of shallow water delta meandering flow type, and further completed the dissection of sand body deposition model. After the development adjustment wells drilled, the coincidence between the actual drilled sand body thickness and the predicted sand body thickness is more than 84%.

This paper explores and obtains the quantitative reservoir prediction scheme of SVR algorithm constrained by geological model under the condition of few wells on the seawhich completes the accurate prediction of the middle and deep distributary channel reservoir in X gas field, and also has certain guiding significance for the reservoir description of the same type of oil and gas fields.

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Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
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Reservoir Valuation and Effective Factors of Generation Capacity Research In long11 Sub-member of Longmaxi formation in Weiyuan area, south Sichuan

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Keywords: logging characteristic interval,stratigraphic division program,lithofacies,production distribution,shale gas

The electrical characteristics of the $Long_1^1$ sub-member in the Chuanqing block, which located in Weiyuan area of South Sichuan, have great lateral changes. Significant differences in the volume fracturing engineering effect and production also indicated variations in shale quality of $Long_1^1$ sub-member in the study area. To find the answer of these question, the stratigraphic identification standard and division program of logging characteristic intervals were established, based on the logging response of $Long_1^1$ sub-member in 12 evaluation wells . Then combined with several experimental methods, such as quantitative analysis of minerals by scanning electron microscope, canning imaging of backscattered two-dimensional multi-scale electron microscope, organic geochemical experiments and analysis of trace elements, the depositional environment, lithofacies , organic geochemical characteristics and key parameters of shale reservoir quality of logging characteristic intervals were analyzed. It is considered that there are No. 1~7 electrical characteristic intervals from bottom to top can be used to describe lateral variation of shale, which are developed completely around Well A in the middle of the block, the upper characteristic intervals was missing in the east area, and some lower characteristic intervals cannot be found in the west area of the block. Through dynamic data, the understanding of stratigraphic distribution regularities and quality differences in the horizontal direction of a single interval was verified. Finally, reliable conclusions about reservoir quality and productivity of characteristic intervals are formed. The neutron and density curves of No. 1, 2, 4, and 6 characteristic intervals are envelope-shaped and have high gas production potential, among them No. 1 and No. 2 intervals have strong mirror image characteristics and are excellent reservoirs. Those conclusions can be used to guide researches such as the selection of favorable areas in the middle and late stages of shale play development and some analysis of production distribution law in horizontal wells.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
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Shale lithofacies and reservoir characteristics of Wufeng Formation-lower Long 1 submember of Longmaxi Formation in western Changning

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Keywords: shale gas, lithofacies, reservoir characteristics, Longmaxi Formation, western Changning

Wufeng-longmaxi Formation shale in Changning area has made a major breakthrough which is a key target of shale gas exploration and development. In order to clarify the lithofacies differences, the vertical and horizontal distribution of lithofacies and influence factors of reservoir development in western Changning area, based on core, thin section observation, X-ray diffraction, logging curves and three-end member diagram of siliceous, minerals-carbonate, and minerals-clay minerals on shale of Wufeng Forming-lower Long 1 submember of Longmaxi Formation, the lithofacies of wufeng Formation- lower Long 1 submember of Longmaxi Formation in western Changning area are divided. On this basis, according to TOC, porosity and hydrocarbon content analysis of different lithofacies, the reservoir characteristics and controlling factors of various lithofacies in the study area are analyzed and predicted. The results show that there are seven lithofacies in the study area: siliceous shale facies, mixed siliceous shale facies, argy-siliceous shale facies, clay-siliceous shale facies, mixed shale facies, clay-siliceous shale facies and argy-siliceous shale facies. The siliceous shale facies mainly developed in sublayer-1 and sublayer-2 of Long 1 submember of Longmaxi Formation is the best lithofacies in the study area because of the abundant biosiliceous and abundant biosiliceous deposits in the depositional environment of stagnation and hypoxia reduction environment, resulting in high TOC content, high porosity and rich gas content of siliceous shale facies. Due to the destruction of anoxic environment in the middle and upper part of lower Long 1 submember of Longmaxi Formation, the mixed siliceous shale facies, greyish-siliceous shale facies, greyish-siliceous mixed shale facies and clay-siliceous mixed shale facies developed in the middle and upper part of lower Long 1 submember of Longmaxi Formation are the sub-optimal shale facies in the study area due to the deterioration of organic matter and pore conditions.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
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Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Characteristics and genetic mechanism of beach bar sedimentary system in the 2nd of Shahejie formation in Bohai Sea Area

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Keywords: beach sand bodies, origin of high-quality reservoirs, formation mechanism, Bohai Sea

In recent years, there has been no major exploration discovery in the 2nd member of Shahejie Formation in Bohai Sea, which is mainly limited by the difficulties such as the exhaustion of structural trap and the large burial depth of reservoir3500m. Based on the "source-sink" theory, this study carries out the sedimentary system of E_2S_2, the genetic mechanism of high-quality reservoirs of deep / ultra deep clastic rocks and the tracing of lithologic traps, and finally predicts the distribution of high-quality reservoirs of E_2S_2. First, clarify the ternary sand control mechanism of "ancient material source, ancient landform and ancient hydrodynamic" of Lake wave transformed fan delta. Establish the development model of fan delta with Lake wave transformation in Shinan steep slope zone, and make it clear that the front edge of fan delta will form coastal beach dam after strong Lake wave transformation; Secondly, it reveals the genetic mechanism of "deep buried and high porosity" reservoir controlled by deep / ultra deep lake wave transformation and dominant minerals. It is innovatively proposed that high-quality reservoirs under deep / ultra deep conditions are jointly controlled by Lake wave transformation and "dominant minerals". The diagenetic dynamic mechanism of "mineral reservoir forming sequence" under Lake wave transformation and deep buried diagenesis is is established. It is clear that the fragmentation and dissolution of potassium feldspar is the basis for the clastic rock to break through the "lower limit depth of low permeability (3500m)" of the reservoir under deep / ultra deep conditions; Third, establish the fine tracking technology of Paleogene local provenance intermittent and multi-stage supply lithologic trap. The prestack random inversion technology constrained by structural model is used to track the deep / ultra deep lithologic traps, and the fine characterization of the plane characteristics of sand body is realized. The plane characteristics of the inversion results are consistent with the sedimentary model. The research results broaden the exploration direction of deep / ultra deep Paleogene clastic rocks in Bohai oilfield. It is proposed that the granite source supply area of K-rich feldspar and the medium coarse sandstone transformed by Lake wave in the E_2S_2 can be used as the practical direction of deep / ultra deep clastic rock exploration.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
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Presentation Preference: Oral Preferred

Sedimentary microfacies and sandbody distribution in shallow continental shelf: A case study of lower member of Silurian Kepingtage Formation in Tarim Basin

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Keywords: Shallow continental shelf, Shelf sand ridge, Sandbody distribution, Sedimentary Microfacies

The sandstones deposited on the shallow continental shelf are generally regarded as good reservoirs. In this paper, the sediments inside the lower member of Silurian Kepingtage Formation in Tarim Basin are taken as the study case to elaborate the corresponding microfacies and characterize the spatial distribution of sandstone in detail. We divide the depositions of the continental shelf sediments into 3 microfacies according to cores, well logs and seismic data here. These microfacies are shelf sand ridge, interridge sandstone and self-mud. The distribution of the sandbody of the former two microfacies is affected by sea level, hydrodynamics and paleogeomorphy. Specifically, the storm wave-drive sediments inside the shelf sand ridge are ranked in reverse graded order. And the major components are the medium sandstone and fine sandstone with a few inserted boulder clays. As the name suggests, interridge sandstones are mainly located between ridges due to the low hydrodynamic energy. The corresponding components inside are fine sandstone, siltstone and mud. Moreover, normal graded bedding, reverse graded bedding and massive texture are exhibited here. According to the vertical profile, the interval of interest can be identified as 3 sand-groups. As the seismic interpretation result shows, a large scaled shelf sand ridge with a thickness up to 30m, a height of 13km and a width of 5km is deposited in the NE direction in the sand-group. Its planar projection is an elliptic whose length-width ratio is 1/3 to 1/2. The shelf sand ridges are distributed as strips in the direction oblique with the shorelines. And the thickness is larger while the acient surface elevation is higher. The interridge sandstones here are small scaled fine-grained sediments with banded and irregular shapes. Notice that, the direction of the banded interridge sandstones is different from the sand ridges. The sandstones of shelf sand ridges are picked up as better reservoirs due to their relatively higher porosity and permeability. They are moving toward the continent due to the relative sea level rising.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
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The coupling relationship between the mantle-derived CO2 and hypogenic karstification in Baiyun sag of the Pearl River Mouth Basin, South China

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Keywords: Baiyun sag, mantle-derived CO2, stable oxygen and isotope, hypogenic karstification

Baiyun sag of Pearl river Mouth Basin is located in northern continental slope of south China Sea, it is characterized by high thermal background, three sets of source rocks and multi-stage magmatic activity, and a large amount of inorganic CO2 was found in the area and its surrounding areasThis article explores the filling of CO2 and transformation effect of fluid by the methods of observation of petrology, fluid inclusions and stable oxygen and isotope. Fluid inclusion test results show that there were three periods of mantle-derived CO2 charging in baiyun Depressionrespectively corresponding to baiyun movement (20.2 ~ 10.2 Ma), early Dongsha movement (9.3 ~ 6.1 Ma) and late Dongsha Movement (4.6 ~ 0Ma). According to the petrological observation, there are a lot of feldspar and calcite dissolution phenomena in sandstone reservoirs in this area, and the feldspar intergranular dissolution pores and intra-granular dissolution pores are developed. Around Baiyun sag, two carbonate cements annules and two abundant authigenic kaolinite precipitation zones are developed (which coincide with the area of gas Wells with or high CO2 content). The carbonate cements are mainly iron-bearing calcite cements of syngenetic and peneogenetic stages and chemical precipitates of hydrothermal fluids in late thermal burial stage. In addition, the hydrothermal authigenic minerals such as dawsonite, authigenic quartz, siderite, Fe-dolomite and albitite are observed in sandstone reservoirs. The values of δ13C and δ18O in the carbonate cements precipitated in the thermal burial stage are respectively range from -20.9‰ to -1.8‰(with an average of -5.26‰), and from -13.7‰ to -5.4‰(with an average of -10.66‰). The low carbon isotope indicates that there may be organic acid infiltration, and the low oxygen isotope demonstates that perhaps the fluid source is deep hydrothermal. Combined with the geological background of the area, it is speculated that the mantle-derived high-temperature CO2 migrated upward through deep and large faults or volcanic associated faults, and then migrated horizontally in the efficient transport layer, a series of hypogenic karstification which is beneficial to the development of deep secondary pore zone has taken place in sandstone reservoir, including solutional processes, and the precipitation of authentic kaolinite, quartz, dawsonite, calcite, dolomite, ankerite, siderite, albite and so on.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
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The Guiding Significance of the Sedimentary Facies Study to the Exploration in the Small-Scale Continental Rift Basin, Offshore Papua New Guinea

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Keywords: Deep-water, Gulf of Papua, frontier exploration, lacustrine rift basin sedimentary facies, quantitative prediction

The study area is located in the deep-water, offshore Papua New Guinea, which belongs to small-scale continental rift basins. The tectonic evolving history of the basin is complicated since it went through two rift and collision cycles. After the separation from the east margin of the Australian continent, the massif drifted northward and finalized in the forebulge zone of the Aure Foreland. The study area belongs to a frontier basin without a single well drilled in the surrounding. Thus, the focus of the exploration potential evaluation is on the study of the syn-rift source rock.

Based on the key questions of the source rock, from directionally to qualitatively and to quantitatively, this article used methods of analogy, characterization, and quantitative prediction firstly proposed techniques of high-quality source rock quantitative prediction, which quantitatively predicted the distribution area and deposition thickness of high-quality source rocks.

Starting from the source rock existence, the technique used oil seepages, structural reconstruction, and seismic facies analogy to determine the main analogous source rock strata intervals and evaluate the potentials of the basin. For the source rock characterization, this article used a four-step method: 1) analyzing the fault activity rate; 2) predicting sedimentary modes; 3) analyzing the sequence stratigraphy; and 4) seismic facies classification(figure 1). It determined the deposition background, distribution area and main stratigraphic intervals of high-quality source rocks(figure 2), and innovatively used relative acoustic impedance inversion NTG truncation method to quantitatively predict the shale thickness.

The results show that the Jurassic source rock in the study area is oil-prone. The high-quality semi-deep lacustrine facies source rocks have several hundred meterd thickness; and the shallow-shore lacustrine facies source rocks have an area of up to 100 km2figure 3. According to the resource calculation of different types of source rocks, the scale of hydrocarbon generation is determined.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Characteristics of favorable reservoir and its distribution prediction in the middle-deep layers in Baiyun sag, Pearl River Mouth Basin

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Keywords: Sweet point, diagenesis,controlling factors, distribution prediction,middle-deep strata,Baiyun sag

Middle-deep layers in Baiyun sag has great potential for unexplored hydrocarbon resources. Reservoirs in the middle-deep layers are generally low porosity and permeability. In order to describe the favorable reservoir characteristics, find the reservoir macro-controlling factors, and to predict the special distribution of the favorable reservoirs, Baiyun 5A structure in Baiyun sag was studied. Take middle-deep layers of Baiyun 5A structures for example, the microcosmic aspects such as reservoir lithology, reservoir properties, and constructive diagenesis and the macro aspects such as facies identification, prediction of progradation complex with thick sand, seismic inversion for sand and porosity, and fracture distribution recognition of reservoir are studied. Reservoir “sweet points” characteristics in the middle-deep layers, controlling factors that can be identified macroscopically, and special distribution of the “sweet points” are studied. It suggests that middle-coarse sandstones with big thickness in the distributary channels and underwater distributary channels in the Baiyun 5A structure developed secondary solution caves and microfractures, and these sandstones can be used as reservoir “sweet points”. Sand body thickness that represents its microfacies and fractures that represent the constructive diagenesis are controlling factors those can be identified macroscopically for reservoir “sweet points” prediction. Progradation complex with thick sand can be identified through the shape of “bump”, the superposed inside structure, and the low part of the microrelief in the seismic data. Composed the results of thick sand body identification, sand and porosity prediction, and fracture distribution recognition, the eastern part of the C block in the Baiyun 5A structure is recognized as the reservoir “sweet points”.

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Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
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Facies Pattern of Large Contiguous Composite Sand and Great Exploration Significance in the Depression-Lacustrine Basina case from Lower Minghuazhen Formation of Laizhouwan Depression of Bohai Bay Basin

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Keywords: Large Contiguous Composite Sand,Facies Pattern,Lower Minghuazhen Formation,Laizhouwan Depression

Laizhouwan Depression is located in the south of Bohai Bay Basin. The Lower Minghuazhen Formation is the shrinkage period of the depression-lacustrine basin, with weak tectonic movement, slow subsidence and obvious peneplanation. As an important target formation, the Lower Minghuazhen Formation is faced with unfavorable conditions such as no hydrocarbon sink structure, no faults, and thin drilled sand thickness, so no commercial oil and gas has been discovered after 30 years of exploration. With the continuous success of lithologic exploration in the surrounding area, the lithologic exploration based on the large contiguous composite sand has become a hotspot. The large contiguous composite sand has the complex sedimentary features, such as wide distribution area, large lateral variation, relatively thin thickness and sophisticated superposition relationship. The exploration process is restricted by the unclear sedimentary model and favorable reservoir development law.

Under the guidance of continental sequence stratigraphy and sedimentology, combined with 3d seismic data, core data, logging data, paleontological data, clay minerals data and other geological data, this paper comprehensively studies the large contiguous composite sand, and discusses the facies types, evolution law, controlling factors and hydrocarbon accumulation significance of the large contiguous composite sand. The results show that: (1) There are three types of large composite sand in the study area. The sheet-sand shallow water delta, which is characterized by the sheet sand with contiguous distribution, develop in the early stage. The formation of the sheet sand is related with the lake wave reconstruction. In the middle stage, the distributary-channel shallow water delta develops. It mainly consists of network connected channel sand and contiguous sheet sand. The fluvial facies develop in the late period, and the sand is isolated in thick layers. (2) Tectonic subsidence rate and paleoclimate variation are the main driving factors of sedimentary evolution. The structural gradient of the Lower Minghuazhen Formation is very slow, and the terrain slope is less than 0.1°. The paleontology data and the clay minerals data indicate the early stage is warm and humid climate. So the lake is large, and the wave transformation is relatively strong. It is conducive to the development of the sheet-sand shallow water delta. Although the accommodation space increases with the gradual increase of regional basin subsidence rate, the paleoclimate become dry and cold, which leads to the shrinkage of the lake, the decrease of source supply, and the gradual enhancement of fluviation. The shallow-water delta evolves from sheet sand type to distributary channel type, and finally fluvial facies developed. (3) Under the guidance of the facies model of large contiguous composite sand, several lithologic traps composed of large contiguous sand body are discovered in Bohai Oilfield, which realizes the lithologic exploration transformation from isolated channel to large contiguous sand, and effectively guides the lithologic exploration of the Lower Minghuazhen Formation of Laizhouwan Depression. KL10-2 oilfield, the largest lithologic oil field in the Lower Minghuazhen Formation of Bohai oilfield, has been successfully discovered.

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Diagenetic mechanism of high-quality sedimentary microfacies by carbonate and kaolinite cements

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Keywords: offshore, Deep-buried, non-homogeneous, carbonate, kaolinite

Flow direction, dynamic and chemical properties change frequently in fluvial and tidal sedimentary environment, the reservoir mineral foundation, diagenetic process is complex and changeable, and the physical property is strong heterogeneity, which has always been the difficulty restricting its exploration and development. In this paper, Pinghu Formation in Xihu Depression of East Sea, China was taken as an example. Material basis, materiality pattern and main controlling factors were investigated in two high-energy sedimentary microphases, namely tidal channel and submerged divergent river channel. Methods were included core observation, pore penetration test, light microscopy, isotope and inclusions. The results showed that: (i) the upper/middle part of tidal channel possessed good physical properties with an average porosity of 18% and permeability of 120mD, while the bottom of tidal channel was dense with an average porosity of 4% and permeability of 0.05mD. The main reason for the inhomogeneity is that the bottom is dense due to carbonate cementation; (ii) the upper part of submerged diversion channel had good physical properties with an average porosity of 5% and permeability of 70mD, while the bottom of submerged diversion channel was dense with an average porosity of 1% and permeability of 0.05mD. The main reason for the inhomogeneity is that the bottom is dense due to kaolinite filling. The above analysis of the non-homogeneity of the main sedimentary microphase of the Pinghu Formation in the Xihu Depression is of great theoretical guidance and practical production value for deeper oil and gas exploration and development. It has important theoretical guiding significance to deepen the law and formation mechanism of reservoir heterogeneity under fluvial and tidal background.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Oral Preferred

Sedimentary characteristics and distribution prediction of the semi-deep and deep lacustrine facies source rocks of Wenchang Formation in the Shunde Sag, Pearl River Mouth Basin

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Keywords: neural network, semi-deep and deep lacustrine facies, sedimentary characteristics, source rock, Wenchang Formation, Shunde Sag

The Shunde Sag in Pearl River Mouth Basin is located in the southwest of the Kaiping Sag, which has made a breakthrough in exploration, so the Shunde Sag is an important exploration breakthrough direction. The distribution and scale of the semi-deep and deep lacustrine facies source rocks in Eocene Wenchang Formation are the main problems in oil and gas exploration in the Shunde Sag. The sedimentary characteristics of Wenchang Formation in the Shunde Sag are analyzed through structural evolution analogy, seismic response characteristic analogy and statistics of fault activity rate. The study shows that the structural setting of the lower Wenchang Formation in the Shunde Sag is similar to the Kaiping Sag, and the faults controlling subsag sedimentation control the development range of the semi-deep and deep lacustrine facies. It is similar to the semi-deep and deep lacustrine facies source rocks in Wenchang Formation of Zhu I depression, and the seismic reflection of the semi-deep and deep lacustrine facies in Wenchang Formation of the Shunde Sag is mainly characterized by low frequency and continuity. The statistical results show that during the sedimentary period of the lower Wenchang Formation, the activity rates of faults controlling subsag sedimentation are greater than 100 m/Ma, which has the development background of the semi-deep and deep lacustrine facies. Comprehensive analysis shows that Wenchang Formation in the Shunde Sag is a river-lake sedimentary environment, mainly developing fan delta, braided river delta, shore-shallow lake and semi-deep and deep lacustrine facies. Constrained by sedimentary characteristics, the spatial distribution of the semi-deep and deep lacustrine facies source rocks in Wenchang Formation of the Shunde Sag was predicted by facies clustering analysis method based on seismic multi-attribute self-organizing map neural network.The study shows that the semi-deep and deep lacustrine facies began to develop from the sedimentary period of Wen 6 member, then Wen 5 member continued to expand, and Wen 4 member reached the largest scale, and the semi-deep and deep lacustrine facies shrank during the sedimentary period of the upper Wenchang Formation. The area of the semi-deep and deep lacustrine facies in Wen 4 member of the northern subsag of the Shunde Sag is 153 km^2 and the volume is 86.5 km^3. The research results can lay the foundation for resource evaluation and hydrocarbon accumulation research in the Shunde Sag, and provide the basis for the exploration target optimization.

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Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
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Impact of depositional process and salt on reservoir property of deep-water sandstonesa case study from the Paleocene-Eocene Wilcox Formation in the Perdido belt, Burgos Basin

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Keywords: submarine system, gravity flow, salt, reservoir property, Perdido Belt

Deep-water sandstones overlain by allochthonous salt sheet in uneven thickness were deposited by various sediment gravity flows in the Perdido belt of the Burgos Basin. Cores and well logs, from 14 wells and high resolution 3D seismic data are used to reconstruct the sedimentary environments and depositional processes of the Wilcox Formation sandstones. A suits of petrographic and geochemical methods, including thins sections, X-ray diffraction(XRF), scanning electron microscope(SEM) and physical property test are conducted to study the reservoir property. The results reveal that depositional process and salt are the primary controls on reservoir property. Six bed types(high-density turbidite, low-density turbidite, hybrid event bed, debrite, slump deposit and bottom-current reworked bed) and five microfacies(channel, proximal lobe, distal lobe, slope and abyssal plain) are identified. The permeability in distal lobe(avg. 118.5mD) is almost twice as high as that in distal lobe(48.5mD). However, greater variations in reservoir property are observed for different bed types of different depositional processes. High-density turbidite, bottom-current reworked bed and the lower hybrid event bed exhibit approximately two orders of magnitude higher in permeability than that of the upper hybrid event bed, low-density turbidite and debrite. Petrograhpic analysis shows that the porosity decreases along with the increase of depth. However, it increases with greater depth when the sandstone is overlain by allochthonous salt sheet. Salt sheet is favorable for both the primary and secondary porosity preservation. Comparison between samples with and without overlying salt sheet exhibit similar reservoir property, porosity type and clay mineral in quite different depth, suggesting that thicker salt sheet with high thermal conductivity are beneficial for supressing the diagenesis.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
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The Cenozoic depositional system evolution and formative mechanism of Southern South China Sea basins

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Keywords: Southern South China Sea, Depositional systems,Difference,Controlling factors,Pro- South China Sea,South China Sea

In order to reveal the Cenozoic depositional system evolution and formative mechanism of basins, Southern South China Sea (SSCS), based on a joint geological, geophysical and geochemical dataset, this paper restored the Cenozoic paleogeography, illustrated depositional system evolution and discussed the controlling factors of basins of SSCS. The results show that there are three types of sedimentary basins in SSCS (including foreland, strike slip and drifting basins), with different sedimentary filling structures. The foreland basins form a depositional pattern of “early deepwater late shallow-water”, which suggests that these basins were dominated by deep-water depositional systems before Early Oligocene, with submarine fans developed. Later, the foreland basins were gradually dominated by shallow water depositional systems, with deltas and shallow marine facies developed, and the formation age of deltas gradually changed younger from west to east. The strike slip basins show the depositional architecture of "early lake and late sea”, which means the basins were dominated by the lacustrine deposits during Eocene, and they entered into marine depositional environment since Oligocene, with delta developed in the west part of the basin. The depositional evolution of drifting basins illustrate the characteristics of “early clastic and late carbonate”, which means the drifting basins were dominated by Eocene-Oligocene shallow marine clastic depositional systems, while carbonate platform started to develop since Early Oligocene, with early in the east and late in the west.

The above-mentioned depositional architecture differences in SSCS are controlled by a scissor-style closure of pro-SCS and progressive-style expansion of SCS. Specifically, the early deep-water sedimentary environment of basins in SSCS was controlled by the distribution of pro-SCS in Eocene. Then, as the scissor-style closure of pro-SCS from west to east during Oligocene to Early Miocene, the northwest of Borneo continued to rise, providing a large amount of clastic materials to the basins, leading to the development of large-scale deltas which younger from west to east. While, the distribution of early lacustrine sedimentation of strike slip basins were affected by paleo uplift and then the basins were transgressed from the northeast and gradually entered into marine sedimentary environment due to the expansion of SCS. Additionally, the expansion of SCS also controlled the sedimentary filling evolution of the drifting basins, which resulted in the basins breaking away from the South China continent and drifting southward. In turn, the drifting basin lack the supply of terrigenous clastic sediments and the development of large-scale deltas, forming a clear water environment which is conducive to the development of carbonate platform, the age of which younger from east to west.

Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
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Utilizing Cryptic Ichnotaxa in Core to Interpret Sedimentary Environments: Upper Montney Member, Northeastern British Columbia, Canada

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Keywords: Trace-fossil types, Ichnotaxonomy, Ichnofacies, Lithofacies, Lower shoreface, Upper Montney Member

This study focuses on a new practice in using trace fossils that are not readily classified to the ichnogenus or ichnospecies levels to interpret sedimentary environments. Two lithofacies are identified from two cores representing the Upper Montney Member from northeastern British Columbia, Canada. Lithofacies 1 (L-1) is composed of highly bioturbated, bituminous, fine- to coarse-grained siltstone. Lithofacies 2 (L-2) consists of interlaminated dolomitic, medium- to coarse-grained siltstone and bituminous, fine-grained siltstone. Sediments in the studied cores are interpreted to be deposited within the fair-weather dominated lower shoreface settings. Owing in part to a lack of grain-size variability, trace fossils observed in both cores are poorly defined, making it difficult to determine the specific ichnospecies or ichnogenera. An alternative approach to the ichnotaxonomy is used, which is classifying trace fossils into types primarily based on their discernible orientation and shape. Herein, four types of trace fossils (Type a, b, c and d) are recognized. Type a and b are vertical to inclined, club to funnel shaped, unlined burrows, with infill typically structureless. They are mostly concentrated in L-1, commonly showing singular occurrence within tempestites, probably attributable to distal *Skolithos* to proximal *Cruziana* ichnofacies. Type c are circular to elliptical unlined burrows. The infill is occasionally vaguely meniscal. Largely, type c are densely distributed in L-1, especially within thick fair-weather deposits, possibly attributable to *Cruziana* ichnofacies. Type d appear as diminutive, circular to irregular dots. Infill always contrasts with host sediments. Type d are sporadically distributed in L-1 and L-2, interpreted to be *Planolites*-like trace fossils. On basis of these four types, L-1 exhibits the highest size-diversity index (SDI) (23-52) and bioturbation index (BI) (4-6). Both SDI and BI decrease gradually from L-1 to L-2, with L-2 largely smaller than 15 and 3. Overall, the sedimentological interpretation is collaborated by the trace fossil assemblage. And there was potentially an oxycline separating the proximal lower shoreface from the distal lower shoreface Thus, each trace-fossil type can represent a group of biogenic sedimentary structures that share ethological affinities, potentially fitted into the Seilacherian ichnofacies concepts. And ichnological data can be gathered from the identified types to interpret the physico-chemical stresses in sedimentary environments.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Oral Preferred

Differential characteristics of Paleogene sedimentary and hydrocarbon source in deep water area of northern South China Sea

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Keywords: marine source rocks, transitional facies source rocks,delta-bay systems; deposit source, the deepwater areas in the north continental margin, the South China Sea,basin structure

The differences of Paleogene tectonic geological settings in deep water area of the pearl River Mouth basin and Qiongdongnan Basin in the northern South China Sea lead to the formation of different sedimentary systems and source systems, and corresponding different oil and gas exploration directions.

The two adjacent basins are influenced by the evolution of the south China sea with the Paleogene tectonic evolution of east early-west night. In early Oligocene of major hydrocarbon source perioddeep water area of Pearl river mouth basin was the fault depression structure, with deep sags respectively have their uniform deposits and settlement centers. The basin accepted the large provenance injection of the ancient Pearl River system out of the basin and adjacent uplift belts in the basin, and developed large delta systems under the environment of the gulf. The deep water area of Qiongdongnan Basin is a faulted depression structure contemporarily, and many rows of small depressions with certain separation are developed in the steps and central lowlands on both sides. Under the influence of short-range provenance, such as the water systems in the south of Hainan Island and the River systems in Vietnam, the barrier coast system and a series of small fan deltas are developed in the enclosed and semi-enclosed bay environment.

The differences of delta systems between the east and west deep water areas have an important influence on the distribution pattern and types of source rocks in the bay. In the east, the large delta in the pearl River Estuary brought a strong terrigenous input, affected the whole bay greatly influenced by terrigenous organic matter, with generally higher abundance of organic matter in the source rocks and good types of source rocks. In the western deep water area, the deltas are small in scale and the influence range of terrigenous organic matter is limited, but the marine mudstone is wide in scope and thick, and the water body sealing is strong and the preservation condition of organic matter is good.

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Scientific Themes: Theme 6. Marine Siliciclastic Depositional Systems
Session T6-9: Marine siliciclastic reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Oral Preferred

Coastal tempestite deposit of the western Zhu I Depression during the early-middle Miocene, Pearl River Mouth Basin

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Keywords: Pearl River Mouth Basin, Tempestite deposit, Middle Miocene, the Ancient Pearl River DeltaEstuarine bar

The Pearl River Mouth Basin is a large petroliferous basin formed in the Paleogene, which is controlled by the NE trending synsedimentary fault zone. The structural unit of the basin has the characteristics of "three uplifts and two depressions". In the west of Zhu I Depression in the Pearl River Mouth Basin, there are secondary structural units such as Xijiang Sag, Enping Sag and Yangjiang Sag.

The Pearl River Mouth Basin experienced a Paleogene fault period and a Neogene depression period. In the sedimentary period of Pearl River Formation and Hanjiang Formation in the early and middle Miocene of Neogene, the ancient Pearl River Delta has been formed and progradated into Zhu I Depression on a large scale from northwest to Southeast. At this stage, the west part of Zhu I Depression is mainly located in the front of the ancient Pearl River Delta, and many underwater distributary channels and estuarine bar sand bodies are developed.

The root mean square amplitude attribute of the third-order sequence extraction of the Pearl River Formation and the Hanjiang Formation in the western part of the Zhu I Depression shows that there are two directions of sand body arrangement: One is the sand body distributed in a lobate and band shape from north to south, which represents the distributary channel and estuary bar deposits of the ancient Pearl River Delta; The second is the annular sand body, which surrounds the front of the lobate body of the ancient Pearl River Delta and is nearly vertical or oblique to the distributary channel at a large angle, oilfield scientists and technicians call it coastal sand ridge or distal bar, which belongs to the sand body caused by wave or ocean current transformation.

Through the detailed observation and analysis of cores, it is shown that these sand bodies distributed around the delta front do not belong to the real coastal sand ridge or distal bar. The particle size of sand body is generally 2-3φ, and usually contains 0-1φ coarse sand, with a single layer thickness can reach more than 10m, but these characteristics are not consistent with the medium and thin silt sand sediments reconstructed by the ocean current. Although there are some sedimentary features transformed by waves, such as wave cross bedding and broken biological fragments of different sizes, can be widely seen in the core, however, a large number of plant debris, desiccation cracks, plant root traces and other sedimentary phenomena above the water surface were not found in the core. On the contrary, there are many sedimentary structures related to tidal action, such as horizontal bedding and tidal bedding in the gray and light gray siltstone and mudstone interacting with the sand body. In addition, part of the sand body particle

size histogram presents double peaks or multi peaks, and the standard deviation is generally between 0.7-2.0. The probability accumulation curve is mainly two-stage, including three-stage or even multi-stage, with the impurity base content of 5-15%, and the impurity base content of some medium and fine sands can reach more than 25%, which shows that the sand body deposition is not a simple wave action. Bottom scouring structures are also common in the sand layer. In some core layers, the bioclastic mixed with sandy particles is not arranged in parallel, some coarse bioclastic are even vertical, and mixing structures can be seen in the silt. These phenomena point more to the intermittent tempestite deposition.

It can be compared that the wave action in the modern Pearl River Estuary is not prominent, and the Pearl River Delta is mainly tidal-dominated delta. However, the storm waves produced by typhoons that occur frequently every summer are the hydrodynamic conditions that cannot be ignored when the coastal debris materials are transformed and transported.

These storm induced ring belt sand bodies can show positive cycle and reverse cycle on GR logging curve, which are formed by the migration and progradation of sand bodies to the sea, and their positions correspond to the seaward side and the land side of the sand body respectively.

Reference

no

Theme7

Carbonate Sedimentation

Session T7-1: Carbonate buildups and reefs through the Phanerozoic

ID: T7-10081

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-1: Carbonate buildups and reefs through the Phanerozoic
Presentation Preference: Oral Preferred

THREE DIMENSIONAL ARCHITECTURE OF A MIDDLE DEVONIAN BIOSTROME EXPOSED IN A CAVE

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Keywords: Middle Devonian, Reef system, Sediment-stressed environment

In Earth's history, reef development reached an acme during the Middle and Late Devonian period. We present evidence from lower Givetian tabular biostromes in Western Germany, documenting a short-lived reefal interval in an otherwise clastic setting. Reefal biota and their host matrix are exposed in three dimensions along the walls and ceiling of the Klutert Cave (6 km accessible passages). Recently cleaned cave walls provide access to 26,000 m^2 of rock surface allowing detailed studies of the biostromes architecture. Stromatoporoids, rugose and tabulate corals are the main reef builders. Associated biota include crinoids, brachiopods, gastropods and cephalopods. Acid digestion data and other lines of evidence indicate that the reef developed in a sediment-stressed environment and collapsed when sediment influx crossed threshold limits.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-1: Carbonate buildups and reefs through the Phanerozoic
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Extracting data from literatures to construct knowledge database using DeepDive: A case study for stromatolites in the geological past

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Keywords: Information Extraction, Relation Extraction, DeepDive, Knowledge Base Construction, Stromatolite, Precambrian

In the field of Earth Science, a large amount of information is buried in various literature which are growing rapidly, so it becomes more and more difficult to manually pick up data swamped in literatures. To explore and summarize a feasible information extraction workflow and therefore further help geologists understand and master the series of text mining techniques, this work takes the construction of stromatolite knowledge from scientific literature as an example to demonstrate the whole extraction process step by step. Firstly, we collecting the stromatolite-related PDF documents and then converting them into text. Secondly, using a glossary of vocabulary and tags labeled by NLP (Natural Language Processing) software, we search for all possible candidate pairs from each sentence. Thirdly, each pair and its features are represented as a factor graph model, with a series of heuristic procedures used to score the weights of each pair's features training the probability of each candidate. This approach achieved 92%/464, 87%/778, 92%/846 and 93%/405 accuracy/distinct pairs on strata, facies, location and age with probability greater than 0.9 respectively from 3,750 scientific abstracts, and 90%/1734, 86%/2869, 90%/2055 and 91%/857 from 11,932 papers. At last, we got 10,072 unique data items after merging them. The newly obtained stromatolite knowledge database deciphers that stromatolites reached a pronounced peak in occurrence during Proterozoic (2500-541 Ma), followed by a distinct fall in earliest Phanerozoic and fluctuations during the Phanerozoic (541–0 Ma). Globally, seven stromatolite hotspots: western United States, eastern United States, western Europe, India, South Africa, northern China, and southern China are identified from the global dataset. Terrestrial stromatolites remained a low proportion (20%) in comparison with marine stromatolites from the Precambrian to Jurassic, and increased significantly in proportion from the Cretaceous to the present, up to 30-70%.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-1: Carbonate buildups and reefs through the Phanerozoic
Presentation Preference: Oral Preferred

Anisian (Middle Triassic) stromatolites from Southwest China: biogeological features and implications for variations of filament size and diversity of Triassic cyanobacteria

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Keywords: Bevocastria, filaments diameter, dissolved oxygen, atmospheric CO2

This study documents new stromatolite deposits from the Anisian succession of the Guanling Formation in the Boyun section of eastern Yunnan Province, southwestern China. The Boyun stromatolites are characterized by undulating laminations, which yield a variety of biostructures and abiotic grains, such as cyanobacteria Bevocastria and Renalcis, microclots, fecal pellets, coccoid-like spheroids, and authigenic quartz. Filamentous cyanobacteria Bevocastria are likely major builder constructing the Boyun stromatolite build-ups. Stromatolites in the Boyun section likely grew in an open, oxic marine environment, differing from the Early Triassic stromatolites that were mostly formed in relatively oxygen-poor conditions of shallow marine settings, strengthening the view that stromatolites are not necessarily indicative of harsh environments. In addition, the global dataset of cyanobacteria filament sizes through the Triassic deciphers that a pronounced increase in the diameter of filamentous cyanobacteria through the Early-Middle Triassic, followed by a decline during the Late Triassic. The developments of marine anoxia in the Early Triassic and Rhaetian coincided with the reduction in cyanobacteria filament diameter, suggesting a causal link between the two. Global data also show that the diversity of cyanobacteria broadly tracks the modeled estimates of O2 during the Triassic, but does not show a significant correlation relationship with any modeled estimates of CO2, indicating that their relationship might be more complex when CO2 levels are below 10 times as present atmospheric level.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-1: Carbonate buildups and reefs through the Phanerozoic
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

A Study on the development characteristics of Early Permian (Cisuralian) reefs of the southwestern Tarim Block, northwest China

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Keywords: Permian,organic reefs,reef-building organisms,diagenesis,sea level

The Permian strata in Southwest Tarim Basin have organic reef with good exploration prospects. Based on outcrop observations and thin section examination of the Permian keziliqiman formation reef in Sangzhu section in Pishan County, Xinjiang, this paper explores the basic characteristics of the reef. Keziliqiman reef is a point reef that grew along the platform margin, and consists of a base, a core, a front, a back and a cap sub-facies. The lithology of the reef core close to the high-energy front is mainly coral skeleton rock, and that of the reef core close to the low-energy back is mainly sponge barrier rock. The development of the reef was subject to the rise and fall of the sea level; it emerged when the sea level rose in southwest Tarim Basin, and disappeared when the sea level fell rapidly. For the fall of the sea level reduced the Sangzhu area to a hot and dry supratidal zone where algae began to flourish, dolomitization intensified, and then reef building organisms died en masse. Paleontological and geochemical characteristics of the Sangzhu reef indicate that the sea-level fall in southwest Tarim Basin was probably related to the early Permian glaciation. When there were no more building organisms, the Keziliqiman reef began to be transformed by diagenesis. Overall, the impact of diagenetic transformation on it was rather small. Furthermore, its diagenetic process had more to do with marine fluids in its sedimentary period than with non-marine fluids, for non-marine fluids was powerful enough to affect biodetritus but powerless to affect argillaceous matrix.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-1: Carbonate buildups and reefs through the Phanerozoic
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Evolution of Cambrian carbonate platform in Tarim Basin: Analysis based on seismic sedimentology

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Keywords: carbonate platform evolution, sedimentary facies, Cambrian, seismic sedimentology

Three-dimensional (3-D) seismic data offers opportunity to exploit the growth pattern, paleoecology and reservoir heterogeneities of ancient carbonate platform systems. However, it is still very difficult to obtain Cambrian carbonate platform evolution and sedimentary facies information in Tarim Basin, because the carbonate rocks are deeply buried and seismic data resolution is low. In this study we try to use an enhanced interpretation workflow to improve facies interpretation in ultradeep (over 7000 m), high-velocity (6000-7000 m/s) carbonate rocks using low-frequency (up to 20 Hz) seismic data.

The study area named Xiaotangnan locates in middle of the east Cambrian platform margin and seismic surveys is about 800 square kilometers. The stacked, migrated seismic data is characterized by a frequency range of 10~60 Hz with a dominant frequency of 20Hz. Phase rotation, frequency decomposition, stratal slicing and RGB (red-green-blue) color blending are used to interpret platform architecture and facies.

The growth of Cambrian platform can be divided into two stages, ramp and rimmed platform. Erosion at the end of Sinian resulted in a gentle slope to the northeast in study area and above the unconformity a carbonate ramp developed in early Cambrian. Contour map of time-thickness (Txsd-Tg8) shows that there is no sudden change in deposit thickness in this period which also can be observed in seismic profiles. During this time, carbonate shoals are widely distributed and most of them are in irregular ellipse shape.

The transition from ramp to rimmed platform began at the end of Xiaoerbulake Formation. Slight rimmed architecture can be observed in seismic profile in this period. At the end of early Cambrian (Wusonggeer Formation), sharp shelf break is distinct in seismic profile and isopach map of Tg7-Txsd where a basin deepens and margin-slope become higher and steeper. Lagoon locates behind the platform margin where lobate tidal deltas were common. Platform interior is characterized by carbonate shoals. The middle Cambrian was the heyday of platform development, as a strongly prograding accretionary platform the edge migrated 3 km to the sea. Rimmed platform and arid climate lead to the deposition of evaporite in carbonate platform.

Seismic sedimentology provides an effective means for deep buried carbonate platform interpretation. Although drilling data is absent in this area, outcrops and modern sedimentary correlation analysis provide support for geological interpretation.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-1: Carbonate buildups and reefs through the Phanerozoic
Presentation Preference: Oral Preferred

The ossicles and fragments of Ordovician crinoid and its palaeoecology from Tarim Basin, NW China

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Keywords: Tarim Basin, Ordovician, crinoid ossicle, paleoecology

Crinoid fragments and ossicles are very common in the carbonate rocks of the Ordovician in the Tarim Basin, in Xinjiang, northwestern China. Different from the previous studies of intact crinoid fossils, this study provides a comprehensive analysis of the types and contents of the crinoids stem fossils including ossicles and fragments, and the taphonomy of the symbiotic fossils from Ordovician cores of 6 wells, as well as the sedimentary environment is performed so as to understand the paleoecology of the crinoids. In the core samples there are 7 ossicles identified: cyclocyclic, pentagonopentalic, pentagonocyclic, ellipocyclic, pentagonoelliptic, corner pentagonopentalic, variabal pentagonalic. 4 ossicle assemblages are classified: Pentameri, Elliptici, Cyclici and Varii. According to the statistics of the shapes, size and percentage of the ossicles, combined with the taphonomic characteristics of the symbiotic fossil and analysis of the sedimentary environments, it is found that crinoids were absent from the community dominated by cyanobacteria and Tetradiid corals of the restricted lagoon environment. Very few slim crinoid ossicles occurred in the biota of gastropods and ostracods of the fine-grained bank facies covering the lagoon facies. Abundant crinoids and various symbiotic bryozoans, Solenopora, dasycladaceans and other organisms were present in the biota of the open platform facies. Both crinoids and bryozoans are filter feeders, and should have a symbiotic but competition relationship in most cases. However, in the Ordovician seas, their difference in body size determined the two groups belonging to different filter feeding groups, which eased the competition between them. In communities dominated by crinoids and bryozoans, crinoid ossicles are the most abundant, and all the four ossicle assemblages were present. Solenopora grew via photosynthesis and had no competition with crinoids. Their relationship with crinoids is a mutualism. The crinoid ossicles in the Solenopora-crinoid community are relatively simple, belonging to the Cyclici type, being big and dense, and their content is the highest. Crinoids are widely symbiotic with dasycladaceans. Due to the influence of the oncoids formed by filamentous cyanobacteria, the number and size of crinoid ossicles and fragments are fewer than dasycladaceans, but they are relatively richer and more diverse, including four types. Therefore, we suggest that the most suitable environment was the open platform for the crinoids in Ordovician of Tarim Basin, and the main controlling factors were hydrodynamic energy and water cleanliness. The higher the hydrodynamic energy was, the cleaner the water was, more flourishing the crinoid was. Low hydrodynamic energy and turbulent water turbidity were disadvantageous to crinoid.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-1: Carbonate buildups and reefs through the Phanerozoic
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Types and formation environment of lacustrine carbonate particles in Bohai Sea area

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Keywords: Bohai, Lacustrine carbonate, Carbonate particles, Ooid, Shell

Carbonate particles related reservoir is a good reservoir of the shahejie formation in BoHai sea areas, in order to define the carbonate particles forming mechanism and forming environment, using rock-mineral analysis and paleontology, element geochemistry research method, on the sedimentary characteristics of the such carbonate particles have been studied in detail, according to the form and structure divides the particle type, the mechanism of formation and distribution of the carbonate particles were analyzed. According to the external morphology and internal structure, three particle types were identified: ooid, sheath particles and oocyte particles. The morphology of carbonate particles is influenced by many factors, including biological types, sedimentary environment and hydrodynamic conditions, as well as biochemical and physical effects.
Ooid formation is closely related to the filamentous cyanobacteria and coccoid cyanobacteria, dominant control filamentous cyanobacteria dark layer formation, as the early core particles of ooid, coccoid cyanobacteria were formed in the coastal and shallow water sedimentary environment rich in terrigenous clasts with strong hydrodynamics and developed in the water depth range of 0.5m-7m, which is an important structural type of granular carbonate rocks; sheath particles are formed by filamentous cyanobacteria and developed in shallow water and lacustrine environments with weak hydrodynamic conditions. They are the main structural components of microbialite. Ospherulites are controlled by coccoid cyanobacteria. They develop in shallow water environment with fast deposition rate and in water depth ranging from 4m to 10m. They are the main structural components of granular carbonate rocks. In addition, the parameters related to the shell and core of carbonate particles were statistically analyzed.It is found that there is no obvious correlation between the core of carbonate particles size and the depth of water, as well as the core-shell ratio (the ratio of the core size to the thickness of the shell). However, with the deepening of water depth, the smaller the thickness of carbonate particles shell, the larger the ratio of carbonate particles major axis and minor axis.

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Paleogeographic features and reef-bank distribution of the Permian Changxing Formation-Triassic Feixianguan Formation in the Sichuan Basin

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Keywords: Petrographic Palaeogeography, Sichuan Basin, Changxing Formation—Feixianguan Formation, Reef-bank

Reef-bank reservoirs have an essential position in global oil and gas exploration, and their oil and gas production accounts for about 50-60% of worldwide oil and gas production from carbonate reservoirs. The Permian Changxing Formation-Triassic Feixianguan Formation is an important formation in the Sichuan Basin for the development of reef-bank, and a large number of high-producing gas fields have been found in this formation. In this paper, through a large number of previous studies and field investigations, we subdivided the Changxing- Feixianguan phase of the Sichuan Basin into six periods according to the principle of "tectonic control of the basin, basin control of the face, and face control of the oil and gas", drew the corresponding petrographic paleogeography maps, highlighted the distribution of reefs and banks, and combined each oil and gas reservoir with reefs and banks. The systemic analysis shows that the petrographic paleogeography has an obvious controlling effect on oil and gas reservoirs, and the tectonic pattern of the Sichuan Basin between uplift and depression provides good conditions for the development of reefs and banks, and the reef and beach spreading patterns have strong regularity. At the same time, due to the high position of the banks, it is easy to be leached by atmospheric fresh water, and dolomitization occurs, which improves the reservoir capacity.

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Evolutionary pattern of metazoan reefs after the Late Devonian extinctions

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Keywords: coral reef, proliferation, mass extinction, glacial-interglacial climate, Mississippian

Metazoan reefs are very important ecosystems in marine environments due to their high biotic diversity and abundance. They are an excellent tool for tracking palaeoecological changes, especially through mass extinction transitions. Although metazoan reefs proliferated during most of the Phanerozoic, metazoan “reef gaps” and “reef-recovery intervals” with microbial resurgence often occurred after extinction events. The largest metazoan-reef ecosystems of the Phanerozoic flourished during the Middle-Late Devonian. They were formed by stromatoporoid sponges and corals. This reef association collapsed and disappeared during the Late Devonian Frasnian-Famennian and end-Devonian Hangenberg mass extinction events, respectively. Afterwards, the Mississippian is commonly believed to be dominated by microbial bioconstructions, such as the Waulsortian mounds. Few small, metazoan reefs of variable compositions were documented during the Middle-Late Mississippian (Visean to Serpukhovian). It is still unclear when metazoan-reef ecosystems recovered and whether a single evolutionary lineage for reef ecosystems appeared after the Late Devonian extinction events.

Based on the high-resolution reef database, four sub-intervals of the Mississippian metazoan reef evolution were distinguished: (1) metazoan “reef gap” phase without metazoan reefs during the Tournaisian; (2) metazoan reef re-establishment phase containing a few metazoan reefs from early Visean to the early late Visean; 3) metazoan reef proliferation phase with global coral reef flourishment reaching its peak in the middle part of the late Visean; and 4) metazoan reef collapse phase with a gradual decline in coral reef abundance during the latest Visean to Serpukhovian.

During the Tournaisian, a widespread marine anoxic event disturbed and further delayed initial phase of metazoan reef recovery. Later, during the Visean, recurrent glacial and interglacial climate may have stymied metazoan reef recovery during this time. However, the late Visean coral reef proliferation clearly shows that the Mississippian was not solely a period dominated by microbial reefs. Their development coincided with increased nektonic and benthic diversity, suggesting that stable marine ecosystems developed during this time. This situation is associated with warm conditions and high relative sea level. Then, with the onset of the major phase of the late Palaeozoic ice age (LPIA) and enhanced climate cooling starting in the latest Visean, and more or less coeval habitat destruction as consequence of the Variscan orogeny, coral reef ecosystems gradually collapsed and became very scarce in the Serpukhovian.

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Lower Devonian reefs – The Emsian Château-Pignon biostrome from the Basque Country (Southern France)

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Keywords: Lower Devonian, Patch-reef, Biostrome, Palaeoenvironment, Palaeoecology

While Silurian and Middle Devonian are well-known for their stromatoporoids-corals reefs development across the globe, the Lower Devonian reefs are less studied. In Southwestern Europe, they are scarce and mostly represented by patchy and biostromal geometries. Most of them have only been identified and summarily studied in larger-scale regional geological studies. Understanding what constraints (i.e. palaeoenvironment, palaeogeography, palaeoecology, etc.) impact reef development and their community structure is still a key question to deciphering reefs' evolution, especially in the Early Devonian.

Herein, we present the first results on the characterisation of the Château-Pignon biostrome (French Basque Country). The Château-Pignon biostrome is located South of Saint-Jean-Pied-de-Port (Hastateguy peak). Heddebaut (1973) called it “a biostrome like reefal limestone” without providing more details. Later, it was interpreted as channel deposits by Perlet (1986). Four field campaigns have been conducted to study and sample the potential reefal layers at Château-Pignon. Overall, the limestone body considered to represent the reefal facies is E-W oriented and measures 100 m in length and 30 m in thickness. Six main carbonate facies (FT1-6) have been determined. The base is characterized by slightly detrital (FT1) crinoidal wackestone to packstone, which formed in tide-influenced inner shelf environments. Then, tabulates corals, stromatoporoids and solitary rugose corals appear progressively in those shallow inner shelf (FT2: Floatstone with few bioconstructors). About 3 meters above section base, the abundance of bioconstructors increases and they start to form patches of heterogeneous composition and density, which are often 50 cm in diameter (FT3 Floatstone with bioconstructor, FT4 Floatstone with a high density of bioconstructors). Facies FT1-4 have a similar micritic matrix and most corals and sponges are reworked. In the upper third of the limestone body, a meter-thick bed is essentially composed of densely packed reworked bioconstructors (FT5 Bioconstructors rudstone). The core of the biostrome is a 1-2 m thick layer composed of densely grown thamnoporid colonies (tabulate corals) and stromatoporids (up to 100 cm in diameter) (FT6 Tabulate corals and stromatoporoids boundstone). The associated fauna comprises brachiopods and echinoderms, which are minly preserved as fragments of various sizes. Very rarely cephalopods can be documented.

Our preliminary results suggest that the Chateau-Pignon body corresponds to a sequence of short-lived, but mostly failed initiations of reef development of moderate-size, in an inner shelf depositional regime. Bioconstructors eventually formed a biostrome, favoured by a local increase in relative sea level. Further environmental parameters will be explored to better constrain the reef growth and the evolution of the community structure.

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Late Permian Reef Buildup in the Upper Yangtze Region and Puguang Gas Field- Study on Typical Sedimentary Outcrops

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Keywords: reef buildup,late Permian, upper yangtze region, puguang gas field, outcrop

The Yangtze region is one of the regions with the best stratigraphic record and the most abundant fossils of the Permian–Triassic in the East Tethys and even in the world. It records the evolution of the Paleotethys, the Permian–Triassic Boundary (PTB) mass extinction, the Emei tafrogenesis and other important geological events. The proposed field trip targets, locating in Upper Yangtze region, including the typical platform margin reefs of Late Permian and grain shoals of Early Triassic at Jiantianba in Lichuan County, at Panlongtong, and Puguang Oilfield in Xuanhan. It is shown how the sedimentological study serves oil and gas exploration successfully, leading to the discovery of the Puguang giant gas field. The Jiantianba outcrop reveals a complete sedimentary succession containing basin, slope, carbonate platform margin, and open-restricted platform deposits, where especially, the platform margin reef core can be observed with very clear assemblages of architecture units and a variety of identifiable microfacies(e.g., Filled-skeleton sponge framestone, Open-skeleton sponge framestone, Binding-skeleton sponge framestone, Segment or cluster bafflestone). Calcisponge is the main reef-building organism with abundant species and various forms. It is one of the most typical reefs of The Late Permian T in The Yangtze region. The platform margin zone across the Permian-Triassic biological mass extinction event is studied at the Panlongdong outcrop, revealing the typical platform margin sedimentary characteristics that the reefs of Changxing stage developed on the lower partT while the shoals of Feixianguan stage on the upper part of the section. Platform margin reef and shoal are superimposed and inherited spatially. The sedimentary evolution succession of reef base–reef core–reef cap is clear and complete. The platform margin shoal is mainly oolitic, and gravel intraclasts the second, with tabular and wedged cross-bedding developed. Puguang gas field is represented by the reef and shoal reservoirs with high porosity and high permeability of the Permian Changxing Formation and the Lower Triassic Feixianguan Formation. This discovery benefited from the breakthrough in The sedimentological study on sedimentary facies and favorable reservoirs. It provids a good reference for the exploration and development of ultra-deep buried carbonates gas fields in the world.

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High resolution stalagmites from southwestern China reveal Indian summer monsoon changes during the Holocene

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Keywords: Stalagmite,Indian summer monsoon,holocene

The Asian summer monsoon (including the Indian and East Asian monsoon), which which affects the live and production activities of one third of the world's population, plays an important role in the global climate system. Detailed studies of the monsoon changes during the Holocene in different regions are critically important for a better understanding of its future trend. Here, we reconstructed the accurately-dated, high-resolved Indian summer monsoon changes, covering the last 9000 years, by using four replicated stalagmites from Shenqi Cave in southwestern China. In general, the oxygen isotope changes of Shenqi (SQ) record are consistent with other stalagmite records from Oman, Indian and monsoonal China, following the northern Hemisphere summer insolation change during the Holocene. It indicates the covariations of the Indian summer monsoon and East Asian summer monsoon on orbital scale. Our record suggest the strongest Indian summer monsoon in southwestern China occurred in the early Holocene. The rapid declining of the Indian summer monsoon after 7000 a BP may be caused by the increase of the Arctic sea ice and ENSO frequence. Seven pronounced weak monsoon events were recorded at 8.27.65.65.35.04.02.3 ka BP in our stalagmites δ18O record, among which the 8.2 ka event was the most remarkable.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-1: Carbonate buildups and reefs through the Phanerozoic
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Facies architecture and palaeoecology of brachiopod-rich Visean (Mississippian) mud mounds from the Derbyshire Carbonate Platform (UK).

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Keywords: mud mound, brachiopod, Mississippian, Visean, Derbyshire

Mud mounds are widespread in the upper Visean of the Derbyshire Carbonate Platform succession, outcropping in the Peak District (UK). In particular, mounds occur in the uppermost part of the Monsal Dale Limestone Formation. Derbyshire mounds are dominated by lime mud derived from in situ precipitation mediated by microbial mats on the seafloor, associated with siliceous sponges (‘automicrite’), and contain skeletal metazoan remains not forming a rigid framework (bryozoans, brachiopods, crinoids). Gutteridge (1990) described brachiopods as concentrated in storm-scoured pockets surrounded by a mound automicrite boundstone facies barren of shelly macrofauna.

Facies architecture was re-studied in several Derbyshire mud mounds developed in different settings on the platform: platform interior (Linen Dale), middle intraplatform ramp (Ricklow Quarry), outer ramp (Rheinstor Rock), platform margin (Pic Tor, High Tor, National Stone Centre). Metre-sized mounds are frequently associated to form decametre-sized complexes. The core of the complexes is similar in all the settings, being a clotted-peloidal micrite boundstone with fenestellid bryozoans, brachiopods, and siliceous sponges, unless for thicker cores where more accommodation space was available. This is indicative of the fact that there were no major changes in the mud mound biotic community in the different settings. Some differences may arise in the flank beds: in the platform interior (Linen Dale near Eyam) these consist of crinoidal peloidal grainstone – packstone, in the intraplatform middle ramp skeletal wackestone-packstone, in the outer ramp skeletal packstone – grainstone, at the platform margin fine wackestone - packstone with skeletal debris and chert towards the platform interior, while skeletal packstone beds with crinoids dip towards the basinal facies of the Widmerpool Gulf. These differences reflect the transition of the mound core facies to the surrounding off-mound facies.

Brachiopods are widespread in every mound facies, and no signs of storm scoured pockets were identified. However, some specimens are concentrated in skeletal grainstone patches in the mud mounds interpreted as the filling of cavities in the mound framework formed by bryozoans, siliceous sponges, and automicrite. Likely, the abundance of brachiopods contributed to the rigidity of the mounds. Brachiopod assemblages are dominated in terms of biovolume by productides, which is indicative of scarce and scattered food resources.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-1: Carbonate buildups and reefs through the Phanerozoic
Presentation Preference: Oral Preferred

Middle Permian carbonates in Iran and the links between distribution pattern of the large test fusulinids and depositional environmental change during Guadalupian

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Keywords: Guadalupian, Iran, carbonates, depositional environments, fusulinids

The Middle Permian carbonates and significant events during this time interval have been studied by many geologists. The Guadalupian carbonates in east-central Iran are known as the Jamal Formation, located in Shotori and Bagh-e Vang Mountains and those in west-central Iran are named as the Surmaq Formation and lower parts of the Abadeh Formation in the Hambast Valley, Abadeh area, within Sanandaj-Sirjan Zone. The Guadalupian gray to cream medium- to thick-bedded carbonates of the Jamal Formation in the Shotori section are composed of the shallowing-upward successions but those in the Bagh-e Vang section contain the interbedding gray medium-bedded limestones and chert bands indicating a deep basin environment (Arefifard and Isaacson, 2011).

In Hambast Valley section, the Surmaq Formation is subdivided into three units (1-3) and consists mainly of light to dark gray medium-bedded shallow subtidal limestone in the Roadian-Wordian Unit 1 followed by the upper Wordian Unit 2 containing light gray thin- to medium-bedded deep basin limestone with chert bands interbeds. The dark gray medium- to thick-bedded shallow subtidal limestones of the upper Wordian-Capitanian Unit 3 overlies the Unit 2 of the Surmaq Formation. The overlying Abadeh Formation in the Hambast Valley section has a conformable contact with the Surmaq Formation and its lower part known as subunit 4a is composed of alteration of the gray to black shales and gray thin- to medium-bedded limestone indicative of a lagoon setting which are dated late Capitanian (Shahinfar et al., 2020). Considering the significance of end-Guadalupian extinction and its impact on organisms especially large test fusulinids, it is necessary to investigate the effect of the depositional environment change on the extinction of these organism at the end-Guadalupian.

Lager test fusulinid occurrences in the carbonates of the Shotori section are low, probably due to the paleotemprature of local ambient sea water above 36º centigrade which was not appropriate for the survival of these organisms. In Bagh-e Vang section, a deep basin environment was unfavorable for occurrence and growth of the large test fusulinids. In Hambast Valley section, the Roadian-Wordian Unit 1 of the Surmaq Formation yields abundant large test fusulinids. In the upper Wordian Unit 2 of the Surmaq Formation, limestones with chert bands interbeds are comparable with their coeval deposits in the Bagh-e Vang section and are lack of large test fusulinids. The cherts abundance in the Unit 2 of the Surmaq Formation and in the Middle Permian Jamal Formation of the Bagh-e Vang section are linked to Middle Permian chert event in South China and North America. These cherts were an indication of eutrophication conditions and high level of nutrients, providing unfavorable conditions for the life of large test fusulinids and their algal symbionts. It can be inferred that the climate change and the increase of nutrient input played major roles in the extinction of these organisms in the study areas of east and west central Iran.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-1: Carbonate buildups and reefs through the Phanerozoic
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Characteristics and evolution controlling factors of platform margin reef-shoal: a case study of Upper Carboniferous-Middle Permian in the northwest of Tarim Basin

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Keywords: margin reef-shoal, characteristics, controlling factors, Upper Carboniferous-Middle Permian, Tarim Basin

Reef-shoal reservoirs play an important role in carbonate reservoirs and are prone to form high-yield oil and gas fields with huge reserves, such as the Ghawar oil field in Saudi Arabia, Zertan oil field in Libya, and Old Golden Lane oil field in Mexico[1]. In recent years, with breakthroughs in reef-shoal facies oil and gas fields of Upper Ordovician Lianglitage Formation in Tarim Basin, Triassic Changxing Formation and Feixianguan Formation in Sichuan Basin, such as Tazhong I Gas field, Puguang gas field and Yuanba gas field, the research interest of reef-shoal facies is increasing [2-6]. Studies show that the favorable area of reef-shoal body in Tarim Basin is $1.58\times10^4 km^2$, and the amount of oil and gas resources is more than $1.5\times10^9 t$, indicating its huge exploration potential [7]. Upper Carboniferous-Middle Permian platform margin reef-shoal reservoirs are one of the most important exploration targets for the northwestern margin of Tarim Basin. To obtain a clear understanding of the controlling factors for the platform margin reef-shoal development, field outcrops in the Wushi area, and northwestern margin of Tarim Basin had been studied in this article by field measurements, thin section identification, carbon and oxygen isotope testing, and ancient provenance analysis. Studies showed that the platform margin reefs in the Wushi area were dominated by algae reefs, and the platform margin shoals are dominated by bioclastic shoals and gravel shoals. The characteristics of algal bind inside grains were common. During the Zhaerjiake period, interbedded reefs and shoals were the main types, and platform marginal reefs were of the progressive type; During the Balediertage period, huge thick platform margin reefs were the main type, platform margin reefs were of accretion-weak progressive type. The development controlling factors of the platform margin reef-shoal are mainly relative sea-level change, palaeosource, and paleogeomorphy. Relative sea-level changes controlled the development characteristics and superposition mode of the platform margin reef-shoal; there were two sides of the influence of the palaeosource on the platform margin reef-shoal; the paleogeomorphology controlled the development position and spreading scale of platform margin reef-shoal. In the covering area, the platform margin reef-shoal reservoirs adjacent to the fault zone and with large sedimentary thickness might have a good prospect for hydrocarbon exploration.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-1: Carbonate buildups and reefs through the Phanerozoic
Presentation Preference: Oral Preferred

Permian-Triassic Boundary Microbia: biological status & ecological position

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Keywords: microbialite, calcimicrobe, Permian, Triassic, carbonate, diagenesis

Permian-Triassic boundary microbialites (PTBMs) are thin (ca 0.06 – 20 m) limestones directly after the end-Permian extinction horizon, concentrated in low latitude palaeogeographic positions and largely Tethyan. PTBMs' constructors are stromatolites and thrombolites when viewed at field scale, but in thin section many thrombolites are composed of calcimicrobes.

Palaeogeographic variations of PTBMs are principally:
1) South China Block (SCB) PTBMs (eastern Tethys): predominantly extensive calcimicrobe-constructed biostromes across shallow marine environments of the Yangtze Platform. PTBMs are pervasively recrystallised, making it difficult to ascertain their full constructing assemblage of microbialite forms. Diagenetic alteration is highly variable, even across distances of a few mm, but the dominant structure in best-preserved material is a lobate-form calcimicrobe similar to, but different from, Renalcis and Tarthinia, named a new taxon Calcilobes (which in SCB is C. wangshenghaii, Kershaw et al. 2021). In contrast to other calcimicrobes, Calcilobes is interpreted to have formed as individual solid round micritic blobs on the sea bed that amalgamated into a framework with geopetals. Dolomitisation is common in Calcilobesmasses, but is non-selective, occurring in both microbial lobes and interstitial sediment. SCB PTBMs also contain minor stromatolites that in some cases bear very small branching microbia called "Polybessurus-like fossils" (PLFs) in layers (Zhang et al. 2021). PLFs also occur as fragments in some thrombolites indicating some transport, yet overall the SCB PTBMs grew in low energy conditions, lack algae and may have formed in water a little deeper than modern coral reefs do. Uncertainty about conditions of formation of SCB PTBMs reflect evidence of both anoxic and oxygenated conditions in their sedimentary material.
2) Western Tethys PTBMs: mainly in Turkey & Iran in palaeogeographic positions including large Tethyan platforms in Cimmeria and northern Gondwana margins. Calcimicrobes are rare in western Tethys, PTBMs being stromatolites and thrombolites composed of clotted sediments. However, discovery of peculiar calcimicrobes in one site in Turkey reveal a different form of Calcilobes (Kershaw et al. 2012, Fig.12C,D, and in prep.). In Iran and Armenia are common occurrence of digitate stromatolites of presumed biogenic. Overall the form diversity of western Tethyan PTBMs is much greater than eastern Tethys, but reasons why the forms are geographically limited is not understood.

Despite substantial effort, major questions remain:
A) were the microbialites photosynthetic, thus cyanobacteria? We may surmise that the stromatolites have the best chance of being cyanobacteria but there is no proof in thrombolites or calcimicrobes, so interpretations including a primary production element, and oxygen production, are attractive but await confirmation.
B) What caused the PTBMs to appear so sharply, and to disappear (almost as sharply) so soon after the extinction, noting that biotic recovery from extinction took several million years? Interpretations of anoxic upwelling and raised bicarbonate levels in the oceans to drive carbonate microbialite production lack conclusive evidence.
C) Why are PTBM calcimicrobes apparently unique in the rock record (since the first microbialites ca. 3500Ma, the only occurrence of Calcilobes is in the PTBMs)?

PTBMs have a bright future: their enigmatic structure presents many research opportunities!

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-1: Carbonate buildups and reefs through the Phanerozoic
Presentation Preference: Oral Preferred

Extracting Limestone Database from Scientific Papers with Deepdive and Constructing the Limestone Knowledge Base

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Keywords: Information Extraction,Carbonate,Limestone,Deepdive,Knowledge base construction

Carbonate rocks are the oldest sedimentary rock on earth, dating back to approximately 3.8 billion years ago. Limestone, as the most widely distributed carbonate rock, its temporal and spatial distribution can help us better understand the precipitation of carbonate minerals in the long-term history. Here, we use a novel method to efficiently extract information and generate the knowledge base from the published literature. First, we collect limestone-related PDF documents and convert them to text by using OCR (Optical Character Recognition) software. We use a glossary of vocabulary and tags labeled by NLP (Natural Language Processing) software, and all possible candidate pairs were searched from each sentence. Secondly, each pair and its features are represented as a factor graph model, with a set of heuristic procedures used to score the weights of each pair's features in order to train the probability of each candidate. Our results include 90%/6542, 92%/2377 and 85%/9225 accuracy/distinct pairs on strata, age and location with probability greater than 0.9 respectively from 27124 papers. After integrating the data, we ended up with 15,144 unique data items. Permian, Ordovician and Carboniferous are the three most commonly stated eras in our findings.
Limestone occurrence shows a low stand before Cambrian (541 Ma), then increases in Cambrian and reaches a subpeak in Ordovician (485-444 Ma). After a short decrease in Silurian-Devonian (444-359 Ma) it comes to a peak in Carboniferous-Permian (359-252 Ma), followed by a rapid fall at the Permian-Triassic boundary, finally descending to a relatively stable level with small fluctuations after Cretaceous (145 Ma). As for locations of limestone, China, the United States, Western Europe and Canada are the four hotpots identified by our data. OCR (Optical Character Recognition), NLP, and DeepDive are used in a pipeline procedure to extract important information from geological publications.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-1: Carbonate buildups and reefs through the Phanerozoic
Presentation Preference: Plenary Talk

Microbial blooms triggered pyrite framboid enrichment and deoxygenation in microbialite systems after the end-Permian extinction

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Keywords: South China, anoxia, dysoxic, Triassic

The widespread occurrence of microbialites immediately after the end-Permian extinction has attracted interest about their formation conditions. Microbialites are generally believed to be formed during microbial bloom in reducing conditions linked to the mass extinction. However, the cause-and-effect relationship between microbe bloom and reducing states of seawater has long been debated. Here, we report redox fluctuations across the Permian-Triassic boundary (PTB) to evaluate links between the two based on analyses of 17,306 pyrite framboid diameters and morphologies derived from 23 PTB sections from basin to platform settings in South China. During the end-Permian extinction, abundant tiny framboids indicate a widespread anoxia that was likely a direct cause of extinction. In the earliest Triassic (Hindeodus parvus conodont zone), pyrite framboids were absent in ramp to basin and shallow, nonmicrobialite platform sections. In contrast, the coeval microbialites yield abundant framboids indicative of dysoxia. The fact that framboids were only confined to PTB microbialites and absent in other habitats indicates that microbe bloom may have stimulated dysoxic watermass and triggered the framboid growth within microbe aggregates. Thus, the PTB microbialites were not built in reducing waters upwelled from deeper water masses, but instead, microbial proliferation caused local, dysoxia within shallow oxygenated platforms after the extinction. The new results also reject the inference that oxygen minimum zone (OMZ) may have controlled redox variations over the P-Tr transition, and also reveal that a widespread but transient de-oxygenation event was coeval with the end-Permian extinction and that the much more prolonged euxinic-anoxic conditions prevailed in the aftermath of the earliest Triassic extinction.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-1: Carbonate buildups and reefs through the Phanerozoic
Presentation Preference: Oral Preferred

Cyanobacteria bloom on shallow platform in South China after the end-Permian mass extinction

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Keywords: Microbialites, end-Permian mass extinction, cyanobacteria

The widespread development of Permian/Triassic boundary microbialites (PTBMs) are widely accepted as a sedimentary response to the mass extinction event. The major constituents of the microbial communities that precipitated these structures, however, remain unknown. Here, we report newly found columnar cyanobacteria from nine Permian/Triassic boundary microbialite successions in South China, which are interpreted as Pleurocapsales (a modern cyanobacterial clade having a strong calcifying capacity). These microfossils are abundant in Permian/Triassic boundary microbialites observed in South China, and four stages of the Pleurocapsales life cycle: baeocytes, juvenile column, mature column, and baeocyte-splitting are recorded, supporting a Pleurocapsale identification. The clustering branches give the Pleurocapsales potential in constructing frameworks to baffle water currents for the development of microbialites. Common occurrence, strong calcification capacity, and baffling framework indicate that Pleurocapsales are important in constructing Permian/Triassic boundary microbialites. Variation characteristics of Mg/(Mg+Ca) ratios from latest Permian to earliest Triassic in PTBMs and the micro-distribution of Mg between fossils and surrounding rock indicate enrichment of Mg by these cyanobacteria.

Session T7-2: Carbonate reefs, mounds and seeps in time and space

ID: T7-20188

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-2: Carbonate reefs, mounds and seeps in time and space
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Characteristics and Differences of the Platform Margin Reef–shoal Complex Reservoir, Changxing Formation, Central Eastern Region, West of the Kaijiang-Liangping Trough

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Keywords: Reef-shoal complex, Reservoir characteristics, Reservoir evolution, Changxing Formation, west of Kaijiang-Liangping Trough

In this study, the margin platform in the central eastern region to the west of the Kaijiang-Liangping Trough was divided into two areas: (1) the main central Longgang area, and (2) the eastern Longgang area, to determine the properties, genesis, patterns and differences of the reservoir. The main Longgang area is a steep-slope platform margin type. The reef–shoal complex growth close to the outer edge of the platform margin has a ridgeline shape, with multiple stages apparent in the vertical direction. The eastern part of the Longgang area is a gently sloping platform margin; the reef–shoal complex is the product of broad horizontal and vertical development. The former type of reservoir space contains constitutively selective intragrain dissolution pores, intergrain dissolution pores and non-constitutively selective dissolution fractures and structural fractures, producing low porosity and low permeability. The latter type consists mainly of intercrystal pores, intercrystal dissolved pores, intergrain dissolved pores and structural dissolution joints, resulting in a fracture-type reservoir possessing extremely low porosity and low permeability. Development of the reef–shoal complex reservoir was completely controlled by atmospheric freshwater dissolution, reflux infiltration and dolomitization, together with early diagenetic near-surface karstification, burial dissolution and buried dolomitization. The water body in the eastern Longgang area was relatively deep, resulting in weak atmospheric freshwater dissolution in the syngenetic stage, and weak near-surface dissolution in the early diagenetic stage. The high-quality reservoir is influenced by fractures and buried dissolution.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-2: Carbonate reefs, mounds and seeps in time and space
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Criteria for recognizing microbial-caddisfly bioherms in lacustrine settings: Paleocene Second Member, Funing Formation, Subei Basin, East China

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Keywords: Trichopteran cases, Agglutinated polychaete tubes, Nested instar cases, Silk larval cases, Helix-shaped cases, Marine incursion

Paleogene carbonate successions from lacustrine basins across East China yield microbial bioherms containing abundant agglutinated fossil tubes. Historically, these have been interpreted as the dwellings of polychaetes introduced by marine incursions. This is problematic, because these tubes are associated with abundant non-marine fauna and algae. Diverse and exceptionally well-preserved fossil tubes from carbonate microbial bioherms were studied in outcrops and drill cores of the second member of the Paleocene Funing Formation, Subei Basin, East China. Detailed macro-, meso-, and micro-structural investigations of these tube-dominated bioherms reveal that the putative “marine polychaete tubes” better fit the morphologies and construction styles of lacustrine caddisfly (Insecta: Trichoptera) larval cases, eliminating the need for a marine influence on this lacustrine setting.

Individual caddisfly cases are commonly 10-25 mm in length and 1-2.5 mm in diameter, and form slightly curved, tapered tubes or coiled spirals. Twelve tubular case construction styles were further identified, based on caddisfly-case wall structures and dominant grain types. Caddisfly cases are commonly single-walled, with rarer nested instar cases comprising double- or triple-walls of different sizes. Most cases are fully agglutinated with neatly arranged, similarly sized and closely connected particles of clastic grains, carbonate particles, plant fragments, and phosphatic fish bones. Sparsely agglutinated cases are also present but much rarer, and conform to the silk larval cases of caddisflies.

The caddisfly cases appear as gregarious aggregations within carbonate microbial-bioherms. The microbial-caddisfly bioherms in this study are commonly developed on carbonate hardground or mudstone within the wave-washed, high-energy, shallow-lacustrine littoral zone and can be traced along the western paleolake margin of the Jinhu Depression of the Subei Basin for up to 60 km. The bioherms are composed of repeated microbial-caddisfly couplets, made up of randomly arranged and similarly sized caddisfly cases encrusted by domed, planar, columnar or cauliflower-like microbial layers. Cyclic microbial-caddisfly couplets fit well with caddisfly biology but are not known to occur with marine polychaetes. This is the first report of microbial-caddisfly bioherms in Cenozoic strata of China, and is the oldest Cenozoic record of caddisflies in China.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-2: Carbonate reefs, mounds and seeps in time and space
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Late Ordovician Colospongia (“Sphinctozoa”, Porifera) from Tarim Basin reveals a shallow water origin of reef-building calcareous sponges

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Keywords: Calcareous sponges, Sphinctozoans, Late Ordovician, Tarim Basin, reef

Calcareous sponges (including Sphinctozoa, Inozoa and Sclerospongiae) are important reef-builders in the Permian and Triassic. Although Sphinctozoans appeared in the Cambrian, there are few records about early Paleozoic reef-building calcareous sponges. At present, the earliest known record of a reef-building calcareous sponge is *Corymbospongia*, a multi-chambered sphinctozoan of the Sanqushan Formation in the late Katian, Zhejiang Province, China, and it is considered that the reef-building sphinctozoans may have originated from the relatively deep-water environment in the back arc basin of the Late Ordovician. We discovered a new species of sphinctozoan from the Late Ordovician early Katian Lianglitag Formation in the Tazhong area, Tarim Basin. The species is characterized by moniliform arrangement, hemispherical or spherical chambers, absence of a central tube and internal filling structures. We named it *Colospongia primitiva* sp. nov., belonging to the family Colospongiidae. *C. primitiva* is one of the important frame-building organisms in the *Tetradium*-?*Archaeolithoporella*-Sphinctozoan reef community. Sedimentary microfacies analysis shows that *C. primitiva* lived in the clear shallow water with weak hydrodynamic conditions in the platform interior, which is very close to the reef-building environment of *Colospongia* from the Permian and Triassic. Discovery of *C. primitiva* extends the appearance of *Colospongia* back from the Carboniferous to Ordovician, and it is the earliest known calcareous sponge involved in reef building. *C. primitiva* and Cambrian single-chambered *Blastulospongia* are the same structural characteristic type of low-grade sphinctozoans. Therefore, it is very likely that *C. primitiva* originated from Cambrian *Blastulospongia* and evolved into vertically stacked multi-chambers. The discovery of *C. primitiva* not only provides more evidence for the origin of *Colospongia* from *Blastulospongia*, but also reveals that *Colospongia* may not have changed much in the long-term evolution. Our discovery further enriches the diversity of reef-building sphinctozoans in the Ordovician, and for the first time shows that reef-building calcareous sponges may originate from the relatively shallow water environment of the platform interior and became a builder of shallow water reefs at least since the early Katian (Late Ordovician).

Reference

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-2: Carbonate reefs, mounds and seeps in time and space
Presentation Preference: Oral Preferred

Comprehensive Geophysical Identification of Reef in Xisha Offshore

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Keywords: Xisha offshore, reef, seismic identification, exploration prospect

Reef is organic construction of carbonate rock generating from reef-building organisms. As the most important reservoir type globally and main exploration prospect of South China Sea, reef reservoir has the characteristics of large reserves and high production. Xisha offshore, lying in the northern of South China Sea, has a good reef construction environment since Miocene and developed on a large scale. Based on the geology research of Xisha offshore, the geophysical corresponding characteristics of reef are synthetically analyzed. First the seismic reflection characteristics are introduced, including colliculus appearance, top interface's continuous reflection of strong amplitude, weakening continuous of bottom interface, unorganized internal reflection, lateral onlap, and draping overlying strata. Four geophysical characteristics are illustrated including high velocity, high wave impedance, no obvious abnormal gravity and abnormal low magnitude. Finally, the hydrocarbon geological condition is analyzed, and the conclusion obtained is that this area is a good hydrocarbon prospect and important exploration target of deepwater in future.

Reference

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-2: Carbonate reefs, mounds and seeps in time and space
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Oldest Phanerozoic calcimicrobial reefs (Cambrian Series 2) in Shandong Province, North China: calcimicrobe distribution and contribution to reef construction

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Keywords: archaeocyath, calcimicrobe, Cambrian, North China, reef

Skeletal organisms first appeared at the end of the Ediacaran, and rapidly diversified in the Cambrian. Skeletal reef-builders (archaeocyaths) appeared during the late Terreneuvian, and had expanded their habitat by Cambrian Epoch 2. Calcimicrobes also became significant reef constructors during this interval. However, in contrast to archaeocyath-bearing reefs, purely calcimicrobial reefs without archaeocyaths have not yet been fully documented. Calcimicrobial reefs with highly diversified calcimicrobes occur in the Zhushadong Formation (Cambrian Series 2) in Shandong Province, North China; these are the earliest Phanerozoic microbial reefs reported from North China. This study examines the age-specific features of the modes of reef construction and calcimicrobe constituents by comparing the reefs in the Sunmayu and Jinhe sections.

In the Sunmayu section, the calcimicrobial reefs consist mainly of *Epiphyton* and *Kordephyton*, with subordinate *Tarthinia*, *Renalcis*, and *Bija*. The reef frameworks are constructed mainly by aggregations of *Epiphyton* and *Kordephyton*, and are encrusted by tubiform microbes. In some cases, the calcimicrobial assemblages exhibit a characteristic succession from a framework comprising *Kordephyton* and *Epiphyton*, to upward and lateral growth of *Epiphyton*, and finally to *Amgaina* aggregations. The interframework areas are filled with sparry cement and ooidal and peloidal grainstone. Bioclasts are very rare. In the Jinhe section, the calcimicrobial composition is similar to that in the Sunmayu section, although *Amgaina* does not occur. Reef frameworks are mainly constructed by *Epiphyton* and *Kordephyton*, with encrustation by tubiform microbes. Micritic masses with mesh-like fabrics representing keratose sponges occur locally within the frameworks. Unlike the Sunmayu section, the calcimicrobial reefs are in most cases intercalated with “nodular limestone”. The interframework areas are filled with lime mud containing bioclasts (trilobites, hyoliths, and sponge spicules). These areas are dominated by tubular or irregularly shaped voids of <1 mm in diameter, possibly related to burrows or decayed microbial matter. Those voids are infilled with spar cement and lime mud.

Epiphyton and *Kordephyton* were thus the main framework builders in the Zhushadong calcimicrobial reefs. Tubiform microbes in part acted as encrusters, enhancing framework rigidity, whereas *Renalcis*, *Tarthinia*, and *Bija* played minor roles as encrusters and consolidators. The reefs in the Sunmayu section, which are associated with spar cement and ooidal or peloidal grainstone, are inferred to have developed in a high-energy shoal setting. *Amgaina*, which acted as a final framework builder, might have exclusively inhabited higher-energy conditions, where other calcimicrobes could not live. In contrast, the calcimicrobial reefs in the Jinhe section, which occur within peloidal wackestone and lime mudstone, are interpreted to have formed in low- to moderate-energy subtidal settings. Their irregular microbial frameworks provided habitats for comparatively dominant reef-dwelling and burrowing organisms. Although archaeocyaths have not been reported from North China, the Zhushadong reefs contain almost the same calcimicrobes as coeval archaeocyath-bearing reefs. Calcimicrobes were thus distributed widely at that time and contributed greatly to microbial reefs irrespective of the presence or absence of skeletal reef-builders.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-2: Carbonate reefs, mounds and seeps in time and space
Presentation Preference: Oral Preferred

Stromatolite or keratolite? Hints from Early Silurian laminated microbialites, South China Block

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Keywords: keratose sponge, Shihniulan Formation, Llandovery, vermicular fabric, spongiostromate structure

Putative keratose sponges in microbialites have attracted great attention not only from palaeontologists, but also from sedimentologists in the last few years. To distinguish from stromatolite, keratolite has been coined to refer to laminated carbonates dominated by keratose sponges. In northern Guizhou Province (Upper Yangtze Platform, South China Block), stromatolites have been described in the Lower Silurian (upper Aeronian, Llandovery) Shihniulan Formation. Due to the lack of attention, however, little is known about the complicated microstructures in these laminated microbialites. Here we investigated the well-preserved vermicular fabric-bearing “stromatolites” in the top part of the Shihniulan Formation at the Chayuan Section in Tongzi County, Guizhou Province. Small cylindrical and dome-shaped stromatolites occur in a 1.5-m-thick reef succession, with individual stromatolitic units generally less than 30-cm-thick. Microfacies analysis shows various fabrics with different microstructures, dominated by vermiform to spongiostromate structures and clotted textures in the layered deposits. The clotted textures are mainly composed of filamentous microbial fabrics. In contrast, the vermiform to spongiostromate structures share similarities with reported keratose sponges. The association of keratolite and stromatolite developed during a regression and was terminated by subsequent exposure of the seafloor. Our results provide the first case of interlayered keratolite–stromatolite consortia in the Silurian, suggesting that these laminated bioherms tend to grow in intertidal environments.

Reference

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Session T7-2: Carbonate reefs, mounds and seeps in time and space
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Biogenic Mg-calcite micropeloids within coral skeletons from Zhongsha atoll, South China Sea

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Keywords: Mg-calcite, peloid, microbe, coral reef, Zhongsha

Micropeloids are common cement types in many limestones, and their formation mechanism is a matter of debate. Inorganic theory supported spontaneous nucleation and precipitation of Mg-calcite in the water column and then settled out of suspension as tiny particles, while the organic origin tended to bacterially-influenced precipitation. In this study, we drilled a shallow sedimentary core from the inundated reef flat in Zhongbei Shoal, north Zhongsha atoll, and probed into the internal relations between ongoing microbial activities and peloidal cements by petrological and geochemical analysis. Micropeloids, 20–100μm in size, occur as interstitial materials in the primary pores of the coral skeleton. Each peloid is assembled by abundant micron-sized rhombic microcrystals of High magnesium calcite (less than 2μm in size). Massive calcified algae/cyanobacteria in vivo were viewed within the peloidal cements, whose calcified sheaths comprised Mg-calcite rhombs, similar to the surrounding peloids. The same distribution modes of the rare earth element and high life-related element (V, Cd) content of the two Mg-calcite rhombs proved that Mg-calcite peloidal cements have a close linkage with microbial metabolism. This study gives a new insight into the organic origin of Mg-calcite peloids during early cementation and enhances the understanding of the pervasive microbial activities in tropical coral reefs.

Reference

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-2: Carbonate reefs, mounds and seeps in time and space
Presentation Preference: Oral Preferred

"Keratose" demosponges in carbonates: comments and new data

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Keywords: keratosan, Porifera, non-spicular, metazoan

"Keratose" demosponge fossils were first recognized in Triassic and Devonian carbonates in 2014 (Luo & Reitner, 2014). Along with accumulating reports of similar structures from Phanerozoic carbonates, and recently even from the Neoproterozoic Little Dal Group (Turner, 2021), some researchers accepted the keratosan interpretation and started to address the role that "keratose" sponges played in reefs and other carbonate deposition systems (Lee & Riding, 2021; Pei et al., 2021). However, validation of this interpretation and the recognition criteria of these organisms are still unsettled questions to other workers. Alternative interpretations include lithistid sponges, Wedl tunnels, *Lithocodium*, and clotted micrites, etc. (e.g., Larmagnat & Neuweiler, 2015; Kershaw et al., 2021). Here, using samples from the Lower Triassic of Armenia and Tommotian of Siberia as examples, we reinforce our original point that "keratose" demosponges were indeed fossilized in some Phanerozoic carbonates. The morphological criteria, which were proposed in our earlier works during 2014–2016 (e.g., Luo & Reitner, 2016), are refined and shown to be useful for recognizing these fossils. Regarding taphonomic mechanisms, the preservation of "keratose" sponges is comparable with that of spicular taxa. The precipitation of automicrites and rapid burial by allomicrites can both mould the organic keratosan skeletons but result in different taphonomic features. Finally, we suggest that the morphology of most known keratosan fossils fit best in the Order Verongimorpha, and verongimorphs may have evolved at the latest by Cambrian Age 3. Nevertheless, in less favorable preservation, "keratose" sponge fossils can be confused with many structures of other origins due to their simple morphology. Broader cooperative efforts are required to forge more precise or quantitative criteria for the determination of these fossils.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-2: Carbonate reefs, mounds and seeps in time and space
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Skeletal-cement-microbial hybrid carbonates in the Pennsylvanian: A case study in Guizhou, South China

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Keywords: Hybrid carbonates, Reefs, Paleoenvironment, Pennsylvanian, South China

Hybrid carbonates, defined as combinations of in situ abiotic, microbial and skeletal precipitates, have changed with biological and environmental conditions throughout geological history (Riding and Virgone, 2020). After a long dual-hybrid carbonate interval, the triple hybrid carbonates became prevalent in the late Pennsylvanian and lasted to mid-Triassic. Reefs from upper Moscovian-Kasimovian (mid-late Pennsylvanian) strata of Guizhou, South China consist of abundant skeletal organisms, microbial carbonates, and abiotic marine cements, which are classified as triple hybrid carbonates. Skeletal components (e.g., phylloid algae, colonial rugose coral *Ivanovia*) and stromatolitic microbial carbonates could build simple frameworks with the growth cavities filled by syndepositional marine cements, automicrite, and sediments. Microbial boundstones constituted by aragonitic cements (e.g., botryoidal cements) and microbial micrite layers are the critical contributor to the buildups as a constructor of the framework, a filler of the cavities, and hard substrate for the encrusting metazoans. The petrographic features suggest the reefs formed at a shelf margin to slope settings with active water circulation. The evolution of Carboniferous organic buildups was primarily driven by the changes in reef-building organisms, closely related to external conditions of the seawater chemistry and paleoclimate. The ubiquitous triple hybrid carbonates in the reefs from South China, consistent with Pennsylvanian tropical shallow-water reefs in their components, are proposed to have been derived from the interaction between decrease in atmospheric CO_2, seawater with high Mg^{2+}/Ca^{2+} ratio, warm tropical water, and the radiation of skeletal organisms in the Pennsylvanian (Fan et al., 2020).

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-2: Carbonate reefs, mounds and seeps in time and space
Presentation Preference: Oral Preferred

The Spatial and Temporal Distribution of Cambrian Maze-Like Reefs in the North China Platform

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Keywords: Maze-like reefs, Sponge, Paleoenvironment, Cambrian, North China Platform

Maze-like reefs, characterized by centimeter- to decimeter-scale branching structures, flourished during the Cambrian to early Ordovician on Laurentia and Gondwana. Maze-like reefs were identified across the North China Platform, and can be subdivided into branching maceriate reefs and columnar maceriate reefs. The maceria structures are made of sponges (e.g., keratosans and lithistids) and microbial components including *Girvanella*, *Renalcis*, and *Tarthinia*, whereas the interstitial material consists of lime mud with bioclasts and intraclasts. The temporal distribution of the maze-like reefs gradually becomes younger from the Drumian stage to the Jiangshanian stage from the northwestern part to the southeastern part of the North China Platform. Detailed facies analysis suggests that depositional environments may have played an essential role in the occurrence of the maze-like reefs in the North China Platform.

Reference

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-2: Carbonate reefs, mounds and seeps in time and space
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Faunal change across the Devonian-Carboniferous transition at Changtanzi section, Longmenshan area, South China

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Keywords: Hangenberg crisis, Carbonate microfacies, metazoan reef, stromatoporoid

This study reports the faunal and facies changes across the Devonian-Carboniferous transition at Changtanzi section, Longmenshan area of South China. Based on the revised stratigraphy, we find the occurrence of diverse organisms in the third member of the Changtanzi Formation, which is uppermost Famennian in age. The fossil assemblage is represented by 19 species of stromatoporoids and corals, including stromatoporoids (*Gerronostromaria angulatum*, *G. regulare*, *Platiferostroma crissum*, *Cystostroma zhonghuaense*, *C. hunanense*, *Stylostroma sichuanense*, *S. huanjiangense*, *S. hunanense*, *Labechia majiaobaensis*, *L. longmenshanensis*, *Labechilla* sp., *Spinostroma aggregatum*), tabulate corals (*Syringopora honanensis*, *S. longmenshanensis*, *Michelinia* sp., *Roemerolites* sp., *Fuchungopora multispinosa*, *F. huilongensis*), and rugose coral *Cystophrentis simplex*. In the uppermost of Changtanzi Formation, a biostrome built mainly by stromatoporoids and tabulate corals appeared, suggesting the recovery of the metazoan reef system, but it disappeared in the subsequent Hangenberg crisis during the D-C transition. Biotic recovery is observed in the lower Tournaisian Majiaoba Formation, represented by solitary rugose corals *Hebukophyllum* sp., *Neozaphrentis* sp. and *Uralinia* sp., as well as abundant brachiopods, gastropods and tube organisms, but the fossils belong to post-disaster fauna of low species-level diversity. This study indicates that the Hangenberg crisis caused sudden and significant influences to marine ecosystems, resulting in the disappearance of coral-stromatoporoid metazoan reefs.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-2: Carbonate reefs, mounds and seeps in time and space
Presentation Preference: Oral Preferred

EBSD, a new technique to understand the formation of stromatolite layers

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Keywords: EBSD, EDS, carbonate, stromatolite, lake, biomineralization

During the last decade, Electron Backscatter Diffraction (EBSD) has been applied to various fields of geology and biomineralization. However, carbonates, one of the most common rock types on the Earth, have rarely been analyzed using EBSD. Until now, only biologically controlled carbonates such as mollusc and brachiopod shells or foraminifera have been studied under EBSD. In this study, we analyzed stromatolites using EBSD for the first time, in combination with Energy-dispersive X-ray spectroscopy (EDS). We analyzed Recent and Pleistocene stromatolites from the Ruidera Pools (Spain), and Cretaceous stromatolites from the Banyawol Formation (South Korea), all of which formed in arid lake environments. The data acquired from EBSD and EDS were complemented by petrographic observations as well as carbon and oxygen isotope analyses.

In both areas, stromatolites consist of alternating micritic and crystalline layers. In the stromatolites of the Ruidera Pools, the crystal co-orientations in both micritic and crystalline layers are very low, indicating a random distribution of the carbonate grains. Both layers mainly consist of low magnesium calcite devoid of siliciclastic grains, with constant elemental composition throughout the samples. In the micritic layers, EBSD misorientation maps show higher values concentrated in areas with smaller grains or in wavy well-defined fronts within bigger crystal units. The high misorientation values are interpreted as the incorporation of extracellular polymeric substances of microbial organisms into the crystal structure. On the contrary, the crystalline layers rarely show high misorientation values among the crystals, indicating abiotic precipitation.

Micritic layers in Banyawol stromatolites are poorly co-oriented and can be further subdivided into two different types based on their grain size, texture, and elemental composition; first, layers with heterogranular grains enriched in elements such as Al, Na, and Si, and second, layers with more homogeneous grains with more Mn. The former is interpreted to have deposited during the rainy seasons when detrital sediments were transported and trapped in stromatolite layers, whereas the latter would have formed in the dry season with more carbonate mineral precipitation. The misorientation value distribution of the Banyawol micritic layers is similar to those of the Ruidera Pools, suggesting the influence of microbial activity. The crystalline layers of Banyawol samples consist of upward-widening fan-shaped crystals. These fan-shaped crystals generally show low misorientation values, although vertically oriented narrow zones with high misorientation values are recognized. These fan-shaped crystals are reminiscent of cyanobacteria filaments observed within some modern stromatolites.

Overall, this study suggests that EBSD and EDS can provide a novel perspective on the biochemical mechanisms of modern and ancient stromatolite formation.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-2: Carbonate reefs, mounds and seeps in time and space
Presentation Preference: Oral Preferred

Carbonate-coated twigs in the Jinju Formation (Lower Cretaceous), southern Korea

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Keywords: Carbonate-coated twigs, lake, stromatolite, oncoid

Distinctive cylindrical carbonate-coated twigs (CCTs), so-called “rod-shaped stromatolites (RSS)”, are reported from the Lower Cretaceous Jinju Formation in Sacheon, southern Korea, which are known to have formed under semi-arid lacustrine conditions. This study focuses on the CCTs collected from two localities of Bito Island and Seonjeon-ri to understand their formative processes and their paleoenvironmental implications. The CCTs are mostly cylindrical and are 1 to 5 cm in diameter and a few cm to >10 cm in length, and are generally similar in their macroscale morphologies regardless of their localities. In both localities, they consist of a central nucleus which is now mostly filled by sparite with minor detrital grains and micrite containing relict plant tissue, and outer micritic- to sparitic layers. The microstructures of the CCTs vary from site to site. The Bito Island CCTs show millimetric stromatolitic columns with laminated fabric in the inner part and thrombolitic fabric in the outer part. Laminated fabric contains undulatory convex-up micritic layers with abundant fossilized microbes such as branching tubular microbes resembling rivulariacean-type cyanobacteria and spherical algal mold (?) *Chlorellopsis*. Thrombolitic fabric is distinguished by millimetric branching digitates with faint laminations and abundant *Chlorellopsis*. In contrast, Seonjeon-ri CCTs are solely composed of millimetric stromatolitic columns of alternating clotted and fibrous layers, with rare fossilized microbes around the nucleus. Clotted fabric is characterized by sand-sized peloids with diffuse boundaries, and fibrous fabric consists of isopachous calcite crystal layers. Morphological characteristics of the fabrics suggest that laminated, thrombolitic and clotted fabrics are microbial in origin, whereas fibrous fabric would have formed by abiotic precipitation. It is interpreted that the microscopic differences between the Bito Island and Seonjeon-ri CCTs, despite their macroscopic similarities, resulted from varied effects of biotic and abiotic precipitations. The dominant precipitation process could have been controlled by temporal/regional differences such as water chemistry during the deposition of the Jinju Formation. This study thus suggests detailed microscopic analyses are required to understand the formative mechanisms of CCTs and their paleoenvironmental implications.

Reference

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-2: Carbonate reefs, mounds and seeps in time and space
Presentation Preference: Oral Preferred

Sedimentary Characteristics of an Oolitic Beach of the Triassic Feixianguan Formation, East of Kaijiang-Liangping Trough, Sichuan Basin, China

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Keywords: oolitic beach, sequence; rise and fall of sea level,Feixianguan Formation,Triassic, Kaijiang-Liangping trough, Sichuan Basin

The aim of this study is to clarify the temporal and spatial distribution characteristics of oolitic beach deposits and the controlling mechanism of sea level change on oolitic beach migration within the sequence stratigraphic framework of Triassic Feixianguan Formation on the east side of Kaijiang-Liangping trough in Sichuan Basin. Lithologic characteristics analysis, identification of sedimentary structural markers and division of sequence stratigraphic framework of sequence boundary have been carried out. The results show that: (1) Two third-order sequences (SQ1 and SQ2) are developed in Feixianguan Formation on the east side of Kaijiang-Liangping trough under the background of continuous regression, which can be further subdivided into five fourth-order sequences (I ~ V). (2) The oolitic beach of Feixianguan formation is mainly formed in sequence I to IV, and the oolitic beach in sequence II is the best, with large monomer thickness and good continuity, but the sedimentary thickness of beach body in sequence III, I and IV decreases in turn, and the worst shows discontinuous and sporadic distribution. (3) Oolitic beach has obvious lateral migration characteristics when vertical aggradation, migrating from the interior of the platform to the slope as a whole, and the characteristics of oolitic beach lateral migration from sequence I to sequence II are the most obvious. (4) The cause of vertical accretion and multi-stage superposition of oolitic beach in Feixianguan Formation in the study area is the synergistic change of high-frequency cycle in local geomorphic highland and carbonate production rate; while the hydrodynamic conditions suitable for beach growth change from local highlands to local depressions, resulting in the evolution of oolitic beach from vertical growth to lateral progradation, when the sea level drops below the base level. (5) On the plane, the oolitic beach of Feixianguan Formation in the study area is mainly distributed along the northwest southeast direction of the study area (i.e. the platform edge), the best areas are Tieshanpo and Puguang, followed by Dukouhe, Qilibei and Luojiazhai. The research results can provide a basis for the exploration of high-quality beach facies reservoirs of the Feixianguan Formation in the Kaijiang-Liangping trough area.

Reference

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-2: Carbonate reefs, mounds and seeps in time and space
Presentation Preference: Oral Preferred

Sedimentary Characteristics of the Qixia Formation in the Shuangyushi area, northwest Sichuan Basin

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Keywords: Shuangyushi area in Sichuan Basin,Lower Permian Qixia Formation,Ultra-deep gas reservoir,Sedimentary characteristics,The geological modeling of the sedimentary phase

Shuangyushi area is located in the front fold belt of Longmen Mountain on the north edge of Yangtze Craton in Sichuan Basin. The strata of the Lower Permian Qixia Formation in the study area are developed in the carbonate platform. Solid drilling in this area proves that the reservoir thickness is thin and mainly fracture-pore reservoir. Multiple well tests obtain high-yield industrial air flow of over one million square meters. The reservoir development is obviously controlled by the sedimentary characteristics, but the sedimentary phase type and space distribution characteristics are unclear, which affects the target deployment of the gas reservoir well position and development mode optimization. In this paper, using the core, sheet, well logging, logging and three-dimensional seismic data, with the research idea of "point-line-surface-body", on the basis of depicting the sedimentary phase type and horizontal and horizontal distribution, the research method combined deterministic modeling and stochastic modeling to carefully describe the characteristics of each sedimentary microphase. The research shows: (1) The form of the longitudinal sedimentary subphase platform edge beach, platform inner beach and open sea recognition mode, which further divides into five sedimentary microphase types. (2) The edge beach of the favorable phase zone is stable in transverse distribution, and mainly distributed in the longitudinal strata. The whole distribution is to north and east, and the development degree of microphase beach is high. (3) The sedimentary phase pattern of the study area was established, and the gas reservoir forms a wide and slow and high zone with relatively flat terrain and high landform. (4) The three-dimensional geological model of gas reservoir sedimentary phase in Shuangyushi area is established, and the spatial distribution characteristics of sedimentary phase were defined. The multi-dimensional research method is useful for the fine description of sedimentary phase features and reservoirs of similar superdeep complex carbonate gas reservoirs.

Reference

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-2: Carbonate reefs, mounds and seeps in time and space
Presentation Preference: Oral Preferred

Stromatoporoids as indicators of pervasive sea-floor lithification in the middle Palaeozoic Era, and implications for reef formation

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Keywords: Stromatoporoid, Palaeozoic, substrates, reefs

Stromatoporoids are abundant in shallow marine carbonate environments of middle Ordovician to Late Devonian strata, representing ca.100 million years. Stromatoporoids are benthic sessile hypercalcified sponges that grew on a range of substrates of clay-rich to pure carbonate, but rare in sandstones, so presumably largely required low sedimentation rates. Stromatoporoids were traditionally viewed as requiring a solid base, such as a shell fragment, for initial growth, after which they could spread on surrounding soft sediment (ambitopic ability). Certainly, stromatoporoids commonly started growth on hard objects, indeed some taxa preferentially encrusted hard substrates such as dead brachiopod and mollusc shells, other stromatoporoids and corals. Nevertheless, repeated observation shows stromatoporoids grew on sediment lacking hard objects, indicating ability to initiate directly on soft muddy surfaces. This capability may partly explain their success throughout their geological history.

However, a feature of stromatoporoid substrates that remained unexplained (best seen in vertical thin sections) is that the base of stromatoporoids very commonly is extremely irregular on a microscopic scale. The initial few laminations follow tiny basal irregularities in complete contact with underlying sediment, observed in stromatoporoids from middle Ordovician through to Late Devonian. How did this irregularity occur? There are two logical possibilities:

1) there was a basal primary cavity - the stromatoporoid base was not in contact with the substrate for much of its distance, potentially a mechanism to escape the choking effects of loose mud; then later the cavity was backfilled leaving no geopetal. Basal cavities with geopetal fills are common, so primary cavities certainly occurred.

2) the sea-floor sediment was partially to completely lithified, either directly on the sea floor, or a short distance below it, followed by current removal of loose sediment leaving a hard substrate that was eroded (perhaps bioeroded) prior to stromatoporoid growth, without evidence of infilled geopetal cavities. This sediment lacks layers or grain-size changes that might indicate successive generations of sedimentary fill, it is simply an amorphous sedimentary deposit upon which the stromatoporoid irregular basal surface sits. So the stromatoporoid encrusted a highly irregular solid surface.

An extension of Point 2 is the common occurrence of very deep basal cavities in stromatoporoid bases, explained only if the stromatoporoid encrusted a prominent object; some are little hills as upper surfaces of limestone beds, others are large lithoclasts. Commonly they are made of only sediment, in other cases they contain bioclasts, yet the pervasive character is stromatoporoid bases in direct contact with micrite sediment.

Comparisons with hardgrounds indicate that highly irregular basal stromatoporoid surfaces are no different from lithified sediment surfaces. Therefore I conclude that the sea floor where stromatoporoids are found was commonly lithified very early, so that stromatoporoids utilised hard sediment substrates. Stromatoporoids with irregular bases occur in level-bottom and reef environments, and reinforce the interpretation that reefs developed not just as dense organism accumulations, but were aided by early lithification as they developed, also explaining common cases of sharp reef margins. For further details see Kershaw et al. (2007, 2018, 2021).

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-2: Carbonate reefs, mounds and seeps in time and space
Presentation Preference: Oral Preferred

Deciphering the variety of microcrystalline carbonate fabrics present in Ordovician sponge mounds, Tarim Basin, China

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Keywords: Carbonate rock fabric, cathodoluminescence, fluorescence, organomineralization, reef evolution

Microcrystalline to finely granular Ca-carbonate represents a major component of the total rock volume of Dariwillian calathid–demosponge carbonate mounds, western Tarim Basin, China. By petrographic means, these kinds of deposits range from microcrystalline sea-floor precipitates (automicrite) to multiple generations of infiltrated sediment accumulation (allomicrite). Here, we focus on the nature of automicrite distinguished by using a spreadsheet that contains six parameters and seventeen characters. There is an *in situ* peloidal–spiculiferous fabric (AM-1), an *in situ* peloidal fabric (AM-2), an *in situ* aphanitic–microtubular to microbioclastic fabric (AM-3), an *in situ* minipeloidal fabric (AM-4) and an *in situ* laminoid–cerebroid fabric (AM-5). Type AM-1 occurs with AM-2 being succeeded by an assemblage dominated by AM-3 and AM-4. Types AM-4 and AM-5 are separated by an erosional disconformity. AM-1 to AM-4 turn out to be non-microbial in origin. Instead, these automicrites represent relics of calcified metazoan tissues, such as siliceous sponges, non-spiculate sponges or even the basal attachment structures of stalked invertebrates. Fabric AM-5 is a microbial carbonate but is post-mound in origin forming a drape within a reefal framework established not until the formation of AM-4. Carbon and oxygen stable isotopic composition of automicrites plot within a range of 0.28‰ to 0.84‰ PDB for $\delta^{13}C$ and -7.23‰ to -5.23‰ PDB for $\delta^{18}O$. A total of 70% of the automicritic samples plot in or near to the field defining Middle Ordovician (Darriwilian) marine calcite. In addition, a good correlation of fluorescence and cathodoluminescence of automicrites indicates that induced and supported organomineralization produced automicrite, probably *via* the permineralization of non-living organic substrates adsorbing dissolved metal–humate complexes.

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Session T7-4: The formation mechanism, characterization and model of paleo-karst carbonate reservoir

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-4: The formation mechanism, characterization and model of paleo-karst carbonate reservoir
Presentation Preference: Oral Preferred

The Control of Fluids to Ordovician Reservoir in Shunbei Area, Tarim Basin,China

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Keywords: fault-karst carbonate reservoir, Formation of reservoir,Fluid source, Ordovician, Shunbei area

The Shunbei area is located in the northern slope of Tazhong Uplift in the Tarim Basin. It is located in the Saddle between the Manjiaer Depression and the Awati Sag, the Shaya Uplift and the Katake Uplift. From north to the south, the tectonic units can be divided into the Shunbei gentle slope, the Shuntuoguole lower uplift and the Shunnan gentle slope. Among them, the Shunbei has made major breakthroughs in oil and gas exploration in recent years, with an exploration area of about 19,900 km2.

Using core observation, imaging logging and casting thin sections analysis, we identified the types of the Ordovician reservoir space in Shunbei area, and analyzed the types and sources of diagenetic fluids of different periods using fluid inclusion, carbon and oxygen isotopes and rare earth elements. Combined with logging data, seismic data and diagenetic phenomena, the controlling factors affecting reservoir formation and the controlling effect of karst fluids and faulting on reservoir formation are discussed.

The study believed that the Ordovician reservoirs in Shunbei area mainly develop fault-karst reservoirs, and the reservoir space is dominated by structural fractures, accompanied by the development of dissolved pores and vugs. Among them, the fractures are mainly single high-angle oblique fractures, the fracture width and porosity are not high, and micro fractures are mainly developed. There are five periods of fluid activities and three types of fluids acting on the Ordovician reservoirs in Shunbei area: the first and second periods are the mixed fluids of contemporaneous seawater and atmospheric freshwater; the third and forth periods are deep hydrothermal fluids; the fifth period is the evolution of formation water. Five periods of fluids mainly experienced two fluid-rock interaction systems: the evolution system of meteoric water-syngenetic seawater gravity flow and that of remote hydrotherm-syngenetic brine mixed upwelling flow driven by igneous activities. The formation of fault-karst carbonate reservoirs is the result of diagenetic karst superimposed on plutonic karst, based on the tectonic activities of strike-slip faults.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-4: The formation mechanism, characterization and model of paleo-karst carbonate reservoir
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Formation mechanism of ultra-deep Ordovician carbonate reservoirs under the couplings of fault and various fluids in the Shunbei Oilfield, Tarim Basin (NW China)

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Keywords: Diagenetic fluids, Ultra-deep carbonate reservoir, Fault-fluid coupling, Ordovician, Tarim Basin

The formation and maintenance mechanism of high-quality carbonate reservoirs in deeply burial realms have received increasing attentions. A consensus is that high-quality carbonate reservoirs are largely attributed to secondary dissolution processes by various fluids that are correlated to fault activities, instead of primary porosity. However, how the fault-fluid coupling processes control the development of carbonate reservoirs remains to be unclear. To unravel this issue, we integrated the petrology, mineralogy, fluid inclusion, geochemistry, and logging data as well as seismic data in newly discovered Shunbei Oilfield (NW China) to constrain the diagenetic fluid types and formation mechanism of ultra-deep Ordovician reservoirs under the fault-fluid couplings.

Results show that strike-slip fault activity was absolutely the primary controlling factor in the development of high-porosity damage zones and dissolution-precipitation processes of various fluids. Various types of fluids, such as meteoric water, hydrothermal silicification, organic acids, and Ordovician formation water, are identified. Layered early dissolution pores leached by eogenetic meteoric water in high-energy facies provided basic channels for later fluid migration. The telogenetic coupling process of the fault-descending meteoric water during the I episode of Middle Caledonian contributes to developing multiple sets of epikarstic, phreatic, and deeper "fault-controlled karst" fracture-cave reservoirs at a depth of 0~430 m, making a great contribution to these Ordovician reservoirs. Subsequently, multi-stage re-opens of deep faults during Late Ordovician to Permian led to the upwelling of organic acids and silica-rich hydrothermal fluids which also created a certain amount of secondary porosity. Collectively, the formation of ultra-deep Ordovician "fault-controlled karst" reservoirs in the Shunbei Oilfield was considered to be an interplay of strike-slip faults and various fluids. A comprehensive development evolution model under the fault-fluid couplings is finally established, demonstrating that fault-fluid couplings play a major role in these ultra-deep reservoirs in the whole Shuntuoguole area.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-4: The formation mechanism, characterization and model of paleo-karst carbonate reservoir
Presentation Preference: Oral Preferred

The characteristics, evolution and constraints on reservoir quality of the eogenetic karst in the restricted-evaporative platform in Ordos Basin, North China

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Keywords: eogenetic karst, physical property inversion, gypsum-bearing dolomite, Ordovician Majiagou Formation, Ordos Basin

The evaporite–carbonate assemblages are often strongly influenced by karstification, which results in dissolution collapse and filling, leading to complex lithology and lithofacies. Therefore, it is difficult to study the transformation process and influence of karstification on this kind of reservoir. There are a great number of nodular evaporites and dolomite symbiosis in the upper Ordovician Majiagou Formation in the northwest of Ordos Basin, which is an ideal target to solve this problem. To improve the accuracy of this study, more than 600 representative core samples were collected, and their petrological and physical properties were comprehensively analysed. The results showed that: Under the background of the restricted-evaporative platform and influenced by the frequent sea-level eustacy, the high-frequency upward-shallowing sequence is developed in M54-M51sub-members of the Ordovician Majiagou Formation, and there are typical characteristics of karst development in the early diagenetic stage, such as selective dissolution, seepage filling, geopetal structure, and in-situ brecciation in the single upward-shallowing sequence.

Further analysis shows that influenced by the exposure time, the dissolution evolution of the eogenetic stage of the gypsum-dolomite assemblages can be divided into five continuous evolution stages: (1) fabric selective dissolution of soluble minerals stage, (2) spongy dissolution stage, (3) the formation of advantage channel and development of karst fissures stage, (4) vertical vadose and horizontal undercurrent dissolution stage (karst zoning), (5). excessive karst stage (overall brecciation). Based on the exposure time and the karst intensity represented by the five evolution stages, the karst dynamic evolution process has been established, and it is further found that the process has the characteristics of optimization and then destruction for reservoir reconstruction, so the reservoir optimization and inversion model of karst intensity control is proposed. The results not only help to understand the characteristics of karst evolution in the eogenetic karst stage and the influence of different karst intensities on reservoirs, but also provide theoretical support for the prediction of such reservoirs and provide new materials for the enrichment of karst geological theory.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-4: The formation mechanism, characterization and model of paleo-karst carbonate reservoir
Presentation Preference: Oral Preferred

Origin of giant Ordovician cavern reservoirs in the Halahatang oil field in Tarim Basin, NW China

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Keywords: U–Pb dating, Clumped isotope, strike-slip fault, karst, Ordovician, Tarim Basin

Cavern and vug porosities in the Ordovician carbonates in the Halahatang oil field are currently hot targets for hydrocarbon exploration in the Tarim Basin, northwest China. Yet, crucially, the formation of cavern and vug porosities has not been fully understood due to multiphase fault-related and unconformity-related diagenetic alterations. Here, we integrated petrology observations and geochemical analyses (C, O, Sr isotopes, trace and rare earth elements, clumped isotope, and laser-based U-Pb dating), aiming at determining the timing for tectonic driven calcite precipitation which is closely tied to karstic reservoir development. Vug-filling calcites were emplaced at the late Caledonian (460.8±3.4 and 448.6±5.3 Ma) and early Hercynian (335±19 Ma). Megacrystalline calcites were precipitated from 324±23 to 300.9±4.8 Ma and 244.13±13 Ma to 240.5±4.1 Ma during the Hercynian. Three stages of fracture-filling calcites were predominantly precipitated at Early Hercynian (~364±53 Ma), Late Hercynian (282.9±5.4 Ma), and Yanshanian (~158±17 Ma), which are intimately grown with fracture-related cavern and vug porosities. Clumped isotopes suggest that these calcites were precipitated from formation fluids, with some localized hydrothermal fluid and meteoric water influxes. This study emphasizes that the main reservoir formation timing for the Halahatang oil field were correlated with the early Hercynian, late Hercynian, and Yanshanian tectonics. The outcomes from study might be able to guide the future hydrocarbon exploration in the Tarim Basin where similar tectonic background present.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-4: The formation mechanism, characterization and model of paleo-karst carbonate reservoir
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Characteristics of carbonate karst assemblage and control of sedimentary factors in Dengying Formation, central Sichuan

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Keywords: Central Sichuan,Carbonate rock,The karst body,sedimentation

In recent years, with the continuous improvement of oil and gas prediction theory and exploitation technology, the exploration and development of carbonate reservoir in central Sichuan has been effectively promoted.Dengying Formation in Gaoshiti district of Sichuan Basin is a set of dolomite formation, which is affected by sedimentation, karst and tectonic evolution during the Tongwan Movement, and karst reservoirs are relatively developed.The study uses outcrop, core, logging and seismic data of Dengying Formation to carry out research on sedimentation, sequence, karst characteristics and paleogeomorphology restoration, and master the formation mechanism and combination characteristics of Dengying Formation karst reservoir.The formation mechanism of dissolution and pore development characteristics of reservoir are clarified, the main controlling factors of reservoir in different well areas are recognized, and the controlling effect of sedimentary factors is studied emphatically.The results show that the fourth Member of Dengying Formation has pore, cavity and cavity fracture reservoirs, and the formation of reservoirs has experienced sedimentary granulation, shelf formation, dissolution and expansion in peneogene, superimposed supergene karstification and burial karstification.The lower part of Deng4 formation is obviously controlled by sedimentation. Dissolution pores can be developed in the grain beach, but the continuity and scale are smaller than that of the supergene karst reservoir. If there are structural fractures, it will be more favorable.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-4: The formation mechanism, characterization and model of paleo-karst carbonate reservoir
Presentation Preference: Oral Preferred

Predicting dissolution patterns and incipient karst evaluation in complex fracture carbonate reservoir system:Insights from reactive transport modeling

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Keywords: reactive transport model, heterogeneity, fracture-caved carbonate reservoir, Dissolution mechanism, karst evaluation;

Karst features in limestone aquifers often exhibit highly heterogeneous patterns, which are strongly governed by structural complexities. Fracture network dominate preferential flow pathways and mass transfer. To understand the role of local reaction and dissolution transport processes in carbonate formation, we developed a reactive transport model by combining a two-scale pore-medium continuum model with a discrete fracture network that effectively quantify the role of dissolution on changing transport properties over a range of scales.

We provide quantitative insight into the early karstification evaluation with three different components: a prominent fracture embedded into a network of smaller fissures and porous matrix. The initial models geometry and parameters of matrix and fracture network model based on a typical core CT scan and outcrop data in Tarim basin. A systematic parameter study is carried out by varying the initial apertures of the fracture networks and heterogeneity of the rock matrix, key parameters such as flow rates, breakthrough times and densities, connectivity, topology and conductivity of fracture networks for the different models are compared.

Numerical experiments show that: (1)The preferential flow paths are closely related to the fracture network conductivity, topology and flow direction. (2)Patterns of local dissolution-induced alterations related to fracture permeability, hydraulic conductivity and extensive dissolution appeared in fracture tips and intersections. (3) The impacts of matrix can be significantly alleviated when fracture network enhances the connectivity and seepage capacity of matrix-fracture system.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-4: The formation mechanism, characterization and model of paleo-karst carbonate reservoir
Presentation Preference: Oral Preferred

Difference analysis of carbonate sedimentary system and karst reservoir of middle and Upper Ordovician in Tabei area, Tarim Basin

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Keywords: carbonate sedimentary system, karst reservoir, karst stage, karst, palaeogeomorphology, platform margin reef beach

The carbonate karst reservoirs in the Tabei area have experienced multiple stages and various types of diagenesis, including cementation and filling, dissolution (or karst), silicification, pressure solution, fracturing and hydrothermal action. The main controlling factor of reservoir development is dissolution.Based on the comprehensive analysis of 3D seismic data, drilling, logging and Core experimental analysis data, the influence of carbonate sedimentary system and tectonic factors on karst distribution difference is analyzed vertically and horizontally.Based on the analysis of lithologic characteristics and freshwater karst characteristics of carbonate sedimentary system in three sets of middle and upper Ordovician strata in Northern Tarim.Combined with regional palaeogeomorphology characteristics, regional karst reservoirs are divided into three karst periods: Yijianfang Formation depositional discontinuity, Lianglitage depositional discontinuity and Sangtamu Formation exposure period.The comprehensive regional geological analysis shows that due to the tectonic movement, the carbonate rocks of the middle and upper Ordovician took place in a wide range of exposure at the end of the deposition period.

During the exposure period, a large number of ancient river system was developed with abundant water and large-scale dissolution conditions, which laid the foundation for large-scale interlayer karst.Because of the different sedimentary characteristics of carbonate rocks in different strata, the lithology is different, which determines the difference of formation dissolution.In general, the carbonate content gradually decreased from bottom to top, while the argillaceous content gradually increased, resulting in the best karst reservoir development in the late sedimentary period of Yijianfang Formation.In the Lianglitage formation, there is a high content of reef beach facies carbonate in the platform margin, while there is a high content of mud in other areas, which results in the difference of lateral development in the altered reservoir area.During the exposure period of the Sangtamu Formation, a large scale ancient drainage system was also formed and the Sangtamu formation is pinched to the north of the study area.Due to the continuous dissolution of carbonate strata in the north of pinching line, a large number of deep channels and residual mounds were formed, and some of them had the characteristics of karst paleogeomorphology.In the south of the pinchout line, the stratum thickness of the Sangtamu Formation increases gradually. Due to the high argillaceous content, effective reservoirs cannot be formed in the Sangtamu Formation, and surface fresh water cannot flow vertically into carbonate strata on a large scale, and the overall dissolution conditions are poor.Based on the above understanding, the matching relation between carbonate sedimentary system and karst reservoir distribution difference is clarified, and it is considered that favorable carbonate sedimentary environment and suitable palaeogeomorphic conditions are favorable conditions for carbonate karst reservoir development in Tabei area.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-4: The formation mechanism, characterization and model of paleo-karst carbonate reservoir
Presentation Preference: Oral Preferred

Intelligent identification of deep carbonate sedimentary microfacies based on decision tree

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Keywords: sedimentary microfacie, deep carbonate rock, Intelligent recognition, logging

Deep marine carbonate is an important field of oil and gas exploration and development, and the identification of sedimentary microfacies is the key to dessert evaluation. Taking the reef- shoal facies reservoir of Yuanba Changxing Formation in northwest china as an example, the reef-shoal facies reservoir has multiple stages of development and lateral superposition, with strong heterogeneity and sedimentary microfacies. The fine division is complicated. In order to improve the prediction efficiency and accuracy of reservoir sedimentary microfacies, firstly determined the division scheme of sedimentary microfacies combined with conventional logging, electrical imaging logging and geological data, and then defined the logging response characteristics of different microfacies, and an intelligent identification sample set of sedimentary microfacies is formed. Aiming at the problems of complex structure and low precision of missing attribute samples in the existing C4.5 decision tree algorithm, a new decision tree method based on Bayesian principle is proposed, which can reduce the uncertainty of tree building and improve the operation efficiency. The identification coincidence rate of 15 wells is 98%. The new method provides a reliable basis for the division of sedimentary microfacies of complex reef-beach carbonate rocks by using logging data.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-4: The formation mechanism, characterization and model of paleo-karst carbonate reservoir
Presentation Preference: Oral Preferred

Discovery and application of paleokarst in slow flow zone in Ordovician of Tahe Oilfield

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Keywords: Internal fracture-cave bodies, Slow flow zone, Paleokarstification, Ordovician, Tahe oilfield

The Middle-Lower Ordovician carbonate reservoirs in the Tahe Oilfield have experienced paleokarstification during the Middle Caledonian-Hercynian orogenies, and developed typical karst landforms and fracture-cavity systems, which are highly comparable with modern karst areas. Since the discovery of Tahe Oilfield in 1997, many scholars have devoted a lot of work to the Ordovician paleokarst. However, due to the limitation of the degree of exploration and development, the early main research focus was the vadose zone and the phreatic zone within the ancient weathering crust 0-150m on top of the Middle-Lower Ordovician strata. With the deepening of deep exploration in the Tahe Oilfield, in 2014, it was discovered that there existed internal karst fracture-cave bodies in the western slope area, represented by Well Tashen 3, which are different from the previous studied epikarst fracture-cave bodies. Based on the interpretation results of high-precision 3D seismic data and drilling data, and referring to theories of modern karst hydrology, this paper describes the geometrical occurrence and distribution range of the inner fracture-cave bodies, and compares their characteristics with the epikarst fracture-cave bodies, and analyzes their occurrence conditions and hydrogeological properties. Therefore, it is pointed out that this set of internal fracture-cave bodies developed vertically in the range of 200-400m below the top surface of the Middle-Lower Ordovician strata, which are different from the typical epikarst zone, and should be slow-flow zone karstification under the phreatic zone. A "slow flow zone" paleokarst model is proposed characteristic of "planar input in the north, medium-deep pressure dissolution, and graded discharge in the south", and the hydrodynamic abrupt change zone developed intensively near the pinch-out line of upper Ordovician strata. The discovery and application of paleokarstification in the slow-flow zone and its associated internal fracture-cavity bodies provide basic theoretical and technical support for the exploration, development and sustainable development of the 100 million tons medium-deep Ordovician oil reservoir in the of Tahe oilfield, and further enrich the paleokarst theory represented by the Tahe oilfield.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-4: The formation mechanism, characterization and model of paleo-karst carbonate reservoir
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Exploring fluid-rock interactions in fractures based on simulated experiments and numerical simulation

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Keywords: channelization,dissolution, fracture,fluid-rock interaction;

It has always been a hot issue that scholars at home and abroad pay attention to the fluid-rock interaction in fractured systems. Fluid flows along fractures, dissolves rocks, precipitates new minerals, exchanges material and energy, changes the storage space, and affects the formation and distribution of carbonate reservoirs and hydrocarbon.

In order to further clarify the fluid-rock interaction process in the fracture system under specific geological background conditions, a series of dissolution simulation experiment based on the Yijianfang Formation in the Tarim Basin was designed and combined with numerical simulation tools such as ToughReact. We investigated geochemically induced alteration of fracture geometry in Yijianfang Formation limestone.

The interaction process of CO_2-acidified brine along fracture was identified. The influence of parameters such as temperature, pressure, fluid composition, and rock heterogeneity on fluid migration, ion exchange/diffusion was investigated. Ion diffusion characteristics in fracture and mineral dissolution/precipitation trends were calculated. This study shows that the fracture as the main flow channel makes the overall trend dominated by dissolution, the fracture volume increases, the sample permeability increases by orders of magnitude, and the porosity is also significantly improved. The overall mechanism is not because more rock dissolves, as would be commonly assumed, but because of accelerated fracture channelization.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-4: The formation mechanism, characterization and model of paleo-karst carbonate reservoir
Presentation Preference: Oral Preferred

Geo-modeling of paleo karstic underground river system in fractured-cavity carbonate reservoir based on geological knowledge base and MPG method

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Keywords: fracture-cavity carbonate reservoir, paleo karstic underground rivers, geological knowledge base, multi-point geostatistics method, training image, geological modeling

Paleo karstic underground river system is one of the three major karst types in Tahe oilfield. Controlled by multiple factors such as fractures, ground water level and lithological differences, the paleo underground river system has poor regularity with various shapes and complex structure. Currently, most people use seismic attributes to scuipt the spatial geometry of the river, but there are some differences between seismic predictions and outcrops in the width of the river, and it is also difficult to characterize the complex internal structure of the river system by using traditional two-point geostatistical methods. Multi-point geostatistical method (MPG) can better represent the developmental morphology and structural patterns of the target body through training images, and at the same time, multiple types of constrained data can be integrated during the construction of training images and modeling, which is a hot spot in the current research of modeling underground river systems. In this paper, geological knowledge base of paleo underground river system is constructed by integrating the outcrop information and reservoir description results. The training images are produced based on the modern karst pipeline and the predicted results of Tahe river system from knowledge base, the predicted width of paleo underground river is corrected by the cumulative probability curve method according to the width of modern karst pipes and their probability distribution. Considering the genesis main control factors, vertical structure and planar morphology of the underground river system, a training image pattern library of the paleo karst river system containing different main control factors is constructed. The training images both simulate the morphological and structural characteristics of typical modern subsurface rivers and reflect the characteristics of the geometric parameters of paleo underground rivers in Tahe area, which are suitable for modeling paleo karst river systems in fracture-cavity reservoirs. Meanwhile, probability body of karst-phase controlled underground river development is constructed based on the frequency of underground river development in different karst zones and different paleolandscapes, seismically constrained underground river development probability body is constructed using the statistical single-well seismic wave impedance and underground river frequency response relationship, and the PR model is used to fuse the two types form a comprehensive probability body of paleo river cave development. Based on the Sensim MPG algorithm, 3D underground river geological model of the S67-T615 is established with a comprehensive probability body as a multivariate constraint. The results show that the reliability of the model is verified by using 3 wells, compliance rate between model and well is increased from 67% to 81.8%, river width is corrected from 30-170 m to 10-50 m, which is more consistent with the reality. The new model realizes the characterization of the structure of the river from a single channel seismic body. New model includes 2 layers of main channels, 6 branch channels, 5 dissolution zones and falling water caves, which effectively characterizes the geometry shape and complex structure of paleo underground rivers, which improves the accuracy of the geological model.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-4: The formation mechanism, characterization and model of paleo-karst carbonate reservoir
Presentation Preference: Oral Preferred

Forgotten eustatic exposure before deep undersea: Paleokarst development of the uppermost second Maokouan member (Guadalupian), north Sichuan Basin, NW South China

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Keywords: Global regression, Paleokarst formation, Paleokarst reservoir, Maokou Formation, Sichuan Basin

The Guadalupian Maokouan limestone of the Sichuan Basin is famous for its gas-bearing paleokarst reservoir. Over the years, the uplift and eruption of Emeishan mantle plume has been considered as the formation mechanism of a long period exposure and paleokarst development of the Maokouan limestone at the end of Guadalupian. Besides, the impacts of the great late Guadalupian regression before plume activity (Shen et al., 2019) on the Maokouan exposure processes have been overlooked.

Collaborations of borehole, outcrop and seismic studies indicate the prevalence of paleokarst limestone at the uppermost part of the second Maokouan member, north Sichuan Basin. From the boreholes of southern hilly districts to the outcrops of mountainous north, the karst layers become thinner whereas the overlying marly limestones of the basal third Maokouan member turn into deep-water silicious mudstones and shales gradually, presenting a northward inclining paleotopography. Paleotopography and sedimentary facies are two major controlling factors of the karst development. As a result, the Maokouan paleokarst reservoirs of the north Sichuan Basin are concentrated in the bioclastic shoals of the southern districts.

The silicious, mud-rich deposits are water impervious layers that can exclude the source of paleokarst water from the top of Maokou Formation. Therefore, there should have been an elder unconformity before the deposition of the third Maokouan member, which was contemporaneous with the lowest stand of the Guadalupian global sea level. That is to say, there are two major unconformities in the Maokou Formation: the former one lied at the top of the second Maokouan member after the great late Guadalupian regression, and the latter one had a regional tectonic origin from the Emeishan plume activity, existing between the Maokou Formation and the Lopingian Wujiaping Formation. Since the paleokarst occurrences are much more frequent in the second Maokouan member than the third member, and the shallow carbonate platform shrinking upwards (Meng et al., 2021), it can be deduced that the preceding exposure process should have exerted a profounder influence on the Maokouan limestone than the final one, which is diverse from the previous consideration.

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Scientific Themes: Theme 7. Carbonate Sedimentation
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Presentation Preference: Oral Preferred

Karst morphological assemblage characteristics of epigenetic paleokarst fractured-vuggy reservoir before the extensive terrestrial plant growth and the macroscopic distribution law of oil and water

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Keywords: Paleokarst landform assemblages, Terrestrial plant growth, Humid tropical/subtropical karst, Fractured-vuggy reservoir, Oil-water distribution

Epigenetic paleokarst reservoir controlled by paleokarst weathering crust is an important type of marine carbonate fractured-vuggy reservoir. In the practice of petroleum exploration and development in northern Tarim Basin, from the perspective of karst hydrogeology and according to the vertical zoning model of modern karst hydrodynamics, the epigenetic paleokarst reservoirs are divided into two subtypes: karst residual hill reservoir and karst paleo-subterranean river reservoir (Lu et al., 2018). Tarim basin is the largest oil-gas bearing basin in Western China. The thick marine carbonate rocks of Lower-Middle Ordovician experienced several tectonic movements and epigenic karstification stages during Caledonian and Hercynian Periods, forming various types of epigenic paleokarst reservoirs (Cai et al., 2020). Since the large-scale emergence of terrestrial plant life was covered by these karstification periods, it is of great geological significance to explore the impact of extensive terrestrial plant growth on the macro karst landform assemblages from the perspective of karst occurrence theory, and it also has important implications for the exploration and development of marine carbonate epigenetic paleokarst reservoirs.

The buried paleokarst landform assemblages in West District 10 of Tahe Oilfield during the first episode of karstification in the early Paleozoic was reconstructed by the high-quality, full-azimuthal 3D seismic technology. With previous geological, geochemical, and paleomagnetic data, from the perspective of karst genesis theory, the four conditions of lithologic structure, hydrodynamic force, climate and duration of karstification during the occurrence of paleokarst in this area are analyzed. Results show that in the early Paleozoic Period before the establishment of extensive terrestrial ecosystems, even if the lithology (pure carbonate rocks), climate (humid tropics/subtropics) and hydrogeological conditions (large uplift of carbonate blocks) were optimal, the karst landform assemblages of peak clusters and depressions could not be formed. Instead, the karst landform assemblages were relatively flat with shallow dish-shaped depressions. It is implicated that extensive terrestrial plant growth plays an important role in creating large-scale karst landform assemblages of peak clusters and depressions (Zeng et al., 2020a).

Compared with the heterogeneity of karst water-bearing medium in modern humid tropical or subtropical regions, it seems that the paleokarst water-bearing medium developed under similar karstification conditions is more uniform before the large-scale emergence of terrestrial plant. This also means that the paleokarst aquifer developed before the terrestrial plant growth has more obvious characteristics of stratoid weathered fissure aquifer. Therefore, after the stratoid paleokarst aquifer formed in the early Paleozoic was buried by mudstone caprock, the paleotectonic pattern between lateral hydrocarbon charging and fractured-vuggy body sealing generally established the macroscopic pattern of oil-water distribution (Zeng et al., 2020b). This has been gradually observed in the development practice of Tahe Oilfield.

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Scientific Themes: Theme 7. Carbonate Sedimentation
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Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Filling characteristics and forming conditions of pale-karst river in carbonate platform denudation zone: A case study from middle Ordovician S65 karst conduit in Tahe Oilfield

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Keywords: Karst conduit,Platform denudation area,Filling characteristics,Formation condition,Tahe oilfield

The Ordovician karst river is widely distributed in Tahe Oilfield. However, the filling mechanism of karst river in the platform denudation area has not been deeply investigated due to its complex spatial distribution and strong heterogeneity. In this study, the development morphology and filling characteristics of the S65 karst conduit in the carbonate platform denudation area in Tahe oilfied were identified and the filling characteristics was summarized by comprehensive application of logging, core, seismic and laboratory data. Additionally, the formation condition was discussed and the filling pattern was established based on the ancient landscape, water system and other factors. These results show that: (1) The single mechanical (sand and mud) filling or the composite filling with mechanism and collapse breccia (sand-mud cemented collapse) distributes in the sinkhole, and the mudstone or muddy cemented breccia filling distributes in the narrow part of the conduit. (2) The filling of collapse breccia and sand or mud occurs in the intersection of the main conduit, the single collapse filling forms in the intersection of the branch conduit. (3) Chemical filling distributes in karst front, convex bank and narrow area of the conduit. (4) In lateral direction, the extension of pipeline was controlled by the paleo-slope and the position of karst conduit was determined by the faults distribution. In vertical direction, the greater differences between the thickness and resistivity of the top of surrounding rock and the bottom of tight layer, the easier to be dissolved and to form karst conduit.

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Scientific Themes: Theme 7. Carbonate Sedimentation
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Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Reservoir forming model and key technology of ultra deep marine carbonate fault solution

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Keywords: Ultra deep layer, Carbonate rock, Paleokarst, Tahe oilfield, Shunbei oil and gas field, Tarim Basin

By comparing and analyzing the geological background differences of karst and fault fracture in northern Tarim Basin, three types of fault controlled karst fracture cave reservoirs are proposed: over dissolution residual reservoir, fracture + strong dissolution reservoir and strong fracture + weak dissolution reservoir. Based on this, the fault solution reservoir forming model is established. The core connotation is: "fault solution controlled reservoir, plate fracture cave, deep fault controlled enrichment, vertical dredging, differential accumulation and segmented reservoir formation", It provides a new field for carbonate oil and gas exploration and development. Based on high-precision 3D seismic data, a fault solution description technology with "structural tensor + ant body + porosity inversion" and "residual wave impedance + discontinuity + automatic fracture extraction" as the core is formed, which realizes the characterization of the external contour and internal structure of fault solution reservoirs of different genetic types, with a coincidence rate of 91%. Key development technologies such as three-dimensional optimization of well layout in fault solution reservoir, multi-target in one well, optimization of drilling target and three-dimensional structure well pattern construction technology in plate reservoir have been further established, which effectively supports the efficient development of this type of oilfield. This achievement guides the deployment of more than 300 wells in deep ultra deep carbonate fault solution oil and gas reservoirs in Tahe Area and Shunbei area, implements 150 million tons of development reserves, and builds a production capacity of 3.2 million tons. It has significant economic and social benefits and has a good prospect of popularization and application. It can also provide reference for similar reservoirs at home and abroad.

Scientific Themes: Theme 7. Carbonate Sedimentation
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Presentation Preference: Oral Preferred

Characteristics of meteoric diagenesis in the penecontemporaneous stage of platform margin shoal of Lower Ordovician Yingshan Formation in Gucheng oilfield

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Keywords: meteoric diagenesis, penecontemporaneous stage, platform margin shoal, Ordovician, Gucheng oilfield

The sedimentary facies of Yingshan Formation of Lower Ordovician in Gucheng area is a rimmed platform, and shoal in the the platform margin has the characteristics of large thickness, high proportion and multicycle. The dissolution of meteoric diagenesis in penecontemporaneous stage is an important diagenesis type of pore development in shoal, and the pore layer formed is an important exploration target area. The diagenesis types of meteoric fresh water in the penecontemporaneous stage of Yingshan Formation of Lower Ordovician in Gucheng area mainly include dissolution and cementation. The former is characterized by selective dissolution of the interior and edge of sand cutting in clastic grainstone, and formed harbor-shaped dissolution edge and intragranular dissolution, intergranular dissolution pore, mold pore and et al. The cement formed by cementation is mainly equiaxed granular and bladed calcite, and the cathodoluminescence of the cement is weak, and the trace elements are characterized by low Sr, Na, Mg and high Mn and Fe. Vertically, the dissolution in this area has cyclicity, and 10-13 cycles are developed, which is roughly consistent with the cyclicity of granular beach; It is mainly developed in the middle and upper part of shoal, and the dissolution degree is weakened and the cementation is enhanced in the bottom of the shoal. The vertical cycle of meteoric diagenesis is closely related to the shallowness and frequent exposure of shoal. Laterally, the amplitude frequency of C isotope in the platform margin is significantly higher than that in the open platform, which shows the characteristics of shallow water and sensitive response to sea level change in the platform margin shoal. Therefore, the exploration of this kind of reservoir should mainly look for the highland appearance of shoal on the platform margin.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-4: The formation mechanism, characterization and model of paleo-karst carbonate reservoir
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Predication of favorable carbonate intraplatform shoals in deep-burial carbonates: constraints from high precision sequence stratigraphy and microfacies

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Keywords: sedimentary microfacies, carbonate reservoirs, high-precision sequence framework, Yijianfang Formation

Abstract: It is of great significance for further exploration in deep-burial carbonates to clarify the distribution of sedimentary microfacies within the high-precision sequence framework and to analyze the influence of sequence stratigraphy and lithologic types on the karst carbonate reservoirs. Based on field outcrop, drilling cores, thin sections, full-bore microscan imaging (FMI) and conventional logging data, the high-precision sequence stratigraphy and sedimentary facies of the Yijianfang Formation in the Tahe Oilfield have been studied to clarify how they control the formation and distribution of carbonate intra-platform shoals. We have identified one third-order sequence, three fourth-order sequences, and then established the high-precision sequence stratigraphic framework. The depositional thicknesses of intra-platform shoal are large in the south and middle of the study area, and are thin in the west and north. In addition, we have identified eight lithofacies types (oolitic grainstone, intraclastic grainstone, bioclastic grainstone, bioclastic packstone, intraclastic packstone, intraclastic wackestone, bioclastic wackestone and mudstone) and four subsequent facies associations were then defined (inter-shoal sea, low-energy shoal, medium-energy shoal and high-energy shoal) within the sequence framework according to different hydrodynamic conditions. Based on the response difference of microfacies types between FMI and conventional logging, we have recognized four response models (blocky, linear, porphyritic and compound). According to the vertical thickness and lateral distribution of carbonate shoal reservoirs, we have concluded the favorable zones of carbonate shoal reservoirs are mainly distributed in the central, eastern and southern parts of the study area. This work provides a basis for predicting the distribution of favorable carbonate shoal reservoirs in deep-burial carbonates worldwide.

Scientific Themes: Theme 7. Carbonate Sedimentation
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Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Discovery and application of paleokarst in slow flow zone in Ordovician of Tahe Oilfield

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Keywords: 3D printing technology,Fractured-vuggy model,Characterization of fractures and vugs,Tahe Oilfield

The Ordovician reservoir in Tahe oilfield has various reservoir spaces, so it is difficult to achieve fine characterization of fracture cavity structure by making fracture cavity physical model based on acrylic or metal container. According to the characteristics of Ordovician reservoirs in Tahe oilfield, a fine imaging technology of carbonate fracture-vuggy reservoir is established, which is based on pre-stack time migration and target fine processing technology,based on the field rock with typical fracture and cavity characteristics, the digital 3D structure of typical core of basic fracture and cavity is proposed. The similarity of geometry, flow and connectivity between the field and the experimental model is compared, and the indoor fracture and cavity physical model which can characterize the fracture and cavity relationship of carbonate rock is established. Deepening the application of 3D printing, the digital 3D model of rock is transformed into the 3D physical model of typical fracture cavity structure, and the effective simulation of complex fracture cavity body is realized. The model breaks through the bottleneck of conventional visualization and pressure bearing, and has the characteristics of true three-dimensional, high pressure bearing capacity (up to 15MPa) and fine characterization, which provides strong support for the in-depth study of oil-water flow law in fractured vuggy reservoirs.

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Session T7-4: The formation mechanism, characterization and model of paleo-karst carbonate reservoir
Presentation Preference: Oral Preferred

Seismic geomorphology of Ordovician paleo-karst in Ordos Basin

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Keywords: paleokarst, paleogeomorphology, seismic geomorphology,carbonate reservoir,Ordos basin

The paleokarst reservoirs of weathered crust are developed on the top of the Ordovician Majiagou Formation in the Ordos basin.Karst paleogeomorphology is one of the factors controlling the reservoir distributions and quality. The residual layer thickness of the Ordovician Majiagou Formation were primarily used to map paleogeomorphology in the Ordos basin.However, the mapping results always are not enough to identify the complex paleokarst geomorphic units,such as erosion groove because it is very difficult to precisely calculate of the residual layer thickness of the Ordovician Majiagou Formation.Depending on three-dimensional seismic data with high horizontal resolution and logging,core data with high vertical resolution,we have applied the principle of seismic geomorphology to map Ordovician paleokarst geomorphic units using identified appropriate seismic attributes to highlight the characteristics of karst paleogeomorphology based on the analysis of the seismic responses of the paleokarst models and seismic-to-well calibration.The method in this presentation have applied in several study areas in the Ordos basin, which greatly improve the accuracy of paleogeomorphology characterization. The results have also provided imporatant indications of the paleokarst reservoir's internal and external architecture and assitted to predict high-quality carbonate reservoirs.Some drilled wells indicate that the mapping geomorphic units of Ordovician paleokarst are refined and reliable.

Scientific Themes: Theme 7. Carbonate Sedimentation
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Presentation Preference: Oral Preferred

Characterization and geomodeling of Ordovician fault-controlled karst carbonate reservoirs in Tarim basin, China

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Keywords: Carbonate, Fault-controlled karst reservoir, Characterization, Geomodelling, Architecture elements, Deep learning

Fault-controlled karst carbonate reservoirs (FCKR) is one of the most important, deeply-buried Ordovician hydrocarbon reservoirs in Tarim basin, China, in which both faults-fractures and karsting features such as vugs and caverns contribute to the reservoir storage spaces. FCKR can further be recognized to be consisted of matrix, fractures, fault core complex, karsting caves, and vugs zone. Seismic texture or tension analysis can be used to recognize and distinguish fault-controlled karst systems from the surrounding matrix without faults; combined curvatures, anttracking and deep machine learning techniques used to recognize the subseismic faults-fractures, fault core complex and caves with higher accuracy and resolution. Geological rock type model is constructed compositely based on hierarchical architecture elements recognized in seismic data and further calibrated with well loggings. The improved relationship of porosity and elastic impedance is used to simulate reservoir porosity model, and all property models are readjusted and calibrated with dynamic data. Geological models built in Shunbei region demonstrate it useful to evaluate wells location before drilling and in production planning.

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Scientific Themes: Theme 7. Carbonate Sedimentation
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Presentation Preference: Oral Preferred

Comprehensive characterization of deep carbonate paleokarst fracture-cavity reservoirs by multiple means: A case study from the Ordovician Yingshan Formation in the Tahe Oilfield, Tarim Basin, Northwest China

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Keywords: Paleokarst reservoirs characterization, Fracture-cavity complexes, Geophysical means, Tahe Oilfield, Tarim Basin

With the improvement of exploration theory and engineering technology, oil and gas exploration has been gradually expanding to deep and even ultra-deep areas around the world. The potential of the deep oil and gas resources in marine kraton basin of China is tremendous, and it is a hot area for research and exploration at present. Compared with shallow layers, deep layers are characterized by deep burial and ancient formation era and large time span, however, the development of deep carbonate paleokarst fracture-cavity reservoirs is almost independent of the burial depth and may form good oil and gas reservoirs. Not to be overlooked is that the multi-phase karst leaching and superimposed fault reconstruction have resulted in a series of problems such as having anisotropy in vertical and horizontal direction and very complex constructional characteristics of deep carbonate paleokarst fracture-cavity reservoirs. To address the above problems, this paper took the carbonate paleokarst fracture-cavity reservoirs of the Ordovician Yingshan Formation in the Tahe Oilfield as an example, (1) identified the small-scale dissolution pores and fractures by optimizing DEN, Vsh, GLLS, and ΔG parameters through logging cross-plot analysis, respectively; (2) divided and characterized different construction units of the reservoir according to karst zoning features by using imaging logging (FMI); and (3) carved fracture-cavity complexes based on 3D seismic multi-attribute to delineate reservoir distribution range. Eventually, a comprehensive multi-means characterization of deep carbonate paleokarst reservoirs had been achieved, and the development pattern of the paleokarst fracture-cavity reservoirs had been established. The results show that the deep carbonate paleokarst fracture-cavity reservoirs of the Ordovician Yingshan Formation in the main area of the Tahe Oilfield are mainly composed of fractures, pores, caves, and other storage spaces, which combine with each other to form a complex fracture-cavity system. The development characteristics of deep carbonate paleokarst fracture-cavity reservoirs are zoned. In the buried hill karst area, crust karst reservoir developed by unconformity karst action and the epikarst - vadose - runoff zones and their construction types are identified. In overlying-aquiclude confining karst area, a great number of bedding karst fracture-cavity complexes develop along the slope controlled by faults, and the development degree of fracture-cavity complexes gradually decreases laterally along the slope direction.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-4: The formation mechanism, characterization and model of paleo-karst carbonate reservoir
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Subsalt karst development model controlled by fault- soluble lithofacies: A case study of middle-lower Majiagou Formation in Daniudi area

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Keywords: Majiagou Formation, bedding karst, fault-controlled karst, Ordos Basin

Supergene karstification is widely developed in Majiagou Formation in Daniudi area, Ordos Basin, and karstic breccia can still be seen below Ma_5^6 sub-member. In order to explore the deep karst development model of Majiagou formation and clarify the paleokarst development mechanism below the aquiclude. the main controlling factors of karst development in the middle-lower Majiagou formation are analyzed and summarized based on the petrological, geophysical and geochemical data. The results show that the sedimentary facies in the Daniudi area evolve from evaporative platform to open platform to restricted platform, and the lithology changes from gypsum-salt rock to dolomite and limestone, partially contains gypsum, and soluble lithology is relatively developed; The faults are S-N, NW-SE trending, and are mainly tectonic faults formed in Caledonian and Yanshanian periods. The faults are zonal in plane and can be seen as "karst zone"; The strontium isotope ranges from 0.7086 to 0.7093, which is higher than that of the sea water in the same period, indicating the atmospheric freshwater karst in the epigenetic period, especially in the Ma_5^6 sub-member. Combined with the karstification of the Majiagou Formation, it presents the characteristics of continuous distribution on the plane and near-fault distribution in the vertical direction, and has a good coupling relationship with the plane distribution area of soluble lithofacies, propose a three-dimensional superimposed karst zone model controlled by "shallow lateral recharge + fault vertical and horizontal recharge + soluble lithofacies". In the shallow surface layer of the weathering crust, the lateral bedding karst superimposes the fault-controlled vertical karst, and the lower layer karst is comprehensively controlled by the fault and soluble lithofacies. This model breaks through the limitations of the previous near-surface karst model in the supergene period in Daniudi area, further clarifies the carbonate karst mechanism in deep karst zone below aquiclude, and expands the exploration of karst reservoirs.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-4: The formation mechanism, characterization and model of paleo-karst carbonate reservoir
Presentation Preference: Oral Preferred

Study on the mechanism of multi-genetic karstification in middle and lower Majiagou Formation of Daniudi gas field

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Keywords: Ordos Basin,Majiagou Formation,karstification, supergene karst,syngenetic corrosion

In Daniudi gas field, supergenetic karstification still exists in the deeper layers beneath the weathering crust at the top of Majiagou Formation, which is critical to develop reservoir spaces for deep tight carbonate rocks. At present, the karstification law of this formation is relatively limited, which seriously restricts the evaluation of karst reservoir. Based on the core, thin section, well logging and geochemical data, combined with regional tectonic and sedimentary background,the karstification mechanism of middle and lower Majiagou Formation was analyzed from the perspective of karst facies. Four types of karst facies with genetic significance were divided including fracture facies, collapse facies, transport facies and paste solution pinhole facies. Each karst facies indicates the intensity and controlling factors of karst development. The middle and lower Majiagou Formation developed supergene and contemporaneous karstification. The supergene karsts was characterized by lateral and vertical karst water superimposed transformation, which was mainly developed in $Ma5_{6\text{-}10}$ submember, especially in $M5_6$ submember. The contemporaneous karst was developed in $Ma5_7$, $Ma5_9$, Ma4 and Ma2 members, mainly due to the weak transformation of atmospheric fresh water in the relative regression period.The karst development mechanism under the constraint of sequence framework was established according to the factors of karst action, which provided theoretical support for the evaluation and exploration and development of middle and lower Majiagou Formation karst reservoir.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-4: The formation mechanism, characterization and model of paleo-karst carbonate reservoir
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

The effects of differential diagenesis on reservoir space of karst paleogeomorphology ---A case study of complex carbonate in Luxi uplift

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Keywords: Diagenesis, Reservoir space, Karst palaeogeomorphology, Luxi uplift

Differential diagenesis results in different space forms and physical properties of paleogeomorphic reservoirs. So analysis and study the different diagenesis, be helpful for effective evaluation of reservoir. An integrated study using cores ,thin sections, field outcrop, geological setting, and geochemistry was performed to investigate the characteristics, discuss the diagenesis, and study the influence factors of reservoir in Ordovician carbonates in Luxi uplift. It is found that there are obvious differences in reservoir diagenesis and porosity and permeability in different areas.The Luxi Uplift mainly experienced early Paleozoic to late Paleozoic and Meso-Cenozoic supergenetic karst. Karst highlands are mainly distributed in the east of Lanliao fault, showing strip distribution, and Karst Slopes and depressions are developed in turn to the East. The reservoir spaces are mainly fractures, fractured-caves and caves. The carbon and oxygen isotope values are highly negative, indicating that the karst highland is affected by atmospheric precipitation dissolution. High angle tectonic fractures, dissolution fractures and vertical tensile fractures-caves are developed. Some of them are filled with later buried calcit,with the temperature of cement inclusions is 100-130°C. The porosity of reservoir space is 14.57% and the permeability is $225.74\times10^{-3}\mu m^2$, with good vertical connectivity.The dissolution fluid in the steep slope zone is two directions: vertical and horizontal. Small caves formed at the intersection of fractures and near oval caves are developed. The filling material is calcite, with an average porosity of 13.06% and permeability of $184.95\times10^{-3}\mu m^2$. The vertical and horizontal connectivity of reservoir space is good. The karst gentle slope zone is mainly characterized by horizontal dissolution, cementation and filling, and develops horizontal tensile caves, which are mostly filled with calcite and mud. Karst depressions are eroded, cemented and filled by non directional calcium rich fluids, which are characterized by scattered solution pores and micro solution fractures. Substances carried in diagenetic fluids form granular calcite cement and argillaceous filling. Based on the above understanding, the differential diagenetic reservoir model of different karst paleogeomorphology is established.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-4: The formation mechanism, characterization and model of paleo-karst carbonate reservoir
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Paleokarst of Paleozoic Carboniferous in Qaidam Basin: evidence from petrology and geochemistry

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Keywords: paleokarst,Paleozoic,geochemistry,stable isotope,Qaidam Basin,

The Paleozoic in the Qaidam Basin has developed several sets of carbonate formations, which have experienced multiple stages of uplift and denudation since the Late Paleozoic (Li Zongxing et al., 2016; Liu Kui et al., 2020), and the regional sedimentation hiatus creates favorable conditions for dissolution. This paper takes the Carboniferous fractures - caves and their fillings as the research target in Qaidam basin, and expounds the paleokarst evidence of petrology and geochemistry.

Most of the large carboniferous fractures and caves in the Qaidam Basin exist near the unconformity surface (<100m), except for a few high-angle/vertical fractures and cave. The petrological characteristics reveal that the fractures and caves traversed multiple formations, and the fillings of the caves with later reformation are similar to the characteristics of the dissolution in the epigenetic period .The characteristics of early cement in karstic fissures with ring bands under cathode ray are consistent with that of the phreatic zones of meteoric water recorded in the literature (Huang et al., 2010). The values of $\delta^{18}O$, which are close between the first-stage grey blackish calcareous fillings and granular limestone matrix , indicating surrounding rock should be the source of black calcium speleothems. More detailedly, the values of $\delta^{18}O$ for the first-stage grey blackish calcium speleothems of -9.60 to -8.45‰ (VPDB) are slightly negative compared with that of bioclastic and granular limestone of -8.78 to -7.72 ‰ (VPDB), possibly because that participation of atmospheric water in corrosion of fractures resulted in new sediments which are slightly more negative in the value of $\delta^{18}O$ than surrounding rock. As for the second-stage fine-middle idiomorphic granular calcite cement, its value of $\delta^{18}O$ is more negative and reaches to -13.20 to -11.04 ‰ (VPDB), but is higher than that of calcite deposited from formation water or hydrothermal liquid and similar to the value of calcite from meteoric fresh water (Li et al., 2014).Matrixes and first-stage grey blackish calcium speleothems have relatively concentrated and similar value ranges of $\delta^{13}C$, which are -0.22 to 3.51‰ (VPDB) and 0.32 to 3.72‰ (VPDB), respectively, and both are largely positive. The relatively expanded value range of $\delta^{13}C$ as for the second-stage fine-middle idiomorphic granular calcite cement is between -3.97 to 2.55‰ (VPDB), suggesting more influential factors involve in the diagenesis process.Fresh water inclusions recognized by raman spectrum are the most direct evidences for meteoric fresh water activities in the Carboniferous System, which are found in all speleothems of karstic fissures and caves, mostly in fine-middle crystalline dirty calcite fillings. The salinity converted from the freezing point temperature of the inclusions shows 0.18 to 0.53 wt% NaCl, which also in the fresh water range and corresponds to the Raman spectroscopy test results. The observation ambient temperature of this inclusion is constant at 24℃ to 25℃, and the freshwater inclusions are in single-phase liquid state. According to the $\delta^{18}O$ value of the fine-medium crystalline dirty calcite filling, the calculated fluid $\delta^{18}O$ values are -9.85 to -8.11‰(VPDB), which are close to that of the current range of atmospheric water.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-4: The formation mechanism, characterization and model of paleo-karst carbonate reservoir
Presentation Preference: Oral Preferred

Research on the simulation and evaluation method of logging response of fracture-vug reservoirs: A case study from the Ordovician in Tahe oilfield, Tarim Basin

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Keywords: well logging, fracture-vug reservoirs, reservoir types, porosity, simulation, interpretation and evaluation

Fracture-vug reservoirs are rich in oil and gas resources, and various types of reservoir spaces are developed by karstification. The pore scales vary greatly, and the filling conditions are complex, thereby resulting in complex logging responses. Therefore, the logging interpretation and evaluation of fracture-vug reservoirs have always been one of the difficult problems in the field of logging research. In view of the difficulty of logging interpretation and evaluation, a set of effective, practical and characteristic logging fine interpretation and evaluation technology for different types of fracture-vug reservoirs have been developed. A set of reduced-scale dual lateral logging response physical simulation system is established to carry out physical simulation, and the three-dimensional finite element method is used to perform the numerical simulation of dual lateral logging response. The combination of the physical simulation system and simulation method produce the dual lateral logging response of fracture-vug reservoirs feature. A logging identification method for fracture-vug reservoir types is established by using the cross-graph decision tree method. A porosity model and a vug and fracture filling identification chart are established by the idea of classification, respectively. A fracture porosity calculation method is established based on the results of numerical simulation. Digital core method is used to establish the permeability model. The classification chart of reservoir level is developed. Finally, the formed logging interpretation methods are organized to form the logging processing interpretation specification for fracture-vug reservoirs, and the logging processing interpretation module is compiled. The processing and interpretation of well data could provide continuous and fine reservoir parameters, afford necessary information for predicting the location of high-quality fracture-vug reservoirs and calculating reserves, and give a reference for logging interpretation and evaluation of the same type of reservoirs.

Scientific Themes: Theme 7. Carbonate Sedimentation
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Presentation Preference: Oral Preferred

Discovery and significance of Ordovician paleo-karst caves in shallow drilling on the southern Ordos Basin

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Keywords: geochemistry, mudstone, cave, Pingliang Formation, Benxi Formation, southern Ordos Basin

The Ordovician sedimentary and karst environment are completely different in the southern margin and central-eastern of the Ordos Basin, and karst reservoir characteristics also are completely different. A shallow drill designed in the southern margin revealed the existence of karst caves filled clastic rock. The shallow drilling encountered two sets of strata in the Benxi Formation and the Pingliang Formation. The lithology of the Benxi Formation is bauxite mudstone. The Pingliang Formation is mainly composed of granstone and algal limestone, in which there are multiple sets of mudstone layers. Using mineral composition, major elements, trace elements and rare earth elements, the source, weathering alteration degree, redox environment, climate and paleo-tectonic environment of the two sets of mudstones were compared and analyzed. Among them, the mudstones of the Benxi Formation represent a higher degree of weathering. The mudstones in the Pingliang Formation are more reductive than the mudstones of the Benxi Formation; the sedimentary environment of the two sets of mudstones was the transitional sedimentary environment of the sea and land in the Late Paleozoic, with frequent climate changes and similar tectonic backgrounds. Mudstone in the Pingliang Formation was formed in a relatively reducing underground environment, wet karst development stage, and southern Ordos basin uplift stage. The composition is terrigenous clastics that have undergone weathering alteration, representing caves and underground river deposits in the pre-Carboniferous karst period. Combined with the widespread development of upper and lower fractures in the mudstone section, it indicates that there was a karst fracture-cave system in southern Ordos basin. Although shallow drilling encountered caves representing collapse and destruction, it can be inferred that there may be residuals in the southern Ordos basin at a suitable paleomorphological location. The fractured caves are the areas that are worth looking forward to for future oil and gas exploration.

Scientific Themes: Theme 7. Carbonate Sedimentation
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Presentation Preference: Oral Preferred

KARSTIFICATION OF THE UPPER CAMBRIAN DOLOMITE RESERVOIRS IN NORTHERN TARIM BASIN,NW CHINA

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Keywords: Karstification, Dolomite reservoir, Upper Cambrian, Tarim Basin

The upper Cambrian dolomite is one of the main potential hydrocarbon producing horizons in northern Tarim Basin. Detailed petrographic and geochemical studies indicate that the genesis of various dolomites is different [1,2] and the development of dolomite reservoirs is still in dispute[3,4].Our research on the cores from TS2 well,YQ6 well and others indicates that karstification probably had played an important role in the development of dolomite reservoirs. A plenty of corrosion pores and fractures are distributed around unconformity, sedimentary discontinuity or strike-slip faults. There is just the significant evidence for karstification that a fracture-cavity filled with sandstones and mudstones was drilled at the depth of 6842m~6846m in TS2 well in platform. It suggest that the fracture-cavity is influenced by terrigenous clastic materials relating to meteoric fresh water on the basis of further mineralogical analysis. We proposed the other strong evidence is that there is a typical vertical percolating zone with massive karst breccias existing in YQ6 well and a plenty of immiscibility inclusions dominantly at 30℃~75℃ in the calcite or dolomite cements, which are the indicator of karstification. It means that a new hypothesis of ultra-deep meteoric fresh water dissolution model may provide a reasonable interpretation about the formation of the upper Cambrian dolomite reservoirs although the exposion period was relatively short. This study provides a useful analogue to understand the development of dolomite reservoirs at deep depth in Tarim basin and elsewhere.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-4: The formation mechanism, characterization and model of paleo-karst carbonate reservoir
Presentation Preference: Oral Preferred

Fractionation mechanism of magnesium isotope in the paleo-weathering crust

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Keywords: magnesium isotope, karstification, paleo-weathering crust, Ordos Basin

Magnesium, as an important constituent element of dolomite, is directly involved in the formation process of dolomite (Zenger et al., 1994). As the first step and one of the most important steps in the global element cycle, the karstification promotes the fractionation of different isotopes (Dessert et al., 2015), and the karst formation are also an important reservoir in dolomite (He et al., 2020). In recent years, with the rise of high-precision Mg isotope experiments, new perspectives have been provided for the continental weathering (e.g. Ning et al., 2020; Gao et al., 2016; Pokrovsky et al., 2011; Peng et al., 2016). In order to improve the fractionation mechanism of Mg isotopes, the Middle Ordovician Majiagou Formation in Ordos was selected as an example, a systematic study was carried out on the influence of the ancient dolomite strata by karstification, and the effect of Mg isotopes on the influence of strong weathering was explored. Combined with petrographic characteristics, C, O, and Mg isotope fractionation, and element concentration characteristics, the results show that Ma51+2 was in the vertical vadose zone, Ma53+4 was in the horizontal underflow zone, and Ma55 was in the deep slow–flow zone. There are two types of dolomitization and three kinds of Mg isotope fractionation trends in the study area.

Various factors control the different trends of δ26Mgdol in karst crust. In the vertical vadose zone, the main control of Mg isotope fractionation is weathering. The δ26Mgdol gradually enriched with the increase of weather intensity, and finally showed downward decrease profile. In the horizontal underflow zone, fluids and late diagenesis jointly control the fractionation of δ26Mgdol, then showed unchanged downward while obviously negative. In the deep slow–flow zone is not restricted by later diagenesis, the main reason for the fractionation was the brine–reflux dolomitization mode, which led to the increase of δ26Mgdol formed later.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-4: The formation mechanism, characterization and model of paleo-karst carbonate reservoir
Presentation Preference: Oral Preferred

Genesis geological model and fine description method of paleokarst reservoirs in China

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Keywords: paleokarst reservoirs,geological model,description method

Paleokarst oil and gas reservoirs are one of the most important fields of oil and gas exploration and development in China. In the past half century, abundant oil and gas resources have been discovered in the paleokarst reservoirs from the Proterozoic to the Cenozoic. It has become two theoretical and technical problems that the industry is concerned about. How to analyze the genetic mechanism of paleokarst reservoirs and establish a geological model? How to describe the reservoir space in detail to support exploration and development?

There are dozens of classification schemes about karstification, and there is a tendency of pan karstification. It should return to the original definition of karstification and highlight the three basic characteristics of paleokarst reservoirs:

geographical environment of long-term exposure of carbonate formations controlled by the third sequence boundaries and up; a fluid environment dominated by terrestrial atmospheric freshwater and coastal mixed water; reservoir space dominated by dissolved pores-fractures-cavities. Through the analysis of typical oil and gas reservoirs in the Tarim, Sichuan, Ordos and Bohai Bay basins, the surface-controlled (Ordos Basin, Ordovician), surface-fault-controlled (Tahe Basin, Ordovician), and surface-face-controlled (Sichuan Basin, Dengying Formation) models were established respectively.

Paleokarst reservoir description methods include: geological analysis, logging, seismic, geological modeling and so on. The content of geological analysis is to establish a detailed genetic geological model through systematic analysis of structure, strata, lithofacies, fluids etc. The content of logging analysis is to identify the storage space type of paleokarst reservoirs and evaluate the reservoirs based on logging data. The content of the seismic description is based on the pre-stack and post-stack seismic data, describing the structure and paleomorphology, stratigraphic structure and lithofacies, and identifying the size and distribution of fractures and caves. The content of geological modeling is to quantitatively describe the boundary, internal structure, physical properties and fluid distribution of paleokarst reservoirs through the integration of multiple disciplines and the support of knowledge data bases. Due to the strong heterogeneity of paleokarst reservoirs and the increasing depth of exploration and development, it is necessary to introduce methods such as big data and artificial intelligence, and establish a multidisciplinary integrated working mechanism to continuously improve the efficiency and effect of exploration and development.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-4: The formation mechanism, characterization and model of paleo-karst carbonate reservoir
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Research progress of Carbonate fault-karst reservoirs and its volume ——Take the Tarim Basin as an example

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Keywords: carbonate rock, fault-karst reservoir, water-rock interaction, reservoir volume, Tarim Basin

The fault-karst reservoir is a concept model proposed in the exploration research on the southern slope of the Tabei uplift. It refers to the fracture-cave reservoir mainly formed karst reformation in the non-carbonate exposed area with faults as the prerequisite.It is different from conventional epigenetic karst reservoirs. In the transition zone between the Tabei uplift and the Tazhong uplift in the Tarim Basin, the Middle Ordovician limestone and the overlying Upper Ordovician mudstone are continuous deposition, and the mudstone is more than 1000m thick. In recent years, high-yield oil and gas reservoirs with “fault-karst bodies” buried deeper than 6000 m have been discovered in this area. Most of the studies have mainly discussed the control effect of faults on the formation of reservoirs, but few studies have been done about the source of fluids and the transformation effect of fluids on reservoirs. Based on drilling data from multiple wells, This paper researched fluid identification and water-rock interaction by rock-mineral-geochemical analysis. Evidence from inclusions, carbon-oxygen isotopes, and strontium isotopes indicates that there are three types of CO2-rich, S-rich and Si-rich hydrothermal fluids. CO2-rich and S-rich fluids have weak effects on reservoir stimulation and contribute to reservoir space Smaller. Si-rich hydrothermal fluids are widespread and strongly reform carbonate rocks. Through the water-rock reaction experiment of silicon-rich fluid and carbonate rock by using fused silica capillaries, combined with regional geological conditions, the reservoir transformation model of deep carbonate formation dissolution-shallow filling is proposed. The silica-bearing hydrothermal fluid migrates upward along the deep and large faults, passing through the Sinian-Lower Ordovician dolomite layer, where the siliceous components will react with the dolomite to form magnesium-rich silicate and CO2. CO2 is an important acidic component, which is conducive to the dissolution of shallow carbonate and the preservation of pores. Decrease in fluid temperature and pressure, and the presence of CO2 result in the precipitation of quartz, forming large amounts of intercrystalline pores. The CaCO3 produced by the dissolution of the surrounding rock was carried into the shallow part of the fault zone to form calcite veins to fill the existing fault fissures. The activities of hydrothermal fluids are restricted by the geothermal field and the distribution of faults. Based on the reformation mechanism of hydrothermal fluids on reservoirs, favorable reservoir development zones and intervals in the Tarim Basin are proposed and confirmed by drilling.

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Session T7-4: The formation mechanism, characterization and model of paleo-karst carbonate reservoir
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Ultra deep fault control type reservoir of oil and gas enrichment regularity and development way

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Keywords: Ultra deep reservoir,fault control type reservoir,Oil and gas enrichment regularity,Oilfield development

Marine Ultra deep fault control reservoir is carbonate rocks is important reservoir type, is also important reservoirs in the recent increase in oil reserve and production in China. Large strike-slip faults control the karst cave, Fracture, holes, discrete distribution, dimension change is big, distribution regularity of understanding difficult. Through the research on static data and development practice, reveals the fault system, karst system, Hydrocarbon Migration Path system is the main controlling factors of oil and gas enrichment: Along the large strike-slip faults vertical oil column height (300-700m), compared with the weathering crust karst , curved shape rivers cave and surface hole growth is less, north east to the main fault Extrusion torsion part tension torsion part and Fault crossing areas in different directions are favorable. Paleogeomorphology slope, Fault connected with the ancient river cave and fracture growth satisfactorily. Along the fault zone of longitudinal cutting depth, strong continuity, outline the space larger volume is good filling system, oil column height. The geological modeling method of "fault control and step-by-step constraint" and the reservoir numerical simulation technology of discrete fracture cave deformation medium are established. Forecasts the development of injection water, gas and nitrogen gas injection effect. Low parts injection water, high parts production, earlier to keep formation pressure, prevent water channeling along the fracture, water injection scheme has been implemented, the effect is better, improve the oil recovery 2-5%.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-4: The formation mechanism, characterization and model of paleo-karst carbonate reservoir
Presentation Preference: Oral Preferred

Controlling effect of Ordovician thrust fault on meteoric karstification in Tahe Oilfield

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Keywords: thrust fault, nose-like structure, paleokarst conduit, meteoric karstification, Tahe Oilfield

Tahe Oilfield is the first marine carbonate petroleum reservoir discovered in the Paleozoic in China. Due to the superimposition of meteoric karstification from the Middle Caledonian to the Early Hercynian, a large paleokarst conduit system was generated on the karst platform in the Tahe oilfield. It is one of the most important objects of hydrocarbon development in this area. However, the formation process and main controlling factors of the paleokarst conduits are still unknown. Based on three-dimensional seismic data, drilling and coring data, the thrust-fault system and paleokarst fracture-cave reservoirs in this area were described, the paleo-structural conditions in the Middle and Lower Ordovician were restored, and the controlling effect of thrust-fault on meteoric karstification was discussed. The following results were obtained. 1) The thrust fault system is developed in S80 well region of the Tahe Oilfield, which extends in NNE direction and goes through from the Upper Cambrian to the Middle and Lower Ordovician in vertical. 2) The paleo-structures of the Middle and Lower Ordovician are generally characterized by NE-SW extending nose-like structure, and secondary nose-like structures are formed on both sides of the thrust fault and dip southward. 3) Large paleokarst conduit developed in the Middle and Lower Ordovician, which shows single branch or labyrinth morphology on the plane. And it extends from south to north, mainly distribute between the T74 and T76 interfaces vertically, and has a multi-layer structure. The paleokarst conduit is mainly distributed in the hanging wall of the thrust fault. Compared with the footwall, the development and preservation degree of paleokarst fracture-caves revealed by drilling data is obviously higher. 4) The thrust fault formed in the Middle Caledonian leads to the folding and deformation of the Middle and Lower Ordovician strata. This results in the formation of synclinal structure between secondary nose-like structures, which influences the confluence range of meteoric water from the Middle Caledonian to the Early Hercynian. Furthermore, the thrust fault has obvious water-blocking characteristics, which makes the hanging wall of the thrust fault rich in karst water locally, and promotes the spatial differentiation of the meteoric karstification. These results are of great significance for understanding the formation mechanism of paleokarst reservoirs.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-4: The formation mechanism, characterization and model of paleo-karst carbonate reservoir
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Geochemical Characteristics of a Ordovician Carbonate Cave in Keping Area, Tarim Basin

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Keywords: carbonate rock,carbon and oxygen isotopes,strontium isotope,karst,Tarim Basin

Affected by multi-stage tectonic movement and fluid activity events, the Ordovician carbonate strata develop complex karst in Tarim Basin. The geochemical characteristics of carbon oxygen isotope and strontium isotope of typical outcrops in Yijianfang in Keping area are analyzed. The results show that the range of filling $\delta^{18}O$ value is -10 ‰ ~ -6 ‰, and the range of $\delta^{13}C$ value is -0.3 ‰ ~ 0.5 ‰, which is slightly different from the surrounding rock.The paleosalinity value is more than 120, indicating that the sediments are marine origin and formed in the middle and late Caledonian. The $\delta^{13}C$ value of the filling in the cave is less than -0.5 ‰, and the paleosalinity value is less than 120, indicating that the sediments are formed by atmospheric freshwater. The obvious negative $\delta^{18}O$ may be due to the influence of late Hercynian hydrothermal activity or the rise of temperature under burial conditions. According to the strontium isotope test, the $^{87}Sr/^{86}Sr$ value of the filling in the cave is between 0.70955 and 0.7106, which is larger than the $^{87}Sr/^{86}Sr$ value of the O_1 formation of the Tarim Ordovician. The $^{87}Sr/^{86}Sr$ value of surrounding rock ranges from 0.7089 to 0.70922, which is close to the $^{87}Sr/^{86}Sr$ value of Ordovician O_1 stratum, and the formation environment of fillings in this area can be judged accordingly. When the $^{87}Sr/^{86}Sr$ value is significantly higher than 0.7091, it indicates that the filling material and siliceous layer are formed under the action of late Hercynian hydrothermal activity. When the value is slightly higher, the filling is formed in the shallow burial stage due to the effect of formation water or the dissolution fluid carrying strontium. To sum up, the formation of cave is affected by Caledonian movement and Hercynian movement. The filling of surrounding rock and cave is the product of late Hercynian heating fluid, which can provide important research ideas and basis for the prediction of carbonate cave reservoir and reservoir development.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-4: The formation mechanism, characterization and model of paleo-karst carbonate reservoir
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Carbonate Formation Feature Detection from New-Generation Oil-Based Mud Microresistivity Image Logs

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Keywords: Vug and Fracture, Carbonate Reservoir, Strata Feature

The Permian Sinian Dengying carbonate formation is one of the main conventional gas production intervals of Sichuan Basin. Vug and cave is the main reservoir space and open fracture is the key to increase permeability. Fracture-vuggy wells typically produce more than 100×104m3/day natural gas and less than 10 ×104m3/day in poor reservoirs. It suggests the formation characterization is key important to Sinian Dengying carbonate reservoirs.

Water-based microresistivity image logs application is relatively mature, However, since those carbonate rocks in Sichuan basin are basically deep or even ultra-deep strata, oil-based mud drilling fluid system has been applied in large scale with a slim hole. What's more, regional study shows that the response of conventional curves to those carbonate reservoirs is often multi-solution. Not only the vug and open fracture will lead to resistivity decrease, but also the formation structure or induced fracuture. The new-generation oil-based microresistivity image logs provide high resolution images with high borehole coverage. It can provide abundant information about vug, open fracture and formation structure to identify different geological significance of resistivity decline.

There are 1 well has new-generation oil-based microresistivity image logs, and then measured water-based microresistivity image logs after replacing mud. The comparation among core data and two different mud system microresistivity image logs in the same interval shows that new-generation oil-based microresistivity image logs can truly reflect vug, fracture and strata structure feature. Due to different principles of measurement, new-generation oil-based microresistivity image logs is more sensitive to strata structure. The size of the fracture and vug has different response on the oil-based mud electrical image logs. The longitudinal width greater than 10cm is characterized by high resistance, 5cm-10cm is characterized by high resistance or low resistivity, and less than 5cm is characterized by low resistivity.

The case study presents how to understand vug, fracture and strata structure feature on new-generation oil-based microresistivity image logs through core and water-based mud microresistivity image logs data calibration. And then, in oil-based mud well, different geological significance of resistivity decline can be realized. It has great guiding significance for reservoir evaluation and fluid identification. Better understanding of reservoir characterization was instructive for acid fracturing design of carbonate gas reservoir as well.

Session T7-5: Dolomite sedimentation: From modern processes to deep-time archives

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-5: Dolomite sedimentation: From modern processes to deep-time archives
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Characteristics and Sedimentary Evolution of Late Ediacaran-Early Cambrian: Insights from Microbialites, Chert, and Phosphorite in South China

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Keywords: Ediacaran-Cambrian transition, Microbialites, Chert, Phosphorite, Sedimentary evolution model

The Ediacaran-Cambrian (E-C) transition period witnessed one of the most important environmental changes in Earth's history. The western margin of the South China Block (SCB), a shallow-water environment, shows a complete sedimentary record of the E-C transition. The lithologies of E-C transition layers are complex; therefore, analyzing the source and formation mechanism in different lithologies and mircofacies can help reveal the sedimentary evolution of the E-C transition. Through the profile surveys, it was found that the lithologies of the western margin of the SCB in E-C transition layers are dominated by dolostone, microbialites, chert, and phosphorite. Synthesizing petrological and geochemical evidence, it is determined that microbialites have stromatolitic, thrombolytic, cavities, and sporadic microbial structures. The different structures of microbialites indicate as light difference in hydrodynamic and water chemical conditions. Microcrystalline dolomites form in the syngenesis stage, and the meso- to macrocrystalline and sparry dolomites form in the burial diagenesis stage. The siliceous component is a hot-water source and is carried by upwelling into shallow-water environments. The phosphoric component is mainly controlled by biological activity and upwelling. In the increasing tectonic activity background of the E-C transition period, cyclical upwelling carries more deep source materials into the shallow-water of platform environments, which result in increases in siliceous components and mass microbial death. With mass microbial death, the phosphoric component is enriched in deep-water environments. Then the siliceous- and phosphoric-rich fluids are carried by upwelling and enter the shallow-water environments again. The phosphoric component eventually enter the small shelly animals and deposited in the phosphoric-rich layers of the earliest Cambrian period.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-5: Dolomite sedimentation: From modern processes to deep-time archives
Presentation Preference: Oral Preferred

A new model for formation of primary dolomite by subaqueous hydrothermal venting

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Keywords: primary dolomites, lacustrine dolomites, rifting basins, northern China

Dolomite is a common constituent of much of the sedimentary record, a host for hydrocarbons and ore minerals, and has attracted immense research interest as an indicator of carbon and magnesium cycles, paleoclimate and the chemical history of seawater. However, modern dolomites are rare in earth surface environment and the processes governing dolomite formation are an actively debated topic of current research.

Our research is motivated by observations of high-temperature dolomite occurring within numerous continental rift basins in northern China, associated with powerful volcanism. These dolomites deposited proximal to normal faults extending from the basement and is interbedded with terrestrially derived lacustrine mudstone. Sedimentological and petrographic characteristics of dolomites reflect their formation in primary and hydrothermal origin. Recently, many batch reactor experiments have successfully synthesized dolomites in the laboratory suggesting that, with a favourable fluid composition, temperatures above 100 ℃ are sufficient to overcome kinetic barriers to nucleation and growth of ordered dolomite. Therefore, integrating our recent field observations with recent experimental results, we suggest that a high heat flow, such as would occur during rifting, could drive convective mixing between hydrothermal and lake waters at temperatures known to facilitate dolomite precipitation. We tend to propose a new model to explain the formation of high-temperature primary dolomites, combining an understanding of the fundamental physics of subaqueous hydrothermal eruptions and known geochemical constraints on the stoichiometry, ordering and Sr and C isotopic composition of the dolomites.

This model has wider application for formations of dolomite in high heat-flux settings such as rifting basins worldwide, as well as implications for high-temperature ore genesis. Furthermore, our work serves to motivate researchers by highlighting the importance of coupling physical and chemical requirements for reactions such as dolomite formation, which will be key not just to understanding dolomitization in rift settings.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-5: Dolomite sedimentation: From modern processes to deep-time archives
Presentation Preference: Oral Preferred

Multiphase Dolomitization and Dolomite Reservoir Characteristics in Lower Cambrian, Aksu Area, Tarim Basin, China

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Keywords: Dolomitization, Reservoir, Cambrian, Tarim Basin

The Lower Cambrian Xiaoerbulake Formation in the northwestern Tarim Basin consists of a sequence of platform carbonates that are extensively dolomitized. These compound dolomitization reservoirs have significant gas exploration potential, but relevant occurrence and distribution are unclear. This study collected core samples covering dolomite reservoirs from the Xiaoerbulake Formation in the Aksu area. A combination of petrology, fluid-inclusion assemblage microthermometry, and geochemistry data was used to define the dolomitization process and its impact on reservoirs.

The initial microbial dolomitization occurs in restricted environments, characterized by microbial dolostone with depleted $\delta^{13}C$ values. These microbialites were of seawater origin, and they share the same REE (Rare Earth Element) patterns and $\delta^{18}O$ values with limestone from seawater. Micritic dolostone from lagoon and sabkha showing the highest $\delta^{18}O$ values represents sabkha and reflux dolomitization. Besides, some fine crystalline dolostone has a high homogenous temperature. However, its isotopic values fall into the relevant ranges of micritic dolostone, implying the influence of reflux seawater seeping deep into the ground. These samples are mainly near or located in the porous platform margin reef and shoal. Most of the medium to coarse crystalline dolostone came from burial hydrothermal dolomitization, with a homogenous temperature up to 170 ℃. However, relative REE patterns indicate that the direct dolomitization fluids are brine and terrigenous water. Thus hydrothermal fluid may play an essential role in forming dissolved pores filled with medium to coarse crystalline dolostone later.

It is concluded that microbial dolomitization generated moldic and breccia pores, and microbial reservoirs of high porosity and permeability. While in fine crystalline dolomite reservoirs, intercrystalline and oversized dissolved porosities are related to sabkha and reflux dolomitization. This work has shown that deeply buried dolomite reservoirs have good porosities, shedding light on the future petroleum exploration in deeply buried sedimentary basins.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-5: Dolomite sedimentation: From modern processes to deep-time archives
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Microstructure of ancient and modern dolomite supports the presence of microbial mediation

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Keywords: dolomite, microbially mediated, microstructure

Dolomite is a common rock in Precambrian strata but only forms in small amounts in modern strata. So far, scientists have still not been able to synthesize dolomite with a 1:1 ratio of Ca^{2+} to Mg^{2+} under normal temperature and pressure. The question of the origin of dolomite has become a huge problem for scientists.

White clasts and globular deposits can be observed in the modern dolomites of the Abu Dhabi Bank. Scanning electron microscope shows that these spheres are partly formed by needle-type minerals and partly composed of rhombohedral crystals (Bontognali et al,2010). Warthmann et al. found dumbbell-type and cauliflower-type dolomite structures in their observations of dolomites mineralized with microbial assistance. They also found dumbbell-shaped pores in dolomite, a structure that suggests that microbially mediated dolomite may be the precursor to ordered dolomite (Warthmann et al.,2000). Dolomite from the Tibetan Plateau (Li et al.,2020) occurs as subspherical and spherical crystals. These crystals are dispersed in the sediment or adhered to the surface of feldspars to form nodular dolomite layers.

The study of ancient dolomites in the Tarim Basin could also find evidence for the presence of microorganisms (You et al.,2013). Microcrystalline dolomite with high euhedral-granular can be observed in the dark layers. The observation of fluorescence microscope for the dark layer shows the possibility that the dark layer is rich in organic matter and a large number of microorganisms exist. Scanning electron microscope observation of the microstructure of the dark layer dolomite can see rhombic dolomite in a relatively good crystalline state and a certain amount of poorly crystallized spherical dolomite. Many spherical grains can be observed on the surface of dolomite crystals at the micron scale, and the dissection of dolomite crystals can reveal a large number of aggregates of small spherical grains.

Currently, three main contributions of microorganisms to the dolomite precipitation process are considered. First, the charged cell surface is easily enriched with metal cations around the surface, creating partial saturation and promoting the nucleation of mineral crystals for production on the microbial surface. Second, the EPS secreted by microorganisms can reduce the activation energy of dolomite precipitation and overcome the kinetic problems. Third, microorganisms change the chemical properties of the solution during the metabolic process to form a high pH environment suitable for dolomite precipitation (Zhang et al.,2015). Moreover, some recent studies have shown that the presence of microorganisms may change the rheological properties of the water column and favor the dolomite precipitation (López H M et al.,2015).

The microstructure of ancient dolomite, which is very similar to that of modern dolomite, largely suggests that microorganisms played a role in dolomite formation. Although the role played by microorganisms in the formation of dolomite is not clearly conclusive, a comparison of the microstructural features of modern dolomite and ancient dolomite can further verify that a large number of ancient dolomites were most likely formed under the process of microbial involvement.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-5: Dolomite sedimentation: From modern processes to deep-time archives
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Study on the formation mechanism and identification marks of microbial dolomite

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Keywords: Carbonate rock,Microbial dolomite,Formation mechanism,Carbon isotope

Abstract: Dolomite is a common carbonate rock, which is widely distributed in carbonate platform. As for its cause, many mechanisms have been proposed by predecessors, but there is no hard evidence for many of them. Recent research results show that dolomite can be precipitated by microorganisms at room temperature to form microbial dolomite. In the early diagenetic process, microorganisms participate in the sulfate reduction reaction and methane anaerobic oxidation reaction, and overcome the thermodynamic obstacles by reducing the concentration of SO_4^{2-} in water, forming CO_3^{2-} and HCO_3^- , increasing alkalinity and pH value, and then precipitate dolomite. In the methanogenesisreaction, CO_3^{2-} and HCO_3^- are formed in the reaction. However, microorganisms in aerobic respiration change the surrounding microenvironment through metabolism to increase pH value and release CO_2 to increase CO_3^{2-} , leading to the medium supersaturation of carbonate to promote dolomite precipitation. The four organic genetic models can aggregate Mg^{2+} and Ca^{2+} in solution to maximize the precipitation of dolomite. Microbial activity and organic matter in the process of dolomite formation is the most important factors affecting the formation of dolomite, and four kinds of organic origin purpose of this article is a systematic mode of basic principle and key data, the formation mechanism of dolomite in carbon isotope characteristics of identification of organic origin dolomite, so as to provide new method and train of thought for the formation of dolomite.

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Scientific Themes: Theme 7. Carbonate Sedimentation
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Stable Carbon and Oxygen Isotopic Characteristics of Dolomite from Ediacaran Dengying Formation in Southeastern Sichuan Basin: A Case Study of Well L1

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Keywords: dolomite, geochemical characteristics, Dengying Formation, Sichuan Basin

The stable carbon and oxygen isotope chemistry is an important method used for researching the genesis of dolomite. The oxygen isotope composition of dolomite is dependent on temperature and the original oxygen isotopic composition of fluid, while the carbon isotope composition is affected by the admixture of different sources of carbon, making the dolomite in variable diagenetic conditions have different characteristics of carbon and oxygen isotope. As an important high-quality reservoir, the study of dolomite from Dengying formation has been widely concerned. However, due to the complex diagenetic evolution history and other factors, exploration in the study area is still in a low level. By means of thin section identification and carbon and oxygen isotope analysis, the forming environment of dolomite in well L1 is studied. The sample mainly adopts fine and medium grained crystalline dolomite. 1.The average values of $\delta^{13}C_{PDB}$ and $\delta^{18}O_{PDB}$ are about 2.88‰ and -5.55‰, respectively. It is consistent with the results of previous studies on Dengying Formation in Sichuan Basin. 2.According to the formula proposed by Keith and Weber distinguishing marine brine and freshwater limestone, the Z value representing salinity averages at 127.30, indicating the dolomite in study area was in marine brine during sedimentary period. The conversion of $\delta^{18}O_{PDB}$ (PDB scale) to $\delta 18O_{V\text{-}SMOW}$ (V-SMOW scale) is based on the formula proposed by Coplen. Assuming that the seawater temperature in the Dengying Age was 30 ℃ and $\delta^{18}O_{water}$ is - 6.4 ‰, the reconstruction of paleotemperature shows that the seawater temperature at that time was about 27.6 ℃, which is closed to the assumed value. 3.Previous studies have found spherical dolomite similar to the morphological characteristics of modern precipitated dolomite was developed in the 4th member of Dengying. Nevertheless, the significantly positive $\delta^{13}C$ value and the $\delta^{18}O$ value that comes between - 6.7 and 5.6 ‰ are closed to the figure of methanogenic microorganisms mediated dolomite.The points above lead to a conclusion that the diagenesis of dolomite in study area is related to methanogenic microorganisms.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-5: Dolomite sedimentation: From modern processes to deep-time archives
Presentation Preference: Oral Preferred

The Cambrian Carbon Isotope Excursions in the Tarim Basin and Its Sedimentary Significance

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Keywords: carbon isotope, geological event, Cambrian, Tarim Basin, depositional evolution

By analyzing the existing $\delta^{13}C$ data of the Cambrian in the Tarim Basin, four obvious carbon isotope excursion (CIE) events are identified. From bottom to top, the order is: (1) BAsal Cambrian Carbon isotope Excursion, BACE, ca. 541Ma, maximum ~ -10‰; (2) Redlichiid-Olenellid Extinction Carbon isotope Excursion, ROECE, ca. 509Ma, maximum ~ -14‰; (3) Drumian carbon isotope excursion, DICE, ca. 506.5~503 Ma, maximum ~ -3‰; (4) Top of Cambrian Excursion, TOCE, ca. 485.4Ma, maximum ~ -7‰. These four CIEs are correlated with coeval tectonic-volcanic activities, bioevents and paleoceanographic/paleoclimatic changes. The specific is as follows. "BACE" corresponds to the expansion of the South Tianshan Ocean, the oceanic anoxic event and the Ediacaran organisms extinction, and a set of black rock series are deposited in the basin. "ROECE" corresponds to the global trilobite extinction, and climate changes from wet to dry, in which lagoon-facies evaporites and lime-/dolo- shale replaced the restricted tidal-flat facies carbonate rocks. Moreover, there might be some volcanic activities. "DICE" corresponds to the climate change from dry to wet and transgression in the same period with evaporites no longer. "TOCE" corresponds to the transgression while the open tidal flat limestone gradually replace the thick dolomite. Considering the biological, climatic and tectonic events at that time, combined with the equal changes of the upper and lower lithofacies, logging facies, and earthquakes of these four excursions, they can be regarded as the secondary sequence interface of the Cambrian in the Tarim Basin. The identification of such CIEs helps to define the Cambrian stratigraphic framework in the Tarim Basin. The origins and sedimentary responses of the CIEs influence the lithofacies, well-logging and seismic facies in the basin. Therefore, these 4 CIEs can be regarded as the secondary sequence boundary of the basin scale, which contributes to understand the depositional evolution.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-5: Dolomite sedimentation: From modern processes to deep-time archives
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Microbial dolomite of ultra-deep Early Cambrian in the Tarim Basin

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Keywords: microbial dolomite, ultra-deep, Lower Cambrian, Tarim Basin

There are widely discussions about microbial dolomite patterns as an important insight to solve the "dolomite problem". This study is the first to introduce the microbial dolomite found in the ultra-deep Lower Cambrian in the Tarim Basin. The sample is cored from the Wusongger Formation in WXH1, located in the northern Tarim Basin, with a depth of about 7355~7358m. Macroscopically, a large number of dark horizontal laminae are developed, with a thickness of about 1~2mm. The color between the laminae is lighter, but the cross section is still dark gray. It has the total characteristics of stromatolites. After acid dripping, bubbles are generated violently, and the lithology is limestone. Microscopically, obvious red-black band differentiation can be seen in the stained slices. The red is micrite calcite, and the black is not stained. It is shown in the fluorescence photos that the unstained has a strong fluorescence effect, while the fluorescence effect of calcite is very weak. Under the scanning electron microscope (SEM) and analyzed by energy dispersive spectroscopy (EDS), a large number of rhombohedral crystals and ring-shaped mineral aggregates were distributed in the unstained part, in which the Mg/Ca ratio was close to 1:1. The above characteristics all indicate that the undyed part is dolomite. Macro and micro petrographic studies indicate that it was deposited in a hydrostatic environment near the redox zone, as confirmed by elemental geochemical data. To sum up, dolomite is more likely to precipitate with a large amount of organic matter in the environment, or in an environment that is conducive to the preservation of organic matter. In other words, active microbes and/or organics might be a trigger for dolomite formation. This is the first instance of suspected microbial dolomite found in ultra-deep marine strata, in which the degree of rock preservation is better than that in outcrops. In the future, the microenvironment of these dolomite precipitations can be studied through the more precise techniques to reveal the influence of ancient organic matter on dolomite precipitation.

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Session T7-5: Dolomite sedimentation: From modern processes to deep-time archives
Presentation Preference: Oral Preferred

Clay mineral-mediated dolomite precipitation: evidence from Neoproterozoic ribbon carbonates, North China

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Keywords: Zhaowei Formation,Niyuan Formation,Organic matter,I/(Ca+Mg),hydroxylated surface

The origin of dolomite, known as “the Dolomite Problem”, has plagued geologists for more than a century. Though recent laboratory studies have revealed that biotic or abiotic substances containing carboxyl or hydroxyl groups could induce proto-dolomite precipitation, their applications to ancient dolomites are still difficult. Ribbon carbonate, a type of carbonate rock with centimeter- to decimeter- scaled alternating of limestone and marlstone layers with the latter rich in dolomite, provides an ideal window into exploring dolomite origin. To address this issue, ribbon carbonates from the Neoproterozoic Zhaowei and Niyuan formations in Xu-Huai area were selected as the target in this study. Comprehensive sedimentological, mineralogical and geochemical analyses were carried out in this study, using SEM, EDS, and MC-ICP-MS. The ribbon carbonates are mainly composed of calcite carbonate mud, with non-zero I/(Ca+Mg) values, and are occasionally associated with hummocky cross-bedding, indicating their deposition in an open marine environment with water-depth close to storm wave base. The carbonate mud in them was likely precipitated from a moderately oxygenated water column. Therefore, variations in salinity were unlikely to result in the differential dolomitization through the mediation by halophilic archaea with high-density carboxyl groups on its cell surface. Pyrite grain is rare in both the limestone and marlstone layers, indicating that bacterial sulfate reduction may not be the primary control for the dolomitization either. The positive correlation between Al and Mg/Ca ratio, and the close spatial association between clay minerals and dolomite crystals, suggest that clay minerals may have played an important role in promoting dolomite precipitation. Previous experiments show that clay minerals with hydroxylated surfaces facilitate dehydration of Mg-H_2O complexes, and can serve as sites for dolomite nucleation. As organic matter is often closely associated with clay minerals, it is difficult to evaluate separately the contribution of organic matter to dolomite formation. Clay mineral and organic matter may have both contributed to dolomite precipitation in marlstone layers. This study provided the first geological evidence for clay mineral-mediated dolomite precipitation, and will further help to elucidate the origin of dolomite in deep time.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-5: Dolomite sedimentation: From modern processes to deep-time archives
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Deposition Model and Main Factors Controlling Depositional Processes for Microbialites in the Fourth Member, Dengying Formation, Central Sichuan Basin

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Keywords: microbialite, sequence stratigraphy, deposition model, Dengying Formation, Sichuan Basin

In the late Ediacaran period, Dengying Formation in Central Sichuan basin developed continuous and thick microbial carbonates on the carbonate platform, with complex and diverse sedimentary characteristics. At the same time, it is easy to form high-quality oil and gas reservoirs. Therefore, the research on the classification of microbial carbonates types, sedimentary environment, reservoir characteristics and genesis is not only a hot and difficult point in the field of sedimentology, but also one of the focuses in the field of oil and gas geology (Liu et al., 2016; Luo, 2013; Wang et al., 2018). A detailed deposition microfacies analysis was carried out on macrostructures and microfabricsShapiro, 2000Han et al., 2009 using data from drill cores and thin sections. The fourth member of the Dengying Formation in central Sichuan Basin includes mainly eight types of lithofacies which are gray-black horizontal-bedding micritic dolomite, dark-gray wrinkle-laminated dolomite, light-gray wackestone to packstone dolomite, light-gray packstone to grainstone dolomite, thrombolite, stromatolite, thin-bedded micritic dolomite, and breccia. The stromatolite can be further divided into wavy-laminated agglutinated stromatolite, wavy-laminated skeletal stromatolite, and flat-laminated fine-grained stromatolite. According to the stacking patterns, these lithofacies are grouped into four types of lithofacies associations, which are subtidal-restricted lagoon deposition, subtidal thrombolites, shallow-subtidal to intertidal stromatolites to shoal complex, and intertidal stromatolites. Based on the macrostructures, microfabrics, and vertical sequence of the microbialites, the deposition model for the microbialites in the fourth member of Dengying Formation is established. The thrombolites were mainly deposited in the subtidal environment below the wave base, with low hydrodynamic. The clots were locally formed by microbial trapping and binding small grains. The wavy-laminated agglutinated stromatolites were mainly deposited in the lower part of intertidal zone, in which various types of microbe flourish. They were formed by microbial trapping and binding ooids and peloids under strong waves and tides. The wavy-laminated skeletal stromatolites were mainly deposited in the upper part of intertidal zone with moderate hydrodynamic dominated by the tide. The sponge structure were formed by microbial inducing precipitation and in situ calcification, and trapping and binding a small amount of pellets. The flat-laminated fine-grained stromatolites were mainly deposited in the upper intertidal zone, and deposition processes are predominantly microbial inducing precipitation. According to the core and logging characteristics, the fourth member of Dengying Formation can be divided into five microfacies: tidal flat limited lagoon, shoals, stromatolite mound, thrombolites mound and mound-shoals. On the basis of microfacies division, the sequence framework of the fourth member of Dengying Formation is established, and the distribution law of microbial carbonates is found out. The microfacies distribution in the sequence stratigraphic framework shows that microbial mounds and shoals were located mainly in the upper part of the sequences, which became better-developed from bottom to top in this member of the Dengying Formation. The mound-shoals were more developed at the platform margin, decreasing in scale and continuity at the restricted platform.

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Session T7-5: Dolomite sedimentation: From modern processes to deep-time archives
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Research progress on the microbial genesis of cold-seep dolomite

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Keywords: seep dolomite, carbon isotope, microbial mechanism, methane-oxidizing bacteria

Dolomite genesis is a long-term concern in sedimentology. Recently, the perspective that microbial activity promotes dolomite precipitation has rapidly developed. Protodolomite had been discovered in hydrocarbon seeps, which provides new thoughts for solving the problem. (Zhao et al., 2021)

In Japan, the Kuroshima Knoll is a typical area for developing cold-seep dolomite in the modern submarine cold-seep system. The chimney-shaped dolomite is mainly cylindrical, circular, and spiral and is formed by cementing sand and mud with dolomite and calcite on the seafloor of Kuroshima Knoll, Japan. The dolomite crystals in the chimney are tiny, and the contents range from 79.2 to 83.2 wt.%. Its $\delta^{13}C$ is -43.6‰ to -17.0‰, $\delta^{18}O$ is 5.66‰ to 7.92‰ (PDB)(Takeuchi et al., 2007; Wang et al., 2022). Takeuchi et al. suggested that methane is produced by methane fermentation of the organic matter in the Shimajiri Group. This methane forms the methane hydrate layer under the seafloor. When pressure or temperature changes, methane hydrate dissociates, causing methane to seep with the light carbon and the heavy $\delta^{18}O$. Microorganisms oxidize this methane from the depths to form methane-oxidizing bacteria dolomite. (Takeuchi et al., 2007).

The formation mechanism of methane oxidation bacteria dolomite is to use methane oxidation bacteria to oxidize methane, reduce the concentration of SO_4^{2-} in water, form CO_3^{2-} and HCO_3^-, increase alkalinity and pH, overcome thermodynamic barriers, and thereby precipitate dolomite(Moore et al.,2004; Wang et al., 2022). The $\delta^{13}C$ of methane oxidized microbial dolomite is usually below -5‰ and can reach -20‰ (PDB)(Bontognali et al.,2008). The $\delta^{13}C$ of this type of dolomite overlaps with that of sulfate-reducing microbial dolomite, but if it is below -10‰ (PDB), it is methane-oxidizing microbial dolomite(Wang et al., 2022).

Ancient cold-seep carbonates containing large amounts of dolomite were developed in Taiwan. Cold seep dolomite occurs as chimneys or lenses in shales of the Early Pleistocene Yanshukeng formation exposed in Chiayi County, southwestern Taiwan, with dolomite as the carbonate mineral and a large number of cold-seep biogenic fossils. The $\delta^{13}C$ of dolomite ranges from -27.08‰ to -10.58‰, indicating that the carbon source may be a mixture of methane and seawater carbon sources. The mean values of Ni/Co and the distribution pattern of REE indicate that the cold seep dolomite was formed in a weakly reducing sedimentary environment(Zhao et al., 2021).

Based on the analysis of the origin of dolomite chimneys distributed in the modern sediments of Kuroshima Knoll, Japan (Takeuchi et al., 2007), combined with the existing knowledge about methane oxidation and anaerobic oxidation of methane (AOM) and the study of the sedimentary environment of the Early Pliocene cold seep dolomite at Chiahsien, Taiwan. It can be speculated that in the weakly reducing depositional environment, methane anaerobic oxidizing bacteria promote the consumption of SO_4^{2-} and the increase of HCO_3^-, which, together with the active microbial action, favor the precipitation of cold-seep dolomite and provide new thoughts to solve the dolomite genesis(Zhao et al., 2021).

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Petrographic, trace elements, and isotope constraints on the dolomite origin of Sinian Dengying Formation(Sichuan basin, south china)

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Keywords: Crystal Structure, Origin of dolomites, Dengying Formation, Sichuan Basin

The origin of ancient massive dolostones, with a thickness >100 m and a platform-wide distribution in the Dengying Formation of the Yangtze platform, is the intractable issue of the 'Dolomite Problem' that cannot be demonstrated by any existing dolomitization models.Here we report that dolomites of different sizes have different structural characteristics. Based on the exploration of dolostones from outcropscoresand thin sections in the Dengying Formation of Sichuan Basin, three types of dolomite were identified micritic dolomite(3μm)(type D1), silty dolomite3-100μm(type D2) and medium-fine crystalline dolomite100μm(type D3), and ten subtypes because of structural and structural differences. The comparative studies of crystal structure and geochemistry were carried out by utilizing X-ray diffraction and geochemical analysis. Results show that: type D1 is mainly characterized by Primary sedimentary structures, such as massive structures, algal lamina, algal mass, sand debris, stromatolites, etc. which cathodoluminescence(CL) is dull red, crystal parameters (a,c) are small, CaO-MgO positive correlation and Fe/Mn value are high. The Sr/Mn values are low, and the ranges of carbon isotope (δ18C) are similar to that of the seawater at that time. The low negative oxygen isotope (δ18O) (>−10‰), and Strontium isotope (δ18Sr) value is similar to that of the seawater in the late Sinian period. The above researches indicate that it can deposit or be early-dolomitized at the nature of seawater; Type D2 is mainly composed of massive and algal structures. Its CL characteristics are bright red, the a and c are relatively large, and CaO-MgO is negatively correlated. The δ18C values are similar to that of micrite dolomite, and the δ18O values are highly negative (<−10‰). The ranges of strontium isotope are similar to that of type D2. The above research indicates that type D2, experiencing High-temperature burial diagenesis occurs in recrystallization, but its element components not be changed by other fluids; Type D3 mainly distributes in voids, and the CL characteristics are bright red or bright dark interphase rhombohedral shape. The order degree of type D3 is the largest, and CaO-MgO is negatively correlated. The Fe / Mn values are the lowest, and the Sr/Mn values are the highest. The carbon isotope is more positive than the sedimentary seawater value in the late Sinian period, and the oxygen isotope is high and negative (<-10‰). The above research indicates that it is formed by multi-stage diagenesis in the late diagenetic stage under the action of multiphase fluids.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-5: Dolomite sedimentation: From modern processes to deep-time archives
Presentation Preference: Oral Preferred

Paleoclimate and paleo-oceanic environment of the formation of Cambrian dolomite in Keping area, Tarim Basin

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Keywords: Tarim Basin,Cambrian,dolomitization,paleo-climate,paleo-ocean,aragonite sea

The Cambrian to Lower Ordovician in the Tarim Basin is a large-scale carbonate platform, in which evidence of microbial-mediated primary dolomite in the ancient Sabha environment is found in the thick Cambrian dolomite strata (You et al., 2013, 2014, 2015, 2018a, 2018b). In recent years, attention has been paid to the formation of dolomite under the background of paleoclimate and paleooceanography. According to the survey, the Tarim block was located in the lower latitudes of the southern hemisphere during the Cambrian period(Huang et al.,2020). Although the sudden change of the global sea level in the Cambrian period may indicate the existence of glaciers, the whole Cambrian period was dominated by a warm "greenhouse" climate. (Babcock et al., 2015). According to measurements of seawater temperature in modern tropical regions, the surface temperature of seawater generally does not exceed 30 °C (Meckler et al., 2015). The temperature of the water for precipitation of dolomite is 30-35 °C. The Awatage Formation in the Keping area in the northwest of the Tarim Basin predominately was deposited in a shallow evaporative environment. The beds are composed of micritic and fine-grained dolomite. They were deposited in the inter-supratidal zone of the lower sabkha and are characterized by frequent sub-aerial exposure surfaces, anhydrite nodules or gypsum pseudomorphs. It was formed in a strong oxidative depositional environment, and was in a strong arid and evaporative environment during this period. The Mg/Ca ratio and Ca2+ concentration of seawater play an important role in microbial precipitation of dolomite. The study shows that the Tarim Ediacaran-Middle Cambrian is a typical glacial-aragonite sea deposit under the background of dry-hot/dry paleoclimate. The dry-hot/dry paleoclimate background and the glacial-aragonite sea deposits have the highest salinity of the diagenetic medium, which in turn affects the degree of dolomitization, resulting in the widespread development of Tarim Ediacaran-Middle Cambrian dolomite (Zhang et al., 2014). Sea water in aragonite-sea deposition was characterized by low Ca2+ content and high SO2- 4 content; salt brine after evaporation was rich in Mg2+, Na+, and K+, from which halite and epsomite (MgSO4) deposited after evaporation, followed by sylvite at last. Paleoclimate and paleo-ocean environment have a controlling effect on the formation and evolution of dolomite reservoirs. At the same time, most of the large-scale dolomite developed in the geological period is closely related to the evaporite. For example, quasi-contemporaneous dolomite appears in the evaporite platform, that is, the period when calcium carbonate sediments have just been deposited and are still in the original depositional environment. The replaced sediments include apatite or micrite magnesium-rich calcite in intertidal-supratidal and gypsum lakes. Evaporite is a soluble mineral that is easily corroded in a short period of time to form pores in humid hot/humid paleoclimates, which may further evolve into porous gypsum (gypsum) dolomite reservoirs with evaporite casting pores. Therefore, most of the Middle Cambrian in the Tarim Basin are the main producing layers of large oil and gas fields.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-5: Dolomite sedimentation: From modern processes to deep-time archives
Presentation Preference: Oral Preferred

Geochemical of carbonate platform dolomite in the South China Sea: Take the Xisha region and Nansha region as examples.

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Keywords: the South China Sea,dolomite,geochemical,dolomitization model

Carbonate platform is one of the most important reservoir types, which contains a large number of biological sediments. The Cenozoic carbonate platform of the South China Sea were developed, and dolomite is common in the carbonate sequences of the Xisha region, and a large number of dolomitized carbonate sequences were developed in Mingji Reef of the Nansha Islands at a similar time of formation. Through the geochemical study of dolomite in well Xike 1, it is found that, the main gas compositions and the lon concentrations of the dolomite-hosted fluid inclusions, and the geochemical characteristics of the carbon and oxygen isotopic compositions of the dolomites indicate that the dolomitizing fluid is concentrated seawater derived from a surface environment. Geochemical studies of the dolomite in well ZK-1 revealed that the selective replacement dolomite is mainly developed at the depth of 180 ~ 289m of the core; In the case of depth exceeding 289m, more occluded replacement dolomite is more common. The pervasive crystallization of dolomite is caused by a combination of slightly evaporated seawater inflow and elevated temperatures, which is considered to occur in the relatively late diagenetic process at larger burial depth. Through the geochemical study of NK-1 core, it is found that the massive dolomite in the middle of Mingji reef is late deposition; their formation is related to the replacement of pre-existing calcite and cement in seawater. Much of the alteration of initial carbonates including dolomitization, probably occurred between about 15 °C and 28 °C and more than 200m below sea level. It is inferred that the fluid composition is related to a brine reflux mechanism. These results help to refine existing dolomitization model of tropical islands.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-5: Dolomite sedimentation: From modern processes to deep-time archives
Presentation Preference: Oral Preferred

Genesis of dolomite in cold spring environment of south China Sea

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Keywords: dolomite,cold spring environment,diagenesis

The origin of dolomite has always been an important problem in the field of sedimentological carbonate rock research. Perfect and ordered dolomite crystals cannot be formed under the test conditions of normal temperature and pressure in the near-surface environment. Dolomite is commonly developed in modern and ancient cold spring environments, and dolomite precipitated in cold spring environments may provide new ideas and new ideas for studying the origin of dolomite in geological history. The cold spring system in the South China Sea develops a high content of dolomite, which is mainly produced in breccia-like, spherical, ellipsoid-like nodules and chimney-like structures with a microcrystalline structure. The carbon isotope values of cold spring dolomite vary greatly, indicating that the main sources of methane leakage from cold springs, dissolved inorganic carbon in seawater, organic matter oxidation, and residual CO2 from methane production, etc., and the changes in oxygen isotope values may be related to the formation of methane hydrate Decomposition, dehydration of clay minerals and deposition temperature, etc. By in-depth study of the relationship between the formation of protodolomite and very high magnesium calcite in the carbonate rocks of the South China Sea and the microbes, it is speculated that the extracellular polymers produced by sulfate-reducing bacteria provide chemically and structurally selectively from the environment. The template captures Mg2+ and Ca2+ in CO32-, and then combines with CO32- to form very high magnesium calcite and dolomite, and finally the very high magnesium calcite is converted into original dolomite. And in the process of dolomite formation, sulfide- and sulfate-reducing bacteria may simultaneously play a role in the precipitation of dolomite.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-5: Dolomite sedimentation: From modern processes to deep-time archives
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Classification and origin of microbial dolomite in Qigebulak Formation, Tarim Basin, NW China

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Keywords: Tarim Basin, Qigbulak Fm, Microbial dolomites

A set of carbonate rocks dominated by dolomites were widely developed in the Tarim Basin during the Late Sinian, NW China. Among which, matted and mounds of microbial dolomites were found in the Qigbulak Fm of the Upper Sinian. However, the genesis and formation environment of these dolomites have not been clearly explained. In this study, geological observation, thin section identification and SEM are carried to pursue the the classification and genetic for the microbial dolomite of the middle and upper Qigbulak Fm. The results show that the stromatolites and clotted dolomites are the main types of microbiolites in Qigbulak Fm. The morphology of stromatolites shows mainly columnar, wavy, conical and horizontal stratified. The microtexture of rich microbial structure layer and sparry carbonate cement interlayer (MS/SP), rich organic matter and sparry carbonate cement interlayer(OR/SP), micritic carbonate minerals and sparry carbonate cement (MC/SP) interlayer and carbonate algal spherulite layer and siliceous cements interbed (OC/SiP) could be found in stromatolites. The morphology of clotted dolomites shows dome-shaped or blocky in macroscopically, which could be dived into micritic carbonate gobbet (MG), cavity texture gobbet (CG) and silk sheath texture gobbet (SG). It is considered that the formation of stromatolites is mainly controlled by hydrodynamic conditions and biological development degree. Micritic carbonate gobbet grow or develop in situ while the formation of cavity texture gobbet may be caused by several genies including bowl-shaped microorganisms, independent bacterial "body cavity" or microbial drilling.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-5: Dolomite sedimentation: From modern processes to deep-time archives
Presentation Preference: Oral Preferred

Microbial dolomite: Sulfate-reducing bacteria promote dolomitization

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Keywords: sulfate reducing bacteria, sulfate reduction reaction, dolomite precipitation

The microbial dolomite model is the most breakthrough dolomitization model proposed in the last 20 years. Sulfate-reducing bacteria promote dolomite precipitation was proposed relatively earlier and studied most carefully. The mechanism was first proposed by Vasconcelos and Mckenzie to precipitate dolomite by sulfate reducing bacteria in laboratory conditions, simulating the hypoxic reducing environment of lagoons. Cyanobacteria and sulfate-reducing bacteria in the modern Marine environment have a certain effect on carbonate precipitation. However, it is generally believed that bacterial sulfate reduction is one of the main factors leading to calcium carbonate precipitation in calcified microbial community. The expression of sulfate reduction reaction is summarized as: $CH_2O+SO_4^{2-}\rightarrow HCO^{3-}+HS^{-}+H_2O$. There are a lot of carbonate precipitation inhibition factors in seawater, which makes it difficult for carbonate to precipitate under the condition of supersaturation. This is mainly because Ca^{2+} and Mg^{2+} can easily form a mate bond with SO_4^{2-}, and sulfate-reducing bacteria consume sulfate ions through reduction reaction, increasing the concentration of Ca^{2+} and Mg^{2+} in seawater. At the same time, the formation of HCO^{3-} increases the alkalinity of the solution, affects the saturation index, and directly precipitates the dolomite. However, this model also has problems. A large number of experiments were carried out based on sulfate-reducing bacteria in the modern environment. However, it is not clear whether sulfate-reducing bacteria in geological history are significantly different from modern ones, and whether they have influenced modern dolomite deposition, which requires further research.

ID: T7-51358

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-5: Dolomite sedimentation: From modern processes to deep-time archives
Presentation Preference: Oral Preferred

The organic substrate suited to facilitate low-temperature dolomite precipitation.

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Keywords: dolomite, organic substrate, low-temperature;

The organic substrate suited to facilitate low-temperature dolomite precipitation.

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Recent studies have shown that microbial-derived organic matter plays a catalytic role in the precipitation of low-temperature dolomite (Bontognali, T. R. et al. 2010), and the presence of EPS can catalyze the low-temperature precipitation of magnesium dolomite under surface conditions. The pathway of this process was later considered to be the dehydration of Mg2 + promoted by carboxyl group, which acted as a nucleation site to overcome kinetic obstacles. Laboratory experiments showed that salinity also had a certain effect on the precipitation of low-temperature dolomite. In addition to increasing the number of nucleation EPS, salinity also increased the number of available Mg ions. With high salinity and transformation from cyanobacteria to chlorella or saline-alkali bacteria, the amount of EPS extracted and the proportion of carboxyl functional groups increased, which was the ligand for the formation of low temperature dolomite. Some results showed that salinity led to the transformation of microbial communities from oxygen-rich phototrophs to heterotrophic organisms, resulting in EPS conducive to dolomite nucleation (Diloreto et al., 2021). Fluctuations in the environment, especially changes in salinity, and changes in the heterotrophic advantage of microbial mats from oxygen to hypoxia create an organic matrix (EPS) that is particularly suitable for promoting the precipitation of low-temperature dolomite. Specifically, the increase in salinity led to a community dominated by anaerobic phototrophs, which degraded EPS produced by cyanobacteria. This leads to an increase in the concentration of carboxyl functional groups. As is known to all, carboxyl functional groups will promote the dehydration of magnesium and subsequent binding with carbonate minerals.

Reference

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-5: Dolomite sedimentation: From modern processes to deep-time archives
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Formation mechanism of dolomite

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Keywords: Primary microbial dolomite, dolomitization, dolomite problem

Formation mechanism of dolomite

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Dolomite has been an important research object of many geologists since it was first described by French historian Deodat de Dolomieu in 1791. As the main sedimentary carbonate rock, the formation mechanism of dolomite has always been one of the most complex, controversial and difficult problems in petrology. Since the 1950s, many experts and scholars have studied modern dolomite and ancient dolomite in the Bahamas, the Persian Gulf and some other areas. They have put forward a series of dolomite chemistry theories, and carried out many important theories and theories on its formation process and mechanism.

The existing studies are preliminarily introduced, including the generation theory of primary dolomite : primary precipitation, quasi-contemporaneous dolomitization, and reflux infiltration dolomitization. It is mainly in a certain hydrochemical conditions replacement precipitation dolomite precipitation way to achieve dolomitization. There are also some theories of secondary dolomite : mixed dolomitization and burial dolomitization ; it is mainly based on the existing calcite and replaces calcium ions in the form of metasomatism under specific water conditions. Although examples can be found to some extent about the previous theories, their harsh formation environment and conditions are not universal. There is still a lack of critical evidence for the specific formation process, and the debates on various theories are still ongoing. In recent years, with the help of microorganisms, some scholars can precipitate and form dolomite at room temperature, which provides a very meaningful direction and idea for the formation theory of dolomite.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-5: Dolomite sedimentation: From modern processes to deep-time archives
Presentation Preference: Oral Preferred

Diatoms Diminish Dolomite

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Keywords: sedimentary dolomite, dissolved silica, the dolomite problem, diatom

There is a great abundance of sedimentary dolomite in the Proterozoic and Lower Paleozoic, but examples of primary dolomite are scarce in the Cenozoic. This discrepancy suggests a poorly understood, but dramatic shift in the geochemical system that inhibited dolomite formation. It has been demonstrated that the presence of 1-2 mM of aqueous $Si(OH)_4$ in high Mg:Ca ratio solutions at room temperature will promote disordered dolomite and even magnesite precipitation and inhibit aragonite formation. Molecular dynamics modeling calculations by show that dolomite growth is catalyzed through adsorption and desorption process of dissolved $Si(OH)_4$ on dolomite surface.

The appearance of diatoms in the Mesozoic greatly impacted the biogeochemical cycle of Si and resulted in the rapid decline in dissolved silica to the micro-molar concentrations observed in the modern surface ocean. To a first-order approximation, the dissolved silica in seawater is positivity correlated with dolomite abundance in marine sediments. This evidence suggests that the diversification of diatoms has greatly impacted the formation of sedimentary dolomite by efficiently removing dissolved silica from seawater. The depletion of dissolved silica in the modern ocean by the effective extraction from diatoms might be responsible for the decline in primary dolomite formation. This study provides a new model for abiotic sedimentary dolomite formation which is likely to be responsible for the significant amount of primary dolomite in the Earth history.

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Fang, Y., and Xu, H. (2022) Dissolved silica-catalyzed disordered dolomite precipitation. American Mineralogist (2022) 107, 443–452 (https://doi.org/10.2138/am-2021-7474).
Hobbs, F. W. C., and Xu, H. (2021) Magnesite formation through temperature and pH cycling as a proxy for lagoon and playa paleoenvironments. Geochimica et Cosmochimica Acta, 269, 101-116 (https://doi.org/10.1016/j.gca.2019.10.014).

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-5: Dolomite sedimentation: From modern processes to deep-time archives
Presentation Preference: Oral Preferred

Abiotic driven primary dolomite precipitation in the Great Salt Lake, Utah, USA, catalyzed by dissolved silica

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Keywords: Dolomite precipitation, hypersaline lake, dissolved silica, primary dolomite, XRD, TEM

Since the discovery of dolomite, numerous attempts have been made to understand its sedimentation and precipitation mechanism. It has been recognized that the dehydration energy barrier for surface Mg^{2+}-water complex impedes dolomite nucleation and growth. The relationship between microbial life and dolomite has been validated with laboratory synthesis that certain organic molecules, such as polysaccharides, exopolymeric substances, and hydrogen sulfide, could promote dolomite precipitation. However, some dolomite appeared to have an abiotic origin, and previous laboratory work shows that dissolved silica promotes disordered dolomite precipitation at room temperature. The modern occurrence of dolomite in the Great Salt Lake (GSL) has been studied since the early last century, with dolomite mainly dominating sediments in the South Arm sediments while the North Arm sediments are primarily aragonite. This heterogeneous distribution of sediments in GSL provides a perfect case study to understand abiotic dissolved silica-driven dolomite formation. Earlier studies proposed that dolomite precipitation in the GSL was possibly induced by microbial activity. However, this could not explain the lack of dolomite in microbial mats, especially on the North Arm, which is constituted by mostly aragonite with no dolomite. This work demonstrated that dissolved silica concentration and dolomite abundance are positively correlated, suggesting that dissolved silica likely controls dolomite formation in the GSL. Even though the North Arm has a much more concentrated Mg and Ca water from lack of freshwater input, dissolved silica levels in the South Arm (> 0.5 mM) are much higher than in the North Arm (< 0.2 mM). Dissolved silica is provided from streams feeding into the South Arm carries about ~0.2 mM, and is concentrated through evaporation. A high concentration of dissolved silica catalyzed the nucleation and growth of dolomite in the South Arm. However, a significant amount of silica was removed from the solution through adsorption on carbonate and authigenic clay mineral precipitation, resulting in silica-depleted lake water in the North. The dissolved silica catalyzed model explains many sedimentary environment settings of Phanerozoic marine dolomite associated with limestone. The new finding could also provide a new proxy for constructing climate changes in GSL area based on dolomite controlled by the abiotic process.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-5: Dolomite sedimentation: From modern processes to deep-time archives
Presentation Preference: Oral Preferred

Characteristics and Genesis of Dolomite in the Lower Cambrian Xiaoerbulake Formation in the Western Margin of the Tarim Basin, China

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Keywords: dolomitization, dolomite, in-situ geochemical test, Cambrian, Tarim Basin

The Lower Cambrian Xiaoerbulake Formation in the western Tarim Basin consist of shallow-water carbonates which have been pervasively dolomitized. Petrological and geochemical analyses were obtained in order to clarify the dolomite genesis and identify the dolomitization model by using the latest core data of Well XKD-1 in the western margin of the basin. The bulk rock geochemical data include strontium, carbon, and oxygen isotopes, and in-situ minor element and rare earth element measurements for different dolomite types by LA-ICP-MS. Four types of lithofacies were recognized in the Xiaoerbulake Formation based on different textures, which are laminated dolostone (LDS), thrombolite dolostone (TDS), bacteria-bonded dolostone (BDS), and grain dolostone (GDS). These lithofacies were interpreted to be deposited from intertidal to subtidal environment in an inner-ramp platform. Two types of dolomites were identified: matrix dolomite (MD) and cement dolomite (CD). MD is the primary type of laminated and bacteria-bonded dolostone, and CD developed mainly from grain dolostone and thrombolite dolostone. The δ13C and δ18O indicate that the grain dolostone and thrombolite dolostone have undergone more intensive diagenetic modification. On the contrary, the diagenetic modification of laminated and bacteria-bonded dolostone are relatively weak, which implies that the dolomitization of the latter two lithofacies occurs penecontemporaneous. The 87Sr/86Sr ratio indicates that the corresponding fluid for dolomitization was seawater or marine-derived fluids. The MD is formed in the penecontemporaneous near-surface stage via the penecontemporaneous dolomitization of seawater or hyper-saline seawater. The dolomitization of CD occurs in the burial environment, but the dolomitization fluid was of marine-source, indicating that the model of dolomitization was seepage reflux. Both types of dolomites are partially affected by hydrothermal activities.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-5: Dolomite sedimentation: From modern processes to deep-time archives
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

The Role of Microorganisms in the Formation of Dolomite

1*

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Keywords: Microorganisms, extracellular polymeric substance, Functional groups

Dolomite [CaMg (CO3) 2] is formed in different environments, such as lakes, shallow water, salt water recirculation zone, regional hydrothermal burial and high-salt brine-seawater mixing zone (Warren 2000). Some people mentioned : ' No rock is more concerned than dolomite ' (Van Tuyl 1916), because the controversy surrounding the origin of dolomite is still ongoing, known as the ' dolomite problem ' (Kaczmarek et al., 2017) ; mcKenzie and Vasconcelos 2009 ; warren 2000). The ' dolomite problem ', which emerged more than a century ago (Van Tuyl 1916), highlights two important aspects of its mysterious origins : 1) dolomite is abundant in rock records but rarely in modern settings ; 2) Dolomite cannot be precipitated in laboratory when near-surface low temperature environments of dolomite are found in simulated nature (Fairbridge 1957, Machel 2004).

The role of microorganisms in mineral formation includes changing their microenvironment by changing pH values and redox potentials, thereby altering solution chemistry to facilitate mineral formation (Benzerara et al. 2011). Different functional groups in microbial extracellular polymeric substances (EPS) have adsorption characteristics and metal binding ability. The affinity of these functional groups to metals depends on the pH value that affects their protonation and deprotonation states (Wang et al. 2012). In addition, some microbial active ion exchange mechanisms accelerate the formation of minerals by increasing mineral supersaturation in their adjacent microenvironment (Obst et al. 2009). Minerals generated during biomineralization are called biominerals (Weiner and Dove 2003), including a wide range of minerals, including silicates, iron oxide / sulfides and calcium carbonate (Gadd 2010). The role of microorganisms in carbonate formation was reported in different environmental environments (Eriksson et al., 2010). Zhu and Dittrich 2016). The ability of microbial communities to control carbonate precipitation stems from the effects of microbial metabolism on carbonate alkalinity and carbonate mineral saturation (Dupraz et al. 2009).

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-5: Dolomite sedimentation: From modern processes to deep-time archives
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Geochemistry data and dolomitization as proxy of environment change during Tertiary

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Keywords: Depositional environments, Tertiary, Carbonate rocks, Dolomitization, Ca/Mg ratio, Iraq.

Change in depositional environments from marine to continental during Eocene to Pliocene has reflected by change in deposits from carbonate rocks to clastic sediments in Iraq. However, identifying different formations (Dammam, Jaddala, Ghar, Dibdibba, and Zahra), which are deposited in the southern Desert of Iraq seems to be difficult due to all of them contain the same type of rocks (carbonate rocks).

Geochemical data of sediment cores was successful employed to establish paleoenvironment, paleosalinity, and paleotemperature1. Thus, twenty-four cores, that contain Tertiary period, were collected from Al-Nasiriya project in the south of Iraq. The results show that the concentrations and ratios of some chemical elements are successful used to discriminate different depositional environments. The concentration average of SiO2, Al2O3, Fe2O3, TiO2, Na2O, K2O, P2O5, and Cl was increased from lower to upper part of the sequence of Tertiary, which indicates change in depositional environment from marine in Dammam and Jaddala formations to continental in Dibdibba Formation. Conversely, the concentration average of calcium, magnesium oxides and loss on ignition for these different formations show inverse patterns comparing with other oxides. Moreover, the ratio of Ca/Mg in carbonate rocks demonstrates that ratio is significant increased with change in these formations upward. The average of this ratio was 2.36 in carbonate rocks belong to Dammam Formation, 12.03 in carbonate rocks belong to Jaddala Formation, 18.84 for Ghar Formation, 17.47 for Dibdibba Formation.

The decreasing in MgO values and increasing in Ca/Mg ratio are agreed with change in age from older to younger for these formations. In addition, these changes in MgO and Ca/Mg indicate decreasing dolomitization from older to younger formations. Petrological study confirms that dolomitization in Dibdibba is the lowest compare with other formation, and it is the highest in Dammam Formation.

Therefore, geochemical data can be use accuracy to discriminate different lithologies, units, and formations although they are deposited in different or similar environments.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-5: Dolomite sedimentation: From modern processes to deep-time archives
Presentation Preference: Oral Preferred

Microbial dolomite in Cambrian stromatolites in the of Tarim basin, northwest China

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Keywords: Microbial mediated dolomite in Cambrian, the Tarim Basin, Cambrian seawater, reconstruction

The “Dolomite Problem” has always been one of the difficult and unsolved enigma in sedimentary, which has attracted the attention of Sedimentologists for over a century. This study focuse on microbial dolomites in Cambrian from the Tarim Basin in China, which is highlighted by both microbial tracers through time and/or as a proxy for microbial origin of dolomite and reconstruction of Cambrian seawater. On the basis of sedimentology, petrology, geochemistry and geomicrobiology, after the detailed field work, the results from high-resolution scanning electron microscopy, isotope geochemistry, trace elements, rare earth elements and PHREEQC are proven approach to the origin of microbial dolomite formation and paleo-environment parameters in Cambrian seawater.

Based on documented data, which are combined the microbial geochemistry conditions in bacterial culture experiments with the natural environmental conditions, microbial dolomite mechanisms are divided into two modes: the anaerobic and the aerobic modes, which is involved in sulfate-reducing bacteria, methanogenic Archaea and halophilic aerobic bacteria.The present is the key to the past. The particular morphological characteristics of microbially-mediated minerals and nanoglobule textures in initial nucleation stage preserved in the geological record may be one of the significant biomarkers.

Stromatolites and thrombolites are recognized as the two major components in the Middle and the Upper Cambrian. The microbial micro-facies combinations are indicated in peleaoenvironments for varying water depths and energy. Although the stromatolitic dolomites experienced burial, petrographic structures appear poorly affected by burial overprint, thus, may preserve potential textural, geochemical and isotopic signatures indicative of microbial tracers and past environmental conditions.

Extracellular polymeric substance (EPS) binds different elements, with preference to Si, Mg and Ca and it is composed of fibres arranged in a reticular pattern, would favor epitaxial crystallisation of dolomite on an organic substrate. The concurrence of suitable composition favoured the mineralized microbes and the dolomite nucleation on the substrate.

Additionally, poorly crystallized dolomite formed nanocrystal aggregates preserved in stromatolites that strongly resemble the morphology and size distribution observed in microbial culture experiments. And the mineralogy is confirmed in micro scale in situ by Confocal Raman Microscopy Atomic Force Microscopy. The spherical dolomite, the diameter of 50 ~ 100nm, composed of small spherical dolomite within or between the dolomite crystals and some times they gathered together dumbbell-shaped and chain dolomite sized 50nm ~ 170nm. The palaeo-temperature during dolomite precipitation are calculated based on the temperature dependent fractionation factor between dolomite and water in cuture experiments. The palaeo-temperature of the stromatolitic laminae matches any assumed seawater temperature very well, which is indicative of penecontemporaneous dolomite formation in microbial mats. The boron isotopes of microbial dolomite gives a “ best guess” paleo-pH in Cambrian seawater. The pH value is approximately between 8.1 to 8.6, which is a slight more alkaline than the pH value of modern seawater. Based on microscope observation, paleo-pH, biological communities in micrboal mat, the high concentration of calcium in Cambrian seawater and REE patterns, in this case the dolomites precipitated in microbial mats and biofilms are mediated by aerobic bacteria rather than sulfate reducing bacteria.

Session T7-6: Carbonates on a changing Planet: from deposition to early diagenesis

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-6: Carbonates on a Changing Planet: From Deposition to Diagenesis
Presentation Preference: Oral Preferred

Characteristics and Genesis of Cambrian Mound shoal complex Reservoir In Tarim Basin, NW China

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Keywords: Platform margin,Mound shoal complex, paleo-karst carbonate reservoir,Cambrian,Tarim basin

Cambrian platform margin mound shoal complex was one of the most important hydrocarbon exploration fields in Tarim Basin with the distribution area exceeding 20000 square kilometers, which has strong heterogeneous characteristics and greatly complex reservoir properties. Based on outcrop, cores, thin sections, CT scanning, physical properties datas and geochemical datas, dolomite reservoir characteristics and its genesis of Cambrian platform margin mound shoal complex of Tarim Basin was revealed. Two new understandings have been put forward.

Firstly, according to observation of hundreds of rock samples, Cambrian platform margin mound shoal complex is carbonate uplift composed of various types of microbial dolomite and granular dolomite, which reservoir spaces is dominated by fabric selective reservoir space including dissolved cavities, intragranular dissolved pores, intergranular dissolved pores and biological mold holes, and also develop some none-fabric selective reservoir spaces including structural fractures and intercrystalline dissolved pores. The reservoir porosity ranges from 2.0%-15.2%, and CT scanning shows pore connectivity ranges from 58.9% to 91.8%.

Secondly, Cambrian platform margin mound shoal complex developed karst reservoir, which mainly related to atmospheric fresh water dissolution and vertical distribution has cyclicity. A large number of bedding dissolution, selective dissolution, biological mold pores and bottom showing structures directly indicated that the mound shoal complex reservoir experienced meteoric water dissolution, in addition, geochemical analysis also provide more sufficient evidencesuch as the value of ^{87}Sr / ^{86}Sr ranges between 0.7095 and 0.7108, which is significantly higher than the global Cambrian seawater valuehigh strontium isotopic value and light oxygen isotopic composition, enrichment of Mn and Fe, V / (V + Ni) < 0.46, Sr / Ba < 1 etc. . Sea level fluctuation cycle characterized by the stable $\delta^{13}C$ shows that the karst reservoir of mound shoal complex generaly developed at lower sea level, and the reservoir physical properties are better in the sea-level decline cycle.

Reference

The relationship between the development patterns of the Cambrian platform margin mound - shoal complex and paleogeomorphology in Gucheng areaTarim Basin

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-6: Carbonates on a Changing Planet: From Deposition to Diagenesis
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Frameworks and sedimentary models of microbial mounds and shoals in the second member of Dengying Formation, Sichuan basin

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Keywords: Sichuan Basin,Deng 2 Member,Microbial mound,Mound beach structure, Microfacies combination, Sedimentary model

Abstract: microbial mounds and beaches in the second member of Dengying Formation in Sichuan Basin are the focus of recent research and exploration, but the understanding of mound and beach structure and sedimentary model is not clear. Taking the typical outcrop profile of Dengying Formation as the research object, this paper dissects the structure of microbial mounds and beaches and establishes the sedimentary model of microbial mounds and beaches by means of profile measurement, thin section identification and UAV aerial photography modeling. The results show that: the main types of rock in the mound are laminated laminated dolomite, residual granular dolomite, breccia dolomite, crocus dolomite, foam dolomite, argillaceous dolomite and grape lace dolomite. Microbial mound can be divided into five microfacies: mound base, mound core, mound wing, mound flat and mound cover. The mound base is composed of laminated dolomite; The dune nuclei consist of dolomite, crocus dolomite and dolomite dolomite. The hill flank is composed of sandy gravel dolomite; The mound is composed of sandy dolomite and breccia dolomite; The dome is composed of laminated dolomite and micritic dolomite. There are four types of microbial mounds and shoals in Sichuan Basin, including Yangmu type, Gaojiashan type, Xianfeng type and Yangba type. Yangmu type microbial mounds and shoals are located in slope facies area, with a single mound and shoal thickness of 10-12m. The interior is dominated by 1-2 stages of mound core superposition development, and vertically is the microfacies combination of mound base, mound core and mound cover; Gaojiashan type microbial mounds and beaches are located in the facies area outside the platform margin and coexist with the front slope of the mound. The thickness of a single mound and beach is 18-22m. The internal mound and beach is superimposed and developed in 3-4 stages. Longitudinally, it is the microfacies combination of mound base, mound core, mound wing and mound flat; Pioneer microbial mounds and beaches are located in the inner belt facies area of the platform margin and coexist with the post mound lagoon. The thickness of a single mound and beach is 14-15m. The internal mound and beach is superimposed and developed in 2-3 stages. Vertically, it is the microfacies combination of mound base, mound core, mound wing and mound flat; Yangba type micro Hill Beach is located in the facies area within the platform and coexists with the platform. The overall performance is that the hill core and hill wing are alternately developed, and the thickness of a single Hill Beach is 11-13m. On this basis, the microbial mound and beach sedimentary model of denger member, Sichuan Basin is established.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-6: Carbonates on a Changing Planet: From Deposition to Diagenesis
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Geological features of slip accumulation in the Lower Cambrian Mantui Formation of the North China Craton Luxi Massif

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Keywords: Mantou formation, Collapse accumulation,Carbonatite

The lower Cambrian Mantou formation can be seen in Quantou village, Linqu County, Shandong Province. As a whole, the Mantou formation is a sedimentary assemblage of platform margin facies, and collapse accumulation is found in Quantou village. The overall thickness is 2m thick limestone, the bottom is cataclastic limestone, the upper lithology is purplish red shale with thin limestone, and the scratch with attitude of 265° 51°can be seen on the section with strike of 220°. Under the microscope, two-stage cracks can be seen. The formation of dark mineral filled cracks is earlier than that of calcite filled cracks, symmetrical folds can be seen at the top of collapse accumulation, and the limestone is "pinched out" as a whole, indicating that there were denuded steep slopes in the region or locally in the Cambrian, The discovery and study of collapse accumulation in Mantou formation is conducive to further understand the Paleozoic paleogeomorphology, sedimentary environment and the formation and evolution of ancient buried hills in North China platform, so as to provide reference for the study of Paleozoic petroliferous basins and buried hills in North China platform and the exploration of oil and gas resources.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-6: Carbonates on a Changing Planet: From Deposition to Diagenesis
Presentation Preference: Oral Preferred

Carbonate deposition in fluvial systems influenced by hot springs

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Keywords: fluvial carbonate, hot spring, sedimentology, fluvial erosion

Fluvial systems are often characterized by erosion or clastic deposition, but they can also form carbonates which are often termed 'fluvial tufas' (i.e. cold-water carbonates) or 'fluvial travertines' (i.e. hot-water carbonates). The lithofacies and facies association of the latter have been described and constructed based on fossil fluvial travertines, but studies about their modern counterparts are scant, limiting our understanding of fluvial travertines. Therefore, we here studied a modern fluvial travertine system at Bagni San Filippo (Italy) and compared it with reported fluvial travertines with the aim of disclosing processes affecting their deposition.

The depositional conditions of fluvial travertines were found to be very strict. Perhaps only rivers in mountainous terrain, which receive Ca^{2+}- and HCO_3^--rich waters from surrounding hot springs, can form fluvial travertine systems. This is mainly because travertine deposition depends on the flow path of hot spring water and without existing river beds regulating the spring water flow direction, travertine deposition would create other build-ups, like mounds, fissure ridges, and slopes.

Lithofacies compositions in fluvial travertine systems are diverse and complex. Carbonate facies, mixed clastic-carbonate facies, and clastic facies can be all observed and the specific lithofacies in different systems are controlled by the relative contribution of spring water to original river water: the higher contribution of spring water, the more abundant of carbonate facies.

Fluvial erosion may be common and unavoidable in fluvial travertine systems, since the fluvial travertine depositional areas are commonly mountainous areas and thus rainfall events can easily trigger flood events, eroding early formed travertine deposition and depositing clastic deposits. Such erosion is very notable in the studied Italian system and generated various erosional micro-landforms. The dominant erosion processes are abrasion and plucking, while dissolution and cavitation are also present.

Fluvial travertine systems can be divided slope-pool-waterfall subsystems and channel-pool-waterfall subsystems. Such subsystem differentiation is largely influenced by river bed geometry: wide and slightly inclined stream beds would yield widespread travertine slopes and associated slope-pool-waterfall subsystems and display high erosional resistance, while narrow stream beds would generate channels and associated channel-pool-waterfall subsystems and experience strong fluvial erosion.

Overall, this study shows that fluvial travertine deposition is controlled by topography, hot spring contribution, original river bed geometry, and fluvial erosion, and might aid in the interpretation of ancient fluvial travertine systems.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-6: Carbonates on a Changing Planet: From Deposition to Diagenesis
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Tectonic inversion of cratonic platform margin and its control on petroleum system—A case study of carboniferous in the eastern margin of PreCaspian Basin

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Keywords: Tectonic imversion, Carbonate plateform, Precaspian Basin, Carboniferous

The PreCaspian Basin is a super petroliferous cratonic basin developed on the Kazakhstan plate. Its eastern margin is adjacent to the Ural orogenic belt, and southeastern margin adjacent to the Tethys fold belt (Volozh et al.,2003; Jin Zhijun et al., 2007). Since the late Paleozoic, the southeastern margin of the PreCaspian Basin has experienced a geological history of stable cratonic platform deposition, evolution of Ural orogenic belt and closure of the Paleotethys Ocean, resulting in the present complex tectonic and sedimentary setting (Alexander, A.C,1999; Liang shuang et al., 2013).

In this paper, the tectonic evolution process of the Carboniferous system in the eastern margin of the PreCaspian Basin is reconstructed by the structural interpretation of the 2D and 3D seismic data and the combination of well-log and seismic data. Based on seismic facies analysis and layer flattening techniques, the favorable sedimentary-diagenetic facies zones such as platform reef, clastic beach and weathered karst zone were identified in comparison with the classical carbonate platform slope deposition models, and the tectonic and sedimentary model in the eastern margin of the PreCaspian Basin was established by structural and depositional reconstruction. The effects of Ural ocean closure and orogenesis on the eastern margin of the PreCaspian Basin is analyzed.

It is concluded that the eastern margin of the PreCaspian Basin underwent slope reversal, fold deformation, strike-slip transformation and differential uplift during the late Hercynian to Indosinian period, resulting in the hiatus, denudation. The hiatus of the Late Carboniferous were favorable to the formation of weathered karst reservoir facies. The tectonic inversion of platform margin carbonate ramp in late Permian was favorable to the formation of limestone shoal lithological reservoirs with updip occlusion. The large strike-slip fault zone is conducive to the formation of fault-fracture compound trap controlled by flower structure, which communicates with deep source rock. The tensional strike-slip fault zone developed in the southern uplift zone is conducive to the formation of fault solution and improves the deep reservoir conditions. Our study reveal the influences of Ural ocean closure and orogenesis on the sedimentation and tectonic deformation of the carbonate ramp of the carboniferous in the PreCaspian cratonic basin, and provide scientific references for the prediction of oil and gas exploration prospects in this area.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-6: Carbonates on a Changing Planet: From Deposition to Diagenesis
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Spatial and stratigraphic distribution of sedimentological and diagenetic features of an Aptian Pre-Salt carbonate reservoir of the Santos Basin.

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Keywords: Pre-salt, Santos Basin, Lacustrine carbonates, Diagenesis, Dolomitization

Aptian carbonate rocks of Santos Basin, in the Brazilian southeastern continental margin, show reservoir quality strongly controlled by the characteristics of the depositional environment and associated diagenetic alterations. This study presents a quantitative approach based on petrography, mineralogy, and geochemical data of the Barra Velha Formation to integrate spatial and stratigraphic distribution of sedimentological and diagenetic aspects and provide insights into the parameters controlling the genesis and distribution of the diagenetic phases of Pre-Salt carbonate reservoirs of Santos Basin.

The Barra Velha Formation consists of a heterogeneous mix of in-situ and reworked grains. The in-situ facies are composed of fascicular calcite (shrubs), spherulites, microcrystalline calcite, and clay minerals, whereas the reworked facies present different proportions of shrubs and spherulite fragments, siliciclastic/volcanoclastic grains, and variable clay content. The facies with higher Mg-clay content predominate in lower structural positions and regions with low relative relief. Higher proportions of spherulites occur in the transitional zones, and fascicular calcite occurs preferentially in the transitional and higher structural positions. Grainstones facies are observed in all depositional environments, but with variations in their composition (intraclasts, siliciclastic/volcanoclastic grain, and clay content). Stratigraphically, facies with higher Mg-clay content predominate in Units 3 (base) and 2 (intermediate), whereas Unit 1 (top) is marked by a greater proportion of grainstones and fascicular calcites. In Unit 1, fascicular calcite crusts tend to expand from the structural high, toward lower areas.

The main diagenetic products and their association with different facies, highlight the roles of depositional setting and primary constituents in the diagenetic processes. The tectonic and climatic context of the BVF favored Mg-clay precipitation that accumulated preferentially in lower structural portions of the basin. Mg-clays also show a preservation pattern strongly linked to the structural setting, with higher structural portions and fault zones more susceptible to their major diagenetic alterations. Dolomite is a major diagenetic phase in the studied samples, followed by silica. These diagenetic phases are largely associated with Mg-clay alteration and predominate in Unit 1. The dissolution of Mg-clays, as well as a major alteration of the carbonate phases, are concentrated in higher structural positions. Given the higher occurrence of faults in these areas and the presence of saddle dolomite, barite, celestine, and fluorite, which are typical products of hydrothermal alteration, part of the dissolution processes may be related to hydrothermal alteration. The depositional and diagenetic aspects indicate a close connection between the hydrochemical evolution of the lake waters and the origin and diagenesis of these deposits.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-6: Carbonates on a Changing Planet: From Deposition to Diagenesis
Presentation Preference: Oral Preferred

The depositional evolution and reservoir origin of Upper Cretaceous Cenomanian Mishrif Formation, SW U.A.E

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Keywords: Cenomanian Mishrif Formation, deposition evolution, bioclastic grain bank, reservoir origin, SW U.A.E.

The Upper Cretaceous Cenomanian Mishrif Formation carbonates are the most important hydrocarbon exploration targets in the Arabian Gulf, such as offshore U.A.E., Oman, and southeastern Iraq. The Mishrif Formation could be subdivided into three members, that is, Member Mishrif-1 (M-1), Mishrif-2 (M-2) and Mishrif-3 (M-3) form bottom up according to the lithology and well log data. Based on the seismic, well log data, core description and thin section analysis, it is a weakly-rimmed carbonate shelf in the age of M-1 and M-2, including open platform, platform margin and slope in sedimentary facies. but the depositional evolution and reservoir origin are still questions in SW U.A.E..

The Mishrif Formation reservoirs have undergone complex diagenesis. The diagenesis sequence is as follows: grainstone- micritization- seawater cementation- freshwater dissolution- freshwater cementation- compaction- the first stage of fracture- shallow burial cementation- the second stage of fracture- mid burial cementation- hydrocarbon injection- burial dissolution- latest calcite filling under CL analysis. The dissolution related to the freshwater in pene-contemporaneous stage and hydrocarbon injection in late Oligocene to mid Miocene is responsible for the reservoir formation and retention.

The diagenesis fluids are seawater modified by freshwater, according to major and trace elements, C-O isotope, Sr isotope and fluid inclusion analysis. The major elements of Na, K, Mn, Fe, Sr, Zr, Ti, and U-Th are 0-0.6ppm, 0.1-0.4ppm, 0-50ppm, 0-2ppm, 300-600ppm, 0.5-0.6ppm, 5-20ppm and 0.2-1.5ppm, respectively, in moldic grainstone and grainstone while 1-2ppm, 0.2-0.8ppm, 50-100ppm, 1-8ppm, 400-500ppm, 0.8-2ppm, 20 -40ppm and 1.6-4ppm in mudstone and wackestone. In contrast to the mudstone and wackestone, the moldic grainstone and grainstone are less in elements Na, K, Mn, Fe, Zr, Ti, and U-Th, which indicate the involvement of freshwater and seawater. The ΣREE value of moldic grainstone is 0.55-17.97ppm, and have relatively consistent distribution patterns of REEs with mudstone, with strong LREE enrichment, which means seawater influence in diagenesis fluids. Moreover, δ13C values range from 2.57‰ to 5.34‰, and δ18O values is from –5.33‰ to -8.81‰, within 18 samples. These carbon stable isotope values are positive and oxygen stable values are negative comparison with the C-O isotopic composition of Cretaceous seawater, with a range from 0‰ to 2.3‰ for δ13C and from −1.3‰ to −4.0‰ for δ18O (Veizer et al., 1999), showing the evaporated seawater modified by freshwater in the diagenesis system. The 87Sr/86Sr ratios for the Mishrif Formation range from 0.707279 to 0.707569 (average 0.707466), close to or slightly positive to the estimated 87Sr/86Sr ratio range (0.70725-0.7075) for Cretaceous seawater (Veizer et al.1999), suggesting the freshwater involvement in seawater. The homogenization temperatures of 19 fluid inclusion analysis are 55°C to 85°C, mostly in the range from 80°C to 85°C and the freezing temperatures are from -12°C to 0°C, with -6°C to -4°C in majority. And the salinity of the fluid inclusions is from 2% to 16%, with 3 samples less than 3%, indicating the freshwater influence. In a word, the Cenomanian Mishrif Formation reservoirs are the complicated products of skeletal grain bank, dissolution resulting from the pene-contemporaneous stage freshwater and hydrocarbon injection.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-6: Carbonates on a Changing Planet: From Deposition to Diagenesis
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When is the Mixing-Zone, not the Mixing-Zone?

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Keywords: Diagenesis, Clumped Isotope,Mixing zone

The Allan and Matthews [1] model, widely used to interprete variations in the $\delta^{13}C$ and $\delta^{18}O$ values of diagenetically altered carbonates, predicts that the covariance between C and O isotopes seen in many young carbonate sequences reflects alteration in fluids that represent mixtures of freshwater (with isotopically negative $\delta^{13}C$ and $\delta^{18}O$ values) and marine waters (with relative more positive values). However recent reinterpretations of this zone of covariance, based on the known changes of sea level and the position of the zone of covariance relative to this change, suggests that the region in which the $\delta^{13}C$ and $\delta^{18}O$ values are strongly correlated actually occurs within the freshwater phreatic zone[2], rather than the mixing zone. In order to distinguish the driving force of diagenesis, from the potential product of diagenesis, we suggest that such trends be termed the zones of covariance, rather than mixing zone trends. If the interpretion of Swart and Oehlert [2] is true, then all the alteration and precpitation of low-Mg calcite, is taking place in meteoric waters, with a greater amount in upper portion of the zone and a decreasing proportion lower in the zone of covariance. It follows therefore that the $\delta^{18}O$ values of the fluids forming the calcite cement will be the same throughout the zone of covariance. This concept can be tested through the use of clumped isotopes, a technique that independently measures the temperature of formation, and can in conjunction with the conventional measurement of $\delta^{18}O$ values, be used to determine the $\delta^{18}O$ of the fluids. In order to test this notion we analyzed the Δ_{47}, $\delta^{13}C$ and $\delta^{18}O$ values and the mineralogy of carbonates throughout several cores in which the $\delta^{13}C$ and $\delta^{18}O$ values of bulk carbonates show clearly defined trends from isotopically negative to more positive values. These results will be discussed in this presentation.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-6: Carbonates on a Changing Planet: From Deposition to Diagenesis
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Carbonate sediment dynamics in the lagoon of Abu Dhabi (UAE): Natural patterns and anthropogenic influence

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Keywords: The Gulf, epeiric sea, carbonate grain, facies distribution

The Gulf is well known for its actualistic sabkha and carbonate depositional environments, but it is also one of the fastest developing regions globally. A shallow-water ramp characterises the southern coastal Gulf with widespread carbonate deposition typified by a series of lagoonal to open marine facies. Previous work compared this setting, specifically the lagoons of Abu Dhabi, with the coastal portions of ancient epeiric seas. To the present day, however, the details of the complex spatial facies distribution and their related sediment particles in the Abu Dhabi lagoons are only in part understood. Here, we present the outcome of a study aiming to provide quantitative data on unconsolidated carbonate sediment components and their spatial and environmental distribution in this region. Data on sediment size, sorting and component analysis of 105 samples are presented. Sediment particles were analysed under a binocular microscope and grouped as bioclasts, lithic clasts, ooids, peloids, micritic sediment and non-carbonate particles. Grain size analysis shows a limited relationship with water depth but a distinct correlation with energy. Sediment samples, collected along a seaward (relatively high energy) to landward (low energy) transect display decreasing grain size. Sorting is typically related to the grain type and depositional setting. Ooid shoals are dominated by very well-sorted and very coarse to coarse ooid sands. Ebb delta lobes, ebb channels and shoreface settings are mainly characterized by well to moderately well-sorted and coarse to medium sized lithic clasts. Mixed bars and relatively deep-water outer lagoon settings are characterised by bioclasts and lithic clasts. Samples collected from mixed bars, affected by current, are typically moderately sorted medium arenitic bioclasts. The sediments from portions of the outer lagoon are rich in lithic clasts and higher concentrations of micrite are present in embayments. Under decreasing hydrodynamic levels, particularly in the middle and inner lagoon, sediments are dominated by poorly sorted medium to fine grade arenites. The abundance of finer-grained micrite increases towards mangrove swamps and islands, reflecting ‘protected waters’ with low energy conditions. Due to higher hydrodynamic levels in the dredged channel systems, sediments of the middle lagoon are moderately well sorted arenitic lithic clasts and peloids. Dredged channels, and other areas with the significant anthropogenic activity of the inner lagoon record a distinct increase of clastic material.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-6: Carbonates on a Changing Planet: From Deposition to Diagenesis
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Development and distribution of lacustrine carbonate deposits in the Basin and Range, USA: Impact of climate, tectonics and substrate

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Keywords: Endorheic Lakes, Basin and Range, Microbialites, Lahontan, Great Salt Lake/Lake Bonneville

The Basin and Range hosted several continental lacustrine systems that accommodated extensive microbial carbonate deposits: the Lahontan on the western side (since 48 kyr cal BP) and the Bonneville (from 30 to 11.5 kyr cal BP) and Great Salt Lake (since 11.5 kyr cal BP) on the eastern side. While the eastern domain of the Basin and Range shows a transition from freshwater to hypersaline conditions, the western domain does not show any significant change from the originally freshwater conditions. Mapping and characterization of microbial deposits in both domains allows for a comparison between the different lakes and their specific spatial distribution. The morphology, size and distribution of the carbonate deposits is mainly affected by environmental changes (i.e., seasonal to long-term water level fluctuations, particular geomorphological heritage, fault-induced processes, groundwater seepage, substrates) and have the potential to provide further insights into the reconstruction of paleoenvironments and paleoclimatic changes through time. Although all the lakes show a paleoshoreline distribution of some microbial-rich structures (crusts, hemispheroid, and part of domes) related to climatic-induced lake level variations, the presence of columns and complex domes in the western Basin and Range seems related to groundwater influxes. In the west, the Winnemucca and the Pyramid Lakes, with extensive springs on the flexural margin and along faults generate bigger structures than the ones observed in the eastern Basin and Range lakes. The presence of large size of thinolites, domes, and columns in the western side of Basin and Range appears to respond to local hydrological, fault-related processes and groundwater flows. This contrast in the distribution, composition, and size of the microbial deposits between both sides of the Basin and Range suggests changes in chemistry, physiography and meteoric/groundwater influxes. Furthermore, this work provides a novel model for the formation of abiotic carbonates in lacustrine settings and identifies the role of microbialites to store carbon.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-6: Carbonates on a Changing Planet: From Deposition to Diagenesis
Presentation Preference: Oral Preferred

On the formation of reefal microbialites

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Keywords: No

Precambrian reefs were sustained by microbial primary production, forming stromatolitic and thrombolitic lithologies. During the Phanerozoic, microbial activity persisted in reef ecosystems, yet microbial carbonate became an accessory component of most reef bodies. Exceptions are bioherms and reefs that formed during periods of major environmental perturbation like the earliest Triassic, the time after the end-Permian extinction event, when microbial mats regained a key role in shaping reef ecosystems. However, in spite of an overall Phanerozoic decline of the abundance of microbial carbonate in reefs, in concert with large, transient fluctuations, microorganisms have always been an integral component of reef communities and have contributed to carbonate production. The two main factors held responsible for the abundance of microbial carbonate in reefs are the carbonate saturation state of seawater and the diversification of metazoan. Here, I will look into the mechanisms of how microorganisms, in particular members of the bacterial domain, contribute to the production of carbonate in reef ecosystems. Although cyanobacteria are expected to contribute to carbonate production – through photosynthetic carbon dioxide removal and the interaction of solutes with extracellular polymeric substances – the great majority of geochemical evidence suggest that sulfate-reducing bacteria are the key players of microbial carbonate production in reefs. One factor that may explain such heterotrophy-driven carbonate production is the circumstance that the majority of microbial carbonate has formed within crypts of the reef framework.

Reference
No

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-6: Carbonates on a Changing Planet: From Deposition to Diagenesis
Presentation Preference: Oral Preferred

Carbonates between early Archean pillow basalts – important archives for reconstructing early Earth's environments

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Keywords: Early Archean, carbonate, REE, Sr isotopic composition

Early Archean carbonates from the Pilbara Craton (Western Australia) occur in a variety of facies, including ca. 3.5–3.4 Ga pillow-basalt interspace carbonates (North Star Basalt, Mt. Ada Basalt, Apex Basalt, Euro Basalt), ca. 3.5 Ga hydrothermally formed bedded chert-carbonates (Dresser Formation), and ca. 3.4 Ga dolomitic stromatolites (Strelley Pool Formation). The carbonates exhibit variable mineralogies, ranging from calcite, through dolomite, to Fe/Mn-rich dolomite (ankerite/kutnahorite). Previous work suggests that the Pilbara carbonates were formed via the following pathways: 1. Abiotic precipitation (interstitial carbonates between pillow basalts); 2. Organomineralization (fine-grained sedimentary carbonates in the Dresser and Strelley Pool Formations as well as carbonate crystals in bedded cherts of the Dresser Formation); 3. Microbially mediated mineralization (stromatolites in the Strelley Pool Formation). Abiotically precipitated carbonates within pillow basalts appear particularly interesting as these records provide valuable insights into environmental conditions and oceanic crust alteration processes on the early Earth. Primary acicular crystal-fans consisting of Mn-rich calcite likely precipitated abiotically from seawater with increased alkalinity as indicated by $\delta^{13}C_{VPDB}$-values (ca. 0±1‰), $^{87}Sr/^{86}Sr$ ratios (0.701795–0.704657), and characteristic REE+Y signatures (LREE-depletions, positive La and Eu anomalies, superchondritic Y/Ho ratios). Their relatively high contents of Mn , Mg and Fe can plausibly be explained by the hydrothermal alteration of the associated basalts, which is well in line with other geochemical characteristics such as relative MREE-enrichments, positive Eu anomalies, and elevated $^{87}Sr/^{86}Sr$ ratios. It seems plausible that the formation of these carbonates was directly linked to intense pumping of seawater through the oceanic crust, and that this process was a significant sink for CO_2 during Archean times. This brief review highlights the meaning of abiotically precipitated carbonates for reconstructing environments, hydrothermal alteration processes, and geochemical cycles on the early Earth.

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Session T7-6: Carbonates on a Changing Planet: From Deposition to Diagenesis
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Dynamic balance of extracellular polymeric substances and degraded organic matter in forming ooids

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Keywords: organic matter, organomineralization, mineralization, laminae, solution saturation

Widespread ooids throughout most of Earth's history have attracted much attention for a long time, especially in the last 50 years. Nevertheless, their formation mechanisms in terms of abiotic or biotic influences remain disputed. Possibly, not just one way of forming ooids exists. The role of organic matter (OM) in forming ooids is investigated herein, differentiating extracellular polymeric substances (EPS) and degraded OM (independent of the living organisms which it derives from) (Suarez-Gonzalez & Reitner 2021). Triassic and modern ooids have been studied, from the Germanic Basin and Great Salt Lake, respectively, because both are extremely comparable, suggesting similar formation processes (Reitner et al. 1997; Pei 2022). By applying analytical petrography and imaging technique, four types of ooids in both places are distinguished based on cortex. Type A is dominated by radial cortex with indistinct growth lines while type B is dominated by tangential cortex with distinct growth lines. Type C is a mixture of both radial cortex and tangential cortex. Type D is an alternation of radial cortex and tangential cortex. Besides, some compound ooids containing several cores are observed. Radial cortex of the ooids grew into the above Triassic stromatolites, confirming that some ooids could form associated with microbial mats or even within them. Our results suggest that the dynamic balance of EPS and degraded OM shapes the ooid types described. When degraded OM controls mineralization (i.e. organomineralization), radial cortex forms, probably because OM has a relatively weak inhibition of precipitation and there is an increased calcium carbonate saturation. The tangential cortex has closer association with EPS (with stronger inhibition of carbonate precipitation), than the degraded OM involved with radial cortex. The process of exactly how OM interacts with Ca^{2+} to form radial or tangential cortex is so far not fully understood. In the near future, OM, including different varieties of amino acids (proteic material) and polysaccharides should be extracted and characterized to carry out experiments.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-6: Carbonates on a Changing Planet: From Deposition to Diagenesis
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Experimental study on bio-induced hydromagnesite mineralization in Bangor Lake, Tibet

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Keywords: Hydromagnesite,Bangor Co,Biogenic

Bangor Co is an inland salt lake in the northern Qinghai-Tibet Plateau with reserves of more than 50 million tons of carbonate (mainly hydromagnesite), and microalgae are widely developed in the lake. At present, there are two main understandings on the formation of natural hydromagnesite: evaporative depositional origin and biological origin. Combined with previous research on the preparation of hydromagnesite in the laboratory, it is found that it is difficult to form huge carbonate reserves under the natural conditions of high altitude in Bangor Co. Therefore, it is speculated that the formation of Bangor's Carbonate may be related to the microalgae in the lake. Based on the above speculations, this study investigated the relationship between the life activities of microalgae and the genesis of Bangor Co hydromagnesite by conducting indoor hydromagnesite crystallization experiments and comparative experiments with or without microalgae natural crystallization. The study found that it is difficult to form hydromagnesite under natural evaporation conditions; Bangor Co microalgae are closely related to the formation of large carbonate reserves in lakes, and microalgae can significantly increase the pH of water (up to 10.564) through photosynthesis , while inducing crystallization and precipitation of carbonate minerals at the nodes of the microalgal network. Therefore, this study confirms that the life activities of Bangor Co microalgae are closely related to the formation of carbonates in the lake.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-6: Carbonates on a Changing Planet: From Deposition to Diagenesis
Presentation Preference: Oral Preferred

Elucidating the role of microbial metabolisms in the formation of biogenic carbonates produced by marine fish

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Keywords: fish, carbonate, microbiome, isotopes, geochemistry

Carbonate precipitates formed in the intestines of marine fish comprise a significant component of the sedimentary budget of tropical, shallow marine environments. These biologically-mediated precipitates, called ichthyocarbonates, are formed in the intestines of marine fish as a result of their strategy to maintain internal salt and water balance. However, despite the early recognition of co-occurring microbial communities, the role of microbes in the formation of ichthyocarbonates remains unclear. Motivated by this uncertainty, we investigated the impacts of fish- and microbe-based contributions to the formation of ichthyocarbonate. In this study, we conducted tank collection of ichthyocarbonate excreted by the Gulf toadfish (Opsanus beta). Geochemical analysis of ichthyocarbonates from the Gulf toadfish revealed that they are composed of up to 7.5% organic carbon. The average $\delta^{13}C_{org}$ value of the embedded organic matter in ichthyocarbonates was -19.3‰ V-PDB, approximately 1‰ higher than co-occurring fecal pellets. CN ratios of the organic matter preserved within ichthyocarbonate ranging from 6.48 to 9.94, consistent with published ranges for both marine bacteria and fish fecal pellets, demonstrating the need for alternative geochemical approaches to quantify contributions from fish and the intestinal microbiome. Petrographic analysis revealed that ichthyocarbonates are composed of micritic carbonate with evidence of microbial cells occurring throughout the micrite, suggesting that ichthyocarbonates originally formed in intimate association with organic matter and microbial cells. Results of initial 16S rRNA gene sequencing indicate that ichthyocarbonates are associated with a diverse assemblage of microbes employing various metabolic pathways, dominated by Vibronaceae, including *Thaumasiovibrio, Photobacterium,* and *Vibrio spp*. In addition, *Desulfovibrio*, a known sulfate reducing microbe implicated in the precipitation of carbonate in other microbial systems was identified. Thus, our initial data from Gulf toadfish ichthyocarbonates suggest that microbial communities are not solely colonizing the exterior of ichthyocarbonates prior to excretion and may play a role in their formation. In concert, these integrative approaches provide new insight into the complex biogeochemistry of ichthyocarbonate formation and highlight the need for further study of the interplay between fish and microbial community influences on the sedimentary record in shallow marine settings through geological time.

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Session T7-6: Carbonates on a Changing Planet: From Deposition to Diagenesis
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Quantifying Sediment Generation Dynamics in a Modern Ooid Tidal Channel: Joulter Cays, Great Bahama Bank

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Keywords: Carbonates, Ooids, Factory, Photosynthesis, Ocean Chemistry

Spatial and temporal changes in sediment factory outputs are one of the primary drivers of facies variability within shallow-water carbonate systems. In concert with sediment transport and deposition, fluctuations in sediment production also plays a key role in determining levels of accommodation filling across carbonate platforms. Despite this, relatively few studies focus on quantifying carbonate sediment production; this study addresses this paucity of data by providing quantitative insights into the dynamics of ooid production within the Joulter Cays grainstone factory on northern Great Bahama Bank.

Four submarine-environment monitoring stations (SEMS) were anchored within an active tidal channel for 8 days in April 2019. This array recorded pH, conductivity, water depth and dissolved oxygen levels along a 3.26 km flow path between the open ocean and stabilized sand flat regions of the sand body. Local weather conditions (barometric pressure, temperature, light levels) were monitored from a nearby island. Ocean water samples were drawn from each SEMS site on a near-hourly basis, over the course of a single daytime floodtide. These samples were filtered, analyzed for pH, and titrated for alkalinity within 24 hours. The results were used to calculate the full carbonate system chemistry using the CO2sys ocean chemistry code. Surficial sediments were collected at each SEMS site along a transect perpendicular to the tidal channel axis. A sonar sounding survey was also conducted for the tidal channel to calibrate a high-resolution bathymetry map generated from SPOT satellite imagery.

Results estimate a maximum calcium carbonate precipitation rate of c.7.5 mg CaCO3 per liter of seawater during the observed flood tide and identify two distinct mechanisms that together, maximize ooid formation within the sand body: (1) CaCO3 precipitation from low-residence, high alkalinity waters, delivered from the open ocean and (2) photosynthetically-induced precipitation from long-residence time, tidally recycled, low alkalinity waters. Sediments collected at the outboard SEMS site contain the largest (350-400 µm), most polished, and most spherical ooids with the least evidence of microbial boring, suggesting that here is where growth is most active. Inboard sediments show mean grain sizes below 100 µm and are dominated by peloids and skeletal fragments which may form ooid nuclei.

Results highlight some important complexities associated with where, how and why sediment production occurs within carbonate environments. These complexities are a key driver of facies variability within carbonate platforms, shelves, and reservoirs.

ID: T7-111827

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-6: Carbonates on a Changing Planet: From Deposition to Diagenesis
Presentation Preference: Oral Preferred

Petrography and biotic/abiotic precipitation of freshwater- spring carbonates in modern caves: example from India

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Keywords: spring carbonate, modern cave, petrography, biocalcification, bacteria, algae

This study investigates the different biotic and/or abiotic mechanisms of precipitation of calcium carbonates in modern spring/tufa system, northeast India. Spring related carbonates hold valuable repositories of information on different mechanisms of biocalcification. A first-time expedition to Mahakal caves near Jayanti, West Bengal, India has been carried out to document and study the stalactite samples. Different stalactites were observed of all forms and shapes. Sample J-2 was collected in an in-situ environmental condition at Dark Zone with Constant Temperature (DZCT), resembling cylindrical shape, converging downward. Sample J-5 was collected at entrance zone (EZ), having irregular shape. Cylindrical, elongated, rod-like stalactites were observed hanging from the cave ceiling. Well preserved architectural structures having alternating laminae/band of mixed calcite and/or aragonite were observed. Petrographical study under microscope reveals evidence in support of neomorphic processes through different mineralogical fabrics and morphologies, along with variations in laminae thickness. Calcified rock sample J-4 was collected from the waterfall cascade along the cave wall. Precipitation of minerals from water dripping is facilitated by different biotic activities. Water sample was also collected to decipher geomicrobiological aspect especially, the diversity of bacteria and algae. Macro-algae, micro-algae and diatoms were observed as well as bacteria were also isolated from stalactite sample to carry out calcite induced experiments in laboratory. The microscopic observation showed Cladophora spp. (macro-algae) filamentous and branched-in nature. Lyngbya (cyanobacteria) and Chlorella spp. (green micro-algae) were also identified. Diatom mainly Navicula spp. was observed during microscopic examination of the same sample. The bacterial sample were isolated after bringing spring water to lab on nutrient agar media. Both gram positive and gram-negative species were present. Morphological features of bacteria such as shape, size surface, color, opacity, elevation and margin were noted after isolating on nutrient agar media. In this research, we have mainly focused on diversity of algae and bacteria and their role in biocalcification.

Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies

ID: T7-70032

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Oral Preferred

Sedimentary facies evolution and gas reservoir development model of carbonate platform reef-shoal deposits: a case study of the Changxing Formation and the Feixianguan Formation in the Kaijiang Liangping Trough, eastern Sichuan Basin, China

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Keywords: Reef-shoal, Gas reservoir, Changxing Formation, Feixianguan Formation, Sichuan Basin

Large and medium-size gas fields have been discovered in the platform margin reef-shoal deposits around the Kaijiang-Liangping Trough. In the study area, the Upper Permian Changxing Formation with eight gas reservoirs and the Lower Triassic Feixianguan Formation with fourteen gas reservoirs have declared proven reserves of 477.6×108 m3 and 2084.66×108 m3, respectively. Although the reef-shoal gas resrvoirs of the Kaijiang-Liangping Trough have a great potential, the distribution and prediction of favorable gas reservoir areas is still facing many challenges. Furthermore, the main controlling factors of reef-shoal gas reservoir differences in both sides of the trough lack detailed study. Therefore, it is of great significance to conduct research on reef-shoal sedimentary facies evolution, reservoir distribution, and main controlling factors of gas reservoirs on both sides of the trough. Based on the high-frequency sequence stratigraphic division, the observation of field outcrop profiles, cores, and microscopic thin sections, as well as the interpretation of 3D seismic sections, the sedimentary microfacies evolution and gas reservoir model, as well as a prediction map of favorable reservoir areas were established. In accordance with the interfaces of lithological and facies transition, exposure of unconformity, and electric mutation the Changxing Formation and the Feixianguan Formation were both divided into two third-order sequences and further subdivided into five fourth-order sequences. The studies conducted on the sedimentary facies types and characteristics revealed that the Changxing Formation is dominated by marginal carbonate deposits which are composed of various types of platform including fault-controlled steep slopes, sedimentary steep slopes, and relatively gentle slopes. The determination of the distribution of reef and shoal deposits on both sides of the trough showed that: (1) SQ1 and SQ2 both developed reef and shoal deposits on the West and East sides of the trough with the reef main development occurring in SQ1; (2) the reef bodies on the western side of the trough are of large scale compared to those of the eastern side which are smaller, more uniform, and better connected; (3) the reefs on the west side of the trough mainly accumulate vertically and the platform margin belt on the east side of the trough tends to regress into the platform. The results of this study show that, tectonic paleogeomorphology controls the stage and scale of reef-bank development, and sea-level fluctuations control the superimposed pattern of reef-bank deposits. Furthermore, primitive structural paleogeomorphology and sedimentary background determine the material basis of reef-shoal facies reservoirs, and early exposure dissolution and dolomitization play an important constructive diagenesis effect on reservoir development. The gas reservoirs on the east side of the trough are mainly controlled by reservoir thickness, porosity and permeability, and reservoir heterogeneity. This research clearly investigates the type and characteristics of reef-shoal gas reservoirs around the Kaijiang-Liangping Trough to contribute in the process of high-efficiency and precise development of gas fields in the eastern Sichuan region.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Oral Preferred

Characteristics and genetic mechanism of middle Permian Qixia Formation dolomite in Western Sichuan Basin

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Keywords: western Sichuan Basin, middle Permian, Qixia Formation, dolomite, characteristics, genetic mechanism

Recently, oil and gas breakthroughs have been made in the middle Permian Qixia Formation dolomite reservoir in Western Sichuan Basin. However, they are highly inhomogeneous and the dolomitization mechanism is not clear, which makes it difficult to predict the distribution of high-quality dolomite reservoir. In this study, the lithological and geochemical characteristics of different dolomite types in Qixia Formation in Western Sichuan were comprehensively analyzed. Combined with sedimentary facies and thermal events of Emeishan Large Igneous Province, the action periods and genetic mechanism of different dolomite types were systematically summarized. The results show that the dolomite of Qixia Formation in Western Sichuan is mainly porphyritic dolomite or stratified, and the dolomite is mainly fine grain, followed by medium coarse grain, micrite and saddle dolomite cements. Micrite dolomite is mainly developed at the bottom of the Qixia Formation, mostly stratiform or laminar, porphyritic as well. It is mainly subhedral-anhedral crystal, often accompanied by strawberry pyrite. Some micritic dolomite are sphaerolitic, dumbbell morphology, cauliflower morphology. The δ13CV-PDB values are negative, and δ18OV-PDB values are in the range of normal seawater. These characteristics suggest that micrite dolomite may be produced by microbial-mediated process. Fine crystalline dolomites are developed in both the first and second member of Qixia Formation, generally porphyritic or stratiform, which are mainly euhedral to subhedral crystals with mist-centered bright-edge structure and brown-dark red inside to bright red outside under cathode luminescence. Fine crystalline dolomites have obvious residual grain structure, indicating that the original lithology is grainstone. The δ18OV-PDB values, δ13CV-PDB values and 87Sr/86Sr values of fine crystal dolomites indicate that the dolomitization fluid is seawater, which may be formed by reflux seepage dolomitization with medium salinity during shallow burial period, and often developed in beach reservoirs with good porosity and permeability. The middle-coarse crystalline dolomites mainly develop in the second member of Qixia Formation, which is porphyritic or stratiform, mainly anhedral nonplanar crystals, and mainly dark inside to bright outside under cathodoluminescence. The δ18OV-PDB values are slightly lower than the normal sea water range, indicating that it has been modified by later fluids. The 87Sr/86Sr values of some middle-coarse crystalline dolomites are higher than seawater of the same period, and they are porphyritic or zebra-like, often accompanied by saddle dolomites in vugs. These characteristics indicate that they are directly influenced by thermal fluids of deep clastic rocks. The 87Sr/86Sr values of middle-coarse crystalline dolomite, which are still in the seawater range without saddle-shaped dolomite, may be derived from recrystallization or thermal adjustment of fine crystalline dolomite. In general, the dolomites of Qixia Formation in Western Sichuan Basin have successively undergone syngenetic microbial-mediated dolomitization, shallow burial reflux seepage dolomitization, and late thermal fluid modification, among which shallow burial reflux seepage dolomitization is the main genetic mechanism.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Research on sedimentary compensation and diagenetic transformation mechanism of lacustrine carbonate rocks in gentle slope platform

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Keywords: Santos Basin, lacustrine carbonate rocks reservoir, carbonate platform,sedimentary compensation mechanism,diagenetic transformation mechanism

The deep-water pre-salt lacustrine carbonate rocks reservoir of Brazil is neither of these margin origin nor has the characteristics of lacustrine basins in China, instead, it is formed into a lake by plate tension and rift, featuring deep water and mesa with gentle slope. Due to the existence of multi-stage lake flooding and unconformity, rapid change of sequence boundary, basement tectonic activity, frequent lake transgression and other factors, the paleogeomorphic changes are significant, which leads to a drastically differential sedimentary compensation mechanism in carbonate plateform. Besides, the development of sequence transformation and the spatial-tempral pattern of paleogeography lead to the intensification of diagenetic transformation under the control of sedimentary model, resulting in technical bottlenecks such as complicated reservoir controls genesis and unclear relationship between reservoir and oil deposit. However, there has been no in-depth study on its sedimentary compensation and diagenetic transformation mechanism. Based on the relationship between the base-level change and the accommodation space of the lake basin, this paper will clarify the sedimentary compensation mechanism and the change process of the paleogeomorphology, and describe the distribution of paleogeography in the sequence transformation mode, and then establish the sedimentary model of the huge thick lacustrine carbonate rock. Furthermore, it is necessary to analyze the complex sedimentary diagenesis of lacustrine carbonate rocks by integrating the main controlling factors of reservoir development, and jointly analyze the diagenetic transformation mechanism of forming hige-quality reservoirs. This study will not only have theoretical significance for the understanding of sedimentary compensation mode and diagenetic transformation mechanism of lacustrine carbonate rock reservoir in mesa with gentle slope, but also make an important contribution to the deep-water oil exploration and development in Brazil's santos basin, helping PetroChina to realize its equity production of 100 million tons of petroleum overseas.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
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Analysis of the Contribution of Different Strike-Slip Fault Zones on Petroleum Charging Episodes in the Shunbei area, The Tarim Basin, NW China

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Keywords: Shunbei area, Strike-slip fault zone, Hydrocarbon charge, Oil inclusion, Contribution, Geochemistry

In recent years, newly discovered ultra-deep fault-karst reservoirs in the Shunbei area of the Tarim Basin have greatly increased the prospectivity of the basin and become a hotspot for further hydrocarbon exploration. However, the formation mechanism of these Ordovician carbonate reservoirs and hydrocarbon charge history appears to be complex and is still the focus of a number of studies. This investigation focused on determining the origin of the reservoir oil based on quantitative gas chromatogram-mass spectrometry (GC-MS) measurements and stable carbon isotope ($\delta^{13}C$) counts. The reservoir oil samples were taken from the Ordovician Yijianfang Formation $O_2yj$and Yingshan Formation$O_{1\text{-}2}y$ in the Shunbei No. 1, No. 5 and No. 7 strike-slip fault zones. It is thought that the Ordovician reservoir oils are derived from source rocks within the Cambrian Yuertusi Formation which were deposited in a highly reducing marine environment. The generated hydrocarbons subsequently migrated upward along faults to the Ordovician reservoir. The reservoir diagenetic sequences were established by observation of thin sections under transmitted light, reflected light and cathode luminescence. The hydrocarbon charge history in the Shunbei area was reconstructed and associated with a series of diagenetic events using fluid inclusion microthermometric measurements, and microscopic fluorescence spectrum parameter analysis, combined with one-dimensional basin modeling. The results show that the Shunbei site has experienced three hydrocarbon charging episodes in total, the first charging episode occurred in the late Caledonian (437.2—405.8 Ma), the second charging episode occurred in the late Hercynian (291.6–236.8 Ma) and the third charging episode occurred in the late Himalayan (23.6–0.3 Ma). Locally, the Shunbei No. 1 and No. 5 fault zones experienced three hydrocarbon charging episodes, whereas the Shunbei No. 7 fault zone reservoir shows no evidence for the last hydrocarbon charge episode. Finally, the relationship between measured QF-535 factors and the API gravity of crude oil was used to predict the API gravity of oil in inclusions. This allowed quantification of the level of contribution of each of the petroleum charging episodes to the No.1, No.5, and No.7 fault zone reservoirs. The results shows that hydrocarbons in the No. 1 fault zone reservoir are mainly derived from the third petroleum charging episode, the No. 5 fault zone reservoir is dominated by the second and third petroleum charging episodes, and the No. 7 fault zone reservoir was charged predominantly by the first petroleum charging episode. Overall, the contribution of early hydrocarbon charging episodes gradually increases from west to east in the Shunbei area. This increase was driven by different tectonic events through geological history and the subsequent evolution of paleo-structural patterns. This study reveals the history and looks at differences in the reservoir hydrocarbon accumulations in different fault zones of the Shunbei area. This information with have a significant impact on marine carbonate reservoir evaluation in strike-slip fault zones in China.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Oral Preferred

Stylolites quantitative characterization and effects on reservoir quality in the ultra-deep limestone reservoirs: A case study of the Lower Triassic Feixianguan Formation, northeastern Sichuan Basin

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Keywords: ultra-deep limestone reservoir, stylolite, pressure solution, reservoir quality, Feixianguan Formation, northeastern Sichuan Basin

Pressure solution, a common and important diagenetic process in carbonates (Koehn et al., 2008; Morad et al., 2018), involves physical reduction of the volume in rocks and chemical dissolution-precipitation process in pores, and thus leads to the significant heterogeneity of reservoirs (Ehrenberg, 2004; Paganoni et al., 2016). This study was based on the ultra-deep Feixianguan limestones (approximately 7000 m) of the Lower Triassic (northeastern Sichuan Basin, China) because of the various limestones and abundance of stylolites. Quantitative characterization of the morphology, distribution, and residual seam composition of stylolites in the Feixianguan limestones were performed to evaluate the intensity of pressure solution. Moreover, the impacts of pressure solution on the evolution of porosity and permeability were revealed via integrating quantitative statistics from cores and thin sections with geochemical data.

The following four types of stylolites were observed in the Feixianguan limestones according to pure geometry, known as wave-like, rectangular, sharp-peak, and seismogram types. From matrix supported limestone to grain supported limestone, the type of stylolites gradually change from wave-like to rectangular, sharp-peak and seismogram types, accompanied by increased surface roughness and amplitudes, and significantly decreased residual seam thicknesses. The stylolite density tend to decrease from the lower to upper part of the sedimentary cycle. In addition, two quantitative analysis methods of studying the intensity of pressure solution were carried out according to the clay mineral content respectively for relatively clean grainstones, and for mudstone, wackestones and packstones.

Calculations prove that the average intensity of pressure solution in mudstones (235.78 mm/m) is significantly larger than that in grainstones (90.42 mm/m), confirming that grainstones are more resistant to pressure solution and more porous. The obvious difference in pressure solution intensity leads to the strong heterogeneity in limestone quality. The values of Al + K + Ti, Zr/Al, and alumina content are negatively correlated with porosity and positively correlated with stylolite density, implying that clay minerals could facilitate the pressure solution. The relatively intensive cementation in proximity to stylolite and the negative correlation between the porosity and intensity of pressure solution indicate that pressure solution has a destructive effect on the pores during stylolite formation. Moreover, pressure solution caused a decrease in the porosity of limestone by approximately 11.31%. However, some calcite cements, abundant pores, and accumulated bitumen within stylolites indicate that the stylolites can act as predominant pathways for fluid migration, which can improve the reservoir permeability by at least an order of magnitude. Concludingly, we highlight quantitatively differences in pressure solution intensity on a millimeter scale.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
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Impact of diagenesis on microbialite-dominated reservoir of the terminal Ediacaran Dengying Formation from the Central to Northern Sichuan Basin, SW China

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Keywords: Diagenetic parasequence, Diagenetic fluid, Microbial reservoir, Dengying Formation, Ediacaran, Sichuan Basin

The central part of the Sichuan Basin in South China shows an excellent exploration potential in the dolomitized microbial reservoirs of the Dengying Formation in late Ediacaran. However, the influence of diagenesis on the formation of high-quality reservoirs is unclear. This study aims to establish the parasequence of the diagenesis in microbial reservoirs and decipher its control on the quality of microbialite-dominated reservoirs. The microbialite of the Dengying Formation consists of stromatolites and thrombolites, which firstly underwent meteoric alteration in the early diagenetic stage. The fabric-selective pores in the reservoir, which are generated by the decline of sea level, reflect freshwater dissolution. Subsequently, the microbialites experienced fibrous and bladed dolomite cementation and dolomitization. Laminated and clotted sedimentary fabrics are well-preserved in dolomite with less than 100μm in crystal sizes. The $\delta^{13}C$ (2.3 ± 1.1‰), $\delta^{18}O$ (-3.8 ± 1.2‰), $^{87}Sr/^{86}Sr$ (0.708717 ~ 0.709322) values, Mn (145.2 ± 45.3 ppm), and Fe (971.0 ± 330.0 ppm) concentrations in the microbial dolomite were similar to the geochemical compositions of Ediacaran seawater, indicating the marine origin of the dolomitizing fluid. The fibrous and bladed dolomite cement filled in the pores with dark-dull red cathodoluminescence has $\delta^{13}C$ (2.1 ± 1.0 ‰), $\delta^{18}O$ (-3.8 ± 2.0‰), $^{87}Sr/^{86}Sr$ (0.709181) values, Mn (187.5 ± 57.6 ppm) concentrations close to the matrix, which means the diagenetic fluid is originated from the coeval seawater. The medium-coarse crystalline granular dolomite cement filled later than the fibrous cement. Its composition of $\delta^{13}C$ (1.7 ± 0.8‰) and $\delta^{18}O$ (-8.2 ± 1.7‰) values indicate the diagenetic fluid derived from marine, and is affected by the recrystallization caused by the temperature rise after burial. Finally, the saddle dolomite cement filled in the fractures and veins, cross-cutting the host rock and early cement. The $\delta^{13}C$ (1.1 ± 1.3‰) value of saddle dolomite is similar to the matrix and early cement, while the $\delta^{18}O$ value is significantly lighter (-10.9 ± 1.0‰). The high Mn (751.4 ± 570.0 ppm), Fe (3872.5 ± 3347.9 ppm) concentrations, homogenization temperature (194 ± 26 ℃) derived from the fluid inclusion within the saddle dolomite, and concomitant silicification suggest its formation of Fe-rich high-temperature burial fluid. For the microbialite-dominated reservoir of the Dengying Formation, first, its initial porosity (34.07 ± 8.80%) is high. Second, porosity and permeability characteristics show dissolution-specific behaviors, suggesting a key factor of meteoric diagenesis in enhancing the reservoir. Third, the early dolomitization helps to resist compaction and pressure dissolution. Fourth, although the cementation of marine-derived fluids occupies the most pore space (28.15 ± 7.89%), hydrothermal fluids slightly influence the quality of the reservoir. Therefore, after multiple fluid diagenetic evolutions, the porosity of the microbialite reservoir in the Dengying Formation is concentrated in 3 ~ 5% with high porosity (6 ~ 10%) locally developed, which demonstrates the exploration potential of the Precambrian deep-buried dolostone reservoir.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Oral Preferred

The formation mechanism and models of paleo-karst carbonate reservoirs of Majiagou Formation in Fuxian area, Ordos Basin

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Keywords: Ordos Basin, Majiagou Formation,gypsum-molded pore,intercrystalline pore,fracture

In the Ordovician, sea level changed frequently under arid climate in Fuxian area in the southeastern Ordos Basin, and the Caledonian movement made the basin undergo 130 million years of weathering and erosion. Three types of reservoirs were identified in the Ordovician Majiagou carbonate rocks in Fuxian area, including gypsum-molded pore-dissolution pore, dolomite intercrystalline pore and fracturedeveloping under distinctive sedimentary environments and experiencing special ways and degrees of karstification.

Gypsum-molded pores and dissolution pores were mainly developed above water-retaining layers and were affected by vertical karstification. As regression occurred and Sabkha dolomitization proceeded, gypsiferous dolomitic flat facies were deposited in the supratidal environment in the period of Ma 5 1st-4th. During the supergenes stage, karst water leached downwards, dissolving the soluble anhydrite nodules in the strata to develop gypsum-molded pores and dissolution poresand the associated pressure release resulted in network fractures communicating pores in the matrix dolomites. On the other hand, filling also played an important role on the effectiveness of gypsum-molded pores. Being the most important reservoirs in Fuxian area, favorable gypsum-molded pore reservoirs mainly distributed on the ancient burial hills and platforms with relatively high ancient landforms where filling were weak.

Dolomite intercrystalline pores were mainly controlled by lateral bedding karstification. During transgressive period in Ma 55thMa 5 7th, Ma 5 9th,thick layers of powder-fine grained dolomites were deposited in the ancient subtidal shoals by seepage reflux dolomitization, with middle size grains and numerous intercrystalline pores. The karst water flowed along the laminar with the tectonic setting of Ordovician high in the west and low in the east , so that the intercrystalline pores were further dissolved and enlarged. In the drainage areas of pressurized water flow, the dolomite intercrystalline pore-dissolution pore reservoirs are locally contiguous, where dissolution is strong.

During the supergenes stage, anhydrite nodules or layered anhydrites swelled and dissolved in karst water, causing the surrounding tight carbonate strata broken until collapsed, resulting in the development of fractures. Fractures were widely spread in the strata of the Ma 5 and Ma 6 members in Fuxian area. The fractures in the thick-layered micrite limestone of the Ma 6 member deposited during the largest transgressive period of the Ordovician and the thick-layered dolomite of the Ma55th sub-member during the largest transgressive period of the Ma 5 are the most typical. Filling in the supergenous and burial periods controlled the effectiveness of fractured reservoirs, which distributed locally.

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Formation Mechanism and Control Storage Mode of Multistage Slope Break of Middle Permian in Sichuan Basin, China

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Keywords: Qixia Formation, Maokou Formation, slope-break belt, platform margin, dolomite

The middle Permian is rich in oil and gas resources in Sichuan Basin, especially dolomite reservoirs. However, the differences in understanding of the sedimentary pattern evolution and dolomite genesis in the Middle Permian lead to unclear understanding of the development law of large-scale reservoirs and restrict exploration deployment. In view of the above problems, based on drilling, logging, seismic and geochemical data, this study proposed the understanding of penecontemporaneous dolomite, sedimentary evolution pattern of multistage slope break and control reservoir model of multistage slope break in Qixia-Maokou Formation. The results are as follows: (1) It is clear that the dolomite of Qixia-Maokou Formation is crystalline, the protolith structure is grainstone, and the dolomitization fluid comes from seawater rather than hydrothermal. The viewpoint of facies-controlled dolomite is put forward. (2) The distribution of high-energy bioclastic shoals was controlled by the multistage slope break paleogeographic pattern, which was formed by the “S” paleo-uplift of central-western Sichuan and tectonic extension, in Qixia-Maokou Formation. (3) A new control storage model of dolomite reservoir is proposed. The "one edge and one slope break" sedimentary pattern of Qixia Formation and the distal steep break zone of Maokou Formation controlled the distribution of dolomite reservoir. The research is guiding significance to the oil and gas exploration of Middle Permian in the future.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Factors Influencing Stylolite Formation in the Cambrian Longwangmiao Formation, Sichuan Basin, SW China

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Keywords: Pressure solution, Stylolite, Quantitative analysis, Sichuan Basin, Longwangmiao Formation

With the deep and ultra-deep exploration of carbonate rocks, more and more evidence has been obtained that shows that the pore reduction effects of compaction, pressure-solution, and cementation are crucial factors for the preservation of carbonate reservoirs porosity (Croizé et al., 2010; Moore et al., 2013). However, most studies of the stylolite in the Longwangmiao Formation were inclined to lack quantitative analysis relating the stylolite distribution parameters and the mineral composition, lithofacies, and rock textural characteristics. To better understand the controls on the formation and distribution of stylolites, the Longwangmiao Formation is selected as an example to examine this hypothesis. Based on the lithofacies, textural constituents, stylolite types, and X-ray diffraction (XRD) data obtained from thin sections, cores, and outcrops, and the results revealed the following that. Dolomite (79.6%), calcite (11.4%), and terrigenous clastic (5.6%) are the main mineral components in the Longwangmiao Formation, Sichuan Basin. The rocks with dolomite content of more than 80%, calcite content less than 30%, and terrigenous clastic less than 1% have low stylolite density and amplitude. Based on the multiple techniques, four types lithofacies of carbonate were recognized, including the grainstone (dolo-grainstone, grainstone), packstone (dolo-packstone, packstone), wackestone (dolo-wackestone, wackestone), and mudstone (dolo-mudstone, mudstone). Moreover, the density and amplitude of stylolites in dolo-grainstone, dolo-packstone, dolo-wackestone, and dolo-mudstone increase in order within the one well. Significantly, the stylolite density and amplitude in the dolo-grainstones are lower when those with grain contents of 50%–70% and cement contents of 25%–30%, which have high average porosity and permeability and are facilitate the formation of high-quality reservoirs. Vertically, the stylolite density and amplitude tend to decrease from the lower to the upper part of the sedimentary cycle, which indicates that the degree of chemical compaction in the lower part of the fourth-order sequences is strong. This study confirms that dolo-grainstone with a high dolomite content (>90%), a grain content of 50%–70%, a cement content of 25%, has a strong pressure solution resistance, which facilitates the conservation of pores.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
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Distribution and characteristics of microbial carbonate reservoirs in the 4-3 submember of the Middle Triassic Leikoupo Formation, Western Sichuan Basin, China

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Keywords: Distribution of microbialites, microbial carbonate reservoir, the Triassic Leikoupo formation, Western Sichuan Basin

Microbial carbonate reservoirs are the main petroleum exploration targets in the third submember of the fourth member of the Leikoupo Formation in the western Sichuan Basin. To improve understanding of the origin of microbial carbonate reservoirs, detailed facies description and reservoir characterization were performed based on sedimentological and petrophysical analysis from cores and outcrops. Compared with modern analogs, the microbialites depositional model is established, and the controlling effect of microbialites on the reservoir is evaluated. Nine facies types can be grouped into five facies associations in the Lei4-3 submember, corresponding to two cycles, portraying an epeiric marine carbonate platform in the western Sichuan Basin. Cycle 1 is dominated by tidal flat environment. Laminated microbial dolomudstone mainly in the southern area of the western Sichuan Basin, representing the intertidal to supratidal settings in the proximal platform, a low gradient area with weak hydrodynamics protected by Longmenshan subaqueous paleohigh. In the central area of the western Sichuan Basin, wavy to domal stromatolitic dolowackestone and thrombolitic dolomudstone are common in the intertidal to subtidal environments, where the substrate gradient is steep, and the seawater circulation is also relatively restricted by the subaqueous paleohigh. Many intraclast dolopack-grainstone on behalf of the shoal or tidal channel environments in the northern area of the western Sichuan Basin, indicating the site is frequently disturbed by tides and waves with better seawater circulation, which may be less limited by the subaqueous paleohigh. Cycle 2 with large preserved thickness only in the central area of the western Sichuan Basin due to varied denudation caused by Indosinian orogeny. With the rise of sea-level, the western Sichuan Basin is less limited by the subaqueous paleohigh. Cycle 2 is mainly a semi-restricted subtidal environment without microbialites. The regional distribution of microbialites in the cycle 1 is controlled by the variation of regional topographic gradients and the tidal and wave energy affected by the seawater circulation. High-frequency relative sea-level fluctuations lead to frequent exposure of tidal flat with meteoric alternation, resulting in the formation of solution enlarged pores from microbial framework pores in microbialites and vugs from interparticle pores in intraclast dolopack-grainstone. The early dolomitization formed the intercrystalline porosity in microbialites or intraclasts dolopack-grainstone and made dolomite more resistant to compaction during burial. The abundant fractures provide channels for the migration of fluid and hydrocarbon, especially in the central area near the Pengzhou hidden fault.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Oral Preferred

Tectono-sedimentary evolution of the carbonate platform in central Tarim Basin during the early Cambrian: New insights from stratigraphic forward modeling

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Keywords: Carbonate Platform, Tarim Basin, Early Cambrian, Stratigraphic Forward Modeling

The Lower Cambrian carbonate platform sequences in the central Tarim Basin play an important role in controlling the development of hydrocarbon source rocks and reservoirs, as well as the formation and distribution of oil and gas. A large number of studies have been conducted on its formation and evolution, but most of them are based on qualitative analysis and paid little attention to the influence of differential deposition of the carbonate platform sequences.

Based on previous research findings and supplementary analysis of key seismic sections, outcrops, well logs, core, and cuttings, we have investigated the Early Cambrian paleoenvironment in the central Tarim Basin. By using the Earth System Science approach, we studied the Lower Cambrian carbonate platform sequences through stratigraphic forward modeling (SFM) by taking into consideration of key geological factors such as the initial paleo-topography, tectonic movement, high-frequency sea-level changes, carbonate growth/denudation, and clastic sediment input. The 3D stratigraphic forward model was calibrated and validated using a variety of geological data.

Through uncertainty analysis of different geological factors and variables, and combined with previous research findings, we have systematically analyzed the tectono-sedimentary evolution process responsible for the development of the carbonate platform margin facies in both time and depth domains and evaluated the contribution of key factors on the evolution of platform margin facies quantitatively, and finally clarified the formation mechanisms and evolution model of the platform margin facies in central Tarim Basin.

The study showed that the initial paleogeomorphology and tectonic subsidence jointly controlled the fluctuation of relative sea level, which determined the migration direction and internal structure of the carbonate platform margin. The differential stratigraphic architecture and stacking patterns of the carbonate sequences were primarily caused by the exposure duration and the slope angles of the platform margin collectively.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

The evolution of diagenetic fluids in Shunbei area, Tarim Basin: Constraints from isotopic geochemistry and U-Pb dating of calcite

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Keywords: Tarim Basin, Shunbei area, U-Pb dating of calcite, fluid-rock interaction, Mid-Caledonian orogeny

Faults are generally considered as the main conduits for the focusing and migration of fluids. This study focuses on the strike-slip faults in the Shunbei area, Tarim Basin, where calcite, autogenic quartz and minor saddle dolomite cements co-occur within the different fault zones. Calcites, as the exclusively vein- and/or fracture-cement in the northern fault zone, have large overlaps in isotopic composition with that of host limestone, indicating that the diagenetic fluids mainly inherited their composition from remnant pore fluids or were buffered by formation water through intense fluid-rock interaction. In addition, the presence of mono-phase fluid inclusion also implies that they were formed in a shallow burial environment with relatively lower temperature. However, the calcite cements in the southern fault zone may have precipitated from more intense water-rock interaction at elevated temperature in view of the relatively lower δ18O values. This inference was also testified by the pervasively occurrence of replacive and fracture-filling quartz, which probably resulted from episodic influxes of hot silica basinal brines from the depth. U-Pb dating of two calcite cements yield isochron ages of 456.38 ± 5.50 Ma and 445.20 ± 14.30 Ma, respectively, definitely falling within the Late Ordovician, thereby attesting to a causal link to the Mid-Caledonian orogeny. At that time, the Katak uplift experienced extensive tectonic overthrusting due to the final closure of North Kunlun Ocean, resulting in a series of nearly NE-trending secondary faults. Afterwards, high-temperature silica-rich fluids had been expelled from depth and driven to migrate upwards into the fractured limestones, resulting in intense dissolution mainly along the fault/fracture networks with subsequent precipitation of quartz and calcite cements. This study provides a useful analogue to understand the diagenetic processes associated with faulting, fluid source and pathway in the compressional setting.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
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Reservoir features and development model of globigerina limestone, southern east Java basin

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Keywords: East Java basin, Globigerina limestone, Reservoir features, Development model

Globigerina is a class of plankton-like foraminifera, which can form reservoirs by accumulation after death. High quality reservoirs can be formed through secondary modifications, and a group of such reservoirs have been discovered globally. In the southern part of east Java basin, the globigerina limestone reservoir is distributed along the relatively high paleography of the shelf margin. The lithology is mainly grainstone and wackstone. The content of bioclasts is high and there are many species, while the influence of terrestrial material was weak. The reservoir has excellent physical properties, with average porosity of 43% and permeability of 120mD. It is the main target of oil and gas exploration and development. According to the analysis and paleontological data, distribution of globigerina limestone reservoirs in southern east Java basin was mainly controlled by four factors: Firstly, the relative height of paleography controls the reservoir quality and scale, the higher paleography the better quality but the thickness decreased, and lower paleography the worse quality but thickness increased. Secondly, the offshore current carried out secondary transformation such as agitation and transportation for the accumulated foraminifera, which accumulated more in the higher paleography and carried away most of the marl. Thirdly, the upwelling current carried the deep foraminifera to the shallow part, and interacted with the offshore current at the margin of the shelf. The uniform deceleration led to the weakening of the carrying capacity. The carrying capacity were further weakened because of the influence high paleography, and it is resulted that the continuous enrichment of foraminifera in the high part of the high paleography at the margin of the shelf. Finally, the lower cutting erosion of the later developed channel affects the local reservoir distribution. The physical properties of globigerina limestone reservoir are controlled by six major factors: grain size, globigerina content, burial compaction, diagenesis, marl matrix content and pore throat radius. According to controlling factors mentioned above, the development and distribution model of the upper Pilocene globigerina limestone reservoir is established in the south of east Java basin, which provides a basis for geological deepening evaluation, exploration and development potential analysis of this type of reservoir.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Oral Preferred

Characteristics and genesis mechanism of present-day low-organic-matter carbonate source rocks in the Middle–Upper Ordovician, Tarim Basin, China

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Keywords: Carbonate source rock, mass balance approach, present-day low TOC, genesis mechanism, platform of Tarim Basin

The continually discovered large volumes of marine hydrocarbons have indicated a huge exploration potential within the carbonates of Ordovician in the Tarim Basin (northwest China); however, the carbonate source rocks of the Middle–Upper Ordovician (O2+3) are at high mature stage. These rocks presently contain a low amount of total organic carbon (TOCpd ≤ 0.5%). In this study, the source rocks that have expelled hydrocarbons are identified by mass balance approach. The characteristics and genesis mechanism of hydrocarbon expulsion from low-TOCpd (present-day TOC) source rocks are studied, which is significant for the marine oil exploration in the basin. Results showed that an O2+3 source rock with low TOCpd having expelled hydrocarbons was of type I and had a very narrow oil window. With high maturity, nearly 80% of the generated hydrocarbons were expelled, and the original TOCo (original TOC) values were over 1%. The oil and source rock extracts were relatively lean in gammacerane and C28 steranes, with the distribution of regular steranes having a V-shaped trend, suggesting a possible genetic relation between the source rocks with low TOCpd and the marine oils in the Tabei area. The genesis mechanism for the low-TOCpd carbonate source rocks is as follows. The main hydrocarbon parent materials were hydrogen-rich planktonic algae or acritarchs, distributed in the subsiding platform-slope facies). Organic matter was preserved under reducing conditions, and source rocks were formed with a good kerogen type and moderate hydrocarbon generation potential. Thus, hydrocarbon expulsion could have occurred, resulting in TOCpd ≤ 0.5%.

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Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
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Characteristics and Reservoir Responses of the Ordovician Hydrothermalism in the Tarim Basin

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Keywords: hydrothermalism, Ordovician, carbonate rock, reservoir responses, Tarim Basin

The alteration of reservoir by hydrothermal fluid is a key issue in the field of Geology. In this paper, the Ordovician carbonate reservoirs in the Tabei-Tazhong area of the Tarim Basin are studied. Based on core observation, thin section analysis and related geological data, through the methods of cathodoluminescence, fluid inclusion analysis, isotope and rare earth element analysis and numerical simulation, the basic characteristics of the Ordovician reservoirs, hydrothermalism characteristics and reservoir responses to different hydrothermal fluids in the Tabei-Tazhong area are systematically studied. A model of carbonate reservoirs altered by hydrothermalism is established.

The Ordovician carbonate reservoir in the study area is composed of micrite limestone, granular limestone, algal bound limestone, dolomite and silicified siliceous rock. The main diagenesis types are cementation, compaction, pressure solution, recrystallization, dolomitization, silicification, fracture, dissolution and filling. The main types of reservoir space are dissolution pores, dissolution caves, fractures and karst caves. In petrology, hydrothermalism in the study area is characterized by thermal fading, thermal cracking and magmatic intrusion. In diagenesis, hydrothermalism is characterized by dissolution and fracture, and the filling of hydrothermal minerals such as saddle dolomite, fluorite and quartz.

The results show that, in the study area, there are mainly two kinds of hydrothermal fluids in the Ordovician carbonate strata: Mg-rich stratigraphic hydrothermal fluid and F&Si-rich magmatic hydrothermal fluid. The minerals formed by Mg-rich stratigraphic hydrothermal fluid are characterized by medium to high homogenization temperatures and salinities of inclusions, medium to negative carbon and oxygen isotope values, positive anomalies of δEu and negative anomalies of δCe. The main active period of Mg-rich stratigraphic hydrothermal fluid is from the late Caledonian to the Early Hercynian. The minerals formed by F&Si-rich magmatic hydrothermal fluid are characterized by high homogenization temperatures and salinities of inclusions, more negative carbon and oxygen isotope values, obvious positive anomalies of δEu and negative anomalies of δCe. The activity of F&Si-rich magmatic hydrothermal fluid is controlled by the tectonic movement in the late Hercynian and the magmatic volcanic activity in the early Permian.

Geological data and the results of numerical simulation show that, the diagenetic response of Mg-rich stratigraphic hydrothermal fluid in the late Caledonian to the Early Hercynian is mainly manifested as dissolution, hydrothermal dolomitization and filling, which has both constructive and destructive effects on the reservoir space, but overall, it was constructive process. The diagenetic response of F&Si-rich magmatic hydrothermal fluid in the late Hercynian mainly characterized by fracturing, dissolution, metasomatism and filling. The fluid has an obvious destructive effect on the reservoir space, but with certain constructive effect. Tectonic movement and magmatic activity provide heat and power source for hydrothermal fluid activities, and the fault system provides channel space. The carbonate hydrothermal altered reservoir is constrained by fault system, and the calcite precipitation filling zone formed in the upper part of the hydrothermal altered reservoirs also played a certain sealing role.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Oral Preferred

Relationship between stylolite morphology and the sealing potential of stylolite-bearing carbonate cap rocks in the deep-burial carbonates in the Tarim Basin, China

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Keywords: Carbonate cap rocks, Stylolite types, Pore structure, Sealing effectiveness, Tarim Basin.

The sealing effectiveness of cap rocks bearing different types of stylolites is analyzed using a combination of petrographic, petrophysical, pore structure and sealing capacity characterization techniques. This study is based on examples of carbonate cap rocks that seal ultradeep hydrocarbon reservoirs of the Tarim Basin (China). Samples from both drill cores and their outcrop analogues are investigated to quantify how morphology does influence the sealing capacity of different types of stylolite-bearing rocks. The study cap rocks consist of mudstone, wackestone to packstone, grainstone and dolomitic limestone. Four types of stylolites are identified: rectangular layer, seismogram pinning, suture & sharp peak and simple-wave like types. The difference in the sealing capacity of carbonate cap rocks is attributed to their pore structure connection and the types of stylolites they develop. Samples bearing simple-wave like stylolites have the best sealing capacity, followed those with rectangular layer and suture & sharp peak types, whereas carbonates hosting seismogram pinning type have the lowest sealing capacity. The impact of stylolite segments on the rock sealing properties, however, differ from one segment to another. Rectangular layer type stylolites can be divided into three distinct segments (with good, moderate and poor sealing, respectively). Both the seismogram pining and suture & sharp peak stylolite types are divided in two parts, with the former one having moderate and poor sealing and the latter exhibiting good and moderate sealing. The simple wave-like type has a good sealing capacity all along the pressure-solution seam. The most effective sealing barriers for vertical fluid flow form when (1) calcite and siliceous cements are pervasively distributed in the vicinity of stylolites, forming highly cemented zones with lower porosity and permeability than their surrounding host rocks; (2) stylolites are enriched in insoluble residues; (3) rare microfractures and dissolution vugs are found along the stylolites. This work provides useful examples for the prediction of the sealing potential of stylolite-bearing carbonate rocks according to stylolite morphology in other geological settings.

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Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
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Impact of diagenesis on the pore evolution and sealing capacity of carbonate cap rocks in the Tarim Basin, China

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Keywords: Carbonate cap rock, Diagenesis, Pore structure evolution, Sealing capacity classification, Tarim Basin.

Analyzing the pore structure and sealing efficiency of carbonate cap rocks is essential to assess their ability to retain hydrocarbons in reservoirs and minimize leaking risks. In this contribution, the impact of diagenesis on the cap rock's sealing capacity is studied in terms of their pore structure by analyzing rock samples from Ordovician carbonate reservoirs (Tarim Basin). Four lithology types are recognized, including highly compacted peloidal packstone-grainstone, highly cemented intraclastic-ooidal-bioclastic grainstone, peloidal dolomitic limestone, and incipiently dolomitized peloidal packstone-grainstone. The pore types of cap rocks comprise microfractures, intercrystalline, and intergranular pores, and dissolution vugs. The pore structure of these cap rocks was heterogeneously modified by six diagenetic processes, including calcite cementation, dissolution, mechanical and chemical compaction, dolomitization, and calcitization (dedolomitization). Three situations affect the rock's sealing capacity: (1) grainstone cap rocks present high sealing capacity in cases where compaction preceded cementation; (2) residual microfractures connecting adjacent pores result in low sealing capacity; (3) increasing grain size in grainstones results in a larger proportion of intergranular pores being cemented. Four classes of cap rocks have been defined according to the lithology, pore structures, diagenetic alterations, and sealing performance. Class I cap rocks present the best sealing capacity because they underwent intense mechanical compaction, abundant chemical compaction and calcite cementation, which contributed to the heterogeneous pore structures with poor pore connectivity. A four-stage conceptual model of pore evolution of cap rocks is presented to reveal how the diagenetic evolution of cap rocks determines the heterogeneity of their sealing capacity in carbonate reservoirs.

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Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

THE CARBONATE RESERVOIR PREDICTION AND DISTRIBUTION IN SEQUENCE STRATIGRAPHIC FRAMEWORK OF THE UPPER CRETACEOUS —TAKING AN OIL FIELD IN CENTRAL IRAQ FOR EXAMPLE

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Keywords: Carbonate ramp, Upper Cretaceous, Sequnece stratigraphic, Reservoir prediction

The Turonian-Lower Campanian Khasib, Tanuma, Sa'adi Formation, three major carbonate reservoir units in central Iraq, contain estimated cumulative reserves of around 9 billion *brl*. Difficultly in predicting the presence of best reservoir units is mainly due to the complex paleogeography.

Sea level change analysis, trace fossils, microfossil communities and microfacies identification indicate that Upper Cretaceous carbonate are deposited in ramp setting, with depositional facies ranging from basin to inner ramp. Basin facies and outer ramp facies consists of argillaceous and marly limestone containing planktonic foraminifera (*Globotruncana sp., Oligosteginids sp.*) and calcispheres. Mid ramp facies is recognized by highly bioturbated (*Thalassinoides-Rhizocorallium*), commonly clay-rich wackestone-packstone. Inner ramp facies is characterized by shoal bioclastic grainstone-packstones intercalated with lagoonal gray-green mudstone.

A sequence stratigraphic framework has been constructed based on cuttings and core samples and wireline logs responses (gamma-ray, INPEFA, density and sonic) from 9 wells. The Khasib, Tanuma, Sa'adi Formations represent a complete 3rd-order sedimentary cycle respectively. Facies can be grouped into transgressive and regressive(T-R) cycles reflecting deepening and shallowing conditions across the carbonate ramp. Lower units of regressive cycles are dominated by outer ramp facies, which grade up to mid ramp proximal facies and then to shoal facies, the sequences capped by basin facies or lagoon. Eustatic changes were the primary control on this sequence development, the growth faults activities also affected the Turonian-Lower Campanian carbonate dispositions.

Petrographic analysis reveals the porosity increasing beneath sequence boundaries due to karstification and meteoric dissolution. The HST (mid ramp proximal) reveals the best reservoir characteristics (thickness, porosity, and hydrocarbon saturation) in central Iraq. The paleogeomorphology map of the three formations studies integrated the well correlation and logging facies analysis showed the distribution of the best reservoir units in the Turonian-Lower Campanian. These units constitute the primary targets for exploration in central Iraq. Such reservoir predicational method may have similar beneficial application to carbonate reservoirs elsewhere in the world.

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Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
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Sequence stratigraphic characteristics and reservoir distribution of ancient rimmed platform: A case study of the third and fourth members of the Sinian Dengying Formation in the Gaomo area of the Sichuan Basin

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Keywords: Sichuan Basin,Ediacaran Dengying Formation,Sequence stratigraphic framework,Reservoir distribution,Sedimentary Palaeo-geomorphology,Favorable exploration zones

In order to study the sequence stratigraphy of the ancient rimmed platform, we take the third and fourth member of Sinian(Ediacaran) Dengying Formation (shortened as Deng 3 and Deng 4 member) in Gaomo area, Sichuan Basin as an example. A comprehensive study is carried out on sequence stratigraphy, sedimentary evolution, reservoir distribution and prediction of favorable reservoir zones through comprehensive analysis of cores, thin sections, logging and seismic data, combined with previous research results. The research results asfollows: (1) Based on the identification of sequence interface, the Deng 3 and Deng 4 member can be divided into SQ3 and SQ4 sequences, which are well-developed in the area and have good isochronicity and traceability. The thickness of SQ3 and SQ4 is obviously different, and the west side of SQ3 is thicker than the east side, while the northwest side of SQ4 is thicker than the southeast side. (2) The sedimentary environment from SQ3 to SQ4 has experienced the evolution from mixed tidal flat to rimmed carbonate platform, and the platform rimmed system on the west side is characterized by the development of platform margin microbial mounds and shoals assemblages. The intra-platform area in the east is a restricted platform facies composed of a variety of dolomite, and there are local micro-geomorphic highlands of different scales, and there are scattered intra-platform mounds and shoals. (3) It is pointed out that the Deng 4 member reservoirs in the study area show obvious phase-controlled characteristics, and are controlled by the third-order sequence and high-frequency upward-shallowing cycles. It is mainly distributed in the high-stand systems tract of the third-order sequence and the upper part of high-frequency upward shallow cycle. On the plane, the reservoirs in the platform margin belt are more developed than those in the intra-platform belt, and the Gaoshiti platform margin belt is more developed than the Moxi platform margin belt. (4) Three types of reservoir favorable zones of Deng 4 Member have been finely described by 3D seismic, among which the mound and shoal facies area developed in the landform highland in the intra-platform can be used as a favorable zone for subsequent exploration. The research results will provide a new idea and reference for well deployment of Deng 4 member in Gaomo area.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Oral Preferred

New insights on the geometry and kinematics of the Shunbei 5 strike-slip fault in the central Tarim Basin, China

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Keywords: Strike-slip faults, The Central Tarim Basin, Geometric characteristics, Kinematic evolution, Reservoir formations

Integrated geological-geophysical methods have been used to depict the geometric characteristics and kinematic evolution of the Shunbei 5 (SB5) and adjacent Shunbei1 (SB1) strike-slip faults in the central Tarim Basin, China. Geometric evidence for strike-slip faulting includes the occurrence of positive and negative flower structures in stepover zones, oblique secondary splay faults, en echelon folds, and adjacent secondary faults. The multi-humped along-strike and along-dip displacement variations of the SB5 fault provide insights into the initial segmentation, interaction and polycyclic growth of the fault zones both in plan and section views: The SB5 fault initiated as an apparent “X-type” conjugate pure shear fault system in the north and a simple shear fault system in the south respectively. At depth (mainly in Cambrian to Middle Ordovician rocks), the northern and southern parts of the SB5 fault exhibit a typical dextral strike-slip architecture consisting of multiple fault segments connected via transpressional push-up or transtensional pull-apart stepovers or bends. The southern part has a linear, narrow sinistral ridge system. At shallower depths (in Upper Ordovician to Middle Devonian rocks), the lower subvertical faults propagated upwards as en echelon normal faults in the north, and as a two-phase, partitioned system consisting of boundary grabens and en echelon normal faults that dissected the early-formed border grabens in the south. With progressive deformation, the northern and southern parts of the SB5 fault reactivated and transferred into one large, sinistral fault in Upper Devonian to Permian rocks. Four major tectonic phases matching the kinematic evolutions of regional fault systems and uplifts in the study region, have also been recognized in the Middle Ordovician to Cretaceous. The pull-apart stepover and single fault zones developed in Middle Ordovician rocks are favorable fracture-related reservoirs.

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Depositional model and distribution characteristics of Cambrian source rocks in Bachu Maigaiti area, Tarim Basin

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Keywords: Tarim Basin,Yuertus Formation,Source rock, depositional model, Spatial distribution

Tarim Basin is the largest petroliferous basin in China ,which is rich in oil and gas resources. This study aims to explore development model and the distribution characteristics of source rocks by using core observation, thin section identification, combined with seismic, drilling, surrounding outcrops and organic geochemical analysis.The results show that From the old to the new, The Cambrian strata in Bachu Maigaiti area develop lower Yuertus Formation (1y), Shorbluk Formation (1x) and Wusonger Formation (1w) ; Middle Shayirik Formation (2s) and Awatag Formation (2a); Lower Qiulitage Formation of upper series (3xq). Cambrian source rocks in Tarim Basin are mainly divided into argillaceous source rocks and carbonate source rocks. Their source rock depositional models are mainly divided into two types: shelf slope facies source rock depositional model related to upwelling current paleomarine deposition and carbonate platform facies source rock depositional model related to intra platform depression lagoon facies deposition. Cambrian argillaceous source rocks are widely distributed in this area. They are developed in the shelf slope sedimentary facies belt in the southwest of Tarim depression and Maigaiti Slope, with a thickness of about 800 ~ 1200m, and gradually thinning to 100 ~ 200m eastward. The quality of carbonate source rocks of Yuertus Formation is the best, and the Yuertus Formation is a set of tidal flat deposits, which is a high-quality source rock with a total organic carbon content (TOC) of 9.67% and an average of 5.1%.Ro is between 2.03% - 4.5%, which is in the stage of high over mature evolution and has great hydrocarbon generation potential.The generally higher than 30m thickness, the good continuity ,widely distribution, the large buried depth (main body is between 4800-5500m) of the source rocks. ensure good sealing conditions of the gas reservoir. The argillaceous source rocks of Yuertus Formation are widely distributed, with high abundance and good types of organic matter; The microbial mound reservoir in the platform is formed in the carbonate rocks of Shorbluk Formation; The Middle Cambrian strata form a set of gypsum mudstone caprocks, which constitute a good source reservoir cap rock combination and have great resource potential.

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Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
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Characteristics and Genesis of Middle Permian Dolomite Reservoir in Sichuan Basin

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Keywords: Dolomite Reservoir,Freshwater Dissolution,Upward Fluid,Dolomitization,Middle Permian,Sichuan Basin

Carbonate platform deposits are widely developed in the Middle Permian in Sichuan Basin, and the early exploration is mainly concentrated in the karst fracture cave limestone reservoir of Maokou Formation around Luzhou paleo-uplift, with high production from individual Wells but small reservoir sizes. Recently, dolomite reservoirs have been drilled in the Qixia Formation of northwest, southwest and middle Sichuan, and the Maokou Formation of north and southeast Sichuan, showing good exploration prospects. However, the development characteristics and genesis of reservoirs are quite different, and the research is relatively weak, which restricts the evaluation and deployment of oil and gas exploration. In this study, based on a large number of drilling cores, imaging logs, outcrops, by means of thin section identification, geochemical testing and analysis, the characteristics and genesis of Middle Permian dolomite reservoir are systematically analyzed. Middle Permian dolomite reservoirs can be divided into two types. The first type is controlled by sedimentary facies, and the reservoir development of this type is related to atmospheric freshwater dissolution and penecontemporaneous marine fluid dolomitization, with the plane distribution mainly controlled by the platform margin of western Sichuan Basin and the uplifted-subsidenced paleogeographic pattern of central Sichuan Basin. The reservoir rock is mainly residual particle fine-crystalline dolomite and the reservoir space is mainly intergranular pore-intergranular dissolved pore, while the reservoir is characterized by wide distribution and good physical properties. The other type is mainly related to the upward fluid modification. The magnesium-rich hydrothermal fluid enters into the bioclastic limestone of Maokou Formation though the basement fault, then causing the stratiform-like dolomitization. This fluid modification, on one hand, physically breaks the bedrock to form fractures and holes, on the other hand , results in chemical corrosion, which both improve the reservoir storage and permeability properties. The plane distribution of such reservoirs is mainly controlled by the basement fault, with the reservoir rock of mainly dark gray fine-medium crystalline dolomite and reservoir space of mainly matrix dolomite intergranular pores and semi-filling dissolved caves.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
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Structural controls on hydrothermal dolomitization of Middle Permian carbonate succession in eastern Sichuan Basin, China: Constrains from U-Pb carbonate geochronology

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Keywords: hydrothermal dolomitization, carbonate U-Pb dating, Sichuan Basin, Emeishan mantle plume

Hydrothermal dolomite (HTD) bodies have been recognized as potentially good hydrocarbon reservoirs and are regarded to be a hot area for hydrocarbon exploration in the future. Although various examples of hydrothermal dolomitization have been documented worldwide, the most challenging point is the timing and the burial depth of dolomitization, which can only be inferred from indirect evidence regarding the regional context and the burial history, bringing uncertainty and limitation to the dolomitization process interpretation. In the eastern Sichuan Basin, thick successions of Maokou formation limestone were alternated by fracture-bound dolomitization, showing typical hydraulic structures and saddle dolomite cementation. Here we investigated these hydrothermal dolomite bodies and recognized two types of matrix dolomites together with three types of cement dolomites based on petrographic observation. In-situ LA-ICP-MS U-Pb ages gave a confidence interval from 251±11 Ma to 264±10 Ma, indicating an early-stage dolomitizing event that may correspond to the activities of the Emeishan mantle plume and its related thermal effects. The high homogenization temperature combined with high $^{87}Sr/^{86}Sr$ ratios and depleted $\delta^{18}O$ in all types of dolomites suggests that the dolomitizing fluid may be derived from deep crustal brines that mixed with down-flowing seawater at very shallow depths. Those syn-depositional fault system, which may relate to the activities of deep major faults, was most likely to provide dominant pathways for fluid migration and mixing.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
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Diagenesis and pore evolution of the Paleogene Shahejie Formation Mixed Siliciclastic-Carbonate Rocks reservoirs in Bozhong sag

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Keywords: Bozhong Sag,Paleogene,Shahejie Formation,mixed siliciclastic-carbonate rock,diagenesis,Pore evolution

The Paleogene Shahejie Formation in Bozhong Sag is an important field of oil and gas exploration in China, and the high quality reservoir of mixed siliciclastic-carbonate rock is developed in the first and second member of Paleogene Shahejie Formation. In order to study the influence of diagenesis on reservoir development and reservoir pore evolution in mixed siliciclastic-carbonate rock, to explore the relationship between diagenesis and pore evolution model, through core observation, casting thin section, scanning electron microscope and other technical means, the reservoir characteristics of mixed siliciclastic-carbonate rock in five wells of QHD29-2E-4, QHD29-2E-5, QHD36-3-2, BZ13-1 and BZ2-1-3 in Bozhong Sag were studied. The main results are as follows:1Mixed siliciclastic-carbonate rock reservoirs dominated by terrigenous clastics, mixed siliciclastic-carbonate rock reservoirs dominated by bioclastics and mixed siliciclastic-carbonate rock reservoirs dominated by chemical carbonates are developed in the Paleogene, the reservoir space is mainly dissolved pores, intergranular pores and a small amount of biological cavity pores, among them, the types of biological cavity pores are mainly spiral cavity pores and mesomorphic cavity pores, and porous reservoirs are developed. 2Compaction has little effect on reservoir during the whole diagenetic evolution, the cementation is the main reservoir destruction, and the dissolution is the main role of reservoir construction, at the same time, the micrite crust in syngenetic stage, the leaching of atmospheric fresh water in syngenetic stage and the quasi-synchronous dolomitization are also three important reservoir constructive effects.3The diagenetic evolution process of the mixed rock reservoir in the study area was quantitatively calculated by ' porosity inversion ',the initial porosity of the mixed siliciclastic-carbonate rock is 54.2 %, During the syngenetic period, the cementation reduced the porosity by 23.68 %, and the primary dissolution increased the porosity by 17.47 %. In early diagenetic stage, compaction reduced pore by 6.7 %. During the middle diagenetic stage, the cementation porosity decreased by 17.43 %, the acid dissolution porosity increased by 4.02 %, and the present porosity was 31.2 %. Clear dissolution and cementation are the main factors affecting reservoir physical properties.

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Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
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Tectono-depositional differentiation of Sinian in Sichuan Basin and its controls on reservoir formation

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Keywords: Tectono-depositional differentiation, reservoir, dolomite, Sinian, Sichuan Basin ,

To understand the sedimentary filling and tectono-depositional differentiating principles in marine craton basins and rebuild the tectono-depositional evolution processes at key tectonic periodsare of great geological significance for characterizing the distribution patterns and formation mechanism of large-scale reservoirs. In this paper, we described the sedimentary filling features and geochemical records, together with the latest exploration progresses, and then summarized the tectono-evolution processes of Sinian intra-craton paleo-rifts in Sichuan Basin and analyzed the geodynamical mechanism according to regional tectonic settings. Based on the reestablishment of Sinianpaleogeography, the diagenetic types and environment were first concluded according to petrography and in-situ geochemical analysis,and the microbial mineralization experiments were then conducted, as such the controlling factors for the formation of large-scale reservoirs were determined. Our studies show that, the tectono-depositional differentiation of Sinian cratons in Sichuan Basin is controlled by the subduction and retreating extension of the peripheral plates since NanhuaPeriod and characterized by the inherited development and intermittent activities. The continuous sedimentary records of deep-water environment for the Dengying Formation in rift trough were discovered in northwestern Sichuan Basin, confirming that the Mianyang-Changning paleo-rift was an inherited negative geomorphological tectonic unit.The rare earth element patternsfrom the layered siliceous dolomite indicate that the Dengying Formation developed along the edge of the rift trough wascontrolled by hydrothermal activities. And the deposits ofthe Doushantuo Formation along the rift trough were thicker, suggestingthatsubsidence occurred at an early stagewith microbial rocks developing along the platform margins andthe basin has a background of periodicalsubsidence. The evidence of onlap and exposure dissolution of stratainside rift trough, confirming that there used to be multi-stage erosion in the Dengying Formation. The formation and distribution of large-scale reservoirs of Sinian is controlled by high-energy facies belt together with early dolomitization and early dissolution. The microbial induction experiments showed that dolomitization at the quasi-contemporaneous periodcould be promoted by specific paleo-ocean, paleoclimate and paleontological conditions,and the organic acids produced by the microbial degradation were beneficial to the early dissolution of carbonate minerals.The frequent exposure and dissolution of microbial rocks in the platform margin zone contributed to the development and distribution of high-quality reservoirs in the Dengying Formation, which was also the basis for the development of lithologic traps in the platform margin zone.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
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Characteristics and Genesis of Dolomite Reservoir in Cambrian Xiaoerblak Formation of Tarim BasinA case study of Xiaoerblak outcrop in Keping area

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Keywords: Characteristics, Main control factors, Dolomite Reservoir , Xiaoerblak Formation, Lower Cambrian, Tarim Basin

Lower Cambrian pre–salt ultra–deep formation (>6500m) is an important exploration field in Tarim basin, NW China, but the features and genesis of reservoir are still unclear. This study took Aksu area (NW Tarim basin) as an example, the lower Cambrian outcropped more than 28km, based on 7 outcrops, more than 800 thin sections and multi-parameter geochemical data, it was found that: (1) The reservoir is mainly developed in Xiaoerblak Fm., and the lithology is mainly microbial dolomite; The thickness of Xiaoerblak Fm. is between 158m and 178m, form the bottom up, it can be divided into four members, Member X1 mainly developed laminated microbial dolomite (LMD) with gentle ripple-like structure and bright–dark pattern; Member X2 mainly developed massive thrombolite dolomite (MTD); Member X3 mainly developed foamy microbial dolomite (FMD), grain dolomite (GD) with microbial bind structure and oncolite domolite (OD); Member X4 mainly developed laminated microbial dolomite with Tepee (LMDT), laminated stromatolite dolomite (LSD), micritic dolomite (MD) and argillaceous dolomite (AD); (2) Vugs, framework pores, fenestral pores, intergranular dissolved pores are the main reservoir spaces; The porosity has high lithofacies selectivity, FMD has the highest average porosity (5.7%), MTD and OD are secondly (4.1%~4.3%), GD and LSD are thirdly (2.2%~2.4%); Generally speaking, the microbial reservoir has the characteristics of middle–high porosity and middle–low permeability, and the average thickness is about 41.3m. (3) Low dolomite order degree(0.45~0.77), relatively low Fe, Mn and high Na content, δ18O(-6‰~-8‰, PDB) and 87Sr/86Sr (0.7090~0.7095) have the characteristics of Cambrian seawater, deficit of light REE and enrichment of heavy one indicate that the dolomitization of microbialite were took place in early diagenetic stage and the main dolomitization fluid is relevant to coeval seawater. (4) Pores were formed in synsedimentary or penecontemporaneous period based on laser U-Pb radiometric dating data (Age of microbial dolomite is 515±30Ma and calcite cement in the pores is 495±12Ma); According the negative excursion points in δ13C curve are correspond with the high porosity zones, it can be clearly prove that there exist disconnected surface of sedimentary, microbialites were dissolved by fresh water in penecontemporaneous period. Cambrian pre–salt ultra–deep microbial reservoir was mainly controlled by lithofacies and high–frequency sequence and early dolomitization. By establishing the reservoir geological model of study area, it shows that microbial mounds in inner to middle ramp around the ancient uplift are the favorable facies zone.

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Reservoir rock classification based on fusion clustering analysis: A case study of M Group in H oilfield, Iraq

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Keywords: H oilfield,M formation,fusion clustering,carbonate rock classification, reservoir type

The carbonate reservoir of formation M in H oilfield of Iraq has strong vertical heterogeneity and complex pore structure. Accurate understanding of the reservoir rock type severely restricts the development and deployment of waterflood in the later stage of the reservoir. Based on the data of core, thin section, logging and petrophysics, a clustering classification method combining petrophysics and geological origin of formation M in H oilfield is established, and five reservoir rock types are divided: mudstone, wackdetone, low-energy granular limestone, mixed granular limestone I and mixed granular limestone II, high-energy granular limestone I and high-energy granular limestone II. The physical properties from good to bad are: high-energy granular limestone I, high-energy granular limestone II, mixed granular limestone I, mixed granular limestone II, low-energy granular limestone, wackdetone and mudstone. The results show that the mixed granular limestone I, the high-energy granular limestone I, and the high-energy granular limestone II have a large oil production index per meter and a long stable production time. The high-energy granular limestone I is an abnormally high-permeability layer, and it is the rock type that should be evaluated during the water flooding process. The classification method of reservoir rock types established in this paper provides a new geological basis for geological modeling, reserve evaluation and waterflooding development plan design.

Reference

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
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Reservoir characteristics and formation model of the Mao-1 Member of Middle Permian in eastern Sichuan Basin

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Keywords: eastern Sichuan Basin, Makou Formation, reservoir characteristics, pore structure, controlling factor, reservoir development model

The Permian is an important period for the transformation of the Phanerozoic global pattern and the Pangea supercontinent began to break up and the Paleo-Tethys Ocean expanded further. The global paleoclimate experienced a transition from cold to warm in Permian and the climate was still cold in the early to middle Permian. Recently, great exploration discoveries have been made in unconventional argillaceous limestone of Mao-1 Member in Middle Permian of borehole JS1 and YH1 in Eastern Sichuan Basin. Based on field outcrop, core description, thin section identification, petrophysical analysis, X-ray diffraction, nuclear magnetic resonance, Ar-ion polishing scanning electron microscope, TOC test and CT scanning, as well as well logging data interpretation, the reservoir characteristics and controlling factors of Mao-1 Member argillaceous limestone have been discussed in this paper. The mudstone, micritic bioclastic limestone, bioclastic micritic limestone and argillaceous bioclalstic micritic limestone dominate in Mao-1 Member with intergranular pores (fractures), organic pores, dissolved pores (fractures), fractures and talc shrinkage pores (fractures) in reservoir spaces. The Mao-1 Member reservoir in eastern Sichuan Basin is low porosity and low permeability. The pores of mudstone are mostly less than 0.1μm in size with unimodal style, 0.69% in average porosity, lower movable fluid saturation and connectivity. As for the micritic bioclastic limestone reservoirs, the pores are dominated by small to medium pores in size of 0.1μm to 0.5μm, with bimodal style, 0.79% in average porosity and grade II connectivity. The bioclastic micritic limestone and argillaceous bioclastic micritic limestone are higher quality reservoirs with medium to larger pores in size of 0.5μm to 1μm, bimodal style, larger movable fluid saturation, grade III connectivity and 1.97%, 2.70% in average porosity respectively. The Mao-1 Member reservoirs in eastern Sichuan Basin is controlled by sedimentary microfacies, organic matters abundance and diagenesis processes. The outer ramp bioclastic micritic limestone microfacies and argillaceous bioclastic micritic limestone microfacies are the most favorable reservoirs with more pores and clay minerals. The pores are close related to the clay mineral. On one hand, the pores are protected through inhibiting calcite precipitation resulting from the organic matter adsorbed by clay minerals. On the other hand, the newly formed micropores and organic pores by clay mineral transformation, which consist of the most part of the reservoir spaces. Besides, the pores related to dissolution and dolomitization occupy another part of reservoir spaces, which would further improve the reservoir quality. Finally, the reservoir development model of Mao-1 Member in eastern Sichuan Basin is established. During sedimentary period, the bioclastic micritic limestone and argillaceous bioclastic micritic limestone have been selectively dissolved by meteoric freshwater, forming dissolution pores and channels for fluid modification. During the medium to deep burial phase, sepiolite underwent diagenetic transformation, forming a large number of clay micropores and organic matter pores. At the same time, the released Mg^{2+}-enriched diagenetic fluid result in dolomitization, so as to improve the reservoir quality. In the deep burial period, the acid fluid further modified the reservoir, to form pressure solution fractures which would further improve the reservoir quality.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
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Compound karst development in carbonate-evaporite basin: models and application to reservoirs of the Ordovician Majiagou Formation in Ordos Basin, China

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Keywords: Carbonate-evaporite basin, Compound karst, reservoirs, Majiagou Formation, Ordos Basin

Abstract: Three carbonate and evaporite sedimentary cycles are well developed in the Ordovician Majiagou Formation. Members 1, 3 and 5 of the Ordovician Majiagou Formation are composed of gypseous dolomite and anhydrite-salt rocks. Members 2, 4 and 6 are mainly carbonate rocks. Reservoirs with prominent characteristic of sandwich-like structure are extensively distributed in basin marginal areas, which is an important field of gas exploration in Ordos Basin. Based on the comprehensive analysis of formation correlation, sedimentary principle analysis and sequence stratigraphic interpretation in evaporite-carbonate successions from wells, cores and field profiles, the following understanding of the genetic model of compound karst and the controlling factors of reservoir development are got as follows1) Thick evaporites must correlate to unconformities in their surrounds, there is an asynchronous time between carbonate in the basin margin and evaporates in basin center. 2) Sequences begin with the evaporites, precipitated as lowstand basin-centre halite fills in complete drawdown basin, and carbonate sediments mainly deposited on shallow-water platforms apron the basin during transgressive and highstand systems tracts; 3) Early dissolution occurred in basin margin, and the edges of a thick evaporite succession where flushing by meteoric water and characterized by layers of thin dissolution breccias when the evaporite dissolves completely, especially in the thin layers of carbonate interbedded with sulphate rocks; 4) It is clear that the stratiform gypsum-dissolved breccia layers are mainly distributed in the outer area of evaporite, the shoal dolomite beds below breccia layer are favorable reservoir segments, and the gypsum-moldic pores were developed outside; 5) The lateral erosion or sedimentary discontinuities are the main factors for the interlayer dissolution, and the multi-stage sedimentary discontinuities control the development range of reservoirs. These models are applied to the Ordovician Majiagou Formation in Ordos Basin, and sequence and parasequence boundaries are identified. Together with regional uncomformity (between Ordovician and carboniferous), shoal facies and fault-reated corrosions, the reservoirs model with features of superimposed compound karst zones are proposed and play significant role in predicting the distribution of favorable reservoir area.

Scientific Themes: Theme 7. Carbonate Sedimentation
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Controlling effect of Cretaceous shoal facies types on reservoir development in Iraq---- Take KH2 Member of Khasib Formation in A Oilfield as an example

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Keywords: Shoal facies type, Cretaceous, Reservoir development mechanism, Khasib member, Iraq

The cretaceous limestone reservior in Iraq A oilfield has complex pore structure and strong longitudinal heterogeneity, and the unclear controlling factors of reservior development seriuosly restrict the oilfield development and recovery efficiency.Based on the data of core, thin section and logging response, the sedimentary subfacies of the KH2 member is divided into intra-platform shoal and grey flat, which are mainly composed of psammitic shoal, bioclastic shoal, algal-clastic shoal and inter-shoal. On the basis of Dunham classification, the KH2 member can be divided into seven lithofacies according to the main particle types, including planktonic foraminifera wackstone, laminar bioclastic wackstone, intraclast bioclastic packstone, patchy green-algal packstone, bioclastic intraclast packstone and intraclast grainstone. The pores of carbonate resevoir are mainly moldic pore, intrafossil pore, intergranular pore and dissolved pore. Based on the differences of sedimentary microfacies, lithology, pore type, physical characteristics and pore structure, it is clear that the type of shoal facies is the main controlling factor of reservoir development. Psammitic shoal and algal-clastic shoal have the best physical properties and have the characteristics of stable transverse distriction. This study reveals the controlling factors of thick shoal limestone reservior and makes it clear that the key factor for the development of such reservior is the fine description and evaluation of sedimentary microfacies and lithofacies.

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Genesis and Classification of Breccia in Cretaceous limestone Reservoir of H Oilfield in Iraq

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Keywords: Iraq,Cretaceous,H oilfield,Carbonate breccia,genetic classification

Breccia rocks with different production and characteristics develop in the Cretaceous reservoirs in Iraq, but they have not attracted enough attention in previous studies.In order to clarify the sedimentary process and diagenesis contained in the breccia, this study classified the breccia according to their origin.Using the drilling core, thin section and logging data in the study area, this study thought Iraq H oilfield Cretaceous carbonate breccia in formation can be divided into two categories: sedimentary origin breccia, for early weak consolidation carbonate geological effect, such as short-term high-energy water transformation, formed in the slope and bottom scour breccia, collapsed breccia and storm breccia, etc; non-sedimentary breccia, mainly karst breccia from unintegrated surface, whose development is related to the unintegrated surface in the top area of Mishrif group.The sea-level drop caused large exposure, forming karst breccia of grey-green mudstone mixed with white carbonate breccia.The sedimentary breccia reflects the slope-ancient uplift area, indicating the development of grain shoal and rudist organic reefs in its adjacent area.Karst breccia indicates the geomorphic units with more obvious topographic fluctuations, such as the residual mound edges in karst slopes and karst depressions.The results support the origin of breccia in carbonate reservoir under similar geological background.

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Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
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Origin of the deep buried dolostone reservoir of the Lower-Middle Cambrian, Tarim Basin, NW China

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Keywords: Origin, Deep Buried, Dolostone Reservoir, Cambrian, Tarim Basin

The origin of the porous dolostone in the deep buried environment arouses the interests of geoscientists and attracts the attention of explorationists. Recent global oil and gas exploration is advancing to deep and ultra-deep ancient marine carbonate rocks, one of such targets is the deep buried Cambrian dolostone reservoir in the Tarim Basin. It is obvious that the deep buried old strata had experienced the processes of sedimentation and diageneses. Sedimentation created the primary pores and the diageneses reworked the pores by enlarging or filing the pore space. For deep buried carbonate reservoir, the diagenetic evolution sounds playing the key role to establish the final reservoir. Based on the microfacies analyses, petrographic research and geochemical analyses of the dolostone reservoir samples from the Cambrian outcrop and well core, we ascribe the origin of the reservoir to the preservation of original pore spaces in the process of burying.

The Lower-Middle Cambrian can be divided into five third-order sequences (SQI-SQV), in which 17 microfacies (MF) types were recognized and further grouped into 7 microfacies associations. SQI-SQIII were mainly ramp deposits which changed vertically from muddy ramp to carbonate ramp and then to mixed ramp, while SQ IV-SQV were weakly rimmed carbonate platform deposits. The reservoir is mainly composed of microbial dolostone (MF9) and grain dolostone (MF10c, MF13). The reservoir quality of grain dolostone is better than that of microbial dolostone. The pore space of grain dolostone reservoir is intergranular pores and intercrystal pores, while the microbial dolostone reservoir is dominated by microbial framework pores, vugs or caverns and fractures.

The grain or microbial dolostones developed as shoals and microbial mounds in the high energy environment had abundant intergranular primary pores, which also deposited as a positive landscape and then be easy affected by the early diagenesis, such as penecontemporaneous meteoric dissolution. When these deposits with high primary and early secondary porosity were buried, the preservation of porosity was attributed to early massive dolomitization and rapid sealing effect of the overlaying thick evaporites. One reason is that the relatively closed buried system can keep pore fluid overpressure and reduced the pressure solution and cementation of the pores. The other diagenetic changes such as deep faulting and related thermal fluids affection might have strong influences on the reservoir quality and distribution, but generally these changes took place in deep environment could only attribute a little or local reconstruction of reservoir space by considering the limited fluids flux and its dissolution ability.

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Characteristics and distribution of microbial-dominated carbonate in the Second Member (Z2dn2) of Dengying Formation in Central Sichuan Basin, China: New insights from 3D sedimentary forward modelling

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Keywords: Microbialites, Numerical Simulation, Dengying Formation, Sichuan Basin

As one of the oldest and deepest carbonate gas-bearing strata in China, Dengying Formation reemerged as the exploration target after the breakthrough of GS1 well in Central Sichuan Basin [1]. Previous studies indicated that reservoirs of Dengying Formation mainly dominated by microbial dolomites, including stromatolitic dolomitess, thrombolitic dolomites and straticulate dolomites [2, 3]. Researches of microbial dolomites characteristics in Second Member of Dengying Formation (Z2dn2) has been carried out via cores, slices, logging and seismic interpretation [4, 5]. However on account of large burial depth and strong heterogeneity, it's hard to accurately predict the spatial and temporal distribution of microbial-dominated reservoirs in Z2dn2. Based on documents investigation, 10 wells cores description, slices observation and samples experiments, we acquired the necessary parameters like simulation duration, palaeotopography, eustatic sea-level change, tectonic subsidence, temperature, salinity, subaerial erosion and microbialites growth fuzzy sets. After multiple parameters calibration during simulation process, we carried out the 3D sedimentary forward modelling of microbialites developments in Z2dn2 using Sedsim software. By comparing simulation results with actual geological data including seismic sections, depositional facies and individual well thicknesses, we confirmed the model validation. Our simulation results indicated that six types of sedimentary facies are developed in Z2dn2, including supratidal facies, intertidal facies, shallow-subtidal facies, deep-subtidal facies, slope and basin facies. Microbial-dominated reservoirs mainly developed in shallow-subtidal facies and abundant high-quality dolomite calcolistolith also occurred in slope and basin facies.

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Application of ultra deep thin layer carbonate reservoir prediction technology under the constraint of sedimentary facies in Qixia Formation of shuangyushi structure

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Keywords: Waveform indication inversion,Seismic facies,sedimentary facies,Thin reservoir prediction,shuangyushi structure

The dolomite reservoir of the Middle Permian Qixia Formation in shuangyushi structure in the northwest of Sichuan Basin has deep burial depth, thin thickness and strong heterogeneity. Under the condition of low resolution seismic data, the reservoir signal is not easy to identify and the reservoir prediction is difficult. Based on high-resolution seismic data processing, well seismic combination, starting from forward simulation and combined with real drilling profile, this study defines the waveform characteristics corresponding to different reservoir development modes. The research shows that the reservoir of Qixia Formation in the area has two response modes of "weak peak" and "complex wave". Through waveform clustering technology and referring to the drilled lithofacies information, a seismic facies plan is formed to finely depict the plane distribution of the reservoir; On this basis, high-resolution seismic waveform indication inversion under facies control constraints is carried out to clarify the distribution range of dolomite reservoir. The actual drilling results confirm that the coincidence rate of reservoir prediction is high, which provides a reference for the prediction of ultra deep and thin reservoirs in this area.

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Influence of current surface stress field on the distribution of deep carbonate reservoirs-a case study from the Upper Member of Yingshan Formation in well S66 area of Tahe Oilfield, Tarim Basin

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Keywords: Carbonate reservoir, Formation pressure, Maximum and minimum principal stress, Stress difference, Upper Member of Yingshan Formation, Tarim Basin

Since carbonate strata is brittle and prone to fracture, the tectonic movement is of great significance to the formation and distribution of carbonate reservoirs, especially the surface stress field is closely related to the reservoir distribution. However, it is still unclear how the surface stress field controls the distribution of carbonate reservoirs. In order to clarify the specific control effect of surface stress field on deep carbonate reservoir, this paper takes the Upper Member of Yingshan Formation in well S66 of Tahe Oilfield in Tarim Basin as an example, and makes full use of geophysical data to carry out comprehensive research in combined with drilling and reservoir engineering as well as other information. Firstly, the overlying strata pressure, formation pressure, maximum and minimum principal stress and stress difference in a single well were calculated. Then the distribution law of surface stress and stress difference in space were determined. In addition, through the comprehensive analysis of the correlation between the parameters such as porosity, reservoir thickness and fracture thickness. Finally, the distribution of surface stress field parameters, and the control effect of current surface stress field on reservoir distribution were determined. The surface stress interpretation data show that the overlying formation pressure of the Upper Member of Yingshan Formation is high in TK629H in the east, S66 in the middle and TK671 in the west, ranging from 129.95 to 130.95 MPa, and is low from TK682 to TK677 well area in the south with a value between 123.2 and 124.56 MPa. The formation pressure is between 57.8 and 61.81 MPa, with an average of 58.2 MPa, and the formation pressure coefficient is between 1.07 and 1.14, with an mean of 1.10, implying a normal pressure system. The maximum horizontal principal stress varies from 151.8 to 160.4 MPa, with a mean of 155 MPa, the minimum horizontal principal stress is between 91.6 and 97.2 MPa, with an average of 95.2 MPa, and the stress difference between maximum and minimum ranges from 58.1 to 63.2MPa, with an average of 59.5 MPa. Study on the relationship between surface stress field and reservoir parameter distribution shows that the high reservoir thickness value area is mainly distributed in the relatively low formation pressure, low maximum horizontal principal stress, high minimum horizontal principal stress and low stress difference value area. The high value area of reservoir porosity distribution is mainly distributed in the high value area of pressure coefficient and minimum principal stress, the low value area of maximum principal stress and stress difference. The high value area of fracture thickness is mainly developed in the low to middle value area of formation pressure coefficient, maximum horizontal principal stress and stress difference, as well as the relative low value area of minimum horizontal principal stress.

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COMPARATIVE EVALUATION OF QUANTITATIVE PETROGRAPHY, MICRO-CT, AND AUTOMATED IMAGE ANALYSIS MEASUREMENTS ON PRE-SALT CARBONATES

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Keywords: image analysis, micro-CT, porosity, pre-salt reservoirs, carbonates

Pre-salt deposits respond for more than 70% of hydrocarbon production of Brazil, and are currently the subject of several petrological, sedimentological and stratigraphic studies. These complex deposits present important reservoir heterogeneities, and their evaluation by different methods is necessary for a better understanding of their petrophysical properties. This study seeks to compare different porosity assessment tools in core samples, thin sections, and digital photomicrographs. Porosity quantification was performed using three methods: (i) image acquisition and processing using a Bruker SkyScan 1173 µ-CT; (ii) thin section point-counting; and (iii) porosity analysis on photomosaics using ZEISS ZEN 3.1 and Bruker CTAn 1.13 image analysis software. The selected samples represent different facies of a cored interval in one well of the Pre-Salt section of Santos Basin, and show different porosity characteristics, owing to different depositional and diagenetic aspects. Samples comprise shrubstones, mudstones, shrubs-spherulstones, and reworked intraclastic facies. The results indicated that the calculated porosity values vary according to the applied method and the resolution of the analysis. µ-CT scanning was performed at a resolution of 10 µm to 7 µm, which yielded higher porosity values. While point-counting petrography resulted in a measurement of 23% of porosity for a sample from a reworked deposit, values between 4% and 5% were obtained through the analysis of a photomosaic from the same thin section. Preliminary quantitative petrography analysis resulted in significantly high porosity values when compared to semi-automated porosity calculation on a photomosaic, which resulted in values close to those obtained through microtomography image processing of a sample. On the other hand, petrography helped to recognize the types and distribution of pores in each facies, allowing the refinement of the regions of interest (ROI) for porosity calculation through image analysis. In addition, detailed petrography was used to understand the possible causes of the discrepancies between the techniques. For example, the microporosity in calcite aggregates and intraclasts present in these lithologies, which is observed in petrography, is not properly assessed by the other techniques, as the micropores sizes are usually below the resolution of the methods. Additionally, it must be noted that the samples cut for thin section preparation and for µCT must be representative of the layer, considering the rapid vertical variation of Pre-Salt deposits. The work in progress aims to gather data for a statistical analysis of the patterns of discrepancy among the results coming from the different methods, as well as to discuss their geological significance, concerning the porosity characteristics observed in petrography and core analysis of the Pre-Salt reservoirs.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
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Well Logging Identification and Application of Carbonate Sedimentary Microfacies of Changxing - Feixianguan Formation in the Longgang Area, Sichuan Basin

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Keywords: Longgang area,Changxing-Feixianguan Formation,Carbonate reservoir,Image logs facies,Sedimentary microfacies

The Changxing-Feixianguan Formation in the Longgang area of the Sichuan Basin is rich in oil and gas resources. However, the development of reservoir evaluation has been severely restricted by the complex sedimentary types, variable lithology and lithofacies, and strong reservoir heterogeneity. Thus, it is great significant to study the logging identification of lithology and sedimentary microfacies in this area .In this study, the carbonate reservoir of the Changxing-Feixianguan Formation in the Longgang area is taken as an example. Based on the cores, thin sections, conventional logs, image logs, experiment and production data, the classification scheme for image logs facies and sedimentary microfacies has been established firstly with the guidance of classic carbonate deposition models. Then, the comprehensive identification chart of sedimentary microfacies has been established by using the method of "conventional + image + core + geological model ", and the vertical continuous identification of sedimentary microfacies of each single well has been achieved. Finally, the relationship between high-quality reservoirs and sedimentary microfacies has been clarified by combining the test data and comprehensive logging interpretation. The results indicated that the sedimentary facies types of Changxing-Feixianguan in Longgang area are mainly platform margin facies, open platform facies, restricted platform facies and slope facies. According to the characteristics, they can be further subdivided into ten subfacies including platform margin beach, platform margin reef-complex, beach interact sea , intra-platform beach, intra-platform reef, open sea, platform flat, restricted lagoon, restricted tidal flat, upper slope and more than twenty microfacies. Meanwhile, the image logs facies of typical sedimentary microfacies in the study area are mainly divided into five categories: layered pattern, linear pattern, strip pattern, spot pattern and massive pattern, which can be further divided into nine sub-categories: laminar pattern, thin-layered pattern, strip pattern, irregular line pattern, single line pattern, bright massive pattern, dark massive pattern, honeycomb dark spots pattern, and blocky dark spots pattern. In addition, the results of oil testing and statistical analysis of comprehensive logging interpretation further prove that microfacies such as high-energy bioclastic beache and dolomitized oolitic beache are favorable sedimentary microfacies for the development of high-quality reservoirs. The research results provide basis for the fine evaluation of reservoirs in the Changxing-Feixianguan Formation.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
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Defining the age of ultra-deep carbonate diagenetic minerals and their fluid sources based on in-situ U-Pb isotope dating, in-situ isotope and rare earth element analysis techniques: A case study of the Cambrian subsalt dolomite reservoir in the Tazhong uplift, Tarim Basin

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Keywords: Cambrian subsalt dolomite, U-Pb isotope dating, Rare earth element, Thermal fluid, Permian magmatic activity

The formation and distribution of diagenetic minerals in reservoirs and the sources of diagenetic fluids are of great significance for analyzing reservoir formation and evolution, limiting hydrocarbon and other geological fluid charging events, and analyzing their related geological processes.

The Lower Cambrian Xiaoerbulak Formation in wells ZH1 and ZH2 in the Tazhong uplift in the Tarim Basin was taken as an example. Based on rock thin section observation, cathodoluminescence analysis, scanning electron microscope observation and energy spectrum analysis, combined with the analysis of the homogenization temperature of inclusions, the mineral type, occurrence and relative diagenetic sequence were clarified. And the ages of carbonate diagenetic minerals and sources of diagenetic fluids were determined by using the methods of laser in-situ U-Pb isotope dating, in-situ carbon and oxygen isotopes, strontium isotopes and rare earth elements (REEs).

The results show that the dolomite reservoirs of the Xiaoerbulake Formation in the Tazhong area mainly develop silty-fine-crystalline dolomite, saddle-shaped dolomite, granular calcite and quartz minerals. The silty-fine-crystalline dolomite is mainly distributed at the edge of the pores and is a relatively early dolomitization product. The cathodoluminescence is similar to that of host rocks. The diagenetic fluid is normal seawater pore fluid. The saddle-shaped dolomite is divided into two stages, with a U-Pb age of 453±7Ma and 435±29Ma. The REE distribution pattern is similar to that of host rock. Therefore, it is a buried dolomitization product and the diagenetic fluid is normal seawater in pores. The U-Pb isotopic dating indicates that the calcite filled with dissolved pores was formed in the Middle Permian (263±9Ma). The analysis of carbon and oxygen isotopes, strontium isotopes and REEs shows that the values of $\delta^{13}C$, $\delta^{18}O$, $^{87}Sr/^{86}Sr$ of calcite cement from ZH1 is close to those of host rocks. The REE distribution pattern is characterized by light REE enrichment and positive δCe anomaly and the total content of rare earth elements (∑REE) is slightly higher than that of host rocks, which reflects that calcite inherits the characteristics of REE in host rocks. This further indicates that the calcite diagenetic fluid is derived from a mixture of diagenetic fluids and hydrocarbon-generating fluids.

Compared with well ZH1, the calcite from well ZH2 has more negative carbon and oxygen isotope values. That is, the average value of $\delta^{13}C$ is -4.3‰ and the average value of $\delta^{18}O$ is -11.0‰. Moreover, some calcites have bright red cathodoluminescence, and the luminescence intensity is higher than that of the host rocks. REE analysis shows that there is a relatively obvious δEu positive anomaly. In addition, the calcite can be symbiotic with quartz in pores and fractures, and the homogenization temperature of primary inclusions is higher than the maximum burial temperature of contemporaneous strata. These indicates that this type of calcite cement is mainly the result of the combined interaction of diagenetic fluid and thermal fluid, and the thermal fluid is probably related to the Tarim Permian magmatic activity.

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Sedimentary and reservoir characteristics of Cambrian Xiaoerbulak Formation in Tarim Basin

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Keywords: Dolomite reservoir,sedimentary facies,Control factors,Xiaoerbulak formation,Tarim Basin

The Cambrian Xiaolbulak Formation in the central and western Tarim Basin is composed of dolomitic limestone, dolomite, microbiolite, limestone interspersed with a small amount of argillaceous limestone and gypsum dolomite. It is dominated by carbonate gentle slope and carbonate confined platform faciesIn the northeast the water deepened to shelf - basin facies, and thirteen microfacies could be identified. Tidal flat facies dolomite and bioherm beach facies dolomite reservoirs are developed in Xiaolbulak Formation. The atmospheric water dissolution and dolomitization in supergene period are the key to formation and development of reservoir. Fracturing and burial (hydrothermal) dissolution improve the reservoir. Tidal flat facies dolomite reservoirs are developed in the restricted environment of middle and inner gentle slope, tight limestone deposits are formed in the middle and outer gentle slope semi-restricted environment, and better dolomite reservoirs are formed in the late platform margin zone. The dolomite reservoir of Xiaoerbulak Formation in northeastern Tahe platform margin and central-western Tazhong area are favorable exploration targets for subsalt deep strata.

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Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
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Differences and pattern of karst reservoirs in the Majiagou Formation in the northern Ordos Basin

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Keywords: evaporated salt minerals, carbonate rock; karst model, reservoir, Majiagou Formation, Ordos Basin

Karst reservoirs are generally developed in the Majiagou Formation in the northern Ordos Basin, but are obviously different from the classic karst model. Through petrological and geochemical analysis, three types of reservoirs with genetic connection and affected by gypsum-bearing strata are identified, and the karst model of evaporated rock in Majiagou Fm. is established. The results show that gypsum mold pore reservoir is formed by the Sabkha dolomitization and rich in evaporated minerals, the sedimentary environment is gypsum-bearing dolomite flat. Dissolved pore-intercrystalline (vug) pore dolomite reservoir is formed by the brine-reflux dolomitization, which fluid comes from the overlying gypsum bearing strata and is mainly developed in shoal facies. Limestone-fractured-cavity reservoir is mainly developed in limestone formations, the original sedimentary environment is limestone flat, and the formation of cracks in (dolomitic) limestone is related to the dissolution and deformation of the underlying gypsum-bearing rock. In terms of spatial distribution in the study area, all three types of reservoirs are distributed in the central and eastern regions, the dissolved pore-intercrystalline (vug) pore dolomite reservoirs developed in the western, and the limestone-fractured-cavity reservoirs in the northern. The same reservoir type also exhibits different rock and geochemical characteristics in different paleo-geomorphic units. The higher parts are mostly characterized by seepage areas. The reservoirs are well preserved, a small amount of filling, and less atmospheric precipitation geochemical characteristics. The lower part shows the characteristics of stagnant water area, with serious reservoir damage, a large amount of calcite filling, and more atmospheric precipitation transformation characteristics.

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Sequence Stratigraphic Framework of Leikoupo Formation of Middle Triassic in Western Sichuan and Hydrocarbon Generation and Reservoir Effect of Tidal Flat Lagoon Carbonate Rocks

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Keywords: Leikoupo Formation, sequence stratigraphic framework, microbial rocks, tidal flat lagoon, hydrocarbon generation and reservoir formation

During the Middle Triassic period, the West Sichuan depression was a closed evaporating tidal flat lagoon sedimentary environment. Ten shallowing-upward sedimentary cycles, which were composed of carbonate evaporates, were identified and subdivided into four third-order sequences based on detailed observation of five outcrop sections and four drillcores. At that time, microbialites mainly composed of columnar stromatolites and clotted agglomerates were extensively present in the second and fourth members of Leikoupo Foramtion. Columnar and wavy stromatolites generally occurred in the lower part of the intertidal-supratidal zone, whereas clotted limestones and oncolites mainly distributed in the lower part of intertidal-subtidal zone during the sea-level cycle of declination. The number and thickness of these microbial rocks are gradually decreasing (thin) from west to east and columnar stromatolites accordingly transform into wavy stromatolites to mound. These microbialites generally exhibit variable reservoir heterogeneity. The high-quality microbialite reservoirs, which consist of stromatolite and clotted limestone, mainly occurred in the rising semi-cycle. In addition, the salt rocks formed in the evaporating tidal flat and lagoon have well hydrocarbon generation potential during the regression period. Therefore, tidal flat and lagoon are favorable sedimentary environments for the foramtion of source rocks.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
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Distribution Characteristics and Sedimentary Model of Gypsum-bearing Evaporite of the Middle Cambrian Gaotai Formation in the eastern Sichuan Basin

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Keywords: Gypsum-bearing evaporite, Eastern Sichuan Basin; Gaotai Formation, Normal lagoon, Mixed deposition lagoon, Depositional model

ABSTRACT Gypsum-bearing evaporite is a globally important oil and gas cap-rock. Sealing of oil and gas reservoirs by gypsum-bearing evaporite is of great importance for oil and gas storage, particularly for natural gas. During the Middle Cambrian, the Gaotaii Formation, gypsum-bearing evaporite was deposited in the eastern Sichuan Basin, which is a key caprock for deep oil and gas resources. Yet little research exists on the gypsum-bearing evaporite of the Gaotai Formation. Based on a field survey, the latest well, lithology, logging and comprehensive analysis of previous data, the lithological division, and genetic type analysis of the gypsum-bearing evaporite, a platform sedimentary model was established. Two sets of gypsum-bearing evaporate associations are developed longitudinally in the Middle Cambrian Gaotai Formation in the eastern Sichuan Basin. The sedimentary environment is divided into normal lagoon and mixed deposition lagoon environments and is influenced by the provenance supply. As sea-level decreased, a “bull’s eye ring banding” pattern of sedimentary units formed in the normal lagoon. When the sea-level rose, thinly interbedded gypsum-bearing evaporite was deposited in both type of lagoons. Overall, gypsum-bearing evaporite has a "broad circular ring" distribution in the northeast direction, indicating that the dry and hot paleoclimate, continuous sea level decrease, incoming materials, and shoal barrier provided favorable conditions for the development of the gypsum-bearing evaporite in the Middle Cambrian Gaotai Formation in the eastern Sichuan Basin. The Jianshen 1 well-Wuxi gypsum-bearing evaporite block and the Taihe 1 well-Shizhu outcrop gypsum-bearing evaporite block were the two primary gypsum-bearing evaporite deposition areas at that time. Increased paleo-temperatures led to the formation of the thinner Gaotai Formation evaporite caprocks overlying the hydrocarbon-bearing reservoirs in the Longwangmiao Formation.

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Scientific Themes: Theme 7. Carbonate Sedimentation
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Sedimentary Characteristics and Developmental Models of the Cambrian Dolostone-evaporite Paragenesis System in the Sichuan Basin

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Keywords: dolostone, evaporite, paragenesis system, sedimentary characteristics, developmental models

Abstract: The Cambrian strata of Sichuan Basin, China, present many dolomite-evaporite paragenesis systems (DEPS), which contain oil and gas resources with industrial exploitation. However, despite their wide distribution, the formation models and influencing factors of DEPS remain poorly understood. Regarding an abundance of literature from China, this study comprehensively summarises the sedimentary characteristics, combination patterns of rocks, and formation models of DEPS. The research significance, research questions, and future research directions of DEPS are also clarified. Firstly, the distribution of DEPS is clarified based on published studies: DEPS are widely distributed in Longwangmiao Formation, Gaotai Formation, and Xixiangchi Formation of the eastern and southern Sichuan Basin. Evaporite and dolostone combination patterns in DEPS include the following modes: interbedding of dolostone and evaporite, evaporite overlying thick dolostone, thick dolostone mixed with thin evaporite, and thick evaporite mixed with thin dolostone. Secondly, five types of evaporites and five types of dolostones have been identified. Thirdly, the spatiotemporal distribution, influencing factors, and developmental models are summarised. Studies on DEPS provide new insight into the origin of dolomite. Such research also provides theoretical guidance for the exploration of oil and gas resources in DEPS.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Oral Preferred

Understanding depositional evolution of ancient carbonate systems using 3D stratigraphic forward modelling: A case study in Puguang area (Late Permian, northeast Sichuan Basin, China)

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Keywords: Puguang area, Late Permian, deep burial carbonates, depositional evolution, stratigraphic forward modelling

Predicting temporal and spatial features of deep burial ancient carbonate depositional systems is challenging, which is limited by the lack of well data, poor seismic quality and unclear sedimentological mechanisms. The formation of carbonate depositional systems is a dynamic evolution process controlled by the interactions between various factors which determine the carbonate system types, geometries and facies distribution. To better understand the evolution history and the interactions between controlling factors of ancient carbonate systems, a quantitative analysis of the Late Permian carbonate depositional systems in Puguang area (northeastern Sichuan basin, China) is performed using iRDS-CarbSIMS, a 3D process-based stratigraphic forward and inverse modelling software able to simulate the sedimentary facies and internal architecture. Qualitative research on depositional characteristics within sequence stratigraphic frame is a precondition for stratigraphic forward modelling. Based on seismic interpretation, cores and well log data analysis, the transition from a carbonate ramp to a high-relief, reef-rimmed platform during the Late Permian Changxing period were investigated. Five main categories of parameters used for modelling were deduced from the geological qualitative research and analogue with modern deposition, including initial topography, sea level curves, subsidence, carbonate production and sediment transport. Modelling results reconstruct the evolution process of the Late Permian carbonate depositional systems in Puguang area, revealing sedimentary facies distribution in areas with sparse wells. Sensitivity analyses of the parameters provide insights into the interactions between controlling factors of carbonate platform growth, as well as the effect of regional controls on differential evolution. The integrated sedimentological approach combining qualitative research and numerical modelling is useful for mining information of geological data to the utmost in deep burial carbonate successions. Stratigraphic numerical models can promote the understanding of mechanisms of depositional evolution, improving the accuracy of sedimentary facies prediction of deep burial carbonate reservoirs.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Oral Preferred

Reformation of the hydrothermal fluid activities to the Lower Paleozoic carbonate reservoir in Dongying Depression

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Keywords: Dongying Depression, The Lower Paleozoic strata, Carbonate reservoir, Hydrothermal fluid, Reservoir property

Abstract: The carbonate reservoir of the Lower Paleozoic in Dongying Depression is controlled by multiple types and stages of hydrothermal fluids after experiencing multiple stages of tectonic activity and volcanic activity after depositionwhich leads to the enhancement of reservoir heterogeneity, and seriously restricts the further exploration and development of the study area. Taking the lower Paleozoic marine carbonate reservoirs in the Dongying Depression as the research object, through the mineralogy and electron probe analysis technology, identified the types of fillings in the fractures (holes) in this study area, and combining geochemical data and pore evolution characteristics, the hydrothermal fluid properties, and the hydrothermal fluid's influence on the reservoir property is explored. The results show that: (1) Thermal fading of the carbonate rocks, hydrothermal fluid activities induced fractures, and hydrothermal minerals are widely developed (such as saddle dolomite, ferroan dolomite, celestite, anhydrite). The fluid inclusions of the fillings have a higher temperature than the maximum burial temperature, and positive Eu anomaly, $\delta^{18}O$ values negative anomaly. These characteristics also indicted that hydrothermal processes exist extensively in this study area; (2) The hydrothermal fluids mainly included the Mg-rich, Ca-rich and Sr-rich hydrothermal fluids in the Yanshan movement period, which precipitated the ferroan dolomites, saddle dolomites, granular ferroan calcites and celestite, respectively. Under the influence of terrigenous clastic materials, the ferroan dolomites and granular ferroan calcites exhibit high $^{87}Sr/^{86}Sr$ values and extremely positive Eu anomalies, respectively. The hydrothermal fluid dissolves the gypsum and salt layers in Sha-3 Sha-4 formation to form S-rich hydrothermal fluid in the Himalayan movement period, dissolves carbonate formation to obtain Ca^{2+}, and precipitates anhydrite in fractures; (3) Reservoir reformation by hydrothermal action controlled by lithology, fault, and fluid properties. The hydrothermal fluids mostly intruded along the dolomite and grain limestone with better original physical properties and formed more dissolution pores; Faults communicate with hydrothermal fluids, and the closer the formation is to faults, the more dissolution pores are developed, and the carbonate reservoirs have the better physical properties; The columnar and meso-crystalline fillings formed by the Mg-rich and Sr-rich hydrothermal fluids can effectively retain the early residual pores and play a constructive role in reservoir properties. The patchy anhydrite formed by S-rich hydrothermal fluids has serious damage to reservoir properties.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
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Sedimentary model of subsalt lacustrine carbonate reservoir in the Santos Basin

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Keywords: Santos Basin, Subsalt, Lacustrine carbonate reservoir, Sedimentary model

The exploration practice indicates that the reservoir sedimentary characteristics are the key factors affecting the oil and gas production of the subsalt lacustrine carbonate rocks in the Santos Basin. The high-quality reservoirs are mainly microbial reefs and shoal carbonate rocks deposited on the ancient uplift. Based on drilling, seismic and gravity data, this paper redefined the subsalt structural unit of the Santos basin and carried out the series research about the core facies-logging facies-seismic facies-sedimentary facies. Then combined with the structural evolution characteristics and the paleogeography during rift period, the sedimentary facies distribution of subsalt depression period was determined, and the sedimentary models for the high-quality carbonate reservoir was established.

Based on the structural analysis of seismic data and gravity data, the subsalt structural layer of the Santos Basin can be divided into five first-order structural units. Seaward, there are the nearshore depression belt, the Oceanic hinge belt, the offshore depression belt, the outer uplift belt and the pelagic structural belt. The outer uplift belt is a unique geological unit for the Santos basin. During the breakup of the South Atlantic, the mid-ocean ridge underwent a transition to the West African side, and the outer uplift belt was developed from the abandoned mid-ocean ridge resulting from the transition. The outer uplift belt can be further divided into three secondary tectonic units, including the western uplift zone, the central uplift zone and the eastern uplift zone. It is very conducive to the development of microbial reefs.

Carbonate platform, depression and semi-deep lacustrine to deep lacustrine subfacies are developed in the strata of the subsalt depression period in the Santos Basin. The carbonate platform subfacies can be further subdivided into four microfaciesincluding the microbial reefs, the shoals (internal debris shoal, medium crust shoal and spherical microbial shoal) and intraplatform depression microfacies. Sedimentary facies studies indicate that multiple carbonate platforms with different sizes were developed during the depression period in the subsalt core area of Santos Basin. There developed a giant carbonate platform in the outer uplift belt, and a series of small-scale platforms were developed in the west and southeast of the outer uplift belt, the offshore depression belt and the pelagic tectonic belt. They were divided by depression facies and deep lake - semi-deep lake facies. According to the characteristics of tectonic evolution and paleogeography during the rift period, four types of high-quality reservoir sedimentary models for high-quality subsalt lacustrine carbonate rocks in the Santos Basin have been established, including the large gentle slope sedimentary model, the isolated platform sedimentary model, the inner highland sedimentary model and the steep slope sedimentary model. The reservoir of the first three sedimentary models has obtained good oil and gas discovery, such as Lula field, Iara field and Carcara field.

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Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
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Sedimentary facies and reservoir controlling factors of Carboniferous carbonate rocks in the eastern margin,Pre-caspian Basin

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Keywords: Carbonate rock,Carboniferous, Sedimentary facies, Main control factors of reservoir, Pre-caspian basin

Carboniferous in the eastern margin of Caspian Basin can be divided into Dune Stage, Weixian Stage and KT-II reservoir group, MKT mudstone section and KT-I reservoir group from bottom to top, among which the subsalt KT-II and KT-I carbonate reservoir groups are the exploration emphases. Using thin section, logging and seismic data, sedimentary facies and reservoir controlling factors of KT-II and KT-I reservoirs are studied.The following results are obtained: Through the study of lithofacies, logging facies and seismic facies, carbonate platform sedimentary system can be established in the eastern margin of the basin.Four sedimentary facies are developed, which are limited platform, open platform, platform edge and platform front slope. Open platform intra-platform shoal subfacies and platform edge reef beach are where high-quality reservoirs develop. The reservoirs in the eastern margin of the basin are mainly develop bioclastic shoal limestone and algal (bonded) limestone, oolitic limestone and a small amount of algal lattice limestone. The reservoirs mainly develop intergranular dissolution pores, intragranular erosion pores, and dissolution expansion pores. The distribution characteristics of reservoirs are controlled by the distribution of "intra-platform shoal & unconformity surface dissolution". Reservoirs develop in multiple layers vertically in the middle and upper part of the high-frequency cycle, and the horizontal discontinuity is widely distributed. The reservoirs have experienced four diagenetic sequences: cementation and dissolution in the (quasi) syngenetic period → shallow compaction and cementation filling in the early diagenetic period → unloading fracture caused by tectonic uplift in the supergene diagenetic period, and ancient supergene karst and fresh water filling cementation → re-burial compaction, pressure dissolution and burial cementation in the middle-late diagenetic period. The main controlling factors of reservoir development are quasi-contemporaneous dissolution of favorable intra-platform shoal subfacies and dissolution of unconformity surface. High-energy platform beach facies deposition is the foundation of reservoir development, with the best physical properties and the largest thickness. The dissolution of atmospheric fresh water in the syngenetic period is the key to reservoir development,which makes the dissolution porosity larger. Unconformity surface corrosion further improves the reservoir quality, and the reservoir with dissolved pores develops.

Through the study of sedimentary facies and reservoir controlling factors, this paper clarifies the sedimentary system in the eastern margin of the basin and the factors controlling the distribution of reservoirs, which provides a basis for finding high-quality reservoirs and then conducting exploration and deployment.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Diagenesis and porosity evolution of microbial carbonate rocks undergone a deep burial history -- Taking Leikoupo Formation of Middle Triassic in Western Sichuan as an example

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Keywords: microbial carbonate rocks, diagenesis, pore types and porosity evolution, Leikoupo Formation of Middle Triassic

Reconstruction of the past diagenetic conditions and porosity evolution in microbial carbonate rocks is often under constrained. The microbial dolomite reservoir of Leikoupo Formation of Middle Triassic in Western Sichuan, as one of the exploration targets with a buried depth of more than 5000 m, provided an excellent example to demonstrate how the lithofacies and diagenesis (Early diagenesis especially) affect the reservoir quality. In this study, we investigate the diagenetic fluid, cementation and their relationship with pore evolution and preservation, based on the detailed petrographic observation and some technical methods, such as casting thin-section, cathodoluminescence (CL), scanning energy spectroscopy (SEM-EDS), fluid inclusion microthermometry, carbon and oxygen isotope analysis for micro-drill sampling, carbonate clumped isotopes (47 thermometer), U-Pb dating of calcite and dolomite, FIB-SEM and so on. The results show that there are three early diagenetic subsystems: open, closed and semi-open (transition), which respectively correspond to humid, arid-climate and interaction between bacteria & microbial and carbonate micrite at synchronously sedimentary in the shallow buried periods. De-dolomitization are supposed to take place either in the early or the burial diagenesis stage, associated with the meteoric water influx in subaerial exposure near the upward-shallowing high-frequency sequence boundary or the infiltration along the fault-controlled fractures. However, the large-scale dolomitization and de-dolomitization occurred in Carnian226.5 ± 9.68 Maand Norian 211.5 ± 1.5 Mastage of Late Triassic, with temperatures of 43℃ and 50.2℃, respectively. Four phases of dolomitization & dolomite recrystallization and four phases of calcites cementation have been identified, showing that the δ18Owater (VPDB) of parent fluids varies between -9.70‰ and -0.83‰ for dolomite, and between -12.94‰ and -1.16‰ for calcites, while the $\delta^{18}O_{water}$ of parent rocks varies from -4.60‰ to -0.94‰ for microbial dolomite and -6.68‰ to -1.68‰ for microbial limestone, respectively. The $\delta^{18}O_{water}$ decrease gradually in response to the increasing of crystallization degrees in the progressive burial or meteoric water influx. Statistics reveal that the main pore types of microbial carbonate rocks are vugs and solution-enlarged fracture (43.69%), framework pore (32.28%) and micro-pore. The good preservation of micro-pores in deep burial is due to the small throat radius and special pore fluid, which inhibits the occurrence of large-scale cementation. In summary, the upward-shallowing meter-scale sedimentary cycle for microbial rock in the shallow subtidal to supratidal zone, combined with the early open to semi-open diagenetic system contribute to the development and preservation of the pores, however, the superposition and transformation of the buried diagenesis lead to the overall reduction of porosity.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Oral Preferred

Characterization of Ultra-Deep Buried Middle Triassic Leikoupo Marine Carbonate Petroleum System (!) in the Western Sichuan Depression, China

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Keywords: Ultra-deep buried, Middle Triassic Leikoupo Formation, Marine carbonate, Petroleum system, Western Sichuan depression

Ultra-deep buried (>5000 m) marine carbonate reservoirs gradually become important exploration targets in recently years. Marine carbonates are among the most crucial hydrocarbon reservoirs that hold up to 60% of the world's oil and gas reserves and many giant carbonate reservoirs are likely to have a production lifetime more than 50 years, most of the larger oil or gas fields occurring in the Middle East, North America, Europe, Latin America and Mexico, Africa, and Asia etc. deposition region. This research focuses on understanding characterization of ultra-deep buried Middle Triassic Leikoupo carbonate petroleum system in the western Sichuan depression, China. Combined with previous studies about source rock characteristics and the hydrocarbon generation processes, the analysis results of seventy three source rocks organic geochemistry, four gas compositions and five C–H–He–Ne–Ar isotopes suggest that reservoir is charged with compound gases from four source rock units including the Permian Longtan, Middle Triassic Leikoupo, Late Triassic Maantang, and Xiaotangzi formations. One hundred and eight samples were collected from 50-m fresh outcrops and 100 m cores from scientific exploration drilling wells YS1, PZ1, XQS1, CK1, XCS1 and TS1, and analyzed for petrography and petrophysics. Thin-section and scanning electron microscope (SEM) observations, porosity and permeability measured by helium, mercury injection capillary pressure (MICP), combined with wire-line logging (5,500–6,900 m) indicate reservoir lithologies including algal argillaceous limestones, dolograinstones, crystalline dolostones, limestones, and thrombolite dolomites. Reservoir properties exhibit extremely heterogeneity induced due to combination of constructive (i.e., epigenic paleo-karstification, burial dissolution, structural movements, pressure-solution [stylolites], and dolomitization) and destructive diagenesis (i.e., physical/chemical compaction, calcite cementation, infilling [e.g., pyritization, celestite, and silicification], recrystallization, and replacement). An unconformity-related epigenetic karstification zone occurs in the upper fourth member of Leikoupo Formation (T_2l^{4a}), with developed solution holes/pores leading to high porosity (1.8–14.2%) and permeability (0.2–7.7 mD). Further below the unconformity (T_2l^{1-4b}), reservoirs become more homogeneous and tighter, characterized by solution pores, intracrystalline pores, fractures, and stylolites, with helium porosity (0.6–4.1%) and permeability (0.003–125.2 mD). Regional seals consist of the Late Triassic Xujiahe Formation ~300 m shales, mudstones and further enhanced by the Jurassic to Quaternary ~5,000 m continental overburden rocks. Effective traps are dominated by the combination of structural-lithological typing. The hydrocarbon associated aqueous fluid inclusions reveal homogenization temperatures of 98–140 ^{o}C and 140–171 ^{o}C, suggests twice hydrocarbon charging

occurred between 220–170 Ma and 130–90 Ma, respectively. One-dimensional basin evolution models with seismic profile have determined hydrocarbon vertical migration and entrapment mainly via faulting-fractures networks and lateral migration through unconformity plane which were driven by buoyancy, fluid flow abnormal pressure and formation overpressure during the Indosinian and Yanshanian orogenies, and then experienced additional transformations during the Himalayan orogengy. These multidisciplinary approaches on the ultra-deep buried Middle Triassic Leikoupo marine carbonate petroleum system (!) have scientific significance and practical applications for potential hydrocarbon resources exploration in deep or ultra-deep basins in China and elsewhere worldwide. We believed that there are significantly hydrocarbon resources still to be discovered in future.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
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Characteristic and controlling factors of fractured-porous carbonate reservoir: a case study of X oilfield, Lower Carboniferous, Eastern margin Pre-Caspian Basin

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Keywords: Fractured-porous reservoir, pore structure, fracture type, Characteristic, Pre-Caspian Basin

Fractured-porous reservoir is one of a complex type of carbonate reservoir. In order to analyze the characteristics, main control factors and distribution of this kind of reservoirs, this paper takes KT-II of middle and lower Carboniferous in X oilfield in the eastern margin of Pre-Caspian basin as an example. Based on the data of core, thin section, scanning electron microscope (SEM), FMI logging and seismic, etc., the research work of sedimentary microfacies, reservoir space, physical property, pore structure, fracture type and its main controlling factors and distribution are carried out. The study shows that the target strata in the study area are open platform subfacies, including high-energy shoal, low-energy shoal and inter-shoal sea microfacies. The reservoir space is mainly composed of intragranular pores, intergranular pores and moldic pores with fabric selective. The fracture porosity is low and the reservoir performance is poor. The porosity and permeability vary in a wide range, and are low to medium porosity and low to extra-low permeability on the whole, in which the physical property of the microfacies of high-energy shoal is relatively good and is characterize by large pores and coarse throat, the physical property of the microfacies of low-energy shoal is relatively poor and is characterize by small pores and fine throat, and the reservoir property of the inter-beach sea is the worst. Fractures are mainly high-angle fractures, and the fracture density of inter-beach sea facies is higher than that of the other two faices. In terms of genesis, the fractures include the associated fracture system of fault and the associated fracture system of anticline. The direction of the associated fracture of fault changes with the change of fault. The associated fracture system of anticline structure is mainly distributed in the high part of the structure, and is dominated by reticular fractures. The development and distribution of reservoir are controlled by sedimentary facies and fracture.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Sedimentary Characteristics and Distribution of Granular Beach in Tongzi - Honghuayuan Formation of Ordovician in Middle - Upper Yangtze Region

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Keywords: Central-Upper Yangtze,Granular beach,Sedimentary characteristics,Distribution law,Ordovician

Based on the data of drilling, logging, core and thin section, the sedimentary characteristics, distribution law and main controlling factors of grain beaches of Tongzi Formation and Honghuayuan Formation of Ordovician in the middle-upper Yangtze region were comprehensively analyzed. The rock types of granular beach in the study area are mainly granular limestone and granular dolomite. The particle types are mainly sand debris, followed by oolitic, raw debris and gravel. Granular beach mainly developed upward shallow, coarse grain size sedimentary sequence, vertical development of restricted lagoon - platform beach - platform, tidal flat - tidal flat - tidal flat, restricted lagoon - tidal flat - restricted lagoon three sedimentary facies sequence ; the continuity of granular beach is good in the horizontal direction, and the distribution of ancient land and uplift is zonal in the plane. After further analysis, it is considered that the relative change of sea level and the level of sedimentary energy control the development scale of granular beach, and the structural conditions determine the continuity and the difference of plane distribution of granular beach.

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Main controlling factors and evolution model of Changxing Formation reservoir in Zhongjiang-Moxi area

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Keywords: Changxing Formation,The main controlling factors of the reservoir,Reservoir evolution model,Sedimentary facies,Paleomorphology

The Upper Permian Changxing Formation in the Sichuan Basin has always been the focus of exploration. At present, the exploration research of this formation focuses on the platform margin area in northeastern Sichuan, and there are few studies on the origin of reservoirs in the vast intra-platform area. Therefore, taking the Changxing Formation in the Zhongjiang-Moxi area as an example, the petrology, physical properties and distribution characteristics of the reservoir were studied by using various data such as core observation, thin section identification, physical property analysis and well logging. The reservoir space is dominated by intragranular dissolved pores and residual intergranular pores, and no strong epigenetic karstification has been observed. There are mainly two types of reservoir models—thin and inter-reservoir models and large sets of thick reservoir models. Reservoir stacking styles and development degrees vary greatly in different models. The study believes that the intra-platform beach reservoirs in the Zhongjiang-Moxi area are typical facies-controlled reservoirs, and the degree of reservoir development is mainly controlled by contemporaneous-paracontemporaneous karstification, in which the multi-level cyclic changes of sea level determine Reservoir thickness, superimposition style, and micro-paleo-geomorphic differences further control the early exposure and dissolution of shoal facies reservoirs. On the basis of the research on the main controlling factors of the reservoir, further use the 2D and 3D joint seismic data, and based on the formation thickness, use the Chang 1 and Chang 2 grain-to-ground ratios to correct the trend surface respectively, and carry out the restoration of the Changxing two-period paleomorphology. , and finally clearly describe the sedimentary evolution characteristics of the reservoir under the two reservoir modes in this area.

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Session T7-7: Ancient and deep carbonate reservoirs: sedimentation, mechanism and case studies
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Karst paleogeomorphic characteristics and their effects on reservoir seismic response in the Gaoshiti-Moxi-Longnüsi area

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Keywords: Karst paleogeomorphic characteristics,Seismic Response Characteristics,Amplitude property

Affected by the TongWan Phase II movement, the fourth member of the DengYing Formation in the Gaoshiti-Moxi-Longnüsi area experienced tectonic uplift and was leached by atmospheric fresh water. The secondary dissolution pores, caves and fractures formed after karst transformation are the main storage space types in the fourth member of Deng 4 Member. Since the interior of the DengYing Formation has suffered multiple exposures and denudations, there is a large error in the restoration of the ancient landform by the 'residual thickness method'. Therefore, this study adopts the "impression method" to restore the karst paleogeomorphology of the Dengying Period. During the large-scale transgression of the Cambrian, the overlying QiongZhusi and CangLangpu formations filled in the denuded landforms in the Dengying period. The bottom boundary of Canglangpu appeared as a strong wave trough on the seismic profile, which is easy to track and compare in the whole area. , so it was selected as the datum surface of the impression method. On the basis of fine tracing of the bottom boundary of CangLangpu, the karst paleogeomorphology was restored, and the GaoMo area was divided into three zones to study the seismic response characteristics of the reservoir. The development of the reservoir at the top of Deng 4 is characterized by the weakening of the peak amplitude of the Cambrian bottom boundary and the wide and gentle trough in the middle. The karst paleogeomorphology restoration results show that the Dengying Formation is characterized by low north and high south, west low and east high. In relatively low-lying areas, the mudstone with higher mud content deposited at the bottom of QiongZhusi has a higher GR value, its impedance value is lower. On the basis of zoning, statistics of reservoir development, seismic response characteristics and amplitude energy of the fourth member of Deng 4 in real drilling are carried out. Set different valve fingers, extract amplitude plane attributes, and accurately describe the range of "weak amplitude" to predict favorable areas for reservoir development.

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Session T7-8: Carbonate sedimentation: From facies analysis to global changes

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-8: Carbonate sedimentation: From facies analysis to global changes
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Lower Cambrian Red Beds in South China: distributions, features, and their palaeoenvironmental significance

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Keywords: "Red Beds" database,redox condition,middle Age 3,Yangtze region

Massive ‘red bed’ deposits are of unique value in reconstructing paleoenvironment conditions due to their potential role in indicating the changing marine redox conditions, especially in the deep-time records. The Cambrian explosion is one of several critical events in the evolution of life, and the redox conditions can be seen to play a vital role in regulating the distribution and development of marine organisms. Multiple geochemical proxies have been applied to reveal the redox variation in early Cambrian. Still, the marine redox state has not been well constrained, possibly due to ubiquitous heterogeneity of oxygenation levels in different regions and times. The study on lower Cambrian ‘red bed’ characteristics may provide a new perspective to understand the marine redox fluctuation at that time. For this purpose, we constructed a systemic database regarding the records of red beds in the lower Cambrian strata of South China, and almost all records indicate that their sedimentary episodes were in middle Age 3. Furthermore, we examined the petrological and mineralogical characteristics of red beds and neighboring strata and carried out a series of element geochemical studies to assess the environmental conditions, i.e., redox, climate, and nutrient level, for ‘red bed’ sedimentation in middle Age 3.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-8: Carbonate sedimentation: From facies analysis to global changes
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Identification, characterization and geological modeling of intergranular pore type and intrafossil pore type in bioclastic carbonate reservoir

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Keywords: Intergranular pores, Intrafossil pores, Bioclastic carbonate, Reservoir characterization and modeling

Intergranular pores and intrafossil pores are two important pore types in bioclastic carbonate reservoirs. The deposition and diagenesis of these two types of pores are different, and the corresponding reservoir properties and micro pore structure are also significantly different. This study takes the Cretaceous H formation of the H oilfield in southern Iraq as an example. Both intergranular pore-dominated reservoir and intrafossil pore-dominated reservoir were developed in this formation, resulting in strong heterogeneity. On the basis of core observation, thin section analysis and mercury intrusion experiment, the coring well pore type was identified. Through core calibration logging, conventional logging curves, gamma spectrometry, nuclear magnetic and other special logging, comprehensively carrying out neural network learning, the logging pore type characterization is completed. Based on seismic inversion data, through sedimentary facies analysis, sedimentary water depth characterization, and the relationship between dissolution and sequence boundary, the distribution characterization and geological modeling of pore types are completed. Based on the sensitivity analysis of numerical simulation, the accuracy of pore type characterization results is verified by production performance data. The research results show that the differences in sedimentary environment and bioclast types are the material basis for the differences in the types of intergranular pores and intrafossil pores. Differences in micrite content, dissolution and cementation are the main controlling factors for the differences in microstructure and reservoir properties between intergranular and intrafossil pore types. It is an effective means of high-precision identification, characterization and geological modeling to integrate various types of static and dynamic data.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-8: Carbonate sedimentation: From facies analysis to global changes
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Spatial Distribution of Sedimentary Facies on Modern Carbonate Platforms Interpreted via Remote Sensing, Northwest Celebes Sea, Malaysia

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Keywords: Carbonate platform, Celebes Sea, Facies, Reef complex, Quickbird

Remote-sensing analysis of high-resolution satellite imagery of Modern carbonate platforms in the Celebes Sea, east of Sabah, Borneo, Malaysia, aimed at mapping geomorphology and sediment. Unsupervised classifications of satellite images interpreted in the context of environments facies of seven isolated carbonate platforms and calibrated using analyses of surface sediments. One hundred and forty (140) sediment samples were collected, analyzed for grain-size distribution, and sorting. The grain-size analysis showed that sediment varied among geomorphic elements: island, island/volcano, reef complex, carbonate sand shoal, grass-covered sand shoal, shallow lagoon, and deep lagoon. To generate carbonate sediment texture maps, the proportion of mud and the grain-size attributes of each sediment sample (mean grain size and sorting) provides a basis to classify it into a rock-equivalent texture. Integrated remote sensing, field, and sedimentological data were used to characterize texture distribution maps and depositional facies maps, where mainly mudstone to wackestone have occurred in the deep lagoon; wackestone to packstone is dominant in the shallow lagoon; carbonate sand shoal is characterized by packstone to grainstone and the reef complex is made up of boundstone to rudstone. These results help in estimating proportions of potential reservoirs and heterogeneity in facies distribution, based on the size of various recent carbonate platforms. Diagenesis notwithstanding, ancient analogs of Selakan and Maiga platforms could be potential reservoirs, whereas Selakan and Gaya platforms display more facies classes and most probably represent a poor potential reservoir

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Presentation Preference: Oral Preferred

Influence of biotic vs abiotic processes on the genesis and REE distribution of non-marine carbonates

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Keywords: Cameroon Volcanic Line, low-Mg calcite, rare earth elements, spring deposits, trace elements, travertines

Terrestrial carbonates and particularly spring carbonates are deemed to be good geological repositories of paleoclimate and paleoenvironmental reconstruction (e.g., Brasier, 2011) and for the characterisation of the interaction of biotic and abiotic processes, and they preserve evidence of the velocity of the flow and the chemical composition of the spring water.

This study focuses on non-marine carbonates from fossil and active springs from the Bongongo and Ngol areas along the Cameroon Volcanic Line in South-West Cameroon (Bisse et al., 2018). Here, hydrothermal fluids reach the surface giving rise to small thermal springs, with temperatures between 31°C and 49°C, and streams creating waterfalls, terracettes, and barrage carbonate deposits (Bisse et al., 2018).

Petrographic analyses of these carbonates revealed that they are made up of stacked laminae of fibrous coarse crystals of low-Mg calcite and laminae of alternate microsparite and micrite. The fibrous coarsely crystalline calcite, often with feather-like fabric, grows from thin layers of micrite and peloids. Filaments of putative microbial origin are preserved within this peloidal micrite. The laminated microsparite and micrite microfacies are characterised by an intricate mesh of hollow filaments of microbial origin.

The long feather-like crystals of calcite formed in fast-flowing water where the enhanced CO2 degassing has favoured the precipitation of CaCO3. The laminated micrite and microsparite, on the other hand, are likely formed in ponds where degassing and CO2 removal was lower and the calcite precipitation was fostered by microbial activity. The fast-forming carbonates show higher Ce contents and very low total rare earth elements, revealing a preferential uptake of Ce with respect to other rare earth elements. This would explain the positive or null Ce anomaly in continental spring carbonates elsewhere.

The geochemical composition of these carbonates can be used as proxy for the characterisation of fluid/rock interactions between the groundwater and the substratum and for the characterisation of the sources of calcium and other elements that constitute tufa and travertines. The samples from Ngol are characterised by light rare earth element enrichment while those from Bongongo are overall enriched in heavy rare earth elements. Carbonates from both localities have a strong positive Eu anomaly (>4), suggesting a contribution from deep-seated, hydrothermal, crustal fluids in contact with volcanic rocks and the breakdown of plagioclase from the Cameroon Volcanic Line alkali basalts.

This study has demonstrated that the strong CO2 degassing, promoted by fast flowing water, resulted in the rapid growth of coarsely crystalline calcite, characterised by overall ∑REE depletion and Ce enrichment. The fast-forming calcite fabrics are therefore characterised by a higher Ce anomaly when compared to the slow forming fine grained, laminated fabrics. It can therefore be concluded that Ce(III) oxidation and scavenging into the coarse carbonates is promoted by fast flowing water and strong CO2 degassing (turbulence). This is an important finding for the interpretation of REE distribution in continental carbonates and provides an alternative explanation for the presence of a positive Ce-anomaly that favours precipitation rates over organic matter contents.

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Session T7-8: Carbonate sedimentation: From facies analysis to global changes
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Sequence architecture and depositional evolution of the Cambrain carbonate platform and its response to sedimentary palaeogeomorphology, climate change and sea-level change, Tarim basin, NW China

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Keywords: sequence architecture, carbonate platform evolution pattern, Tarim Basin

A comprehensive analysis of sequence stratigraphy and sedimentary evolution is conducted by using field outcrops, drilling, core and seismic data of Cambrian system in Tarim Basin. Research shows that Cambrian carbonates of the basin can be divided into 3 secondary-sequences which are defined by large-scale unconformity surfaces and 6 composite sequence, each sequence contains a regional sedimentary cycle, and it mainly consists of transgressive systems tract (TST) and highstand systems tract (HST), and can be further subdivided into 16 third-order sequences according to the secondary transgression-regression cycle at the carbonate platform marginal zones. The Cambrian system in study area is mainly consisted of carbonates, orderly depositing evaporated platform, restricted platform, open platform, platform margin and slope sedimentary facies belt from interior of the carbonate platform to basin. Inheriting the differentiation of east-west sedimentary pattern of Sinian, the marginal slope at the west of Manjiaer rift controlled the development of the Cambrian carbonate platform margin, which underwent the evolution process of ramp, non-rimmed platform, weak-rimmed platform and rimmed platform. Due to the wide-slow slope in the north and the narrow-steep slope in the south, the platform margin in Lunnan-Caohu area rapidly migrated eastward, which is obviously different from the vertical growth pattern in Gucheng area. Owing to the high yield of carbonate in Xiaoerbulake formation, it forms a series of low-angel progradation sediment at the north of manxi margin area. Combined drilling data and 3D seismic data, palaeobathymetric can be measured by flattening paleo-water level which could rebuild the paleogeomorphy of the slope and describing the shape of progradation volume with compaction-restoring calculation. The result shows that the paleo-water depth of manjiaer area in Xiaoerbulake formation is 1053 meters, within range of shelf slope environment, which is apparently different to the opinion of many studies supporting it belongs to bathyal or abyssal sea. Sedimentary paleogeomorphology, sea-level change and climate change collectively control the sedimentary system, which restricts the type and growth style of carbonate platform. Due to the vital influence of paleo-water level and water circulation environment to the carbonate yield and sediment lithofacies, the sedimentary paleogeomorphology plays an important role in controlling the sedimentary types and distribution style of sedimentary facies belt. In addition, the transgression-regression cycles of the entire Cambrian carbonate system are comparable and occur almost simultaneously in the whole basin, indicating that the sequence structure of the cycle is basically controlled by the rise and fall of sea level. In terms of climate, it is obvious that the interior of the Cambrian carbonate platform is a semi-confined and confined environment, but the extensive development of evaporated lagoons and evaporated tidal flat in the Middle Cambrian indicates that the arid climate environment in the Middle Cambrian had a significant impact on the sedimentary evolution.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-8: Carbonate sedimentation: From facies analysis to global changes
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Application of Graph Theory Based Rolling Maximum Inscribed circle Algorithm for Intelligent Characterization of seismic geomorphology in Carbonate Tidal Channels system

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Keywords: Graph Theory,Rolling Maximum Inscribed circle Algorithm,seismic geomorphology,Tidal Channel system,Quantitative Characterization

This paper presents the first graph theory based rolling maximum inscribed circle algorithm on and applies it to the quantitative characterization of seismic geomorphology in tidal channel system located at the MB1 layer of the Mishrif Formation in the Middle East A oil field. In this paper, the morphological characterization problem of tidal channel system is transformed into a graph-theoretic algorithm, and the quantitative characterization problem of channel parameters is transformed into a rolling maximum Inscribed circle mathematical algorithm, and the automated statistics of channel parameters are performed by establishing a geometric model of channel parameters. The graph theory-based rolling maximum inscribed circle algorithm is a method that uses graph theory algorithms to decompose the skeleton of the geometric centerline network into points and edges for graph construction, and uses rolling maximum inscribed circle for each edge to perform intelligent statistical calculation of parameters. The statistical parameters include length, width, vector distance, curvature, thickness, aspect ratio, and width-thickness ratio. The algorithm is applied for quantitative characterization of tidal channel system in the study area to study the variation pattern of river parameters. Within the tidal channel system, five types of tidal channel genesis units can be identified: river mouth tidal channel, main tidal channel, branch tidal channel, break tidal channel and delta tidal channel. The geological and geomorphological characteristics of these tidal channels are as follows: river mouth tidal channels are characterized by large width and low curvature; main tidal channels are characterized by large length and thickness of filled granular tuffs; branch tidal channels are characterized by relatively high curvature. The channel parameters of the break tidal channel and delta tidal channel are relatively close, their lengths, widths and thicknesses are small, and the curvature of the channel is low. As an intelligent algorithm, the graph theory based rolling maximum inscribed circle algorithm is more accurate and faster than the traditional manual quantitative seismic geomorphic analysis method. The graph theory based rolling maximum inscribed circle algorithm uses pixel points as the basic calculation unit, which greatly improves the accuracy of the river parameter statistics and greatly increases the statistical efficiency with the powerful computing power of computers. As an extension of the application, the algorithm can also be applied to the quantitative geomorphology study of global river-delta channel system based on remote sensing data. Therefore, the graph theory based rolling maximum inscribed circle algorithm based is of great significance in promoting the development of quantitative geomorphology techniques.

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Session T7-8: Carbonate sedimentation: From facies analysis to global changes
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The Middle-Upper Cambrian boundary in the Tarim Basin, NW China: changes in geological characteristics and the global Cambrian SPICE event correlation

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Keywords: Middle-Upper Cambrian boundary, unconformity, Carbon isotope excursion, Tarim Basin, Global comparability

The subdivision and correlation of the Cambrian System have long been controversial globally with multiple schemes. This is especially the case for the Tarim Basin, western China where regional and global correlations of the Middle-Upper Cambrian boundary are hampered by incomplete biostratigraphy. The Middle-Upper Cambrian boundary (T_8^1) in the Tarim Basin is characterized by an abrupt switch of lithological and sedimentary facies, a sudden change of wireline log responses, and as well as the contrasting seismic features, structural styles and carbonate platform architectures. This boundary is also marked by a negative excursion of $\delta^{13}C$ from 0.1‰ to -0.2‰ and a positive excursion of $\delta^{18}O$ from -6.1‰ to -5.8‰. The T_8^1 boundary can be identified all over the Tarim Basin and manifests in various forms and styles including syn-sedimentary unconformity, overlapping unconformity, tectonic unconformity, multi-stage superimposed unconformity, parallel unconformity and conformity. According to the characteristics of the tectono-sedimentary evolution from the Nanhua to Ediacaran periods, it is shown that each manifestation type of the T_8^1 boundary was influenced by at least one of these factors including paleo-geomorphology, tectonic movement, eustacy, and climatic change. Therefore, each manifestation type can also be used as a marker for the evolution characteristics of tectono-sedimentary sequences. By correlating with changes in carbon isotopes and sedimentary characteristics in various regions worldwide, we propose that the $\delta^{13}C$ weak negative excursion after the sharply positive excursion of the Late Cambrian SPICE event can be used as an isotope stratigraphic marker for the T_8^1 boundary. The top of the Awatag Formation (the top of Middle Cambrian) in the western Tarim Platform should thus be correlated to the top of the Mohershan Formation in the eastern Tarim Basin, corresponding to the top of the Miaolingian Stage. We also conclude that the absence of the SPICE event in the western part of the Tarim Basin may have been caused by the development of the basin-wide unconformity of the T_8^1 boundary.

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A record of enhanced water cycle in the late Carboniferous icehouse

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Keywords: late Carboniferous, South China, sedimentology, paleoclimate, precipitation.

Located in the northeastern Paleo-Tethys Ocean and near the paleo-equator during the late Paleozoic, the South China Block is an ideal region to study the paleoclimate and paleoceanographic conditions of the late Paleozoic ice age. Here, we present detailed sedimentological and biostratigraphic works of a late Carboniferous succession from the southeastern South China Block to explore its sedimentary responses to paleoclimate variations. The Outangdi succession consists predominantly of various shallow-marine carbonate facies, episodically interlayered with fine-gravel to coarse-sandstone facies. Fusulinid and conodont biozones indicate that the succession formed during an interval of the middle to late Moscovian. Detailed facies analysis suggests that the succession was deposited on a carbonate ramp, but episodically punctuated by braid delta sedimentation. We interpret that the abrupt increase in coarse-grained siliciclastic influx during the late Moscovian resulted from an enhanced precipitation event. Regional and global correlation of changes in magnitude of sea-level fluctuation reflects a change in paleoclimate regime during the middle to late Moscovian.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-8: Carbonate sedimentation: From facies analysis to global changes
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Depositional processes of the mixed siliciclastic-carbonate system in the Xiannüdong Formation in the northern Sichuan Basin, South China

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Keywords: Mixed siliciclastic-carbonate systems, depositional facies, Oolite, calcimicrobial–archaeocyath bioherms, Xiannüdong Formation, Sichuan Basin

Mixed siliciclastic-carbonate systems contain significant heterogeneity of facies associations which complicates the interpretation of depositional environments and platform evolution. The Early Cambrian Xiannüdong Formation (Fm) in the northern Sichuan Basin develops the hybrid depositional system which is characterized by the non-skeleton grain (ooids and microbialites) dominated carbonates mixed by siliciclastic rocks. Such a depositional system provides a template to decipher the depositional process and facies variability. Based on facies analysis in outcrops and cored wells and observation of thin sections, sixteen lithofacies were identified and grouped into six lithofacies associations which representing a shallow-marine environment dominated by wave and storm activities. The distribution of the terrigenous materials indicates that the provenance of the terrigenous deposits is mainly supplied by the Kangdian and Bikou massifs. The vertical facies stacking pattern of lithofacies in the Xiannüdong Fm shows a regressive cycle during the deposition of Xiannüdong Fm and this regressive cycle can be subdivided into four sub-cycles (S1 to S4). The four sub-cycles were appeared to the upward-shallowing pattern and bounded by flooding surfaces. The spatial distribution of lithofacies suggests a low-angle ramp with widespread hybrid oolites and calcimicrobial–archaeocyath bioherm. The ramp was separated from the western massifs (Kangdian and Bikou) by the Mianyang-Changning trough. The migrating ooid shoals together with the storm activities prevent the ramp from evolving into a rimmed shelf.

The mixture of carbonate and siliciclastic sediments occurs at compositional scale. The detrital proportion is higher in the lower part of Xiannüdong Fm (S1 and S2) than in the upper part (S3 and S4). This difference in detrital proportion is likely produced by the relative sea-level fluctuation. The coupled relationship between terrigenous content and growth of calcimicrobial–archaeocyath bioherms suggests the nutrition supplied by the input of terrigenous matters controls the growth of bioherms in the Xiannüdong Formation. High siliciclastic sediments influx would also influence the ooid growth by serving as nuclei and promoting abrasion, which resulted in a smaller ooid size compared to the relatively pure oolite. Meanwhile, the difference in density of carbonate and siliciclastic grains promotes smaller siliciclastic grains deposited together with larger carbonate grains.

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Session T7-8: Carbonate sedimentation: From facies analysis to global changes
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Evolution of of the Late Oligocene carbonate system on the Xisha Islands in the South China Sea

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Keywords: Carbonate system, Sequence stratigraphy, Coral reef, South China Sea

Sedimentological, paleontological, and mineralogical data from core XK-1 in the Xisha Islands allow for a detailed lithologic and sequence stratigraphical analysis on the Late Oligocene interval in the Xisha Islands. In this study, 13 facies are differentiated and a depositional model of a carbonate-dominated system is established. Variation in facies stacking patterns, changes in composition and grain size, and fluctuation in abundance of terrigenous matter are analyzed, and sequence division is interpreted at two different hierarchal levels. In the Late Oligocene interval of core XK-1, a total of thirteen small-scale sequences and three medium-scale sequences are divided out, with one medium-scale sequence mainly composed of four small-scale sequences. Based on the available timing constraints, the durations of the small- and medium-scale sequences are estimated to be 100 kyr and 400 kyr, respectively. These small-scale and medium-scale sequences are thus inferred to be primarily controlled by orbital forcing. The long-term evolution between 24.3 and 23.6 Ma was controlled by the eustatic sea level, while it was more influenced by a tectonic subsidence linked to the ridge jump event in the South China Sea after 23.6 Ma. Our study demonstrates that eustatic sea level fluctuations had a significant impact on the initial carbonate development at various scales in the northern South China Sea, while tectonic movement also played an important role in shaping the secular carbonate evolution.

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Presentation Preference: Oral Preferred

Sedimentary processes and carbonate δ13C records during late Pennsylvanian to early Permian in South China

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Keywords: Late Paleozoic Ice Age (LPIA), South China, late Pennsylvanian, early Permian, Sedimentology, δ13Ccarb

The Late Paleozoic Ice Age (LPIA) recorded a critical transition from icehouse to greenhouse climate states during the late Carboniferous to early Permian. Reliable carbonate carbon isotopes ($\delta^{13}C_{carb}$) can provide valuable information on variations in global carbon cycling, and thus the paleoclimate and paleoceanographic conditions. However, the $\delta^{13}C_{carb}$ values are not only related to the global carbon cycle, but also controlled by regional water cycle and diagenesis. During the LPIA, advance and retreat of the Gondwanan ice sheets resulted in cyclic sea-level changes with multiple periods of significant depositional hiatus in low-latitude regions. Frequent subaerial exposures and stratigraphic discontinuities potentially altered the primary $\delta^{13}C_{carb}$ signals, which hampers a valid global correlation. In this study, we present high-resolution sedimentary facies and $\delta^{13}C_{carb}$ records on three continuously deposited carbonates slope successions from South China to explore sedimentary responses to glacio-eustatic changes and evaluate the reliability of $\delta^{13}C_{carb}$.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-8: Carbonate sedimentation: From facies analysis to global changes
Presentation Preference: Oral Preferred

Karst: valuable geological relics of carbonate rocks - ruins and reverse karst of top ecological landscape

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Keywords: Shidao Xisha Islands, Laolongtou, carbonate karst, precious geological relics, top ecological landscape, countermeasures

Karst landform corresponds to Guilin landscape and Yunnan Shilin. It is a synonym of top geological relics and ecological landscape and the result of carbonate karst.The best oil and gas reservoir formed by underground deep carbonate karst is the research object of petroleum industry for decades.

This paper focuses on the karst of modern Marine carbonate-ecological landscape, and points out that the karst restoration of queen head calcareous mudstone in Yeliu Park, Kaohsiung, Taiwan failed, resulting in thin neck or broken neck. South China Sea modern Marine reef carbonate rock shocking karst from the Shi island of Xisha Islands.

Shidao is a small island with the highest altitude in the South China Sea. It stands in a weak consolidated reef - carbonate rock - Laolongtou that looks like a dragon head. Laolongtou is the only dragon rock found in nature on earth so far, which has become a symbol of national totem. Therefore, Laolongtou is a top ecological landscape and precious geological relic resources. In global climate change, however, the context of rising sea levels, the south China sea two-way monsoon, semidiurnal tide, the harsh tropical storm surge wave flow, high temperature, high humidity and high salt and fresh water leaching dissolution eight natural force to old faucet, is happening from loss, damage, damage to the karst collapse destroyed, become old faucet regression.

This paper is the first public report on the investigation and monitoring of surface and underground karst in Laolongtou for more than ten years and the characteristics of its current situation. It puts forward that inverse karst: theoretical research, natural restoration, nano geological ecological engineering restoration, and construction of theoretical and engineering technology system.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-8: Carbonate sedimentation: From facies analysis to global changes
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Evolution and characteristics of Late Oligocene-Miocene carbonates in the southern continental margin of the South China Sea

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Keywords: South China Sea, carbonates,Tectonic evolution

Numerous shallow-water carbonates were extensively developed in the southern margin of the South China Sea during the late Oligocene-Miocene. The development and demise of carbonate deposition provide good constraints on the paleo-environment and tectonic-sedimentary evolution for the southern margin of South China Sea. Although a few previous studies about carbonates deposition focused in the shelf area, the depositional models of carbonate systems in the deep-water basin have not been fully illustrated because of limited data. The purpose of this stduy is to investigate the temporal and spatial distribution characteristics and development of the late Oligocene-Miocene shallow-water carbonates in the southern margin of South China Sea based on high-resolution multichannel seismic data and recently published drilling data.

Two types of carbonates which are carbonate platform and reef as well as sub-types are identified.The reefs developed in the study area are divided into five types: pinnacle reef, patch reef, horseshoe reef, atoll reef and platform marginal reef. According to the tectonic genetic environment classification, the carbonate platform developed in the study area can be divided into different types, including fault block platform, thrusting top and forebulge platform, offshore isolated platform and magma diapir platform.

The development of carbonates in the study area almost experienced initial development stage, flourishing stage and extinction/sustainable development stage. However, relatively differential carbonate systems have evolved in each basin of south margin. The development and evolution of carbonates in the southern part of the South China Sea are considered to be closely related to the regional tectonic evolution of the southern margin, South China Sea. Since the closure of Proto-South China Sea possibly occurred in a "scissor-like" fashion from northwest to southeast, and the South China Sea basin gradually expanded from southeast to northwest, the southern continental margin sedimentary basins were depressed as differential tectonic history, which resulted in the remarkable difference in the development history of carbonates in each basin. In the Liyue basin, the thermal subsidence stage initiated in the early late Oligocene and the tectonic activity was stable, so carbonates began to grow. In the Zemgmu basin, the foreland basin stage began in the late Eocene and few carbonates began to develop at the same time. After the Sabah Orogeny movement, the structure of Nankang platform tended to be stable, and the carbonates were developed widely. Finally, the passive continental margin was developed, and a large amount of clastic sediments from Sarawak hinterland have been deposited, which inhibited the development of carbonates. In the Beikang basin, the foreland basin began to form in the early Miocene, and carbonates began to grow on the structure high. During the late Miocene, the rapid rise of relative sea-level induced by rapid tectonic subsidence terminated development of carbonates.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-8: Carbonate sedimentation: From facies analysis to global changes
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Nutrient level controll on the evolution of carbonate platform types

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Keywords: carbonate platfroms, Cretaceous, Iran

The type of carbonate platform had repeatedly changed from carbonate ramp to rimmed platform during the Cretaceous. The pervious studies interpreted that the transitions were caused by sea level rising which drown carbonate platform in part. However, the rate of sea level rising should never outpace the production rate of carbonate in an ‘ice-free’ world. Thus the mechanism between the transitions of carbonate platform types remain unsolved.

To solve this problem, we take the Albian-Cenomanian carbonate strata exposed in south Iran as the target. The studies reveal the following trends by microfacies analysis and carbon isotope stratigraphy: (1) there are three sea-level rising events during the Albian-Cenomanian; (2) the carbonate deposited in a carbonate ramp during the Albian, and switched into a rimmed platform during the Cenomanian; (3) The organism association was changed from orbitolinid and green algae with positive $\delta^{13}C$ excursion to rudist during the Cenomanian with negative $\delta^{13}C$ excursion.

The orbitolinids lived in a mesotrophic environment whereas the rudists lived in an oligotrophic environment. The covariation of carbon isotope and the organism association also confirm the changed nutrient level. During the Albian, the mesotrophic environment favors the high primary production, therefore the carbon isotope shifted positively for the burial of abundant organic carbon. The carbon isotope shifted negatively in the Cenomanian for the lowered primary production within an oligotrophic environment. Furthermore, the types of carbonate not changed during the three sea-level rising events. Therefore, it is the nutrient level, not the sea level changes, that influences the transition from ramp to rimmed platform.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-8: Carbonate sedimentation: From facies analysis to global changes
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Facies analyses and depositional setting of the Middle Jurassic Callovian-Oxfordian stage in the Western Amu Darya Basin, Turkmenistan

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Keywords: Amu Darya Basin, Callovian-Oxfordian stage, Facies analyses, Depositional setting, Carbonate platform

The Middle-Upper Jurassic Callovian-Oxfordian stratum, consisting of carbonate sedimentary assemblage, is the most important hydrocarbon-bearing formation in the Amu Darya Basin. It is unconformable contact with the underlying the Middle-Lower Jurassic coal-bearing clastic rock that can act as source rock, and in conformable contact with the overlying Upper Jurassic Kimmeridgian gypsum-salt rock that can act as caprock. The Callovian-Oxfordian stage in the study area developed 8 layers form bottom to up, which are XVI, XVa2, Z, XVa1, XVhp, XVm, XVp and XVac. According to the logging curve and lithological combination, the target layer is divided into three sequences in which the water body becomes shallower (SQ1, SQ2, SQ3). Of these sequences, SQ1 is composed of four lithologic layers (XVI, XVa2, Z, XVa1) that are equivalent to the Callovian, SQ2 consists of three lithologic layers consists of three lithologic layers (XVhp, XVm, XVp) that are equivalent to the early period of the Oxfordian, and SQ3 is comprised of one lithologic layer (XVac) that are equivalent to the late period of the Oxfordian. By observing and characterizing core and conducting well log interpretation, it is found that, under the control of the high paleo-geomorphology, a set of carbonate rock with distinct features of shallow platform facies was deposited in the study area. Shallow water platform facies zone contains evaporitic platform, restrict platform and open platform. Evaporitic platform is present in the XVac layer in the east of the study area only, which develops some sets of thick anhydrite. Restricted platform is present primarily in the XVac layer throughout the whole study area, and is dominated by interbedded gypsum and limestone. Open platform is present broadly in various layers, which is dominated by granular limestone deposited in high energy bank environment, such as oolitic limestone and bioclastic limestone. Longitudinal, whether from the three sequences (SQ1, SQ2, SQ3) or the entire target layer in the study area, the sea level falls during the Callovian-Oxfordian stage. Horizontally, the landforms in the western and central parts of the study area are similar, manifesting as open platforms and restricted platforms. While the eastern part of the study area is closer to the platform margin with higher landforms, developing open platforms, restricted platforms and evaporitic platforms.

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Session T7-8: Carbonate sedimentation: From facies analysis to global changes
Presentation Preference: Oral Preferred

Middle Ordovician carbonate slump structures and their transformational successions from the northwestern margin of the North China Block

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Keywords: Slope facies, carbonate, slump, debris flow, soft-sediment deformation structures

A variety of carbonate mass-transport deposits, including slumps, debrites and deep-channel-confined density flow deposits, occur in Middle–Upper Ordovician slope deposits in the western margin (Wuhai, Inner Mongolia, China) of the North China Block. This talk focuses on the slump structures in the Darriwilian (Middle Ordovician) Kelimoli Formation which is characterized by thin-bedded lime mudstone interbedded with marl in the lower member and black shale in the upper member. The slumps from the Xilaifeng section host remarkable folds, chaotic beds and imbricated beds that reflect differences in both rheology and position on the slope. Based on the laterally successive exposure, the spatial and genetic relationships of different deformational structures are analyzed. We noticed that individual slump sheets show gradations between undulating laminae, inclined and recumbent folds, highly deformed folds, and chaotic textures upslope from the toe region. Debrites are commonly interbedded with slump deposits, whereas imbricated beds are present in the middle and lower parts of the toes of slump sheets near the terminal wall. Reconstruction of the downslope architecture of a slump toe, in combination with stratigraphic trends in the type of deformation structures, reveals aspects of the evolution of the sedimentary system through time. The stratigraphically upward increase in abundance and bed thickness of slump sheets, and general intensity of deformation in the Xilaifeng section, suggests an increase in sediment supply, tectonism and possibly the gradient of the palaeoslope over time.

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Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Sedimentary facies of carbonate rocks in the middle and lower assemblages of Majiagou Formation in Daniudi Gas Field, Ordos Basin

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Keywords: Ordos Basin,Danudi gas field,Majiagou Formation,Carbonate,sedimentary facies

Due to the unclear sedimentary facies of the middle and lower assemblage of Majiagou Formation in Daniudi Gas Field, Ordos Basin, which seriously hinders the development of the next step, comprehensively using core, thin section and logging data,a detailed analysis of the carbonate rock types and logging response characteristics of the middle and lower assemblages of the Majiagou Formation in this area was carried out, and seven sedimentary microfacies were further divided.The 1st member of Majiagou Formation to the 3rd member of Majiagou Formation are evaporative platform subfacies, mainly depositing salt lake, gypsum dolomite flat and gypsum lake microfacies from bottom to top;The 4th member of the Majiagou Formation is an open platform subfacies, mainly depositing limed flat, limed dolomite flat and a small amount of dolomite limed flat and gypsum dolomite flat microfaciesdolomite limed flat and gypsum dolomite flat microfacies are mainly distributed in the upper part of the 4th member of the Majiagou FormationThe 5th member of the Majiagou Formation is a limited platform subfacies, and the microfacies of dolomite flat, gypsum dolomite flat and dolomite limed flat deposit are deposited.The changes of sea level from the 1st member of the Majiagou Formation to the 5th member of the Majiagou Formation show periodic fluctuations.The study found that the fluctuation of sea level not only controls the changes of sedimentary subfacies, but also controls the changes of microfacies within each subfacies.The division of the carbonate sedimentary facies of the middle and lower assemblages of the Majiagou Formation in the Daniudi gas field in the Ordos Basin has promoted the development of the next step and also provided a strong geological basis for the later research.

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Presentation Preference: Oral Preferred

Sequence stratigraphy and depositional evolution of a terminal Ediacaran platform in the Central to Northern Sichuan Basin, Southwest China

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Keywords: lithofacies, depositional system, platform evolution, Dengying Formation, Sichuan Basin

The succession in the late Ediacaran Dengying Formation in the Sichuan Basin provides well-preserved sedimentary records for the investigation of Precambrian microbialites and platform evolution. However, in the central to northern Sichuan Basin where an intraplatform rift trough developed, the depositional evolution of the platform has not been fully illuminated, as previous studies mainly focused on the broad platform-basin architecture. Based on drilling wells and outcrops data, twenty lithofacies are identified and grouped into eight lithofacies associations including peritidal flat, shallow subtidal flat, lagoon, mixed tidal flat, slope, basin, coast and shallow sea. Moreover, two transgressive-regressive depositional cycles (i.e., Cycle 1 and Cycle 2) are recognized based on the five shallowing-upward (i.e., type A-E cycles) and three deepening-upward cycles types (i.e., type F-H cycles). A ramp-like epeiric platform with a gentle slope developed in Cycle 1 dominated by the shallow subtidal grainstones and peritidal microbialites. In the transgression of Cycle 2, a siliciclastic-dominated environment consisting of the coast and shallow sea developed on the shelf. Then it evolved to a rimmed platform in the regression of Cycle 2 with the accumulation of shoal grainstones and peritidal microbialites in the platform margin. The water mass was thus restricted to be a lagoon with scattered shoals and peritidal flats towards the proximal platform. In the distal setting, slump structures and cherts are identified in the steep slope and basin environment, respectively. Eustatic sea-level fluctuation and climatic change controlled the lithological transitions between carbonate and siliciclastic deposits. The platform configuration change is the result of intense differential subsidence and sedimentation rates between the trough and platform which were caused by activities of pre-existing basement rifts and coeval growth faults. This study provides a detailed depositional history of the Ediacaran Dengying Formation around the intraplatform rift trough and contributes to the Precambrian carbonate platform research.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-8: Carbonate sedimentation: From facies analysis to global changes
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Distribution characteristics of sedimentary microfacies of carbonate rocks in the 4th member of the Cretaceous Sen-Norman order M group in A oilfield in Iraq

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Keywords: Iraq Region,The Cretaceous Sen-Norman order,Carbonate,sedimentary microfacies

The M group reservoirs in A Oilfield are highly heterogeneous and difficult to develop, mainly due to unclear sedimentary microfacies types and fuzzy sedimentary environment.Based on a large number of cores, thin sections and logging data, through the analysis of particle assemblages, sedimentary fabrics, etc., and combined with the logging response characteristics, the sedimentary microfacies of carbonate rocks in the Cretaceous Sen-Norman order M Group 4 in the A Oilfield in Iraq were identified, divided into four types of microphases.The algae-poor bioclastic shoals are mainly distributed in the middle and upper part of the 4th member of the M group, and contain a lot of biological debris, mainly echinoderms, foraminifera and bivalves, etc., and the algae content is less than 40%.The algal debris shoals are mostly found in the middle and upper part of the fourth member of the M group, with a particle content of 50% to 80%. The inter-shoal microfacies are mainly distributed in the lower part of the 4th member of the M group, which are relatively low-lying deposits between the shoals, with low energy, fine sediment particle size, low particle content, high stucco content, and low porosity.The biological layer is found in the middle and lower part of the 4th member of the M group in the structural high position, the particle content is more than 80%, the biological types are diverse, the pore combination type is poor, the pore connectivity is poor, the heterogeneity is strong, and relatively rare, the biolayer has strong hydrodynamic conditions. The mud content is low.The study found that the distribution of sedimentary microfacies in the plane is relatively stable, mainly controlled by tectonic movements; it is more variable in the vertical direction, mainly controlled by the change of sea level. The division of the carbonate sedimentary facies of the fourth member of the M group in the A oilfield has promoted the development of the next step, and also provided a strong geological basis for the later research.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-8: Carbonate sedimentation: From facies analysis to global changes
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

The late Paleocene–early Eocene carbonate system in the North- East of Sultanate of Oman: An overview from the outcropped Jafnayn Formation

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Keywords: Late Paleocene- Early Eocene, Lithofacies, Microfacies, Depositional Model

The late Paleocene–early Eocene carbonate system in the North- East of Sultanate of Oman: An overview from the outcropped Jafnayn Formation

Introduction

In Oman, there are some exploration activities taking place in North- West Oman in carbonate rocks (Late Paleocene- Early Eocene) like in Umm er Radhuma (UER) Formation in North Oman. These explorations give a promising future in oil production. The spatial and temporal distribution and types of diagenetic changes and the subsequent effect on the porosity and permeability amounts and distributions within depositional facies and sequence stratigraphy of Umm er Radhuma carbonate rocks reservoirs are still poorly investigated.

Objective

Jafnayn formation in Oman is a Tertiary carbonate rocks mainly composed from marl, shale, dolomite and limestone (Nolan et al., 1990). This formation distributed from north East of Oman (called Jafnyan) to North West of Oman (Called Umm er Radhuma). During the Maastrichtian all the proto- Oman mountains have been subjected to subaerial erosion and weathering which cause a gradual subsidence followed by deposition of Early Tertiary sediments. In Paleocene and Early Eocene, the subsiding of sediments is less rapid which cause to form a shallow carbonate shelf facies (Jafnayn Formation) (Nolan et al., 1990). So, this studies will investigate the carbonate depositional environment of this formation and compare it with equivalent formation at the North- West of Oman to reduce hydrocarbon exploration uncertainty through integrating regional geological understanding of the Jafnayn formation with the time equivalent subsurface reservoir. This will help both potential (offshore) and proven (onshore) reservoir to be well-understood.

Methodology

This studies will investigate the same formation but in North- East Oman. Collecting data from Late Paleocene- Early Eocene surface outcrops (North to South-west Oman) by field work and by describe the petrography by using data of more than 85 samples/ thin section to bring together a wide variety of approaches to improve our understanding of petrophysical properties of the carbonate reservoir and quality prediction in outcrop equivalents in the Late Paleocene to Early Eocene rocks.

Discussion

The detailed evaluation of the mineral content (i.e., carbonate constituents and diagenetic alterations) and the texture of this reservoir will be combined with facies analysis using petrography in a sequence stratigraphy context and geochemical Analysis (major, minor, and trace elements as well as stable and radiogenic isotopes) to create a predictive model for the distribution of reservoir quality.

Result

These rocks are mostly wackestones/packstones rich with large foraminifers. The lithology shows that it composed mainly of a carbonate sequence with thin layers of marl/ shale unit. These carbonates are slightly dolomitic limestone which can give a good porous bed. The marine fossils indicate that the depositional environment is a shallow marine environment.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-8: Carbonate sedimentation: From facies analysis to global changes
Presentation Preference: Oral Preferred

Microfacies and facies-zone analysis of the Upper Bassein carbonate succession, Bombay Offshore Basin across the Eocene-Oligocene Transition (EOT)

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Keywords: Standard microfacies, facies zonation, Eocene-Oligocene transition (EOT), carbonate ramp, Bombay Offshore basin, Bassein Formation.

The Cenozoic sedimentary succession of the Bombay Offshore basin developed over the undulating topography of the Deccan Traps. In this basin, the hydrocarbon-producing middle Eocene subsurface Bassein Formation of the Mukta Field is, as encountered in the wells, dominantly composed of limestone and minor mudrock intercalations deposited along a homoclinal ramp – in both open and restricted settings. The limestones are compact and indurated, with moderate to poor porosity developments, where the primary and most of the secondary porosities are occluded by different phases of cementation. Carbonate sediments, with their significant biogenic contents, e.g., benthic foraminifera, corals, algae, and bryozoan fragments, were deposited in an open-marine setting. Carbonate lithounits, which is predominantly benthic-foraminiferal wackestone with micritic matrix, are intermittently intercalated by deposition of more argillaceous lithounits marking turnover into the restricted-marine condition at the platform interior. The study has been carried out on the offshore Upper Bassein horizons of the Mukta field. Microfacies analysis is used here for characterizing the standard microfacies types (SMF; sensu Wilson, 1975). Using multiple independent proxies, e.g., microfacies analysis and major changes in the fauna, the transitions occurring across EOT can be established.

The Bassein carbonates encountered belong to the SMFs 8 (wackestone with whole organisms, fine micritic matrix), 10 (packstone/wackestone with coated and abraded skeletal grains), and 16 (non-laminated packstone with small-sized peloids). SMFs 8 and 10 belong to the facies zone (FZ; Flugel, 2010) 7, i.e., open-marine setting within platform interior. SMF 16 pertains to the FZ 8 of the restricted region in the platform interior. Both these FZs belong to the inner ramp above the fairweather wave base. Apart from the SMF classification, the biotic assemblages provide with biostratigraphic age determination, paleobathymetry, and paleoenvironment of deposition. The high abundances of Lituonella sp. along with Coskinolina sp., Halkyardia sp., lockhartia, miliolids suggest a middle Eocene, tropical, shallow restricted-marine carbonate ramp setting; whereas the abundance of Nummulites sp. with Asterigerine sp., Bigerina sp., Heterostegina sp., Lepidocyclina sp., Operculinoides sp., Cibicides sp. refers to an early Oligocene tropical shallow open-marine environment. Thus, a biotic reorganization and facies change across the boundary suggest a change in relative sea level. The early Oligocene succession unconformably overlies the middle Eocene succession. The restricted shallow marine condition prevailing in the middle Eocene is succeeded by an erosional late Eocene relative sea-level fall and consequent unconformity, which cannot be delineated in the core because of congruent facies superposition. However, the event resulted in the development and abundance of open vugs and fracture porosity in the upper part of the middle Eocene interval. The early Oligocene brought about a relative sea-level rise by reestablishment of the open ramp condition.

This integrated multi-proxy approach, involving microfacies, facies zones, and biostratigraphical study of the shallow carbonate ramp Bassein Formation, document the relative sea-level fluctuations and transition from restricted marine to an open marine setting across the EOT separated by late Eocene forced regression. This causes modifications in the shallow-marine biotic productivity, thereby, leading to a biotic reorganization above and below the unconformable boundary.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-8: Carbonate sedimentation: From facies analysis to global changes
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Microfacies analysis and depositional environment of a Permian carbonate-dominated succession from central China

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Keywords: microfacies, sea-level change, South Qinling belt, eastern Paleo-Tethys, LPIA

The Paleo-Tethys experienced major geographic, climatologic, and environmental changes during the Permian. A newly documented carbonate-dominated succession (> 3km) in the Xikou section, Zhen'an, Shaanxi, central China is a complete Permian aged rock record and provides a unique opportunity to document its depositional environment, sea-level changes, and associated paleogeography and paleoclimate in eastern Paleo-Tethys. Eighteen microfacies were recognized within the Xikou section, which can be grouped into a (mixed-) inner, middle, or outer ramp facies. Their distributions in the Xikou section represent an evolution involving thirteen depositional phases and indicate a fluctuated sea-level during the Permian, which dropped slightly in the Asselian to Sakmarian and then gradually rose from the Artinskian to middle Capitanian with a distinct rising at the Kungurian. The sea-level then significantly dropped during the late Capitanian to early Wuchiapingian, which was followed by a gradually increasing trend superimposed with high-frequency fluctuations and reached its maximum during the middle Wuchiapingian. The sea level then gradually dropped until the middle Changhsingian and returned slightly during the late Changhsingian.

The sea-level curve in the Xikou area reflected the global climatic changes and was associated with eastern Paleo-Tethys evolution. The relatively low sea level associated with high-frequency fluctuations during the Asselian to Artinskian may relate to the expansion of glacial (P1 and P2), while the followed significant rising at Kungurian may reflect the major deglaciation of the Permian glacial or even the Late Paleozoic Ice Age (LPIA). The abrupt falling of sea level at the end of the Capitanian was globally synchronous and may be relevant to mid-ocean ridge spreading and superimposed with global cooling (P4), which was in accord with the skeletal grain replacement of the fusulinaceans and dasyclads by small foraminifers and *Gymnocodium*, and was considered as a major reason for Middle Permian Extinction. The early Wuchiapingian characterized by densely mixed sequences of carbonate strata and siliciclastic strata had a highly frequent fluctuating sea level, which may be influenced by high frequent short-term climatic variations. The sea-level falling after it reached its highest stand during the middle Wuchiapingian, was suggested as a result of a regional tectonic transition from extension to compression relevant to the eastern Paleo-Tethys evolution, or as a far-field response to the expansion of the Permian glacial episode P4. In addition, the overall rising trend of the sea level and the thick succession in the Xikou area suggest that the South Qinling belt was primarily under an extensional setting during the Late Carboniferous to Early Triassic, in response to Tethys rifting, which may imply the subduction of Mianlue Ocean was possibly beyond the Permian.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-8: Carbonate sedimentation: From facies analysis to global changes
Presentation Preference: Oral Preferred

Evolution of an Aptian mixed carbonate-siliciclastic carbonate ramp in a shallow marine bay setting

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Keywords: Aptian, Iberian Basin, climate.

The sequence stratigraphy and palaeogeographical evolution of an Aptian shallow-marine ramp, developed in a shallow marine bay in the Western Tethys, has been reconstructed through detailed analysis and correlation of 10 high-resolution logs spanning the Forcall and Oliete formations of the Oliete subbasin (Maestrazgo Basin, Eastern Iberia). Tow long-term transgressive-regressive (T-R) cycles have been identified. The siliciclastic-dominated Forcall Formation represents a highly asymmetric T-R cycle, with a short transgressive hemicycle culminating in a condensation level with diverse ammonite faunas of the Deshayesites forbesi biozone, and a regressive hemicycle representing the transition from distal and mid-ramp environments, characterized by silts and marls and cm-thick sandstone levels with hummocky cross-stratification, to inner ramp environments characterized by sandy floatstones with orbitolinids, echinoids, and disarticulated endobenthic bivalves (Pholadomyidae, Trigoniidae), and cross-stratified coarse bioclastic sandstones. A prominent discontinuity surface on top of the Forcall Formation marks a sharp change in the depositional system towards the carbonate-dominated bioclastic packstones and marls of the lowermost Oliete Formation (Cabezo Negro member), which contain colonial corals and abundant Thalassinoides. These levels represent the transgressive hemicycle of a second T-R cycle, which culminates in a marl-dominated interval (La Dehesa member) preserving an abundance of articulated gastropods and endobenthic bivalves, as well as scarce ammonites of the P. melchioris and A. nolani late Aptian biozones. The regressive hemicycle is represented by bioclastic-cortoidal packstones and grainstones (Los Estancos member), which are topped by a karstified discontinuity surface recognizable basinwide. Periodic siliciclastic-carbonate alternations in the Forcall and Oliete formations have been tentatively linked to climate oscillations.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-8: Carbonate sedimentation: From facies analysis to global changes
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Abrupt Middle Eocene climatically-controlled facies shift: the Middle Eocene Climatic Optimum (MECO) in a shallow carbonate platform

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Keywords: Middle Eocene Climatic Optimum, Nummulites, Cenozoic warming events, Facies analysis, Carbon isotope stratigraphy.

In the Southern Neo-Tethys margins (Tunisia) the Middle-Late Eocene deposits are arranged in NW–SE oriented facies belts with clear variations in terms of thickness and facies. Shallow carbonate platform facies of the Cherahil Formation (Fm.) pass gradually into globigerinids-clays of the Souar Fm. along a homoclinal ramp. Synsedimentary tectonics, sea-level oscillations, and warming event have imposed major controls on the central Tunisia platform. Facies associations are attributed to at least three sedimentary models. Sequential analysis of the Cherahil Fm. point towards shallowing upward trend interrupted during the lower Bartonian by a major transgression. This sea-level rise coincides with a shift towards a short maximum nummulite carbonate production absent since the nummulitic limestones of the El Garia Fm. (Ypresian). The lower Bartonian transgression is marked by the lithostratigraphic unit named the Siouf member (Mb.) and its lateral equivalent the Reneiche Mb., which is the primary target for hydrocarbon explorations in central Tunisia and the Gulf of Gabes. The Reneiche/Siouf Mb. has been proved as a reliable level for platform-to-basin correlation, although it was not present in the deepest parts of the basin. Proximal facies of dominant lumachellic marls shift to a thickening-upward sequence of transgressive facies culminating in a maximum nummulitic carbonate production during the middle Eocene transgression and coincides broadly at the global scale with the occurrence of the Middle Eocene Climatic Optimum (MECO). The position of the Reneiche/Siouf Mb. is confirmed also by the bulk carbon isotope record (δ13C) characterised by negative carbon isotope excursion in the middle of the Siouf Mb. followed by a positive excursion at the top of this member which is comparable to the δ13C record through the MECO in the northern and eastern Neo-Tethys and also in the Atlantic Ocean.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-8: Carbonate sedimentation: From facies analysis to global changes
Presentation Preference: Oral Preferred

An Ordovician chronostratigraphic record of carbon- and oxygen isotopes for the western Tarim Basin, China

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Keywords: Great Ordovician Biodiversification Event (GOBE), carbonate factory, drowning, black-shale, algae evolution

Here we explore depositional facies and diagenesis in concert with a first component-specific data-set of $\delta^{13}C$ - $\delta^{18}O$ values for Middle to Late Ordovician of the western Tarim Basin. By integrating filtered literature bulk-rock data, a synoptic chemo-chronostratigraphic sequence is presented along a Wheeler-diagram. There are chemostratigraphic segments lasting from tens of Myrs to several 100 kyrs. There is a long-term trend of increasing $\delta^{13}C$ values culminating in the early Katian at 3.2 ‰ followed by a steady decrease. This tipping point is associated with a precursory baseline shift that appears to interfere with the short-term Guttenberg carbon-isotope excursion (GICE) identified with caution on the basis of an associated positive shift of $\delta^{18}O$ values. The baseline shift was driven by regional effects of photosynthesis and a boosting (dasycladacean-related) production of aragonite along the Sandbian-Katian boundary interval. There is a medium-term (Darriwilian to earliest Sandbian) negative $\delta^{13}C$ excursion coinciding with both a basal positive $\delta^{18}O$ excursion and the demise of the Darriwilian carbonate ramp (*Suecicus*-Event, new term). It might represent the effects of volcanism/SO_2-outgassing (volcanic winter) during the regional switch from a passive to an active continental arc. This event masquerades the widely recorded middle Darriwilian carbon-isotope excursion (MDICE). More caution is needed to consider the Tarim realm for global Ordovician chemostratigraphy.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-8: Carbonate sedimentation: From facies analysis to global changes
Presentation Preference: Oral Preferred

The upper Eocene Loza-Moraza Formation: Lacustrine-palustrine facies in a syn-tectonic compressional context (Miranda-Trebiño piggy-back basin, Western Pyrenees, N Spain)

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Keywords: Miranda-Trebiño basin, Pyrenees, lacustrine-palustrine facies, late Eocene

Interest in lacustrine-palustrine environments has increased worldwide in last years due to the high sensitivity and different responses of these continental depositional systems to tectonism, climate and marked changes in global environmental conditions. This work focusses on the stratigraphy and facies architecture of the late Eocene Loza-Moraza Formation, which is the basal unit of the thick continental sedimentary succession infilling the Miranda-Trebiño piggy-back basin, on the western prolongation of the south Pyrenean thrust front (Basque Pyrenees, N Spain). The Loza-Moraza Fm. ranges 25-286m in thickness and occurs forming a series of outcrops extending laterally for about 35km along the southern margin of the Miranda-Trebiño basin. The stratigraphic unit consists of siliciclastic, mixed and calcareous deposits representative of alluvial to palustrine-lacustrine environments, which unconformably overlay Cretaceous to Paleocene coastal to shallow marine sedimentary rocks. Previous paleontological studies allowed constraining the bulk of the Loza-Moraza Fm. within the MP 18 Biozone (Priabonian, late Eocene). With the aim of recognizing the depositional conditions and the paleogeographic evolution of the Miranda-Trebiño basin during the deposition of the Loza-Moraza Fm., this work provides information about its constituent lithofacies, the integrated sedimentary model and analyzes the potential factors that controlled the dynamics of the late Eocene lake systems. They involve the general compressional tectonic setting, the effects of local diapirism and the series of climate changes recognized for the Priabonian and the Eocene to Oligocene transition (EOT).

The three internal sedimentary sequences (SEQ1 to SEQ3) of the Loza-Moraza Fm. consist of fluvial-alluvial siliciclastics (mudstones and lithic conglomerate-sandstone packages) that grade both vertical and laterally to successions of massive to well-stratified palustrine-lacustrine carbonates (marlstones with discontinuous calcretes, intraclastic limestones and bioclastic limestones). The sequence boundaries are erosional discontinuities associated to net changes in the sedimentary regime. These major facies changes are likely indicative of pulses of generalized tectonic uplift of the basin margins, enhancement of erosional processes and terrigenous supply and a coeval sharp reduction in the areal extent of the stacked continental wetlands. In addition, the local activity of the Peñacerrada and Ocio-Buradon diapirs and the syn-sedimentary folding of the Cretaceous-Paleocene substrate strongly influenced the basin paleotopography and the distribution of the different alluvial to lacustrine environments, as recorded by the occurrence of onlap-truncation relationships and significant lateral variations in both thicknesses and lithofacies types. The studied successions also record some significant changes in the local climatic regime, which according to key facies evolved from overall semiarid to arid during SEQ1, to a higher humidity interval during SEQ2 and, finally, into enhanced drying under renewed semiarid conditions during SEQ3. Although more detailed analyses are needed, this local evolution largely agrees with the climatic conditions established for western Europe during the Priabonian stage and the global climate variations across the EOT.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-8: Carbonate sedimentation: From facies analysis to global changes
Presentation Preference: Oral Preferred

Eustasy in the Aptian: a basin-wide vision from the Maestrat Basin (E Iberia)

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Keywords: Platform carbonates, sea-level changes, eustasy, sequence stratigraphy, Aptian, Iberia

Several Lower Cretaceous basins located in different tectonic plates include incised valleys of Aptian age with depths ranging from metres to tens of metres. These incised subaerial unconformities are found in both carbonate and siliciclastic systems. In the Maestrat Basin, which is in the eastern margin of the Iberian Plate, two episodes of Aptian major relative sea-level fall and erosion were recorded in a marine carbonate succession. The first episode was of late early Aptian age (intra *Dufrenoyia furcata* ammonite Zone), occurred in less than 0.9 My according to the current Geological Time Scale and had an estimated magnitude between 60 and 70 m. This relative sea-level drop and the subsequent base-level rise have been classically studied in the Galve sub-basin (western Maestrat Basin), i.e., in the proximal platform settings of Camarillas and in the platform-to-basin transition area of Las Mingachas. In Camarillas, during sea-level fall, incised valleys were carved into inner parts of an aggrading highstand platform. Later, during the following transgression, these incised valleys were back-filled with tidal-influenced high-energy carbonate deposits. In Las Mingachas, the records of this relative sea-level fall and subsequent base-level rise correspond to a detached basin-floor component and to lowstand and transgressive platforms, respectively. Incised erosional surfaces, forced regressive wedges and lowstand platforms resulting from this late early Aptian lowering of sea level are also recognizable in other localities of the Galve sub-basin as well as in other depocentres of the Maestrat Basin such as the Morella and La Salzedella sub-basins. This contribution will also discuss the divergent interpretations that exist regarding the sequence stratigraphy of Las Mingachas outcrop. The second episode of major relative sea-level fall and rise was of early late Aptian age (upper *Epicheloniceras martini* and lower *Parahoplites melchioris* ammonite zones). The latter sea-level event had an amplitude of more than 100 m, occurred in less than 3 My and was firstly identified in the northern Morella sub-basin as a deeply incised subaerial unconformity also carved into an aggrading highstand platform. Fieldwork carried out during the last years throughout the basin has permitted to recognize this erosional subaerial unconformity in the Galve sub-basin. These two episodes of major relative sea-level change are interpreted to be mainly eustatic in origin given their basin-wide and likely global significance.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-8: Carbonate sedimentation: From facies analysis to global changes
Presentation Preference: Oral Preferred

Carbonate Depositional model based on microfacies analysis: a case study from the Lower Mahil Formation (Outcrop Khuff-Equivalent (Ks-1)), Jabal Akhdar, Northern Oman

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Keywords: Saiq Plateau, Wadi Sahtan, Khuff

Here a carbonate depositional model is generated based on a detailed microfacies analysis from the Saiq Plateau and Wadi Sahtan sections in Jabal Akhdar of Northern Oman. The Wadi Sahtan section is paleogeographically located more distal than the Saiq Plateau section. The two sections of the Lower Triassic Mahil Formation (Khuff outcrop equivalent (KS-1)) were measured bed by bed along with a depositional dip. A detailed sedimentological description for Saiq Plateau and Wadi Sahtan sections was performed using Dunham's classification, and lithology samples were taken every 50 cm. One hundred and eighty half-stained thin-sectioned from several lithofacies were prepared. The point-counted tool was used to reconstruct the original components of the Lower Mahil Formation. Consequently, twenty-four microfacies were identified; four are only recognized in the Wadi Sahtan logged section, twelve are restricted to the Saiq Plateau logged section, and eight are common for both sections. Microfacies were grouped into three facies association (backshoal, shoal, and foreshoal). The Lower Mahil Formation consists of the inner ramp to mid-ramp carbonate facies, with ramp crest facies restricted to the Saiq Plateau section. The inner ramp facies was characterized by microbial lamination; the ramp crest was mostly Oolitic packstone-grainstone and the mid-ramp carbonate facies was indicated by the weakly developed hummocky cross-stratified beds.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-8: Carbonate sedimentation: From facies analysis to global changes
Presentation Preference: Oral Preferred

Early reefal cements of the Late Permian and their palaeoceanographic implications

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Keywords: Early reefal cements, REE, Permian, South China

During the Middle-Late Permian transition, the oceans witnessed the eruption of Emeishan Large Igneous Province and the subsequent mass extinction event. Previous researchers have performed a series of studies on the biocrisis, redox conditions, C-N-S cycles, and climate and environmental variations during this critical period, but little is known about the seawater compositions and their evolutionary trend, especially for the REE characteristics. Numerous isolated carbonate platforms with a large amount of stacked reef architecture and rare terrigenous admixtures can provide good non-skeletal carbonate materials, e.g., early cements of reefs and grainstones, for restoring seawater REE characteristics, which reliability and validity have been demonstrated in some recent studies (Li et al., 2019; Wallace et al., 2017). Here, we reported a preliminary result on the REE characteristics sourced from the early reefal cements of the Maokou, Wujiaping, and Changxing formations from Middle to Upper Permian strata in South China, which uniformly show modern seawater-like shale-normalized REE patterns and superchondritic Y/Ho ratios with various signatures of the Ce anomaly and total REE concentrations. These data may indicate the oscillated seawater REE compositions during the Middle and Late Permian transition and show the potential significance of REE signatures in revealing the change of seawater compositions in a relatively short time scale.

Acknowledgement
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Session T7-9: Microcrystalline Ca-carbonate: Origins and significance

ID: T7-90035

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-9: Microcrystalline Ca-carbonate: Origins and significance
Presentation Preference: Oral Preferred

Sedimentary Features and MISS of Lacustrine Microbialites: A Case Study of the Cenozoic Formations in the Western Qaidam Basin

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Keywords: lacustrine carbonate, Miss,thrombolite, stromatolite, saline lake, Qaidam Basin

To document characteristics of lacustrine microbialites and microbially induced sedimentary structures (MISS) in saline lakes in the western Qaidam Basin, numerous outcrops, cores, thin sections, and analytical laboratory data were used to evaluate the sedimentary environments of microbialites in Cenozoic saline lakes of the region. The spatial and temporal distributions of microbialites were analyzed, rock types and lithofacies assemblages were classified, and MISS were identified in addition to analysis of their internal structures. The biological, physical, and chemical influences on MISS structural diversity was also investigated. The results show that: (1) Cenozoic saline lake margins and shallow lakes in the western Qaidam Basin were conducive to the development of microbialites that primarily included thrombolites and stromatolites that were typically interbedded with granular limestone to constitute fan-controlled and lake-controlled lithofacies assemblages. (2) The microbialites in fan-controlled lithofacies assemblages were dominated by thrombolites that were large and with thicknesses in the range of ~50 cm to 3 m (maximum of 5 m). In contrast, the microbialites in the lake-controlled lithofacies assemblages were featured with coexisting of thrombolites and stromatolites and were small and with a thickness mostly between 30 to 50 cm (maximum of 2 m). Different types of microbialites developed in different sedimentary environments, thereby forming different lithofacies assemblages. (3) Eight types of MISS were identified, and it is argued that MISS types were mainly determined by internal biological attributes including the manifestation of multiple behavioral adaptations to external environments. Further, the MISS comprehensively reflected fluctuations and balance of environmental deposition rates (υenv) and microbial growth rates (υmicro). (4) The MISS also included modifications by physical and chemical influences (e.g., erosion and wrinkle marks, sponge pore) that formed due to hydrodynamic forces and physical factors (e.g., evaporation and drying), respectively. Burial dissolution and weathering dissolution occurred in the diagenetic and post-diagenetic stages, and the processes confirmed that chemical influences on structures.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-9: Microcrystalline Ca-carbonate: Origins and significance
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

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Keywords: microbialites, cryptocrystalline, microcrystalline, fabric-selective

The Qaidam Basin is an excellent place to study Chineses Cenozoic lacustrine carbonate rocks, especially lacustrine microbialites. The lower Ganchaigou Formation of Oligocene in Western Qaidam Basin is a set of lacustrine microbialites with large scale, multiple types and close relationship with oil and gas. Based on the detailed anatomy of the Oligocene microbialites in Xichagou and Liangdong areas of Qaidam Basin, it is found that the microbialites formed in the stage of rapid lake transgression and developed on the hard basement such as glutenite and siltstone. In the late stage, the microbialites gradually died out due to the shrinkage of the lake basin. Lacustrine microbiolites consist of thrombolites and stromatolites, and alternate compound types with strong lateral ductility and outcrop of several kilometers. Other carbonate particles include peloids, ooids, biodetritus and aggregate grains. Under the microscope, the thrombolites are characterized with clotted structure and cryptocrystalline cohesive framework, with abundant bioclasts and a small amount of peloids. The stromatolite shows slow undulant features, with typical alternating light and dark lamina. Microbial laminae and clots experienced fabric-selective dolomitization and are preserved as cryptocrystalline and microcrystalline textures. A large number of framboidal pyrite and cryptocrystalline and microcrystalline dolomite particles exist in the form of intergranular mosaics, indicating the role of their sulfate-reducing bacteria in dolomitization. The systematic macro-micro characteristics of lacustrine microbialites in the Upper Ganchaigou Formation of the Oligocene in the western Qaidam Basin will further help understand the types and formation mechanisms of lacustrine microbialites, and guide the Cenozoic oil and gas exploration and the study of reservoir rock types and characteristics.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-9: Microcrystalline Ca-carbonate: Origins and significance
Presentation Preference: Oral Preferred

Controlling effect of lake salinity on the development of carbonate rocks: A case study of paleogene in western Qaidam Basin

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Keywords: carbonate rock,palaeosalinity,the upper member of lower Gaichaigou formation,Paleogene,Yingxiongling structral belt,Qaidam Basin

In order to comprehensively evaluate the oil and gas exploration prospects of Paleogene Oligocene lacustrine carbonate rocks in the middle and eastern segments of Yingxiongling tectonic belt in western Qaidam Basin, and predict favorable exploration zones and exploration targets, this paper takes the upper member of Ganchaigou Formation (E32) as an example. Based on the comprehensive analysis of core observation, drilling / logging data and three-dimensional seismic data, combined with the analysis results of rock thin section, chloride ion content, whole rock mineral analysis, gypsum rock distribution and geochemical sensitive parameters, the paleosalinity and carbonate sedimentary evolution of E32 in this area are studied in detail. It is considered that lake salinity is the main control factor of lithologic change and development degree of carbonate rocks. The results showed that : First, the water in the lake changed from brackish water and salt water to saline water, the salinity was increased continuously from early to late in the upper member of lower Gaichaigou formation. The salinity was decreased from Yingxi to Yingdong area in a plane, which resulted the gypsum-salt rock developed poorly. Second, the mineral composition complex and the lithology multiplicity of the carbonate in Yingxiongling area, the lithology changed in each region obviously. In the longitudinal direction, the carbonate rock developed in the early better than in the late, and in a plane, the carbonate rock distributed mainly in the Yingxi and the north of the Yingzhong area, secondly in the south of the Yingzhong area, thirdly in the Yingdong area.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-9: Microcrystalline Ca-carbonate: Origins and significance
Presentation Preference: Oral Preferred

Fluid Occurrence Characteristics and Mobility Evaluation of Lacustrine Microcrystalline Dolomite Reservoirs

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Keywords: Dolomite intercrystalline pores, Qaidam basin, Unconventional oil and gas reservoir, Fluid occurrence

The study area is located at the northwest end of Qaidam Basin. The exploration target horizon of the study area is the Paleogene Lower Ganchaigou Formation, which is a set of shore-shallow to semi-deep lacustrine sediments. The rock composition is characterized by the mixed deposition of argillaceous, carbonate and clastic particles. The main reservoir types are micro- and nano-scale dolomite intercrystalline pores. A large number of intercrystalline pores were formed during the process of penecontemporaneous dolomization (Zhang et al. 2021). Samples were taken from the drilling cores at a sampling depth of 3100m-4050m.

The petrologic characteristics, pore types, pore distribution and pore structure were studied by multiple methods, including thin section analysis, SEM, EPMA, mercury-injection test and NMR. The distribution characteristics of the movable fluid and the change of the centrifugal process were analyzed by means of NMR and centrifugation. Observation under the scanning electron microscope found that the diameter of dolomite crystals was 1 μm to 5 μm, and there was oil distribution in the intercrystalline pores, but the pore was poor connectivity. The pore throat distribution range of the samples with carbonate intercrystalline pore in the lower Ganchaigou Formation of Yingxi area in the process of mercury injection was 11 nm to 220 nm, and the pore throat distribution range in the process of mercury ejection was 40 nm to 1500 nm.

The relaxation time was positively correlated with the pore throat radius. The relaxation time <1ms corresponded to micropores, the relaxation time between 1-10ms corresponded to small pores, the relaxation time between 10-100ms corresponded to mesopores, and the relaxation time >100ms of the corresponding large holes. Through saturated fluid state NMR test, it was believed that the pore throat radius of intercrystalline pore developed samples was 0-160nm, he movable fluid accounted for 13.7%. The NMR imaging of the fluid-saturated sample with intercrystalline pores showed that the fluid in the sample was distributed in a planar shape. The total amount of fluid decreased less during the centrifugation process. The NMR relaxation spectrum changed significantly during the centrifugation process. The peak value of the NMR relaxation spectrum before centrifugation was between 1 ms and 10 ms, and the peak value of the relaxation spectrum after centrifugation was about 1 ms. Before centrifugation, the relaxation time of the fluid distribution in the intercrystalline pores was 0.1ms-10ms. The proportion of fluid distribution was maximum in 1ms-10ms, and the proportion was 50.81%. During centrifugation, the maximum reduction of fluid was in the 1ms-10ms, and it accounting for 75.2% of the total reduction. The fluid in dolomite intercrystalline pore was mainly distributed in micro and small pores, The proportion of fluid in micro and small pores was 84.23%, and the fluid which could be drove out in centrifugation process was mainly distributed in small and medium pores.

Reference

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-9: Microcrystalline Ca-carbonate: Origins and significance
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

The Indicative Significance of Cenozoic Formation Water Distribution on the Sedimentary Evolution of Lacustrine Carbonate in the Western Qaidam Basin

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Keywords: formation water, saline lake basin, lacustrine carbonate rocks, geochemical indicators

As an inevitable product of the evolution of saline lake basins, lacustrine carbonate rocks have become an important field of oil and gas exploration, the formation water that occurs in lacustrine carbonate rocks has unique geochemical characteristicsand the research on the chemical composition of formation water has important guiding significance for the sedimentary evolution of lacustrine carbonate rocks and oil and gas exploration. Through chemical analysis of nearly 300 water samples from the Paleogene-Neogene in the western Qaidam Basin, the relationship between various characteristic ions, calcium and magnesium coefficients, desulfurization coefficients, and metamorphism coefficients in formation water were comprehensively compared. The geochemical means of the sedimentary evolution of salt rocks have played an important role in clarifying the differential sedimentary characteristics of salt lakes in the western Qaidam Basin. The results showed that: 1.The hydrochemical characteristics of the saline lake basin are obviously different from east to west, showing the characteristics of high in the west and low in the east. The salinity parameter is inherited, which is consistent with the migration law of the deposition center. 2. The vertical change of the sedimentary paleoenvironment is staged, the “salinization degree” is different, and the sedimentary distribution characteristics of the Paleogene-Neogene lacustrine carbonate rocks are quite different. 3. The variation law of formation water chemical characteristics further reveals the source and evolution of fluids in the basin, provides more dynamic information for the determination of the basin salinity center, and also provides a strong basis for clarifying the distribution law of favorable lacustrine carbonate reservoirs and source rocks.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-9: Microcrystalline Ca-carbonate: Origins and significance
Presentation Preference: Oral Preferred

Evolution characteristics of lacustrine carbonate gravity flow deposits

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Keywords: lacustrine carbonate, gravity flow deposit, saline lake, salt lake

In order to clarify rock characteristics of lacustrine carbonate gravity flow in the western Qaidam Basin, we studied lacustrine carbonate rocks of the upper segment of the Xiaganchaigou formation (E) of Oligocene through various approaches, such as drilling data, core analysis, thin-sections observation, seismic and geochemical tests, to define sedimentary characteristics, depositional model and genetic mechanism in the western Qaidam Basin. In this study, there are three different types of gravity flow deposits and associated sedimentary models are recognized, Including steep slope with high gradient (more than 3°), Ordinary slope with medium gradient (2°-3°) and gentle slope with low gradient (less than 1°). It was found that the syn-sedimentary fault is the main trigger mechanism for the formation of gravity flow deposits, and during the formation period of the Es sequence, sedimentary environments in the western Qaidam Basin are salinized lakes so that lacustrine carbonates mixed with terrigenous detrital minerals, clay minerals, and evaporite minerals are formed. A large number of carbonate gravity flow sediments developed in the salt lacustrine slope zone. The results showed that: 1) Based on the core and thin section, 8 types of carbonate gravity flow sedimentary facies can be identified. They are included in deformed carbonates, breccia carbonates, limy carbonates with breccia, coarse gravel carbonates, fine gravel carbonates, packstone, wackstone, turbidite. The single-layer thickness of breccia carbonates and limy carbonates with breccia is mainly 1-2 m, with the maximum of tens of meters; the single-layer thickness of deformed carbonates, coarse gravel carbonates and fine gravel carbonates is mainly tens of centimeters, with the maximum of 1-2 m; the single-layer thickness of packstone, wackstone and turbidite is mainly mm-cm scale. 2) The formation mechanism of lacustrine carbonate gravity flow deposits include three processes: initiation, transportation, and resedimentation. The sedimentary facies and lithofacies are controlled by creep deformation, in-situ fracture, debris flow, granular flow and turbidity current. 3) Through the restoration of paleogeomorphy, five typical geomorphic units are figured out, including uplift zone with low gradient (in front of Kunlun Mountain, the slope angle is 1°-4°), fault terrace belt (the slope Angle is 2°-5°), Uplift belt with high gradient (in front of Altun Mountain, the slope Angle is 3°-7°), Slope belt (the slope Angle is 0-2°) and depression area (the Slope gradient is generally less than 1°).

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-9: Microcrystalline Ca-carbonate: Origins and significance
Presentation Preference: Oral Preferred

Analysis of the types and characteristics of platform margin belts and the differences of reefs developed in different platform margin belts: Taking Changxing Formation on both sides of Kaijiang- Liangping Trough in Sichuan Basin as an example

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Keywords: the Sichuan Basin, the Changxing period, the structure of platform margin, reef, sedimentary characteristics

Up to now, the exploration and research on the Changxing Formation of the Upper Permian in the Sichuan Basin have been carried out for more than 70 years, and fruitful results have been achieved. However, with the continuous deepening of basic geological research and the degree of exploration and development, it is gradually revealed that there are certain differences in the reef reservoirs of the Changxing Formation on both sides of the Kaijiang- Liangping Trough in the Sichuan Basin, and it is preliminarily recognized that there are differences in the structural characteristics of the platform margin belts. But, these understandings are mainly aimed at the macroscopic research of platform margin belts, and there is no systematic research and comparison on the structural characteristics of different platform margin belts and the development law of reefs. Based on this, this paper takes five typical 3D seismic explored blocks on both sides of the Kaijiang-Liangping Trough as the key research areas, takes 35 drillings data and 4,142 km2 seismic data as the research basis, and tries to summarize the themorphological characteristics of platform margins, the external morphological characteristics and internal structural characteristics of reefs in different areas through the geometric morphology of platform margins and different characteristics of reefs. In addition, The differences in sedimentary characteristics and distribution laws of reefs are studied. The results show that: (1)influenced by sedimentary palaeogeomorphology and differential fault activities, three types of platform margin belts were developed in the Changxing period on both sides of the Kaijiang-Liangping Trough: steep slope platform margin belt controlled by faults, steep slope platform margin belt controlled by sedimentary palaeogeomorphology, and gentle slope platform margin belt controlled by sedimentary palaeogeomorphology; (2)the reefs developed in different platform margin belts show different sedimentary characteristics. Among them, the two types of platform margin belts, "steep slope platform margin belt controlled by faults" and "steep slope platform margin belt controlled by sedimentary palaeogeomorphology", have a narrower horizontal distribution, and the reefs are characterized by "the growth law of large sedimentary thickness and mainly aggradational sedimentary texture". In contrast, platform margin belts such as “gentle-slope platform margin belts controlled by sedimentary paleogeomorphology” have the characteristics of significantly wider horizontal distribution, and the reefs are characterized by "the growth law of multi-row reefs development, thinner sedimentary thickness, and obvious migration";(3)The various sedimentary textures in different platform margin belts at study area are controlled obviously by comprehensive factors, which includes the scale of synsedimentary faults and the differences of sedimentary paleogeomorphology. The development characteristics of reefs in different platform margin belts are further influenced by comprehensive factors such as the differential structural characteristics of platform margin belts, synsedimentary differential sagging, sea-level change, paleoecological environment, and other factors.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-9: Microcrystalline Ca-carbonate: Origins and significance
Presentation Preference: Oral Preferred

Tectonic inversion of cratonic platform margin and its control on petroleum system—A case study of carboniferous in the eastern margin of PreCaspian Basin

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Keywords: Tectonic inversion , Carbonate platform,PreCaspian Basin,Carboniferous

The PreCaspian Basin is a super petroliferous cratonic basin developed on the Kazakhstan plate. Its eastern margin is adjacent to the Ural orogenic belt, and southeastern margin adjacent to the Tethys fold belt (Volozh et al.,2003; Jin Zhijun et al., 2007). Since the late Paleozoic, the southeastern margin of the PreCaspian Basin has experienced a geological history of stable cratonic platform deposition, evolution of Ural orogenic belt and closure of the Paleotethys Ocean, resulting in the present complex tectonic and sedimentary setting (Alexander, A.C, 1999; Liang shuang et al., 2013).

In this paper, the tectonic evolution process of the Carboniferous system in the eastern margin of the PreCaspian Basin is reconstructed by the structural interpretation of the 2D and 3D seismic data and the combination of well-log and seismic data. Based on seismic facies analysis and layer flattening techniques, the favorable sedimentary-diagenetic facies zones such as platform reef, clastic beach and weathered karst zone were identified in comparison with the classical carbonate platform slope deposition models, and the tectonic and sedimentary model in the eastern margin of the PreCaspian Basin was established by structural and depositional reconstruction. The effects of Ural ocean closure and orogenesis on the eastern margin of the PreCaspian Basin is analyzed.

It is concluded that the eastern margin of the PreCaspian Basin underwent slope reversal, fold deformation, strike-slip transformation and differential uplift during the late Hercynian to Indosinian period, resulting in the hiatus, denudation. The hiatus of the Late Carboniferous were favorable to the formation of weathered karst reservoir facies. The tectonic inversion of platform margin carbonate ramp in late Permian was favorable to the formation of limestone shoal lithological reservoirs with updip occlusion. The large strike-slip fault zone is conducive to the formation of fault-fracture compound trap controlled by flower structure, which communicates with deep source rock. The tensional strike-slip fault zone developed in the southern uplift zone is conducive to the formation of fault solution and improves the deep reservoir conditions. Our study reveal the influences of Ural ocean closure and orogenesis on the sedimentation and tectonic deformation of the carbonate ramp of the carboniferous in the PreCaspian cratonic basin, and provide scientific references for the prediction of oil and gas exploration prospects in this area.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-9: Microcrystalline Ca-carbonate: Origins and significance
Presentation Preference: Oral Preferred

Types and differential distribution of Cenozoic lacustrine microbialites in western Qaidam Basin, China

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Keywords: the Qaidam Basin, microbialites, types, differential distribution

As an important type of carbonate rock, microbialites are widely distributed globally, with external morphology and internal structure. The research of microbiolites has always been a hot topic in sedimentology. The Qaidam Basin, with an area of 121,000 km^2, is a Mesozoic and Cenozoic intermountain basin situated in the northern Qinghai-Tibet Plateau. Influenced by the uplift of the Qinghai-Tibet Plateau, a large salt lake developed in the western Qaidam Basin during Oligocene to Miocene, and microbiolites of saline lacustrine were deposited. To clarify the sedimentary characteristics and distribution of Cenozoic microbialites in the western Qaidam Basin, based on the data of outcrops, cores, and thin-sections, the classification, and characteristics of microbialites were carried out to study the differential distribution of different types of microbialites. The results showed that there are four types of Cenozoic microbialites in the western Qaidam Basin, including stromatolite, thrombolite, oncolite, and biogenic grainstone. The lacustrine microbiolites in the western Qaidam basin are mainly developed in the basin margin and shallow water environment, and their distribution is controlled by the combined impact of palaeogeomorphology, sedimentary environment, climate, and hydrological conditions. Based on the analysis of palaeogeomorphology and sedimentary environment, six sedimentary models of microbiolites can be established in high energy coastal zone, high energy steep slope zone, low energy deep water zone, low energy fault zone, low energy gentle slope zone, and low energy deep water uplifts zone in the western Qaidam Basin. Influenced by the changes in the sedimentary environment, the microbiolites in the western Qaidam Basin are developed in different strata, which are relatively independent. In addition, the thickness of each stratum is relatively thin, and the distribution of microbiolites has obvious migration characteristics. We found that intercrystalline pores, dissolution pores, and fractures constitute the main reservoir space of the microbiolites in the western Qaidam Basin, which are mostly characterized by medium-high porosity and permeability. And they are vertically interbedded with lacustrine source rocks, which can form a high-quality source rock and reservoir assemblage, which will be an important exploration field in the western Qaidam Basin.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-9: Microcrystalline Ca-carbonate: Origins and significance
Presentation Preference: Oral Preferred

Dissolution mechanism and effect of acidic fluid under high temperature and pressure in a deep reservoir: A Case Study from Baiyun Sag, Pearl River Mouth Basin

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Keywords: Pearl River Mouth Basin, deep reservoir, high temperature and pressure, acid fluid,dissolution

Deep oil and gas exploration is an important direction of current and future oil and gas exploration. Acidic fluid is the main medium of material migration and energy exchange in petroliferous basins and an important geological condition for the formation of secondary pores. Baiyun Sag in Pearl River Mouth Basin has the tectonic geological background of high temperature and high pressure in deep reservoir, rich in organic acid and CO2 acid hot fluid activity, and the deep clastic rock develops secondary pore zone. Using the water-rock reaction device under high temperature and high pressure, combined with scanning electron microscope(SEM) observation, reservoir physical properties, cast thin section, XRD, ICP-OES test and other methods to carry out experimental study on the diagenetic reaction between deep sandstone composition and acid fluid, which is of great significance for revealing the dissolution of deep clastic rock reservoir and the development mechanism of secondary pores, and promoting deep oil and gas exploration. The experimental results showed the following results: (1) CO2-rich fluid has obvious dissolution effect on potassium feldspar, albite and calcite under high temperature and high pressure. The main dissolution temperature pressure window of the three minerals is between 150℃~300℃ and 45~60MPa.Under the condition of high temperature, the change of pressure affects the solubility of CO2, and then affects the dissolution effect and dissolution strength of sandstone components.(2)Organic acid fluid has obvious dissolution effect on core samples under high temperature and high pressure, nine groups of core samples have ion migration phenomenon and release K+, Ca2+, Na+, Mg2+ and other cations. After the reaction, the porosity of the sample increases by 5.6 % on average. It is concluded that the deep reservoirs in The Pearl River Mouth basin have the potential to develop secondary pores. The content of soluble components in rock and the difference of primary mineral structure are the key factors affecting whether the geological fluid can enter the reservoir. (3) The two experimental results reveal the diagenesis mechanism of secondary pores formed by water-rock reaction of deep source-reservoir combination and hydrothermal rock reaction of deep hydrothermal fluid background, respectively. Using core samples to conduct experiments of water-rock reaction is an effective way to offer basic evidence for areas which has no wells. Under the current tendency of high cost and risk for oil and gas exploration, it is a meaningful way to predict and explore resources in deep reservoir.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-9: Microcrystalline Ca-carbonate: Origins and significance
Presentation Preference: Oral Preferred

Seismic Progradational Reflection Characteristics and Sedimentary Model of Lower Permian Limestone Formation,Eastern Margin of the Pre-Caspian Basin

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Keywords: Pre-Caspian Basin,seismic progradational reflection, carbonate rocks depositional model ,lower Permian

The Pre-Caspian basin has rich oil and gas resources in pre-salt carbonate reservoir. In recent years, The Carboniferous sedimentary reservoir in the eastern margin of the basin were studied more , but less on the sedimentary characteristics and depositional model of Permian carbonate rocks. A large number of intra platform progradation reflection structures are found in the 3D seismic data of the lower Permian in the eastern margin of the basin. The progradation direction is roughly distributed along the SE-NWdirection, which is different from the characteristics and direction of Carboniferous carbonate platform progradation, and the relevant research has not been reported in the public literature. Therefore, based the 3D seismic data and combined with the calibration of drilling data, compared and tracked the multi-stage progradation seismic reflection structure of the lower Permian,The Arsse stage sedimentary filling sequence , and the sedimentary model are established to clarify the evolution process of the carbonate rocks of the lower Permian. The main conclusions are as follows: The ancient landform of Arsse stage controls the development of two types of carbonate rocks in this area:In the early stage of Arsse ,under the control of inherited ancient landform of Carboniferous, the limestone shoal deposits were developed in the western low convex zone ,and the lithology is algal limestone and bioclastic limestone, while the shelf facies calcilutyte is developed in the eastern part In the middle and late Arsse stage, with the intensification of the Ural orogeny, the southeast part of the study area was gradually uplifted, forming a low and gentle slope paleogeomorphology distributed in the SE-NW direction, and limestone formation with multi-stage S-shaped oblique progradation was developed. The multi-stage progradation developed in the middle and late Arsse stage is mainly controlled by tectonic uplift and slow decline of relative sea level in highstand stage, and continuously migrates along the sedimentary slope break of platform margin. Favorable reservoir facies such as algal limestone, cohesive granular limestone and biological skeleton limestone are developed on the foreset slope break and its continental side. The foreset slope break of each stage is identified by using of seismic reflection structure to find the development facies belt of reservoir rocks, which is helpful to the next step of fine reservoir prediction and the implementation of exploration targets in this area; At the same time, the above analysis of sedimentary process based on seismic progradation reflection structure provides a certain reference for studying the detailed process of Ural tectonic movement of Arsse stage in Lower Permian.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-9: Microcrystalline Ca-carbonate: Origins and significance
Presentation Preference: Oral Preferred

Geological Characteristics and Exploration Potential of Lacustrine Carbonate Rocks in West Qaidam

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Keywords: saline lake,carbonate rock,reservoir characteristics,exploration potential,Qaidam Basin

Abstract:With the rapid development of tight oil and shale oil, the study of lacustrine carbonate rocks has received more and more attention. Many theories and models of marine carbonate rocks cannot be completely copied to lacustrine carbonate rocks. In recent years, the Qaidam Basin has made many breakthroughs in the exploration of lacustrine carbonate rocks. Therefore, a systematic summary of the sedimentary distribution characteristics of lacustrine carbonate rocks has been carried out to point out the direction for further exploration of favorable zones. Influenced by paleogeomorphology, paleoclimate, paleo-source and paleo-salinity, the western Qaidam region forms four types of carbonate rocks: algal lime dolomite, granular lime dolomite, micrite lime dolomite and lime shale. Dolomitization is the basic condition for the formation of reservoirs. Various dissolution and tectonic actions can transform the reservoirs to different degrees, and high-efficiency reservoirs can be formed. Along with the migration of the lake basin, different types of carbonate rocks were developed in the Paleogene and Neogene in the western Qaidam, with a superimposed area of up to 8000km2. Carbonate reservoirs and high-quality source rocks are inter-distributed, with the characteristics of source-reservoir coexistence and source-reservoir integration. The cumulative thickness of favorable source-reservoir assemblages is 300-800m, which is the main area for intra-source oil and gas exploration in the basin. At present, the scale of Yingxiongling shale oil reserves has been confirmed, and the next step will continue to expand the blank area of Yingyingling sag. In addition, the carbonate rocks in Xiaoliangshan sag and Zhahaquan sag are also worthy of risk exploration and are expected to achieve greater breakthroughs.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-9: Microcrystalline Ca-carbonate: Origins and significance
Presentation Preference: Oral Preferred

Formation mechanism and controlling factors of microbial reservoir in Dengying Formation, Sichuan Basin

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Keywords: Microbialite, Reservoir Space, Karst, Sedimentary Geomorphology

The Dengying Formation of Sinian is the most important gas bearing formation of Precambrian in Sichuan Basin. Based on the macro and micro data of drilling cores and outcrop samples, combined with the corresponding geochemical data, the characteristics, formation mechanism and main control factors of microbial dolomite reservoir of Dengying Formation in Sichuan Basin are studied in detail. It is considered that: the rock types of dolomite reservoir of Dengying Formation mainly include algal thrombolite dolomite, algal dolarenite dolomite, algal stromatolite dolomite, etc; The reservoir space is divided into five categories, among which the main reservoir space of Dengying Formation is lattice (residual) pore-cave, intragranular (solution) pore, intercrystalline (solution) pore, small and medium-sized solution pore cave and fracture. Lattice (residual) pore cave and intergranular pore are mainly affected by the sedimentary structure of microbialite. Algal thrombolite dolomite and algal dolarenite dolomite have the best porosity and are most developed in the platform marginal zone. In intra-platform zone, they are mainly stromatolite, laminated and mud crystalline dolomite, and the primary pores are relatively undeveloped; Small and medium-sized karst caves are developed in scale and are the most important reservoir space. Three kinds of karst processes coexist in penecontemporaneous stage, early diagenetic stage and burial stage, among which the early diagenetic stage is the most important. The microstructure of microbialite is the internal cause of selective dissolution. It has obvious characteristics of facies control and geomorphic control on the plane. Vertically, the water resisting layer and high-permeability layer are superimposed in multiple cycles to form a complex karst cave system; Multi-stage structural fractures improve the seepage capacity of Dengying Formation reservoir, and there is an obvious negative correlation between gas production and distance from fault; Dengying Formation has a complex diagenetic history. Diagenesis such as compaction, cementation, filling and siliceous metasomatism are important factors for reservoir damage; Sedimentary geomorphology and syn-sedimentary faults control the favorable sedimentary facies belt, and then control the favorable lithology and the development of primary pores, and affect a series of karstification in the later stage, which is the fundamental control factor of reservoir development of Dengying Formation.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-9: Microcrystalline Ca-carbonate: Origins and significance
Presentation Preference: Oral Preferred

Characteristics of tight lacustrine carbonate reservoir and its oil and gas significance

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Keywords: carbonate, tight reservoir, oil displaces formation water, Qaidam Basin

A large area of lacustrine carbonate rocks developed in the Cenozoic strata in the western Qaidam Basin in China, which is characterized by vertical layers and large cumulative thickness. It is the main reservoir of oil and gas. Under the influence of periodic oscillation of lake water and terrigenous detrital material supply, large scale mixing of carbonate rocks is observed. Algal limestone and oval-aggregate limestone are mainly developed in the basin margin and shallow water environment, while organic-rich lamellar limestone is developed in the deep water environment of basin. Although the reservoir is tight, the rock pore throat is small, and the pore structure is complex, the combination of lattice pore, dissolution pore, intergranular pore and microfracture in the reservoir forms the efficient reservoir space of the fine-grained carbonate reservoir, with the porosity ranging from 1.2% to 13.27%, with an average of 6.8%. In order to explore the mechanism of oil enrichment in tight carbonate reservoirs, algal limestone and limestone samples were selected for oil displacing formation water simulation experiments.

The results show that there is little displacement difference between algal limestone and limestone reservoir, and the oil displacement effect is better in high porosity samples. In tight samples, the filling degree is greatly affected by pore connectivity, and both oil and water are difficult to enter and leave the pores, forming low-saturation reservoirs. The breakthrough pressure of crude oil decreases slightly during secondary charging. With the increase of displacement time, the amount of crude oil increases, and the wettability can reduce the displacement resistance in the reservoir and make it easier to be filled, leading to the shortening of oil saturation time. When the oil is injected into the sample containing micro-fractures, the oil migrates preferentially along the fractures, which shortens the oil saturation time and reduces the oil saturation in the core column. Based on the above research results, it can be concluded that the water in the near-high-quality source rock reservoir are strong displaced, the favorable reservoir with high porosity can be fully filled, and the oil saturation is high, which is an important direction for middle-shallow exploration in the northwest Qaidam Basin.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-9: Microcrystalline Ca-carbonate: Origins and significance
Presentation Preference: Oral Preferred

Micrite Envelope Microstructure and Forming Stage Characterization and its Control on Siliciclastic and Carbonate Mixed Reservoir of Bohai Sea Area

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Keywords: Micrite Envelope Microstructure, Forming Stage, FBI, Mixed Deposits, Bohai Sea area

1. Introduction

In recent years, a large number of large and medium-size mixed deposits with huge discovered reserves were discovered in Bohai sea area. Our research shows that micritic envelopes are pervasively developed and micrite content are correlated well with high quality intervals of the mixed deposition.

2. Methodologies

In order to further clarify the relation of micrite envelope with high quality reservoir forming mechanism, advanced experimental techniques were adopted. Microstructure of micrite envelope was identified and characterized by Focused Ion Beam(FIB) and Electron Probe, and mineral composition of micrite envelope was determined by X-ray diffraction. The C\O isotope characteristics and forming environment of micritic envelope were determined by Laser Micro Samping analysis of carbon and oxygen isotope and Electron Probe. The biogenesis of micrite envelope was analyzed by Focusing Ion Beam(FIB) with Maps. The difference of dissolution ability of micritic envelope and dolomite and calcite is analyzed through reservoir physical simulation experiment.

3. Result

The result shows that micritic envelope can be classified into algal-bacterial perforated, micritic nucleation and micritic texture forming, micrite molding and complete micritization stage based on different tectonic and sedimentary environment. The preservation and dissolution ability of micritic envelope varied significantly.

3.1 In off-shore marine carbonate basement uplift background bioclastic dolomite reservoir which is of calcareous conglomerate and clastic dolomite mixed deposition

Micritic envelope is of algal-bacterial perforated stage, micritic nucleation stage and micritic texture forming stage, which is of the early diagenetic stage. As fungi and algae needed to absorb nutrients and minerals, and search for habitation to hide, they would repeatedly perforate inside and outside of the carbonate particles, resulting in blocky and metasomatism of micrite. Micrite envelope is finally formed in this process. This process was found at the border of bioclasts, as well as of some carbonate lithoclasts, some are dissoluted, some are not. The permeability of micritic envelope provide sufficient fluid exchange with the outside world, which will lead to dissolution of bioclastics. Aboundant bioclastics molds preserved by micrite envelopes and nano-scale micropores in micrite envelopes were observed by high magnification emission scanning electron microscopy, which proves the permeability of micrite envelope.

3.2 In near-shore gentle slope and steep slope background and volcanic basement reservoir which is of bioclastic dolomite and fan delta dolomitic conglomerate mixed deposition.

Micritic envelope experienced micrite molding and complete micritization stage, which is of late diagenetic stage. Micritization often appears as a thin micrite envelope around particles, it prevents the development of cements syntaxial overgrowths and thus preserves reservoir property. During algae growth prcoess, the lattice support structure of micrite envelope can form stable complex which is of acid and alkali resistance. Micrite envelope dolomite will become the crystalline nucleation and provide attachment point for isopachous rim dolomite growth. We can observe that some micrite were transformed into peloids by pervasive micritization which have dirty cores and clear rims. And this stability of dolomitization process is favorable for the preservation of pores.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-9: Microcrystalline Ca-carbonate: Origins and significance
Presentation Preference: Oral Preferred

Carbonate laminites from the Nanzhang-Yuanan fauna in the Lower Triassic Jialingjiang Formation, South China: Origins and Significances

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Keywords: P-T boundary, biomineralization, organomineralization, automicrite, taphonomy

The famous Early Triassic Nanzhang-Yuanan fauna (marine reptile Lagerstätten) has well documented the recovery of marine ecosystems after the Permian-Triassic mass extinction. These marine reptiles were preserved within laminated limestones (laminites) of Lower Triassic Jialingjiang Formation in Nanzhang and Yuanan, Hubei Province, central China. However, the formation mechanisms of these laminites, their indicative depositional environments as well as their significance on the excellent preservation of marine reptile Lagerstätten are still unknown. In this study, field observation in combination with petrographic and diagenetic analysis under normal light, cathodoluminescence, fluorescence and scanning electronic microscopes, as well as geochemical analysis were conducted to solve these problems. Microbially Induced Sedimentary Structures (MISS) and Reticulated Ridge Structures (RRSs) were developed on the surfaces of laminites. These laminites could be divided into two layers, respectively the light particle-rich layer and the dark organic-rich layer. Laminites packages could be classified as straight-dense laminae, wavy laminae and discontinuous laminae. There are abundant organic maters, extracellular polymeric substance (EPS) and framboid pyrites as well as clay minerals preserved within the dark layers, while light layers are rich in calcite crystals with a few celestite and dolomite crystals but rare clay minerals. *In situ* LA-ICP-MS analysis indicates different REE patterns and Ce abnormalities within different laminae. These all indicate a microbial origin of laminites (microbial laminites or biolaminites) deposited in a stagnant, reduced, hypersaline supratidal flat pond environment. Microbial-induced and/or -influenced biomineralization and organomineralization plays a very important role on the excellent preservation of Nanzhang-Yuanan marine reptile Lagerstätten.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-9: Microcrystalline Ca-carbonate: Origins and significance
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Influence of limestone caprock on differential enrichment of Cambrian shale gas in southern China

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Keywords: limestone caprock,shale gas reservoirs, Cambrian shale

In recent years, the Silurian and Cambrian shale gas exploration practices in different areas of southern China have shown that the gas material foundation is good, and the organic-rich shale reservoir roof and floor structure with well-developed storage space is the key factor for the evaluation of favorable shale gas reservoirs. It is also one of the main reasons for the differences in shale gas exploration in different regions of southern China.In this paper, the Cambrian Shuijingtuo Formation shale in Hubei area is analyzed by sample observation, mineral analysis, total organic carbon content test, pore structure parameter test and the reported well profile data obtained from the Cambrian Shuijingtuo Formation shale gas exploration gas. The vertical configuration relationship of gas-generation-reservoir-caprock assemblages is studied, and it is found that relatively tight and thin-layered marlstone is mainly developed at the top of the lower organic-rich shale of the Shuijingtuo Formation, and the bottom limestone has certain large pores, and the storage space is relatively small. In comparison, thin-layered and tight limestone caprocks are mainly developed in the lower part of the top of the organic-rich shale in the upper member with high TOC content. The organic pores generated in the process of organic matter cracking, evolution and hydrocarbon generation are one of the main storage spaces for shale gas. The generated fluids dissolve the lower carbonate minerals, making the lower organic-rich shale floor poor in sealing, resulting in high hydrocarbon expulsion efficiency, the fluid pressure in the voids decreases, which is not conducive to the preservation of voids in the shale under the action of compaction; while the upper and lower organic-rich shale roofs and floors develop relatively tight limestone caprocks with good sealing properties, which are shale gas The preservation of shale plays a good role in isolation, and it forms a good source-reservoir-caprock configuration relationship with the organic-rich shale reservoir with high porosity in the vertical direction. Finally, through the optimization of high-quality organic-rich shale reservoirs in the study area, a model for the preservation conditions of high-quality organic-rich shale reservoirs in the Shuijingtuo Formation is summarized. Through the study of limestone caprock, which provides a new way for the evaluation of Cambrian shale reservoirs in southern China.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-9: Microcrystalline Ca-carbonate: Origins and significance
Presentation Preference: Oral Preferred

Deposition Rate of the Paleogene in Yingxiongling Depression, Qaidam Basin and its significance for oil and gas exploration

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Keywords: shale,Milankovitch cycles,Deposition rate,organic matter, Qaidam Basin

The Yingxiongling Depression is located in the northwest margin of the West Qaidam Depression in The Qaidam Basin. It is a key area of shale oil and gas exploration in the Qaidam Basin. Due to its proximity to fault XI, the formation is relatively complex, and the sedimentary rate research is weak and rarely discussed Milankovitch cycles was used to identify the layer thickness and the corresponding astronomical period of the cycle. Acycle module in MATLAB was used to identify milankovitch cycle, so as to calculate the deposition rate Spectral analysis and filtering analysis were carried out on GR logging data and measured TOC data of key wells in Yingxiongling Depression. After the deposition rate was demonstrated, the following understandings were obtained :1. The development of shale in Yingxiongling Depression is caused by seasonal water stratification of salt lake, and the growth period of one light and one dark lamella is one year. 2. The deposition rates of shale with different sedimentary structures are different, and the deposition rates of stratified shale are higher than that of lamellar shale. 3. The footwall deposition rate of fault XI is higher than that of the upper one, resulting in a huge difference in deposition thickness. 4. The existence of salt rock will increase the deposition rate; 5. Sedimentation rate is one of the important factors controlling organic matter enrichment and affecting the formation of organic-rich shale.This study provides a new method and means for the future research of stratigraphic analysis, identification of sedimentary cycles with high precision, division and establishment of high-frequency sequence units in the Qaidam Basin.

Session T7-10: Dolomitization and dolomite reservoirs

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-10: Dolomitization and dolomite reservoirs
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Analysis of the dolomite genesis in Lower-Middle Ordovician carbonate rocks in the Yingshan Formation, Gucheng Area, Tarim Basin—Evidence from petrography and geochemical data

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Keywords: Dolomitization, Recrystallization, Geochemical Characteristics

Various degrees of dolomitization are widely present in the Yingshan Formation in the Gucheng area of the Tarim Basin. To determine the origin of the massive dolomites present, a rich combination of tools was well used, including previous research results, core and thin-section samples, cathodoluminescence, carbon (C-) and oxygen (O-) isotopes, strontium (Sr-) isotopes and content, and burial-thermal history data. The results of this analysis successfully reveal three primary matrix dolomites and three special cements, as follows: (1) microcrystalline to very fine crystalline nonplanar-a dolomite (MD1); (2) very fine to fine crystalline planar-s to planar-e dolomite (MD2); (3) medium to coarse crystalline nonplanar-a to planar-s dolomite (MD3); (4) coarse crystalline nonplanar-a saddle dolomite cement (SD) and (5) medium to coarse crystalline calcite cements (C1 and C2). With increasing crystal size of dolomite, the luminescent intensity of matrix dolomites (MD1, MD2, MD3) gradually escalates under cathode rays, presenting uniform very dull to dull red light. In addition, among them, some MD3 shows different luminescent property, as a dull to dull red light internally and a relatively bright but extremely thin red light at the crystal edges; the Sr content (60.35-205.54 μg/g) and $\delta^{18}O$ (-9.45~4.81‰VPDB) decreased gradually and there was no significant difference in $\delta^{13}C$ values (-1.90~0.01‰VPDB). Reference to the estimated range of early-middle Ordovician marine dolomite (Veizer et al., 1999), the Standard conversion formula of PDB/SMOW and Temperature/SMOW (Friedman and O'Neil., 1977), dolomitization and multiple recrystallization of these three matrix dolomites are supposed to occur during burial process under the influence of slightly evaporated seawater and exogenous hydrothermal fluid: MD1 precipitated from the reflux of mildly evaporated seawater. Some of them underwent significant recrystallization to form MD2, and some of them experienced second significant recrystallization to form MD3 in medium-burial environments. Besides, a portion of MD3 was determined to be the product of the third significant recrystallization under the action of mixed hydrothermal fluid of mantle-derived fluid and Cambrian hot brine due to its special cathodoluminescence, high $^{87}Sr/^{86}Sr$ value (0.709105~0.709265) and special associated minerals (saddle dolomite (SD) and autogenic quartz (QZ)). Furthermore, negative $\delta^{13}C$ values (-2.78~-2.01‰), weak cathodoluminescence, different associated minerals, distinct $\delta^{18}O$ (C1: -12.69~-8.73‰; C2: -8.63~-8.03‰) and $^{87}Sr/^{86}Sr$ isotope characteristics (C1: 0.709212~0.709527; C2: 0.708724~0.708995) indicate that C1 and C2 have different origins: C1 was formed in buried formation water of Himalayan period which was close to the CH_4 charging event; and C2 is related to the late Caledonian and early Hercynian orogeny, which was formed by matrix limestone dissolved under pressure solution and reprecipitated in fractures and caves.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-10: Dolomitization and dolomite reservoirs
Presentation Preference: Oral Preferred

Multi-stage dolomitization and other diagenetic processes and its impact on the reservoir character of the late Triassic (Rhaetian) Kingriali Formation, Upper Indus Basin, Pakistan

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Keywords: Kingriali, Petrography, Dolomitization, Porosity enhancement

Multiple episodes of dolomitization of the shallow marine carbonates of the Late Kingriali Formation resulted in regional scale mapable dolostone geobodies in the Kohat and Potwar sub-basins. Except few unaltered patches of the host limestone, more than 90 % carbonates of the studied formation is diagenetically altered by replacive dolomites with associated dolomite cementation. Petrographical and geochemical data interpretation reveals that during the initial stage of dolomitization, the precursor limestone was significantly modified by the fabric retentive replacive dolomite (RD-I) and produced bulk dolostones with non-planar-a to planar-s crystals. Neomorphic recrystallization (RD-II) was observed as overgrowth of the already formed RD-I dolomite crystals during progressive dolomitization. At shallow depth, the seawater enriched with Fe-ions as a result of interacting with Fe-rich beds within the studied formation. The modified seawater actively participated in the formation of ferroan replacive dolomites (RD-III). Stable isotopic composition of the unaltered Echinoderm plates, calcite cement (CC-I) and RD-I demonstrates signatures of δ18O and δ13C within the limit of late Triassic marine seawater or modified seawater. Depletion in the stable oxygen isotopic composition (from -0.99‰ to -3.75‰ V-PDB) interpreted that RD-II and RD-III were formed in a sequence with progressively high temperature fluids than normal seawater. Precipitation of dolomite cements as cavity filling rhombs (DC-I) and crystal overgrowth (DC-II) with highly depleted δ18O values (-5.44 to -7.45‰ V-PDB) interpreting dolomite cementation at higher temperature and greater depth. The highly depleted values of δ18O (upto -9.16‰ V-PDB) and (upto 0.42‰ V-PDB) for δ13C of saddle dolomite (SD-I), indicates the precipitation of SD-I as a cavity filling dolomite at considerable depth. Calcite cementation and calcitization actively participated in the early, middle, and late diagenetic modifications as interpreted from their petrographic and stable isotopic studies. Porosity enhancement is clearly demonstrated by dissolution, stylolization, fracturing and replacement dolomitization. Dolomite and calcite cementation resulted negative impact on the reservoir character and occluded the dolostone porosity to a greater extent.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-10: Dolomitization and dolomite reservoirs
Presentation Preference: Oral Preferred

Formation mechanism of the Upper Ediacaran microbial-dominated dolomite reservoirs in the northern Tarim Basin, China

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Keywords: microbial dolomite, Upper Ediacaran, reservoir property, formation mechanism

The Upper Ediacaran Qigebrak Formation of the Tarim Basin consists of various microbial dolomites and is considered as a potential hydrocarbon exploration target for deeply-buried carbonate reservoirs. However, the formation mechanism of the Qigebrak dolomite reservoirs has not well been understood yet, hampering the predictions of high-quality reservoirs. This work was conducted based on detailed petrological, geochemical, and petrophysical investigations, aiming at understanding the diagenetic processes and influences on the porosity generation and preservation. The microbial dolomites of the northern Tarim Basin can be divided into four types based on different scales (macro- to micro-) of observation: microbial laminite, stromatolite, spongiomicrobialite, and microbial-peloidal wackstone/mudstone. The main diagenetic products consist of three types of dolomite (microbial dolomicrite, early-stage fibrous dolomite cement, and late-stage pore filling dolomite cement), quartz, calcite and bitumen fillings. Pore spaces are dominated by vugs, solution-enhanced pores, microbial framework pores, intercrystalline pores, micropores and fractures. The development of high-quality dolomite reservoirs in the studied area was essentially controlled by three controlling factors: microbial mat deposition, early dolomitization, and meteoric karst leaching. Microbial mat deposits can be considered as the foundation to form framework pores. Furthermore, the early dolomitization increased the resistivity of the studied microbial dolomites toward chemical and physical compaction, during which abundant micropores are generated. The meteoric karst dissolution, which is related to the uppermost Qigebrak Formation unconformity surface, is the crucial controlling factor that enhanced the porosity via forming a large quantity of vugs- and solution-related pores. Results presented here show that the Precambrian deep-buried dolomicrobialites could serve as potential reservoir geobodies targeted for hydrocarbon exploration.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-10: Dolomitization and dolomite reservoirs
Presentation Preference: Oral Preferred

Structurally-related hydrothermal alteration and/or dolomitization in the Lower Paleozoic carbonates of Tarim Basin: A review

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Keywords: Lower Paleozoic carbonates, Tarim Basin, Hydrothermal alteration and dolomitization, hydrothermal dissolution, Permian igeneous activity

The Paleozoic carbonates, particularly the Lower Paleozoic (Cambrian to Mid-Lower Ordovician) platform successions in the Tarim Basin overwhelmingly comprise dolostones of variable origins from syndepositional to burial even telodiagenetic processes. Those hydrothermally-altered dolostones commonly occurred in association with either intrusive magmatism (diabases) of Early Permian large igneous province (LIP) (ca. 290 Ma) or related faulting or fracturing. They are characterized by extensive recrystallization of nonplanar-a matrix dolomite mosaics and void- and/or fracture-filling cements of saddle dolomites and other later diagenetic mineral phases. Saddle dolomites generally yield isotopic (C, O, Sr) data similar to those of matrix dolomites, of which some even yield lower Sr isotopic ratios than the matrix dolomites particularly occurring along the intrusive bodies, indicating the hydrothermal fluids were derived mainly from the ambient carbonate formation fluids, locally mixed with basic magmatic fluids. Fluid inclusion microthermometry of saddle dolomites suggest the temperature of fluids responsible for dolomite precipitation was higher than the ambient formation. In this case, the magmatic emplacement of linked to the Early Permian LIP activity could have caused not only the thermal anomaly but also fracturing in the Paleozoic carbonates that were penetrated by the intrusions, enhancing the thermal diffusion and hydrothermal fluid migration (although minor volumes of thermal fluids from the basic magmas) through the fracture/fault systems, thereby resulting in contact metamorphism (or marbleization), recrystallization of matrix dolomites and dolomite precipitation commonly in primary dolostone successions. On the other hand, hydrothermal fluids could have also caused dolostone dissolution, although not extensive, along the faults or fractures probably through retrograde dissolution as the fluid temperature dropped during upward migration. This may account for the voluminous unfilled large voids/cavities in the deep-buried Cambrian dolostones as recovered in the ultra-deep borehole well TS1 (up to 8408 m).

Comparatively, the Lower Paleozoic limestones, although limitedly distributed, occur on the northeastern flank in the Quruktagh area of Tianshan Mountains, and are dominated by basinal thin-bedded lime mudstones. Subordinate dolostones occur as by light-colored beige, anastomosed dolostone geobodies along the faults and fractures cross-cutting the well stratified limestones. These dolostones comprise matrix dolomite and cement dolomites (saddle dolomites) locally with brecciated and/or zebra fabrics. Isotopic (C, O, Sr) data of dolomites suggest dolomitizing fluids were largely inherited from or buffered by the host formation fluids with elevated temperatures and inputs of Mg and radiogenic Sr from the host limestones through enhanced rock-fluid interactions. The fault- or fracture-prevalent dolomitizing process probably took place during the Hercynian orogeny, as the Tarim block collided with the Tianshan island arc chains to the north and northeast through which the secondary tensional faults and fractures within the overall compressional setting could have acted as the favourable fluid conduits recharged by the Mg-rich fluids expelled from the depths, leading to the dolomitization along the faults/fractures.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-10: Dolomitization and dolomite reservoirs
Presentation Preference: Oral Preferred

Microbial dolomite precipitation mediated by methanogen in a Permian lake, NW China

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Keywords: microbial dolomite, dolomite nanoglobules, methanogens, biosignature, lake sediments, Permian

Microbes can mediate dolomite precipitation in laboratory experiments, but until now linkage of microbes to ancient dolomites remains poorly constrained. This paradox is usually due to the lack of diagnostic biogeochemical signatures and mineralized microbial remains in the rock record. Here, we report the occurrence of methanogen-mediated dolomite in a Permian non-hypersaline lake from NW China. The clumped isotope (Δ47) temperature provides direct evidence of a low-temperature origin (typically < 40 °C). The extremely positive δ26Mg (up to +0.44‰) and δ13C (up to +19‰) values in the dolomite suggest authigenic precipitation in methanogenic lake sediments. Micron-sized spheroidal bodies, filamentous and sheet-like structures are interpreted as mineralized coccoid archaea and extracellular polymeric substances (EPS), respectively; they exhibit a granular texture consisting of dolomite nanoglobules (mainly 40–100 nm in diameter). A combination of both geochemical and microscale evidence strongly confirms a microbial origin of dolomite induced by methanogens. Moreover, the formation of dolomite is characterized by a non-classical pathway including metabolic incubation, heterogeneous nucleation, and aggregative growth. Dolomite nanoglobules initially nucleated on the surfaces of methanogen cells or EPS, and then merged into larger aggregates. These findings provide valuable clues to decipher the biosignature of ancient dolomites and better understand dolomite formation.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-10: Dolomitization and dolomite reservoirs
Presentation Preference: Oral Preferred

LA-ICP-MS U-Pb Age, SEM and isotope constrain on the origin of Ediacaran dolomite

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Keywords: Dolomite precipitation, SEM, Microbial mediation, Seawater geochemistry, LA-ICP-MS U-Pb Age analysis

Huge thick succession of dolostone developed in Ediacaran in typical platform sedimentary area of China (Bao, 2019). But lomestone developed around the paleouplift, slope environments (Jin, 2019). Multi-sections study show that these dolostone structures differ from the dolostone with replacement in Phanerozoic and their origins are in dispute with primary or secondary. Because of the flourishment of microbes in PreCambrian, many researchers tended to explain with microbial origin. Many similar microbial proofs like spherulitic dolomites were discovered in the dolostone with microbial structures. However, the surrounding rock are very fine-crystal dolostone and the cements and fillings are pure dolomites with rare calcite. Geochemical data show that they were not replaced from calcite. LA-ICP-MS U-Pb Age analysis result of these dolomites are about 554My, which means that they were penecontemperaneously formed. Modern dolomite experiments and dolomite precipitation in super-salinity environment show that microbes play significant fuction in the dolomite precipitation. But more researches show that the more important function of microbes is that they changed the microenvironment of marine water and the dolomites were easy to precipitate. Or the aragonites were easy to transfer to dolomites. This aragonite-dolomite sea is different with the calcite sea and aragonite sea in Phanerozoic. The flourishment of microbes will change the chemical characteristics of marine water in platform area and lead to widespread dolomite precipitation. However, the restricted microbe scale in non-platform area were insufficient to the widespreas dolomite precipitation.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-10: Dolomitization and dolomite reservoirs
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Hydrothermal dissolution of deep-buried dolomites and its significance to the hydrocarbon exploration in the Tarim Basin, NW China

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Keywords: Tarim Basin, Hydrothermal dissolution, Deep-buried carbonate, Dolomite reservoir

Dolomites pervasively occur in the deep/ultradeep buried carbonates, especially in the Early Paleozoic, in the Tarim Basin, NW China. This study focuses on the Upper Cambrian dolomites of SHNP1 well in the Shunnan area, Tarim Basin, which still preserved abundant dissolution pores and/or vugs at depth over 7500 m. Integrated isotopic geochemistry (C, O and Sr) and fluid inclusion microthermometry suggest that dolomite recrystallization and subsequent precipitation were closely associated with fault-related hydrothermal fluids migrated from greater depth. In addition, the diameter of dissolution pores are gradually increasing with progressively burial. This variation also verified that they were formed by upward migration of tectonically driven hydrothermal fluids rather than infiltration of subsurface water with progressive burial. Moreover, the anisotropy of reservoir space revealed by full diameter CT scanning illustrated that fractures induced by hydrothermal dolomitization could significantly improve the quality of carbonate reservoir, particularly of permeability. Hydrothermal-related dolomite reservoir may be extensively present in the deep/ultradeep buried carbonates in the Tarim Basin in view of the occurrence of such phenomenon in the borehole TS1 in the northern Tarim Basin. This study demonstrates the constructive role of hydrothermal dolomitization in improving the property of carbonate in ancient cratonic basin. It thus deserves to pay more attention to the hydrothermal-altered dolomites than ever before during hydrocarbon exploration in the Tarim Basin and elsewhere.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-10: Dolomitization and dolomite reservoirs
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Origin and reservoir implications of Lower-Middle Ordovician burrow-associated dolomites of Tarim Basin (NW China)

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Keywords: Burrow-associated dolomites, Isotopic geochemistry, Reservoirs, Tarim Basin, Lower-Middle Ordovician

The origin and reservoir implications of burrow-associated dolomites (BADs) are still not well defined. The study carried out comprehensive analyses of petrography, fluid inclusion microthermometry, and isotopic (C-O-Sr) geochemistry on the burrow-associated carbonates (dolomite and calcite) of the Yingshan Formation of the Lower-Middle Ordovician in the Tarim Basin (NW China), in order to figure out the controls on the dolomitization of burrow infills and the effects on petroleum reservoir quality. The tempo-spatial distributional patterns of the burrow-associated carbonates within the sequence stratigraphic framework indicate that the development of different types of burrow-associated carbonates was dictated by the interplay of depositional environments and sea-level fluctuations of variable orders. The BADs were formed in a lagoonal setting during the lowstand of long-term sea level, whereas the burrow-associated calcites (BACs) were precipitated in a water circulation-improved lagoonal environment during the transgression of long-term sea level. The geochemical data reveal that the variably-evaporated (i.e., mesosaline to penesaline) and nearly normal seawaters were responsible for the development of BADs and BACs in the Yingshan Formation, respectively. In the anoxic near-surface to shallow burial settings, sulfate-reducing bacteria and a sufficient supply of dolomitizing fluids enriched in magnesium ions and their Mg^{2+} concentration may have played a significant part in the precipitation of BADs. Due to the burrowing process, the burrowed sediments became more permeable and served as conduits for the parental fluids responsible for the development of BADs, which have higher salinities and higher Mg^{2+} concentration than normal seawater. In such circumstances, burrow infills were favorably dolomitized. In contrast, the fluids with seawater-like Mg^{2+} concentration led to the formation of BACs. Under the conditions of a persistent supply of dolomitizing fluids, the dolomitization fronts may extend into matrix limestones and result in the creation of massive matrix dolomites. With the progressive burial, the overgrowth of BAD crystals was ceased by the emplacement of hydrocarbons from underlying source rocks of the Cambrian to Lower Ordovician. This led to that the better petrophysical properties (porosity and permeability) of BADs were retained and they can act as potential hydrocarbon reservoirs. The results could advance the understanding of the formation and reservoir implications of BADs in the geological records.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-10: Dolomitization and dolomite reservoirs
Presentation Preference: Oral Preferred

Dolomite genesis of Lower Cambrian in Tazhong area, Tarim Basin

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Keywords: dolomite genesis, ultra-deep dolomite reservoir, dolomitization model, Tarim Basin

Due to the good capacity of resistant to porosity-reducing effects by the compaction and pressure solution (Schmoker & Halley, 1982; Lucia, 2004), dolomite can preserve the pores during long-term burial. Dolostones can be high-quality oil and gas reservoir in ultra-deep (>6000m) strata (Lucia, 2004). So the formation of dolomite is of great significance to the preservation of the reservoirs (Rott & Qing,2013; Chen & Qian, 2017; Ye et al., 2019).

High quality reservoirs were well developed in the Lower Cambrian Xiaoerbrak Formation in Tazhong area of Tarim Basin, with average porosity of 9.01% (17 full diameter core samples). Core samples were collected from wells ZH1 and ZH2 in Tazhong area, petrographic observation and geochemical testing of 82 samples have been completed. Combined with the characteristics of in-situ trace elements, the main formation environment of dolomite and the dolomitization model of the Lower Cambrian in the Tazhong area is illustrated.

The research shows that the Lower Cambrian dolomite developed in the background of transgression during the sedimentary period of the Yurtus Formation and subsequent regression during the Xiaoerbrak period. The dolomite was formed in the tidal flat facies. The $\delta^{13}C$ of 82 samples have values of -3.11‰ – 0.48‰ (VPDB), with an average value of -1.15‰ (VPDB), the $\delta^{18}O$ values range from -9.32‰ to -5.39‰ (VPDB), with an average value of -6.99‰ (VPDB). These results are larger than those of limestone in the Lower Cambrian. Moreover, the rare earth elements (REEs) pattern of dolomite is similar to that of limestone. The in-situ trace element analysis of the pore lining cements and intergranular cements in the dolomite shows that the REEs patterns of the cements and the matrix are completely consistent. Ni/Co, V/(V+Ni) and Sr/Na ratios of dolomite indicate that dolomite was formed in a high-salinity and slightly reducing environment. A few strontium isotope values are close to the values of ancient continental aluminosilicate rocks. The carbon and oxygen isotope values and Z values of the Tazhong dolomite are positively correlated with the distance to the ancient continent. There are limestone intervals in the Wusonger Formation in Wells ZH1 and ZH2. All the evidences indicate that the dolomitization fluids derived from evaporating seawater. Seepage–reflux pattern is dominating fluxion mode of the dolomitization fluids during penecontemporaneous at the eogenetic to early mesogenetic stage. The formation of dolomite is related to the supply of evaporative fluid controlled by eustatic change. When sea level rises leading to insufficient supply of evaporative fluid, the limestone section is developed. While the periodic eustatic change and meteoric dissolution in the penecontemporaneous period, the cyclic dolomite reservoirs is formed. Therefore, the early-formed dolomites is crucial for the preservation of ultra-deep reservoirs.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-10: Dolomitization and dolomite reservoirs
Presentation Preference: Oral Preferred

Genetic types and distribution of lower Paleozoic dolomite in Bohai Oilfield

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Keywords: Key words: lithofacies paleogeography , dolomite genetic differentiation marker , reservoir characteristics , dolomite distribution

Palaeozoic group is looking for bohai oilfield under the formation of large and medium gas fields, in view of the upper Paleozoic dolomite with high value exploration, but its genetic type and distribution of ambiguous exploration problems, the use of petrology, isotope and element geochemical method to carry out the lithofacies palaeogeography of the bohai sea lower palaeozoic era, the upper Paleozoic dolomite genesis identification mark, Research on genetic model, reservoir potential and distribution law and form four understandings:1) based on the outcrop of Cambrian and ordovician drilling fine contrast and sedimentary facies research, the bohai rim region in early Paleozoic of palaeogeographic pattern of the north-south high, intermediate low, are given priority to with water carbonate sedimentary, and sums up the early Paleozoic sedimentary characteristics and control factors of sedimentary evolution of the bohai sea and the surrounding lower palaeozoic era is established model, The lithofacies palaeogeography of bohai Sea and its surrounding area in four periods of early Paleozoic is described. 2) There are four kinds of dolomites in Bohai Sea: evaporative dolomite, reflux dolomite, mixed dolomite and burial dolomite. The differences of carbon and oxygen isotope characteristics, petrology, trace elements, diagenetic temperature, rare earth elements, paleo-oxygen facies, paleo-weathering and paleo-terrigenous dolomite were established. 3) To establish the genetic model of bohai dolomite and analyze its reservoir characteristics; The evaporative dolomite is mainly characterized by ultra-low porosity and density. The reservoir space of dolomite of osmotic backflow origin, mixed water origin and burial origin is characterized by pores, caves, structural fractures and related dissolution fractures, and the physical properties are mainly low porosity and low permeability. 4) the analysis summary different genesis of dolomite longitudinal and plane distribution of the bohai sea, evaporation causes dolomite development horizon confined to Cambrian zhangxia group - multifunction mountain, seepage reflux genesis of dolomite in the massive distribution, southern bohai sea is advantageous in seepage reflux formation dolomite development area, and has a decrease trend from the south to the north, Mixed water dolomite is developed in zhangxia Formation and Middle Ordovician along the karst slope of each paleo-uplift in The Bohai Sea, and buried dolomite is distributed in all layers, among which hydrothermal dolomite is mainly distributed along the fault zone.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-10: Dolomitization and dolomite reservoirs
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

A Dolomitization model of the Lower Cambrian Longwangmiao Formation, Sichuan Basin, Southwestern China

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Keywords: Longwangmiao Formation, dolomitization model, evaporation pump, seepage reflux, C-O-Sr isotopes, Sichuan Basin

The lower Cambrian Longwangmiao Formation (LWMF) dolostones are the most important producing strata in Sichuan Basin, SW China. The dolomitization model has been established for the LWMF dolostone in this paper through core description and outcrop investigation, cathodoluminescence, geochemical analysis such as major elements, trace elements, fluid inclusion and isotope of carbon, oxygen and strontium. The LWMF are mostly composed of dolostone, dolomitic limestone and calcareous dolostone, limestone in lithology. In Central Sichuan Basin (CSB), dolostones dominate while dolostones and partially dolomitized limestones can be found in Southern (SSB) and Eastern Sichuan Basin (ESB). In CSB, the δCe index of almost all of the samples takes on an obviously positive anomaly while the δEu index shows a negative anomaly (the δEu index of a few dolograinstones is positively abnormal). In ESB, the δCe index takes on an obviously positive anomaly while the δEu index shows a negative anomaly (the δEu index of a few samples from WT1 are positively abnormal). In SSB, δCe values of all the samples are positive abnormal and δEu index is positively abnormal. The MgO-CaO content of all the samples is positively correlated in CSB, but negatively related in ESB and SSB. In CSB, dolostones have the highest content of element Na (The average of element Na >350 ppm). the $\delta^{13}C$, $\delta^{18}O$ and $^{87}Sr/^{86}Sr$ values of dolostones generally greater than range of seawater. In fluid inclusion analysis, the homogenization temperatures and salinities indicate that the dolomitization fluids of the LWMF in CSB have low temperatures and high salinity, but the dolomitization fluids of the LWMF in SSB have high temperatures and high salinity. In SSB, dolostones have the lower content of element Na (The average of element Na >100 ppm), which is due to the leaching of atmospheric fresh water and the influence of hydrothermal fluid during the deposition period. The $\delta^{13}C$ and $\delta^{18}O$ values of samples in SSB are obviously positively correlated and the $^{87}Sr/^{86}Sr$ values of generally greater than range of seawater. In ESB, the $\delta^{13}C$ and $\delta^{18}O$ values of dolostones have the highest content of element Na (The average of element Na > 200 ppm). The $\delta^{13}C$ and $\delta^{18}O$ values of dolostones are more positive than those of seawater. The $^{87}Sr/^{86}Sr$ values of dolostones generally greater than range of seawater. We believe that the dolomitization model of the LWMF is an evaporation pump + seepage reflux model. During the sedimentary period of LWMF, the Sichuan Basin is a carbonate ramp with three-stage stepped deposits, which is high in the west and low in the east. The seawater gradually becomes open from west to East. The seawater is the most restricted in CSB, followed by the seawater in SSB, and the least limited ESB. The dolomitization also decreases with the gradual opening of the seawater. In CSB, The dolomitization fluid is palaeoseawater-oriented. In the SSB, the dolomite formed in seepage reflux, and is overlapped by hydrothermal fluid later and atmospheric fresh water. In the ESB, a seepage reflux mode of continueous seawater concentration.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-10: Dolomitization and dolomite reservoirs
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Reservoir development characteristics and main controlling factors of Dengying Formation in Sichuan Basin

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Keywords: Sichuan Basin, Dengying Formation, Carbonate rock, Reservoir characteristics, Main control factors, Favorable development zone

Large packaged gas fields such as Weiyuan and Anyue have been found in the carbonate rocks of Dengying Formation in Sichuan Basin. However, there are some problems in the reservoir, such as strong heterogeneity, large changes in physical properties and various reservoir types, which makes oil and gas exploration and development more difficult. In order to further understand its oil and gas types and distribution law, the data of core description, logging interpretation, cast thin section, cathodoluminescence and high-pressure mercury injection are used to analyze the reservoir development characteristics and main controlling factors.

The reservoirs of Dengying Formation are stably distributed horizontally and developed in second member and fourth member longitudinally, with the characteristics of wide range and large cumulative thickness. Under the sedimentary background of shallow tidal flat, lagoon and mound beach, the reservoir of Dengying Formation mainly develops algal agglomerate dolomite, algal laminated dolomite, algal arenaceous dolomite, algal laminar dolomite and argillaceous dolomite, and different lithology shows specific development characteristics. The physical properties of Dengying Formation reservoir are characterized by strong compactness of ultra-low porosity and permeability, and locally high porosity and permeability. Among them, the porosity is distributed between 0.77% ~ 10.32%, with an average of 2.26%, and about 73% of the samples are concentrated between 1% ~ 3%. The permeability is between 0.0047 ~ 24.7md, with an average of 0.75md, and about 75% of the samples are less than 1md. A small number of rock sample data show the characteristics of low porosity and high permeability, reflecting the existence of fractures and micro fractures. The reservoir types of Dengying Formation vary widely. Intergranular solution pores, intragranular solution pores, mold pores and intergranular solution pores are developed in the micro, and karst caves, solution fractures and structural fractures exist in the macro. Combined with the lithology and physical properties of the reservoir, the reservoir space types are divided into 11 types of 6 styles in 3 categories.

The reservoir development of Dengying Formation is mainly controlled by two factors. (1) Favorable sedimentary facies. Mound and beach facies are favorable sedimentary facies of Dengying Formation with obvious facies control. High energy mound and beach facies rocks such as arenaceous dolomite, tufted dolomite and laminated dolomite have an average porosity of more than 3.5%. (2) Supergene karstification. Among the high-energy mound beach facies developed in the early stage, the physical properties are good. The reservoir can be used as the transmission conductor of karst water, dissolve and expand the early pores, and transform them into a karst superimposed and expanded pore system. On this basis, the favorable areas for reservoir development are predicted and divided into three favorable areas. (1) The most favorable area is the superposition area of karst platform or karst slope and Hill Beach complex. (2) The favorable development zones are karst platform, karst slope zone or Hill Beach complex area. (3) The more favorable development zone is karst highland or internal rift of Zitong-Junlian craton (limited lagoon sedimentary area).

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-10: Dolomitization and dolomite reservoirs
Presentation Preference: Oral Preferred

Isochronous dolomite models since early Neogene in isolated deep-water reefs on continental slope: spatial evolution, atomic characteristics and multiple genetic mechanisms

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Keywords: spatial evolution since reef formation,algal reef dolomite,tight dolomite,ankerite,primary dolomite,Transmission electron microscopy

The concentric circle model for the study of dolostone on isolated islands is a good example, which illustrates the process, results and mechanism of the interaction of dolomitization between water and rock along the flow path from the shelf edge to the center of the island.

In this paper, the characteristics, results and mechanisms of water-rock interaction of dolomitization during the early Neogene since the formation of the reef were studied by drilling through the exploration Wells of the Reef family of Xisha Islands to obtain the complete core. The occurrence, distribution and spatial evolution of algal reef dolomite, ankerite and tight dolomite since the formation of the reef were explained. A multi-mechanism isochronous genetic model for the formation of deep dolomite (≥1000m), middle deep dolomite (500-1000m) and shallow dolomite (≤ 500m) in different periods since reef formation has been established. It is pointed out that the formation of tight dolomite follows the filling failure mechanism and the dense accumulation mechanism of round particles with different diameters, which has significance for oil and gas exploration.

TEM has been used to study the crystal lattice constants, types and spatial point group characteristics of 1-5 nanoscale dolomites with the highest resolution to date. Dislocation, significant line defects and changes along the deep, middle and shallow layers have been revealed, and the dolomite atomic image model has been established.

It is pointed out that the original dolomite synthesized by the experimental synthesis technology is 3nm, which is similar to the original dolomite-ankerite found in the core of different layers in The Science exploration well. The original dolomite is clean, euhedral to semi-euhedral, and is enriched in pores, holes and fractures, and benefits from the promoting effect of microorganisms.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-10: Dolomitization and dolomite reservoirs
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Effects of Deep Fluids on Middle Permian Dolomite Reservior of the Western Sichuan Basin

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Keywords: Deep fluids, Hydrocarbon accumulations, Dolomite Reservoirs, Sichuan Basin

Deep fluid activity is closely related to carbonate reservoir transformation as well as oil and gas accumulation. The large-scale deep fluid activity caused by Emeishan Large Igneous Province (ELIP) brought a lot of deep material and energy to Sichuan Basin, changed the paleogeothermal and geochemical field of the region they flowed through, which had an important impact on the formation of Middle Permian dolomite reservoir in Western Sichuan. Through comprehensive analyses of petrographic, geochemical and fluid inclusion data from two drill core and three outcrop sections of the Middle Permian Formation in the western Sichuan Basin, the dolomitizing fluid, dolomite genesis and affect of deep fluid were discussed. The dolomite were divided into four types which are matrix dolomites (Md1, Md2 and Md3) and cement dolomites (Cd). Among them, the Md1 were formed in penecontemporaneous seawater by seepage reflux dolomitization, while Md2 were formed in heated Permian seawater through thermal convection. In the NW, the Md3 and Cd were formed by higher-temperature thermal convection without hydrothermal.In the SW, the lower $\delta^{13}C$ value and Sr contents, higher Mn contents and $^{87}Sr/^{86}Sr$ ratios, positive Eu anomalies as well as much higher Th and salinity values of inclusions shows that hydrothermal participated in the dolomitization, forming the Md3 and Cd through structure-hydrothermal dolomitization and the thermal convection of seawater mixed with hydrothermal. The deep fluid activities of ELIP provided both the material source (Mg^{2+}) for the dolomitization process and the migration motive power for the dolomitization fluid. From SW to NW, with the deep fluid activity decreasing, the abundance of Md3 and Cd which are closely related to the hydrothermal solution reduced.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-10: Dolomitization and dolomite reservoirs
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Characteristics and genetic mechanism of porphyry dolomite in the Longwangmiao Formation in the central Sichuan area

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Keywords: Longwangmiao Formation,Porphyry dolomite,reservoir characteristics,formation mechanism

The Lower Cambrian Longwangmiao Formation in the Moxi area of central Sichuan Basin is the largest single-packed marine carbonate gas layer discovered in China, The Longwangmiao Formation reservoirs have significant heterogeneity and mostly contain bitumen-infested dark patches .Based on the analysis methods of core observation, thin section identification, fluorescence reaction, cathodoluminescence and scanning electron microscope observation and geochemical characteristics, the research on the reservoir characteristics and genetic mechanism of the piebald dolomite in the Longwangmiao Formation in the central Sichuan area is carried out. The following research results are obtained(1) the porphyry dolomite in Central Sichuan are developed irregularly with black spots and white spots . Due to the strong heterogeneity of pores, the porphyry dolomite is filled with asphalt to form "dark patches", while the porosity with dense lithology or not filled with asphalt forms "white patches".(2)The solid bitumen in the Longwangmiao Formation reservoir in the central Sichuan area mainly comes from the Lower Cambrian source rock, and the oily bitumen mainly comes from the Lower Silurian Longmaxi Formation, and the genetic types of the bitumen are diverse. (3)The Longwangmiao Formation reservoirs in the Sichuan Basin are divided into porphyry-pore-type reservoir, porphyry-pores-vugs-type reservoirs, and porphyry-karst-type reservoirs in the study area according to the porphyry shape and void relationship. (4)The lithology and genesis of different types of "porphyry" reservoirs are also different.,the porphyry-karst-type reservoir is mainly formed by the epigenetic karstification of micrite (sand) dolomite; the porphyry-pores-vugs-type reservoir is due to the selective dissolution of granular dolomite; The porphyry-pore-type reservoir is due to the selective dissolution of micrite grain dolomite along biological burrows.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-10: Dolomitization and dolomite reservoirs
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Genesis and distribution of thin dolostone in Early to Middle Permian Sichuan BasinChina

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Keywords: Dolomite genesis,Distribution characteristics,Early-middle Permian,Sichuan basin

Most of the previous studies believed that the middle-lower Permian dolomite in Sichuan Basin was formed by tectonic hydrothermal action, and the distribution of dolomite was closely related to the distribution of basement faults. Through the analysis of petrological and geochemical characteristics of a series of outcrops and drilling cores, and according to the statistics of dolomite development in drilling, the results show that: (1) The thin-bedded dolomite can be divided into leopard porphyry grain dolomite and massive grain dolomite in macroscopic occurrence. The dolomite is mainly euhedral to semi-euhedral mesocrystalline dolomite. The original lithology is mainly sparry or micritic bioclastic grainstone, indicating that the dolomite is mainly developed in the grain beach facies. (2) The distribution range of carbon isotope of dolomite is similar to that of limestone and sedimentary seawater, and oxygen isotope is slightly higher than that of limestone, which may be due to the dolomite being subjected to high salinity dolomitization fluids. Strontium isotopes of limestone and dolomite are distributed in the Permian seawater range. The ree distribution curve of the macerals of the dolomite is "left inclined shape" with LREE deficit and HREE enrichment, which is the same as that of the seawater. Geochemical results show that the dolomite fluid is mainly Marine fluid with high salinity, not hydrothermal dolomitization. (3) The plane distribution of dolostone is characterized by continuous distribution around sedimentary landform highland, and the thickness of single layer is mostly in the range of 1~3m. Longitudinally, the dolomites are mainly distributed in the middle and upper part of the sedimentary cycle and are controlled by high frequency sequences. Combined with the geochemical characteristics and distribution characteristics of the dolomite, it is considered that the early-middle Permian dolomite in Sichuan Basin was formed by penecontemporaneous reflux infiltration dolomitization. Due to the high frequency variation of sea level, it is easy to form the leopard porphyritic dolomite with thin monolayer thickness and incomplete dolomitization.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-10: Dolomitization and dolomite reservoirs
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Mineral and REE characteristics of the surrounding rocks of the first member of the Sanya formation in West Ke 1 well, Paracel Islands

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Keywords: Xike 1 well,Surrounding rock,microcosmic, rare earth element,Distribution mode,Diagenesis

Abstract: the characteristics of rare earth elements in dolomite, such as content, distribution mode and some important rare earth element parameters and their variation rules, are of great significance to study the genesis, provenance properties and paleoenvironment of dolomite, especially to establish genetic model. However, dolomite is easily affected by multi-stage diagenesis evolution in the formation process, so its geochemical characteristics are uncertain. It has only been more than ten years since the discovery of tight dolomite in well Xike 1. Predecessors have completed the research on petrology, Geochemistry (isotope tracing, etc.) and reservoir characteristics, but their rare earth element characteristics and micro regional petrological characteristics are the links less studied by predecessors. On this basis, the author takes the core of the first member of Sanya formation of well Xike 1 as the research object, and first distinguishes the surrounding rock and debris of tight dolomite, Through microscopic equipment, it is observed that the surrounding rock dolomite is in close contact, most of which are fine-grained particles, and the pores are small. The fine-grained dolomite includes automorphic, semi automorphic and heteromorphic, and a typical fog core bright edge structure is developed. At the same time, the rare earth element composition of surrounding rock is measured by laser in-situ denudation technology. The overall rare earth element distribution mode is in line with the rare earth distribution characteristics of normal marine carbonate rocks, which is manifested in LREE loss and CE negative anomaly. At the same time, the possible influence in the process of diagenesis is is discussed and analyzed by calculating the abnormal values of other specific elements.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-10: Dolomitization and dolomite reservoirs
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Tight dolomite and its dedolomitization in Well Xike 1 in Xisha Shidao

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Keywords: dedolomitization, tight dolomite, Well Xike 1, calcite rhombohedral pseudomorphic, speckled calcite

Dolomite is an important storage space for oil and gas including oil and gas in the South China Sea, and it is also a hot spot and frontier in basic research. This study focuses on the dedolomitization of tight dolomite in Well Xike 1. Contrary to dolomitization, dedolomitization represents the dissolution of dolomite and the formation of calcite, which can cause a series of changes in the original porosity, structure and mineral properties of dolomite. In this paper, using X-ray powder crystal diffraction, scanning electron microscopy and alizarin red staining analysis techniques, on the basis of the analysis of the lithological characteristics of the core, the phenomenon of dedolomitization was found by dyeing thin sections. The phenomenon of dedolomitization in the well section of this study is widespread, but the overall phenomenon is weak, and there is no obvious dedolomitization limestone layer. The overall performance is as follows:(1) Calcite completely replaces dolomite to form other shape granular; (2) calcite metasomatizes dolomite to form calcite rhombohedral pseudomorph; (3) Dolomite has speckled or plaque-like calcite; (4) Dolomite is selectively leached and dissolved; (5) Calcite fills dolomite dissolution pores; (6) Visible Dedolomitization of saddle-shaped dolomite. The dedolomitization of the first member of the Sanya Formation occurred in the environment of stagnant dedolomitization fluid and lower formation temperature, and the equal volume metasomatism of calcite to dolomite often occurred, so the effect on porosity and permeability was small.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-10: Dolomitization and dolomite reservoirs
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Early dolomitization and subsequent recrystallization of Middle Ordovician carbonates in the Western flank of the Ordos Basin, Northern China: Implications for hydrocarbon exploration

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Keywords: early dolomitization,recrystallization, isotopic geochemistry,diagenesis,Ordos Basin

The pervasive dolostone from the Middle Ordovician Zhuozishan Formation in the Ordos Basin (Northern China) are considered as potential hydrocarbon reservoirs. Three types of matrix dolomites (Md) are recognized: 1) very fine to fine crystalline, nonplanar-a to planar-e dolomite (Md1); 2) fine to medium crystalline, nonplanar-a to planar-e dolomite (Md2); and 3) medium crystalline, planar-s to nonplanar-a dolomite (Md3). The initial dolomitization of Md1 and Md2 dolomites is inferred to have taken place in the presence of seepage reflux of slightly evaporated seawater in the near-surface to shallow burial settings, and insignificant recrystallization occurred in the process of being buried again, according to petrography, trace elements, and oxygen-carbon-strontium isotopic geochemistry. Coarser crystals with cloudy cores and clear rims consist of the Md3 dolomites, and the texture shows irregular contacts between planar-s and nonplanar-a crystal. Geochemical analysis reveals that the Md3 dolomites have a negative shift in $\delta^{18}O$ values with increasing Mn contents, and a negative $\delta^{18}O$ trend with depth in the same well, while the $\delta^{13}C$ does not tend to correlate with the oxygen isotopes. Additionally, the $^{87}Sr/^{86}Sr$ ratios of Md3 dolomites are relatively higher due to contribution of radiogenic ^{87}Sr. Petrological attribute and geochemical evidence suggest that the massive Md3 dolomites can be due to significant recrystallization of earlier formed dolomites during burial period. The unevenly distributed pores in Md3 dolomites suggest the heterogeneous structure of the precursor dolomites, which may be the Md2 dolomites. The residual particles of Md2 dolomites indicate the precursor limestones were deposited in a relatively high-energy part of the shoal. Hence, the wide distributed Md3 dolomites show salient facies-controlled characteristics, which suggests strategies for hydrocarbon exploration of potential heterogeneous dolomite reservoir.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-10: Dolomitization and dolomite reservoirs
Presentation Preference: Oral Preferred

Recrystallization of the Ediacaran cap dolomites from south China

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Keywords: Cap dolomite, Recrystallization, Ediacaran, Stoichiometry, Snowball earth

Using the globally distributed Ediacaran cap dolomites to understand the post-snowball earth after the Marinoan glaciation is hindered by potential alterations of the original environmental signals preserved in the rocks. The Ediacaran Doushantuo cap dolomites deposited on an open shelf in south China were studied and compared with the Cenozoic marine dolomites. The Doushantuo cap dolomites are (1) composed soley of LCD (low-calcium dolomite, %Ca < 55%); (2) near-stoichiometric (average %Ca = 50.8%); (3) characterized by high cation ordering (average cation ordering = 0.83); (4) featured by blocky nanotopography on the etched crystal surface which is typical for LCD; (5) dominated by nonplanar and planar-s fabrics; and (6) consisted of matrix dolomite crystal ~5–80 μm and void-filling crystals ~20–1000 μm in diameter. The above features differentiate the Doushantuo cap dolomites from many Cenozoic seawater dolomites such as the Miocene dolomites on the Cayman Islands, which are fabric-retentive with dolomites characterized by higher average %Ca and lower cation ordering, and comprise LCD and HCD (high calcium dolomite, %Ca >55%). Recrystallization that transformed the Doushantuo cap dolomites from metastable calcian dolomite to more ideal dolomite is pervasive and facies independent, during which the original geochemical signatures in the dolomites could have potentially been modified .

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-10: Dolomitization and dolomite reservoirs
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Evolution of Microbial Carbonate Platform in NW Tarim Block during the Late Ediacaran

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Keywords: Microbial carbonates, facies, sequence stratigraphy,platform evolution.

Microbial carbonates are widespread in the Ediacaran Qigebrak Formation in the north-west (NW) Tarim Block. Their potential for oil-gas reservation has been revealed by recent exploration. However, this potential was hindered by the controversial depositional evolution of the Qigebrak Formation. Here, we carried detailed studies on depositional facies and sequence stratigraphy on the microbial carbonates in the Qigebrak Formation. 18 types of facies, 8 types of depositional environments, and 3.5 T-R sequences were recognized. We identified the platform-margin stromatolite reefs in the Qigebrak Formation, and suggested two categories of carbonate platforms developed in this period, including the ramp in early stage and the rimmed shelf in the late stage. Evolution of the carbonate platform was controlled by the tectonic activities, which were possibly related to the Pan-African Orogeny.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-10: Dolomitization and dolomite reservoirs
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Difference of hydrothermal reformation mechanism between matrix limestone and dolomite: a case study of Middle Permian and Upper Sinian in central Sichuan

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Keywords: Hydrothermal reconstruction, Deep faults, Upper Sinian, Middle Permian, Geochemistry, central Sichuan Area

Difference of hydrothermal reformation mechanism between matrix limestone and dolomite: a case study of Middle Permian and Upper Sinian in central Sichuan

As an important reservoir forming mechanism of carbonate reservoirs, hydrothermal alteration is a focus in the field of reservoir geology. Since the 1980s, petrological and geochemical evidences of hydrothermal alteration have been found in carbonate reservoirs of many petroliferous superimposed basins such as Western Canada Basin, Michigan Basin, Sichuan Basin and Tarim Basin in North America and West China. However, most studies only focus on the alteration results of matrix limestone by hydrothermal fluid, and propose specific alteration modes such as hydrothermal dolomitization, dissolution, recrystallization and filling. In recent years, some scholars have realized that there is a evidence system similar to matrix limestone in matrix dolomite, and proposed constructive alteration modes such as dissolution, recrystallization and hydraulic fracturing. However, in matrix limestone and matrix dolomite, hydrothermal alteration has formed different rock fabric types, with different geochemical enrichment and different alteration modes. Therefore, it is necessary to analyze the factors leading to the significant difference of hydrothermal alteration in different matric rocks. There are abundant hydrothermal fluid activities in Upper Sinian dolostone and Middle Permian limestone in Central Sichuan Basin, which provide excellent research objects for analyzing the genesis, stages, alteration modes and reservoir formation effect of hydrothermal fluid in different host rocks under the same geological background.

Based on core observation, thin section identification, cathodoluminescence, fluid inclusions, C, O, Sr isotopes and REE analysis, combined with geophysical data, the differences of hydrothermal alteration in matrix limestones and matrix dolomites are discussed in terms of rock fabric, geochemical characteristics, alteration mode and action sequence. Three types of hydrothermal rock fabrics are developed in the Middle Permian matrix limestones in the Central Sichuan basin, namely fine-meso-crystal hemihedral dolomite (RD2), saddle dolomite (SD) and other hydrothermal minerals (quartz and fluorite). Fine-mesocrystalline hemihedral dolomite (RD2) is the recrystallization product of low-temperature origin dolomite (RD1), resulting in slight loss of $\delta^{18}O$, significant enrichment of Mn-Fe and 87Sr/86Sr, positive Eu anomaly, forming temperature 133 °C on average. Fluorite, quartz, and sellar dolomite (SD) are directly crystallized from hydrothermal solution. The average temperature decreased gradually (146 °C, 132 °C, 126 °C, respectively), and the alteration sequence showed hydrothermal dissolution, quartz-fluorite filling, hydrothermal dolomitization and recrystallization, saddle dolomite filling. The same three types of hydrothermal rock fabrics are formed in the upper Sinian matrix dolomite. The fine- to medium- crystalline dolomite (FD) is the product of hydrothermal recrystallization of matrix micritic dolomite, resulting in slight negative anomaly of $\delta^{18}O$, significant enrichment of Mn-Fe and $^{87}Sr/^{86}Sr$, and positive Eu anomaly. The modified sequence is characterized by saddle dolomite and quartz filling-hydrothermal recrystallization. Deep basement faults and small fracture triggered by Xingkai and Emei movement comprise hydrothermal fluid migration conducting system, and the Middle Permian only affected by the second phase of taphrogenic activities. This study suggests that chemical composition and hydrothermal temperature of matrix rock are main factors controlling the difference of fabric and alteration sequence.

Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-10: Dolomitization and dolomite reservoirs
Presentation Preference: Oral Preferred

Decoding dolomites with curved crystal faces

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Keywords: dolomite, saddle dolomite, curved crystal, zonation

Dolomite, $CaMg(CO_3)_2$, is a common rock-forming mineral. It can form as a primary precipitate, a diagenetic replacement of aragonite, calcite, an earlier dolomite phase, or a direct pore-filling hydrothermal phase in a wide range of sedimentological, diagenetic, hydrothermal and metamorphic environments. Among the many subtypes of dolomite, one of the most spectacular forms is the saddle-shaped dolomite (saddle dolomite, baroque dolomite etc.). Saddle dolomites are characterized by curved (warped) crystal faces, curved cleavage, and sweeping extinction under cross-polarized light. It is commonly assumed that saddle dolomites indicate precipitation in deeper burial diagenetic environments and related elevated fluid temperatures of at least several tens of degrees Celsius. To the present day, however, the mechanistic origin of the warped crystal surfaces is still under debate, and the link between this unusual morphological feature and environmental conditions (fluid chemistry, temperature, etc.) is unclear. We selected four natural saddle dolomites (F9, L1.2, VS10_1, VS 10_6) from the Triassic Latemar buildup in the Dolomite Mountains of northern Italy with different curvature levels as test materials for the present study. Firstly, the surface curvature of the saddle dolomite crystals in each sample was quantitatively determined and statistically analyzed depending on the high-resolution scanning images of corresponding thin sections. The results reveal that the curvature level of four samples can be ordered as F9 ≈ L1.2 VS10_1 VS 10_6. EPMA analyses show that the four saddle dolomites are composed of $CaCO_3$, $MgCO_3$ and $FeCO_3$, with minor $MnCO_3$. $CaCO_3$ is the main component, ranging from 49.8 to 55.2 mol%, and $MgCO_3$ ranges from 42.7 to 50.4 mol%. The composition of the least curved sample, F9, is closest to the ideal stoichiometry of dolomite (Ca:Mg = 1:1). As the curvature increases, calcium in saddle dolomite becomes increasingly excessive in VS10_1 and VS 10_6. Surprisingly, L1.2 is the sample with the highest Ca-excess, attributed to secondary processes. Interestingly, the $FeCO_3$ content is positively correlated with the curvature level of saddle dolomites, i.e., the average Fe content is 0.38, 0.35, 0.79 and 0.91 mol% in F9, L1.2, VS10_1 and VS 10_6, respectively. In addition, element distribution maps show that Ca is nearly homogeneously distributed in all four samples, while Mg distribution maps displays small-scale changes, indicating a slight zonation. By contrast, the distribution of Fe shows strong zonation in saddle dolomites, especially in VS10_1 and VS 10_6. Zonation generally results from several pulses of dolomitizing fluid. We speculate that the dolomitizing fluid and environmental conditions associated with Fe enrichment are key to the formation of saddle dolomite. Alternatively, iron in the structure may be directly related to saddle dolomite's warped morphology. In addition to the data discussed here, we are presently performing dolomite precipitation experiments, aiming to reproduce dolomites with curved crystal surfaces.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-10: Dolomitization and dolomite reservoirs
Presentation Preference: Oral Preferred

Diagenetic alteration of early-formed dolostones by fault-controlled hydrothermal convection of entrapped seawater: the middle Permian Qixia Formation in central Sichuan Basin, SW China

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Keywords: hydrothermal dolomitization, carbonate U-Pb geochronology, Emeishan Large Igneous Province, middle Permian, Sichuan Basin

This paper integrates petrography, carbon-, oxygen- and strontium-isotope geochemistry, and in-situ U-Pb geochronology on the middle Permian Qixia Formation dolostones in central Sichuan Basin, SW China, in order to get further insights into the conditions of their origin and diagenetic evolution. The Qixia formation dolostones in the study area, typically thin-bedded and alternating with limestones, consist of three dolomite phases, a replacive phase (Rd) and two void-filling phases, i.e., vug-filling coarse crystalline euhedral dolomites (Dc) and vug/fracture- filling saddle dolomites (SD). These dolomite phases show comparable carbon-, oxygen- and strontium- isotope compositions that could be easily interpreted to indicate similar diagenetic conditions, probably during a continuous dolomitization event. However, the obviously different U-Pb ages of these dolomite phases suggest that they were more likely precipitated in different episodes. The U-Pb ages of Rd and Dc, ~284 Ma to 272 Ma, roughly coinciding with the depositional age of Qixia Formation (284-273 Ma), imply a syn-depositional origin of these two phases, which, together with the stratabound occurrence of Rd and vug-filling Dc, and their affinity of carbon and strontium isotope compositions to those of the middle Permian seawater, suggest an reflux dolomitization event by penecontemporaneous seawater. In contrast, the saddle dolomite cements (SD) yield U-Pb ages ~10 Myrs younger than the Rd and Dc, which, in combination with the occurrence of SD in both dolostone and limestone intervals, indicate an alteration event of the early-formed replacive dolostones (Rd), probably by hydrothermal fluid flow. Furthermore, the precipitating timing of the vug/fracture-filling saddle dolomite cements is fairly close to the rifting phase associated with the Emeishan Large Igneous Province (ELIP) during the terminal middle Permian, which leads us to link the origin of these saddle dolomites to the influx of hot fluids along rift-related faults. Finally, a fault-controlled, hydrothermal alteration model of penecontemporaneous dolostones by ELIP-induced thermal convection of entrapped marine connate waters was proposed to elucidate the formation and evolution of these dolomites.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-10: Dolomitization and dolomite reservoirs
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Discovery the earthquake-related-proto-dolomite veins of Ediacaran Dengying Formation, in the North Sichuan basin

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Keywords: primary dolomite, bead, arrow or blunt-toothed pierced structure, liquefaction, 2nd-member of Dengying formation,Northern Sichuan

The soft sediments deformation caused by gravity imbalance, slide, slump, liquefaction and earthquake has always been one of the focuses geo-hazards in sedimentary geology. The definitive criteria for identifying the triggers of its deposits are still under construction. This paper reports a new discovery of a special kind of dolomite vein in the Upper Sinian Dengying Formation in northern Sichuan. This "bead-, arrow- or blunt-tooth-shaped" rhombic micrite dolomite vein, pierces into microbial dolomite with development of the radial-ring inner with grape and belts-likely outer structure, accompanied by the phenomena of convolution, pinch and swell, micro-folds and upward branching shear fractures, breccia, pseudo-nodules and water escape and sediment-injection structures in situ. It's laterally continuous and vertically repeated, separated from un-deformed or without extreme features layers. This dolomite vein, characterized by the relative high value of $\delta^{13}C$ or the turning period from rise to fall of sea-level, were identified as liquefaction and fluidization related to be seismic shocks in the weak extensional tectonic environment. The Neoproterozoic aragonite-dolomite seas with a viscous soft sediment at bottom, high Mg / Ca ratio and pH value promote the growth of microbial mats and formation of proto-dolomite. There are at least two to four episodes of seismic shocks in an approximate 5.5 Ma for the deposition period of 2nd-member of Dengying formation. Moderate to weak earthquakes, successively induce the liquefaction flow, heating of pore fluid and cooling of pore fluid during upward piercing which further result in the direct precipitation of primary dolomite due to the supersaturation. This study provided a new novel explanation to the origin of Neoproterozoic primary dolomite.

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Scientific Themes: Theme 7. Carbonate Sedimentation
Session T7-10: Dolomitization and dolomite reservoirs
Presentation Preference: Oral Preferred

Sedimentology and petrography of the limestones from a Neoarchaean dolomite-dominated platform: clues for understanding dolomitization in the Transvaal Supergroup, South Africa

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Keywords: Limestone, dolomitization, carbonates, carbonate diagenesis, Lime Acres Member, Transvaal Supergroup

The Neoarchaean Lime Acres Member of the Campbell Group in the Griqualand West sub-basin, Transvaal Supergroup, represents one of the oldest, well-preserved carbonate platform successions in the stratigraphic record. The Lime Acres Member is the most limestone-rich unit in a dolomite-dominated carbonate succession and holds important clues as to when and how dolomitization occurred. Previous studies have not indicated whether the unit has been dolomitized or never underwent dolomitization. The Lime Acres Member strata consist of various carbonate lithofacies (mostly well-preserved stromatolitic limestones) interbedded with carbonaceous shale and chert. The carbonate lithofacies include stratiform, domal and columnar stromatolite limestones, massive micritic, laminated and fenestral limestones and, intraclast limestone breccia. Detailed study of the morphology and microstructures of these carbonate lithofacies and their relationship with surrounding sedimentary rocks are employed to reconstruct the depositional environments and deduce the diagenetic history of the Lime Acres Member carbonates.

Sedimentological and petrographic examination revealed a cyclic sedimentation shallowing-upward pattern, which reflects variations of the sea level during the deposition. The Lime Acres Member was likely deposited in a transgressive shallow marine environment. The presence of wavy and flaser lamination provides evidence for bi-directional currents. Pore-filling, vein-fills, fenestrae and stylolites provide evidence for early diagenetic processes. Organic matter locally occurs along the cortices of allochems and laminations.

Despite being a limestone-rich unit, dolomite is present but rare. SEM-EDS analysis using a Tescan-integrated-mineral-analyser (TIMA) documents that dolomite is restricted to stratiform and cross-cutting veins. The frequent occurrence of angular clast of the host rock (limestone) within the dolomite veins indicates that the veins were generated by hydraulic fracturing. Elemental and mineral phase maps show that most limestone layers consist of> 95% calcite, implying that the Lime Acres Member is devoid of significant dolomitisation.

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Theme8

Modern Sedimentary Process

Session T8-1: Surface dynamic and stratigraphic development of fluvio-deltaic systems: Autogenesis and allogenesis

ID: T8-10021

Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-1: Surface dynamic and stratigraphic development of fluvio-deltaic systems: Autogenesis and allogenesis
Presentation Preference: Oral Preferred

Contribution of the allogenic sediments to the source-to-sink system in the sequence of rifting, insight from the case study in Qiongdongnan Basin

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Keywords: Breakup sequence, Source-to-sink system, Rfting stages,Detrital zircon U-Pb,

Continental margin rifting basins underwent a crust lithofacies breakup period and formed a distinct source-to-sink system. Mass sediments deposited in the proximal margin area have been accepted in many case studies worldwide. Unlike traditional continental margin rifting basins, the mass of allogenic sediments is migrated in the drainage basin in the North continental margin in the South China Sea (SCS) and rebuilt its stacking pattern. To clarify the allogenic sediments' contribution, we selected the Qiongdongnan Basin (QDNB) in the north margin of SCS to explore the various growth patterns during the breakup sequence. According to the 3D seismic profiles interpretation and core samples description, we recognized the sediments' stack pattern. Then, with the U-Pb age data and the heavy mineral assemblage, we identified allogenic sediments' provenance and recovered the source-to-sink system in QDNB. The results show that, during the Eocene to the early Oligocene, autogenic sediments are dominated at the sync-rifting stage, while during the transitional stage, allogenic from central Vietnam migrated to the eastern of the drainage basin and then to the post rifting stage during Miocene, it wholly mixed with the autogenic sediments from the proximal area. According to the calculated subsidence rate and their topography variety, we rebuilt the source-to-sink system accompanying the rifting process and divided them into three types: narrow-deep, wide-shallow, and wide-deep. The steep slope in the western W-QDNB, its prograding deltas are observed as more coarse-grained accumulated in the upper slope and the proximal outer continental margin area. The eastern W-QDNB mainly developed fine-grained sediments along the gentle slope. Combining the sedimentary process numerical simulation results, we get that the allogenic sediment injection makes the high-angle graben pattern make more sediments migrate from the proximal outer continental margin area to a distal area. With the statistical method, we highlight the vital role of local forcing factors in controlling the sediment distribution during the rifting stage. During the sync-rifting and transitional stages, we found that the terrane height in high-angle slope areas controlled by the accommodation space provided by the fault's displacements or the terrain height, and the allogenic sediments' injection would decline the terrane height's controlling factor to the source-to-sink system volume. As to the post-rifting stage, sediments supply shows high relevancy to the depositional volume, and accommodation space is the less one, while the injection of the allogenic sediments enhances the controlling factors of sediments supply.

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Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-1: Surface dynamic and stratigraphic development of fluvio-deltaic systems: Autogenesis and allogenesis
Presentation Preference: Oral Preferred

Stabilization and destabilization of downstream alluvial channels in a non-deltaic transgressive system: A tank experiment

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Keywords: alluvial channel, autostratigraphy, length scale, non-deltaic, sea level rise, transgression

The autostratigraphy theory tells that the downstream alluvial plain with an area (A) exceedig a critical value (A_{crt}) can no longer maintain deltaic sedimentation during relative sea level rise, but is forced to retreat as a non-deltaic transgressive system where the A reduces asymptotically toward A_{crt}. The morphodynamics of alluvial channels evolving in such a system are investigated through a series of tank experiments, bringing the following notions. At early times of the transgression ($A >> A_{crt}$), the alluvial channels tend to be stabilized, but their mouth lobes tend to backstep in a linear trend. As the alluvial plain continues to contract ($A \rightarrow A_{crt}$), the channels' lateral mobility synchronously increases along with intensified lateral shifting of the mouth lobes, in correspondence with continuous increase in aggradation rate. Eventually the alluvial plain area reaches the critical value ($A \sim A_{crt}$). Given a hinterland slope being smaller than an imaginary foreset slope that locally the system might prograde with, the alluvial plain area no longer reduces, while the non-deltaic transgression is retained. During this particular A_{crt} stage, the alluvial channels are fully destabilized with incessant lateral migration and/or frequent avulsion to build autosteps. These experimental observations support the validity and significance of autostratigraphic scales of length (Λ_{3D}) and area ($\Lambda_{3D}^2 = A_{crt}$) as a fundamental control on the spatial growth of deltaic and non-deltaic systems under relative sea level rise. Stabilization and subsequent destabilization of alluvial channels recognized in a stratigraphic succession can thus be autogenic in some part, particularly when the alluvial plain progressively contracted toward A_{crt}. With an anticipated rate of anthropogenic sea level rise for next centuries, most of the existing alluvial-deltaic systems on marine coasts will have been in a state of over-expansion ($A >> A_{crt}$). These systems will inevitably become non-deltaic transgressive systems evolving in a way from a channel-stabilized stage to a channel-destabilized one.

Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-1: Surface dynamic and stratigraphic development of fluvio-deltaic systems: Autogenesis and allogenesis
Presentation Preference: Oral Preferred

Sedimentary model and controlling factors of Yuanzigou alluvial fan in Daihai Lake, Inner Mongolia

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Keywords: Alluvial fan ,Formation process, Fluid type, Influencing factors ,Sedimentary model

Alluvial fan depositional systems are widely developed across the country, especially in the margins and interiors of major continental hydrocarbon-bearing sedimentary basins in my country. They are characterized by large scale, diverse systems, and well-configured source-reservoir-caprocks, and contain huge exploration potential. Therefore, in this study, the 300-m alluvial fan section exposed in Yuanzigou, Daihai Lake, Inner Mongolia, was used as an example to describe the field outcrop section and the exploration trench. According to the grain size and arrangement of the site, 7 lithofacies and 6 vertical assemblages are divided; the fluid types deposited in the Yuanzigou alluvial fan are divided into three types - clastic flow, torrent, and tractive flow. The main control fluid types of the stages are different, and the sedimentary evolution process is divided into three stages, which have a good corresponding relationship with the changes of the Daihai Lake climate. At the same time, AMS14C dating was used to identify the sedimentary interface, and the denudation of sediments and the difference in provenance supply caused by changes in slope, precipitation and temperature were analyzed. The sedimentary modes are: slope-driven detrital flow type, precipitation-slope co-driven torrent type, high temperature and high precipitation-driven tractive flow type

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Session T8-1: Surface dynamic and stratigraphic development of fluvio-deltaic systems: Autogenesis and allogenesis
Presentation Preference: Oral Preferred

Sea-level changes and strait topography control the distribution and facies development of the Changjiang coastal mud wedge

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Keywords: Changjiang coastal mud wedge, Min-Zhe Mud Belt, coastal mud, shallow-marine mud, Taiwan Strait, East China Sea

The coastal mud wedge is one of the most important settings where shallow-marine muddy deposits accumulate. However, until recently, there are very few detailed sedimentological studies on it. To investigate the sedimentary processes of one of the largest coastal mud wedges, the Changjiang Coastal Mud Wedge (CCMW), we used chirp shallow seismic stratigraphy and carbon dating of a sediment core from the northern end of Taiwan Strait to provide a regional stratigraphic framework. Sedimentological observations and organic geochemical analysis of the sediment core, combined with detailed comparison with the eustatic sea-level curve, permit estimation of the changing paleowater depths and sedimentary processes responsible for the coastal mud wedge. The clay mineralogy and U–Pb detrital zircon geochronology were analyzed to illustrate the provenance evolution.

Three regional unconformities were identified that probably correspond to the last three glacial maxima, MIS 2, MIS 6 and MIS 8. The MIS 6 and MIS 8 unconformities display pronounced incised valleys that were likely carved by the Minjiang River. The strata between the MIS 2 and MIS 6 unconformities (seismic unit 2) have 14C ages that indicate that the valley filling occurred during the long-term sea-level fall of MIS 3. The lower part of this valley fill is composed of bay-head delta plain to delta-front deposits, from base up. A provenance study of the lower fill reveals the predominance of the Minjiang sediments, with some Changjiang sediments, which confirms a deposit that accumulated in the Minjiang estuary, with some southward transport of Changjiang mud by the Zhe-Min Coastal Current. The middle valley fill contains shallow-marine mud that comprises significant amounts of Changjiang sediments. While the shoreline lay seaward of the core site (i.e., during initial filling of the valley), the main sediment supply was by the Minjiang, but after the shoreline moved landward of the core location (middle valley fill), the Minjiang contribution decreased (presumably because it was trapped in the contemporaneous estuary), and the contribution from the distant Changjiang became important/dominant. During the transgression of the shoreline, the Minjiang estuary was inundated and became a partially filled incised valley. The clay mineralogy of the upper valley fill (coastal mud) reveals the predominance of the Changjiang sediment, which suggests that the remainder of the valley was filled by the CCMW. This is also for the first time that the existence of the CCMW during MIS 3 is reported.

Integrated water-depth estimates, provenance and core observations reveal the presence of distinct shallow-water and deep-water facies within the CCMW. The shallow-water (<20 m water depth) facies contains fluid-mud layers, highlighting the role of waves and tides in resuspending previously deposited muds. The deep-water facies consist of muds that were influenced by ocean currents and are more intensely bioturbated and local rich in shells. The succession here is dominated by muddy deposits that initially look "simple", but upon closer examination have a very complex sediment provenance, and with many unconformities, due to sea-level fluctuations during MIS 3, in what might initially look like a continuous sedimentary succession.

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Shoreline autoretreat in salt-bearing basins: Insights from numerical modelling

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Keywords: shoreline autoretreat, salt tectonic, sea-level, numerical modelling, sedimentology

Shoreline autoretreat is an autogenic nonequilibrium response of deltaic systems to constant sea-level rise. The theory of this phenomenon has largely guided our understanding of the evolution of deltaic clinoforms. Until now, the shoreline autoretreat is only modelled in tectonic-quiescent settings where the basin has constant slopes. Here we extend the model to salt-bearing basins to investigate how the moving of underlying salt exerted by overlying sediment affects this process. We use finite element modelling to investigate three sediment filling and sea-level rise scenarios. In these 3 models, the sedimentary wedges have the same depositional slopes including the hinterland slope, the topset surface slope and the foreset slope. In Model 1, both rates of sediment supply and relative sea-level rise were constant. Model 2 had the same sea-level rate as Model 1 with a higher sediment supply. In Model 3, we forced an increasing rate of sea-level rise and the sediment supply kept up with the rise. In all of these models, the gravity force exerted by the overlying sediment drives the depositional wedge to extend seaward. The topset of these models inevitably modified the process of shoreline autoretreat compared to cases without the viscous salt. In Model 1, the shoreline cyclically changed its phase from progression to regression, indicating a periodic autoretreat. In Model 2, as the sediment supply increased, the length of the topset strata also increased and the shoreline continuously moved seaward without retreat. In Model 3, the sea-level rose with increasing sediment supply, which resulted in the chaotic lateral seaward movement of the shoreline and no obvious autoretreat processes occurred. Our study suggests that shoreline autoretreat is ineffective in salt-bearing basins due to the viscous salt layer which accelerates the progradation of sediments, elongates the delta topset, and slows down the height of relative sea-level rise.

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Influence of laumonite cements in Shaximiao Formation of Middle Jurassic on reservoir development in central Sichuan Basin

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Keywords: Laumonite, Shaximiao Formation, Central Sichuan Basin, Pore type, Reservoir development

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Laumonite cement is a typical authigenic mineral in sandstone reservoirs, but its influence on sandstone reservoirs remains controversial. Shaximiao Formation of Middle Jurassic in Central Sichuan Basin is one of the hot strata for tight oil and gas exploration and development in China (Yang Yueming et al., 2016), and the secondary dissolved pores of laumontite have been considered to be the most important reservoir space type (Lu Wenzhong et al., 2004; Yang Xiaoping et al., 2005). In this paper, the middle Jurassic Shaximiao Formation in central Sichuan Basin is taken as the research area, and the research is carried out systematically from four aspects : reservoir pore types, occurrence state of laumontite, formation time of laumontite, and relationship between laumontite and reservoir evolution. The results show that the pore types are mainly primary intergranular pores, and few secondary dissolved pores in laumontite. Laumontite cements often exist in sandstone reservoirs in two forms: one is filled in intergranular pores in the form of continuous crystals, and the other is star-like or spot-like when the content of laumontite is relatively low, which exists in the form of metasomatic plagioclase and is often distributed along the cleavage fracture or bicrystal grain of plagioclase. Laumontite is often developed outside the secondary enlargement edge of quartz, and chlorite film is developed outside the quartz particles. It is judged that the formation time of laumontite is later than that of authigenic quartz and authigenic chlorite. Laumontite has no direct relationship with early-stage crystalline calcite, but associated with late-stage crystalline calcite. The content of laumontite has a negative correlation with the porosity. The higher the content of laumontite is, the lower the porosity is, indicating that laumontite hinders the development of pores to a certain extent and has a certain destructive effect on reservoir porosity. The whole Shaximiao Formation is buried shallowly (about 2600 meters). It is estimated that the formation temperature of laumontite should be higher than 80 °C. The laumontite may be the product of A-B stage in the middle diagenetic stage. Under the microscope, plagioclase dissolution and metasomatism are found, and a large amount of Ca^{2+}, Na^{+}, K^{+} can be precipitated. The plagioclase dissolution and metasomatism residual is mainly albite. Due to the special molecular structure of zeolite, ions with positive charge (such as Na^{+}, Ca^{2+} and other alkali metals or alkaline earth metal ions) are needed to neutralize in the formation process. The middle diagenetic stage A is alkaline pore water environment, and abundant plagioclase in stratum is more favorable for the formation of laumontite, so it is speculated that the formation of laumontite is mainly caused by albitization of plagioclase. The diagenesis intensity of Shaximiao Formation sandstone is weak, so the primary intergranular pore is the main pore type in the reservoir, not the secondary dissolved pore of laumontite. To sum up, the emergence of zeolite in a certain extent will bring destructive effects on reservoir development.

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Scientific Themes: Theme 8. Modern Sedimentary Process
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Characteristics and Main Controlling Factors of the Paleogene Sedimentary Sequence in Maxian District, Qaidam Basin

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Keywords: sedimentary sequence,tectonic subsidence,the Paleogene,Maxian district,Qaidam Basin

The Maxian district is located in front of the Qilian Mountains thrust belt in the northern margin of the Qaidam Basin. Through core description, logging and seismic data, we identified the sequence interface of the Paleogene in the Maxian district, and definituded the sedimentary filling pattern by combining with seismic facies. The results showed that two first-order, one second-order and one third-order sequence interface were developed in the Paleogene of the Maxian district, and alluvial fan braided river delta sedimentary system was formed. Controlled by the Xiannan fault and the Mabei fault, barrier island was generated in the Paleogene of the Maxian district. Under the tectonic framework, the sedimentary filling pattern of a strike-slip pull-apart basin was developed, with the characteristics of north-south zoning and east-west block. Factors controlling the sedimentary sequence of the Paleogene in the Maxian district include tectonic subsidence, supply of sediments and lake level fluctuation. Firstly, in evolution of the sequence of the Paleogene, the Indian plate subducted and collided with the Eurasian plates. Meanwhile, the Qilian Mountains, situated in the northeast of the Maxian district, uplifted rapidly at a rate of 60m/Ma to 100m/Ma. The uplift of the Qilian Mountains provided clastic matter for the Maxian district situated in the expot of provenance system named Yuqia. In addition, the uplift of the Qilian Mountains contributed to quick subsidence of the piedmont depression belt. The subsidence rate surpassed 300m/Ma in the late Paleogene, which was more than twice of the early Paleogene. Because the subsidence rate of the basin exceeded the falling rate of lake level, the lake level rised continuously. The rasing lake level and provenance system collectively worked together to control the formation of progressive and regressive sequence of the basin. Finally, as a result of oblique strike-slip pull-apart accompanying the uplift of the Qilian Mountains, main boundary faults in the Maxian district were generated. These boundary faults together with Xiannan fault in south and Xianbei fault in north of the Maxian district constituted tectonic framework of barrier island, and controlled the sedimentary filling pattern.

Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-1: Surface dynamic and stratigraphic development of fluvio-deltaic systems: Autogenesis and allogenesis
Presentation Preference: Oral Preferred

Anatomy of a third-order transgressive–regressive sequence along the western coast of the late Pennsylvanian North China epeiric sea: Linking hydrodynamics to architectural development

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Keywords: Third-order transgressive–regressive sequence, architectural development, late Pennsylvanian, epeiric sea, shoreline morpho-hydrodynamic evolution

The Ximing Sandstone–to–No. 8 Coal succession of the Taiyuan Formation in the Linxing gas field records complex internal architecture of a transgressive–regressive sequence (i.e. T–R Sequence S8) developed along the western coast of North China epeiric sea during the late Pennsylvanian nonglacial period of the Late Paleozoic Ice Age (Liu et al., 2020). Based on facies analysis, sequence stratigraphic analysis, and hierarchical architectural classification (Vakarelov & Ainsworth, 2013) of seismic, outcrop, core, and well log data, T–R Sequence S8 was first subdivided into transgressive and regressive element complex assemblage sets (TECAS8, RECAS8) by a maximum flooding surface (MFS8) that is embedded within a carbonate- and/or shale-rich condensed section and up-dip within a coal seam, and is locally truncated and replaced by a regressive surface of marine erosion (RSME6). Within the framework of TECAS8, RECAS8 and their bounding surfaces, fourteen types of element complexes (EC) associated with hydrodynamic process dominance (Ainsworth et al., 2011; Rossi et al., 2017) were differentiated on individual cored and/or wireline-logged wells, which quantitatively or qualitatively characterizes the relative influences of wave, tide and fluvial processes on the development of channel, onshore, mouth bar, tidal flat, funnel basin, transgressive lagoon, transgressive lag, barrier, offshore transition, beach, and lagoon element complexes. These element complexes were grouped into five distinct element complex sets (ECS) and four element complex assemblages (ECA) on interwell-scale or field-wide, core and well log-based cross-sections, reflecting a progressive change from a tide-dominated, wave-influenced and fluvial-affected (Twf) incised-valley estuary–barrier system (ECA-A) through a Twf-transgressive coastal plain–lagoon–barrier system (ECA-B) to a wave-dominated, tide-influenced and fluvial-affected (Wtf) transgressive coastal plain–tidal shoreface–inner shelf system (ECA-C), and finally to a Wtf-regressive coastal plain–lagoon–beach system (ECA-D). The high-amplitude third-order sea-level change coupled with the high-gradient coastal profile (i.e. coastal gradient > gradient of shoreline trajectory; Catuneanu & Zecchin, 2016) is the dominant control on the stratal stacking patterns. The channel migration, peat compaction, shoreline auto-advance (Guerit et al., 2021) and auto-retreat, and bedrock inheritance modified the depositional response to third-order relative sea-level change through time. This study contributes to a better understanding and prediction of near-provenance epeiric shoreline morpho-hydrodynamic evolution in response to third-order relative sea-level change (Yoshida et al., 2007).

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Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-1: Surface dynamic and stratigraphic development of fluvio-deltaic systems: Autogenesis and allogenesis
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Analysis of Sedimentary Microfacies of the thick sandstone on the Oligocene Huagang Formation in the Central Part of the Xihu SagEast Sea BasinChina

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Keywords: braided delta, sedimentary microfacies, the upper of Huagang Formation, huge thick sand bodies, Xihu Sag, East China Sea basin

The upper member of Huagang Formation in the Central Reversal belt's central aera of the Xihu sag in the East China Sea basin developed thick clastic sand bodies, the theory that it formed in rivers, foreshores, deltas, river-delta superposition, etc. is constantly updated, there still exists great dispute over its sedimentary microfacies and origin. The research comprehensively used the cores and logging data of the three wells in the study area, as well as a series of laboratory analysis, and with the three-dimensional seismic profiles formed by the three wells, studied the core facies markers and logging facies characteristics of the upper Huagang Formation, especially the 3rd member of the Huagang Formation in the three wells. The core facies, single-well facies and profile facies of three wells are established, at the same time, the research results of regional sedimentary evolution and sedimentary environment characteristics are combined to analyze the microfacies types, sedimentary environment and facies distribution of the sandstone in the upper member of the Huagang Formation in the study area. The results show that the upper member of the Huagang Formation in the study area mainly develops the braided river delta-front subfacies, the 3rd member of Huagang Formation mainly develops the braided river delta-front underwater distributary channels microfacies, while the 2nd and 1st member of Huagang Formation develop the braided river delta front underwater distributary channels and interdistributary microfacies, and their interdistributary microfacies relatively more developed. It's not developmental of facies markers indicating marine facies and transgression in the upper member of the Huagang Formation. Vertically, multi-stage underwater distributary channel sand bodies superimpose and featuring large thickness, the lower part of the upper member of the Huagang Formation has more developed sand bodies and appears "sand-covered mud", while the upper sand layer is relatively thin, showing "mud-covered sand", sandstone has great horizontal extension. Laterally, the underwater distributary channels are characterized by tree-like bifurcation and continuous distribution from northeast to southwest, with its provenance in the northeast. It is believed that a lacustrine-delta sedimentary system of continental setting exists in the study area and is typical traction current deposits without any transgression sequence, but there are thin interlayers of sandy debris flow locally, and the whole is caused by the deposition of high-energy flowing water.

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Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-1: Surface dynamic and stratigraphic development of fluvio-deltaic systems: Autogenesis and allogenesis
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Sedimentary filling evolution controlled by basin-mountain coupling: A case study of the Xujiahe Formation in the Northeast Sichuan Basin

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Keywords: Braided delta, provenance direction, sedimentary microfacies, basin-mountain coupling, Xujiahe Formation

It is of great significance to clarify provenance direction for sedimentary filling evolution in the study area. The lithology and rock composition of the Xujiahe Formation in the northeast sichuan basin differ significantly in different depositional periods. The provenance of the xujiahe Formation in different depositional periods is determined by heavy mineral analysis, stratigraphic thickness variation and rock mineral genesis analysis. Braided delta deposits are mainly developed in the study area , the sedimentary facies and lithofacies characteristics of Xujiahe Formation in northeast Sichuan basin are studied based on logging, core, outcrop and geological data. For sedimentary analysis, core and outcrop observation is the most direct and effective method, and the response relationship between logging and lithology can help us predict sedimentary facies. In addition, the introduction of the outcrop improves the forecasting accuracy and continuity, this study analyzes the multiphase superimposed sedimentary sand body and identify which due to factors such as water effect strength formed by various sedimentary structure, sedimentary sequence structure characteristic is the main research area. These results provide evidence for the development of multiphase channel deposits in the study area under the influence of provenance changes and tectonic evolution. A new method of comprehensively analyzing sedimentary filling evolution from outcrop - core - logging data is established. In addition, the intervention of the above methods provides a feasible method combining logging and core for the identification of sedimentary microfacies in Xujiahe Formation, the establishment and restoration of upstream sedimentary model and the verification of basin-mountain coupling mechanism of delta sedimentary facies. The results showed that under the influence of activity surrounding orogenic belts, the source can be divided into three directions, respectively from the Longmen mountains, MiCangShan and Dabashan mountain, but in different sedimentary period, the direction of provenance and significant differences source input, in addition content source input material and can let a space rate of change was the key to analysis of sedimentary evolution. Based on the above analysis results, the sedimentary facies response characteristics and logging curves of the study area are established, and the sedimentary filling processes in different sedimentary periods under the control of tectonism are recovered. The results show that the sedimentary filling evolution is controlled by the coupling of the basin tectonic evolution and the activity of the surrounding orogenic belt, and they interact to form the palaeogeomorphic pattern.

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Session T8-1: Surface dynamic and stratigraphic development of fluvio-deltaic systems: Autogenesis and allogenesis
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Depositional architecture and process of lacustrine delta-sublacustrine controlled by high-resolution sequence stratigraphic frameworkA case study of the second Member of Dongying formation in the Nanpu sag of the Bohai Bay Basin, eastern China

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Keywords: Faulted lacustrine basin, delta, sublacustrine fan, sandy debris, turbidite

The deltas and sublacustrine fans in continental faulted basins are the key targets of oil and gas exploration and have good oil and gas prospects, but their sedimentary patterns and distribution characteristics are complicated, posing challenges to oil and gas exploration and development. In this paper, the delta-sublacustrine fan depositional model and its main controlling factors are studied in combination with 3D seismic data, core data and well logging data of the second member of the Dongying Formation in No.4 structure in the Nanpu sag. Based on high-precision seismic interpretation and single-well logging response feature interpretation, it was identified that the depositional period of the second member of the East was divided into 1 third-order sequence, 3 system tracts, and 9 fourth-order sequences. Consequently, the depositional characteristics and depositional model of a delta-sublacustrine fan of fourth-order sequence are investigated and established based on core observation, seismic reflection and well log response. Results show that during the sedimentary period of the second Member of the Dongying Formation, the tectonic activity was weakened, the paleogeomorphology, lake level fluctuation and paleoclimate became the main controlling factors of the delta-sublacustrine fan sedimentary model.Meanwhile, the paleogeomorphology mainly controlled the provenance direction of the second Member of the Dongying Formation and formed four channels that provided favorable migration channels for the development of the delta.Furthermore, the delta-sublacustrine fan depositional scale and sedimentary model was controlled by lake level fluctuation and climate change. The study also shows that there was a dry-wet climate transition during the depositional period of the second member of the Dongying Formation. Firstly, during the period of the highstand tract system, the climate was dry, the lake level dropped rapidly, the provenance supply was sufficient, and a large number of terrigenous detritus entered the lake basin.In this period, the delta was mainly prograded along the provenance direction, and the distributary channel was dendritic with weak bifurcation ability. While the sublacustrine fan has higher sand content and stronger erosion energy, and the sedimentary type is mainly channel-fill sandy debrites and sand-rich lobe deposits. Secondly, during the deposition period of the lowstand region, the climate was humid, the lake level rise slowly, the sediment supply gradually decreased, the flow increased, the terrigenous detritus changed from coarse sandstone to fine sandstone, and the deltaic channel bifurcation ability increased, forming a network distributary channel system. Meanwhile, the sublacustrine fan has stronger erosion ability and higher mud content. Therefore, the main depositional elements are channel-fill turbidites and mud-rich lobe deposits. Thirdly, during the period of the transgressive tract system, the lake level rise rapidly, and although the climate was humid, the provenance supply was further increased. Under such circumstance, the network distributary channels were the main depositional element of the delta, and it was difficult to form large-scale sublacustrine fan deposits at the far end of the delta. In general, the established delta-sublacustrine fan depositional model in this study will help provide guidance for oil and gas exploration and development.

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Characteristics and Influence of coarse particle Sedimentation in terrestrial facies Source-Sink System3D tank experiments

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Keywords: coarse particle,3D tank experiments, sedimentary process

Coarse particles refer to particles that are not easily transported after being deposited under the action of external forces such as hydrodynamics due to their own conditions such as volume and gravity. In the simulation experiments, we found that in the study of a complete terrestrial facies source-sink system (including sedimentary facies such as alluvial fans, rivers, deltas, etc.), the distribution position and stacking style of coarse particles affected the sedimentary process and sand bodies of the sedimentary facies belt. form, which in turn affects the entire associated source-sink system.

In alluvial fans, the location of coarse particle is mainly affected by tectonic movements and topographic conditions. Affected by faults, particle transport is hindered. At this time, coarse particles often accumulate near faults to form water-dividing shoals, and reverse sand-gravel bars with coarse particles are developed near bulges or folds.

In fluvial fan, the development location of coarse particle is mainly affected by factors such as river type, hydrodynamic conditions and migration frequency. During the development of a single channel, the coarse particles were mainly concentrated on the head of the tongue-shaped sand dunes and the edge of the channel, and a small amount appeared in natural dikes carried by floods. The coarse particle of braided river are mainly concentrated near the distributary shoal of the central bank. The reduction of the flow velocity caused by the division of the river promotes the unloading of the coarse particle here. The increment of coarse particles is positively correlated with the longitudinal extension of the shoal. Coarse particles in meandering rivers are mainly concentrated on the convex bank, while stable meandering rivers will unload a small amount of coarse particles at the edge of the channel.

In the delta, the development location of coarse particles is mainly affected by factors such as channel hydrodynamics, topographical conditions, and wave action near the lake shoreline. During the flood period, a large number of coarse particles were transported by the surface of the sand body.

Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-1: Surface dynamic and stratigraphic development of fluvio-deltaic systems: Autogenesis and allogenesis
Presentation Preference: Oral Preferred

Remote sensing analysis methods and application of modern source-to-sink systems

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Keywords: source-to-sink system, modern sediment, coarse-grained fan, northwest Junggar basin

The study of source-to-sink systems is an important topic of great concern in the field of earth science in the world today. The division of source-to-sink system units are the basis for the quantitative research, and fine anatomy of source-to-sink systems; however, reports of the division of source-to-sink systems, and their characteristic analysis at home and abroad is relatively rare. Preferably, it is more focused on the coupling of source-to-sink systems, the prediction of sedimentary pattern scales, and the analysis of its control factors. In this paper, a quantitative remote sensing analysis method of modern sedimentary source-to-sink system based on DEM (Digital Elevation Model) is proposed. The remote sensing, digital elevation information and spectral information are fully used to introduce remote sensing terrain analysis technology into the field of modern sedimentology, which is used to divide the spatial distribution of source-to-sink system elements and quantify the element characteristics of source-to-sink system. The modern coarse-grained alluvial fan at the northwest edge of Junggar basin was selected to carry out an example dissection. The boundary of the source area of the Liushugou fan, the sediment transport channel, and the sediment aggregation area of the Liushugou waterway was accurately divided. In addition, the lithogic geomorphological parameters of the channel area and the morphological parameters of the channel area, and the sediment distribution parameters of the sink area were quantitatively depicted. The remote sensing analysis technology of modern source-to-sink system effectively makes up for the defect that other source-to-sink analysis methods cannot quantitatively extract sedimentary elements, and expands the traditional source-to-sink sedimentation analysis method from qualitative to quantitative, making it a new technical means for the analysis of modern sedimentary source-to-sink system, which has important reference value for the quantitative research and fine anatomy of source-to-sink system, and provides a basis for the analysis of the sedimentation process of source-to-sink system.

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Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-1: Surface dynamic and stratigraphic development of fluvio-deltaic systems: Autogenesis and allogenesis
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Fossilized Autogenic Responses of Grain-Size Transition to Sediment Supply and Water Discharge: Alluvial Fan Experiments

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Keywords: Autogenic process, grain-size transition, upstream boundary condition

Autogenic processes can produce large-scale, organized stratigraphic signatures that manifest morphodynamic changes associated with upstream boundary conditions. However, the connection between upstream boundary conditions and their depositional patterns built by autogenic processes has not been thoroughly investigated. Here, the combination of theory, experiment, and field application explores the possibilities of short-term autogenic change of lithofacies as a stratigraphic indicator of upstream boundary conditions. A series of six experiments was conducted to test the effects of sediment supply and water discharge rates on autogenic advance and retreat of the lithofacies boundary (grain-size transition) in a bimodal alluvial fan. For each experiment, time-lapse images and laser topographic scans of the fan surface and sliced cross sections of the final deposits in radial coordinates were collected to quantify characteristic timescales of the autogenic processes. The timescales captured in the time-series data for fan-margin migration and surface wet-fraction change, and the grain-size transition (GST) trajectory shown in the final deposit as a zigzag pattern generally shorten as sediment supply rate increases and water discharge rate decreases. Increasing the sediment supply accelerates the filling of the fluvial sediment buffer and takes a short duration of the fluvial sediment storage and release cycle—producing high frequency and high magnitude of zigzagness in the GST trajectory. Increasing the water discharge tends to widen channels and takes a long duration of the fluvial sediment storage and release cycle—constructing low frequency and low magnitude of zigzagness in the GST trajectory. Furthermore, the relationship between upstream boundary conditions and the patterns of GST trajectory prove the possibility of autogenic stratigraphic signals as a tool to infer the boundary conditions.

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Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-1: Surface dynamic and stratigraphic development of fluvio-deltaic systems: Autogenesis and allogenesis
Presentation Preference: Oral Preferred

The intrinsic curvature of non-deltaic transgressive shelf profiles: The autostratigraphic rationale

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Keywords: Autostratigraphy, non-deltaic transgression, physical and numerical simulation, shelf profile

The shelf, a key element of the source-to-sink sediment routing system, exhibits generally a landward steepening profile. Existing models ascribe this curvature to reduced impact of sea level rise (i.e. increase in sediment supply and/or deceleration of sea level rise), or redistribution of sediment by marine processes to build an equilibrium shelf surface. Here we present a totally different rationale derived from the autostratigraphy theory, which suggests that during constant rise of relative sea level, (1) the downstream alluvial river has the limit in length beyond which it cannot sustain deltaic sedimentation, and (2) the "over-extended" river inevitably shrinks in a non-deltaic transgressive regime whereby the local shelf surface immediately basinward of the shoreline steepens landward. With this background, our two-dimensional geometrical modeling leads to the finding of a simple governing equation that can be described with normalized alluvial length and alluvial slope, and can account for the intrinsic curvature of the shelf profile. The validity of this model and related notions is supported by flume experiments and applications to modern systems, providing a baseline for understanding the origin of the curvature of natural transgressive shelf profiles.

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Session T8-1: Surface dynamic and stratigraphic development of fluvio-deltaic systems: Autogenesis and allogenesis
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

The Depositional Filling Pattern of the Progradation Sequence and Exploration Significance : A Case Study of Chang 6 Member of Triassic Yanchang Formation, Ordos Basin

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Keywords: sequence stratigraphy,the sedimentary model of progradation complex of shallow braided delta,secondary distribution,high-quality reservoirs

Yanchang Formation is rich in oil resources in Ordos Basin. In recent years, with the popularization of 3D seismic, many progradation complex reflections can be seen in the seismic profile of the middle and lower members of Yanchang formation. Compared with the traditional lithologic strata, seismic strata has obvious layer crossing phenomenon. In order to explain the phenomenon and improve the exploration benefit, the paper studies Chang 6 progradation complex based on the principle of sequence stratigraphy and establishs corresponding filling pattern and clarifies the law of oil enrichment.Through logging-seismic comparison, three sets of "sand-mud combination" marker layers in the progradation complex are established for the very first time, and a reliable sequence-stratigraphic division and comparison framework is established. In this paper, the sedimentary model of progradation complex of shallow braided delta is established (which is different from the blanket type and the Gilbert type). This paper believes that there is a secondary distribution of sedimentary bodies and sedimentary facies. The sedimentary genetic types of progradation complex sand body are mainly multi-stage mouth bar, single-stage mouth bar, river bar superposition, short distance slumping, distal sand bar and turbidite fan. There are two combinations of plane facies belt distribution: one is multi-stage mouth bar - single-stage mouth bar - river + mouth bar - slumping body; The other is multi-stage mouth bar - single-stage mouth bar - river + mouth bar. The reservoir is evaluated according to the porosity, permeability, oil-water content and oil test results of logging interpretation. The result is that the river-bar combination reservoir in Chang 6 is the best, followed by the mouth bar and semi-deep lake slumping reservoir, however, turbidite fan and short-distance slumping reservoirs are average. Relatively high-quality reservoirs (river-bar superimposed type) developed at the top of Chang 6_3^1, Chang 6_2^1, and Chang 6_1^1, and gradually migrated eastward with the progradation complex.This study provides a new idea for the study of sequence stratigraphy of the Triassic Yanchang Formation in Ordos Basin, meanwhile, provides a typical example for re-characterizing the distribution of sand body, and also plays an important guiding role in oil and gas exploration and development. The study enriches the theory of stratigraphic sequence stratigraphy in continental basins in China, and has important reference significance for seismic sedimentary research in other similar domestic and abroad basins.

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Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-1: Surface dynamic and stratigraphic development of fluvio-deltaic systems: Autogenesis and allogenesis
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Characteristics and distribution of sedimentary facies of xu4 and Xu6 members of Lower Triassic in Wubaochang-Huanglongchang area

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Keywords: xujiahe formation,sedimentary facies,wubaochang-huanglongchang area in northeastern

Taking xujiahe Formation in Wubaochang-Huanglongchang area as the research object, based on various drilling data and modern sedimentology theory, the sedimentary facies types and their distribution, evolution and facies models in this area are further studied to provide a basis for the search of favorable exploration zones.

According to the classification and analysis of sedimentological, paleontological and logging facies, the fourth and sixth member of Xujiahejie Formation in the study area mainly developed differentiated river delta sedimentary facies. The provenance of this period mainly originated from the northeast daba Mountain, and the subfacies can be divided into the Banbian River delta plain and banbian River delta front according to the thrust direction of the sediment source. Microfacies include distributary channel, marsh and interdistributary bay.

According to the analysis results, the sedimentary facies plane distribution of xu4 - Xu6 member is drawn. The results show that: 1. The lake basin shrank and the river energy increased during the sedimentation of the fourth Member of Xudian Formation. The delta plain expands to south west and develops flood plain subfacies. Distributary channel sandbodies were generally developed in the study area during this period, and their quantity and thickness increased greatly, and fluvial sedimentation became stronger. During the sedimentary period of xu5 Member, the lake basin expanded and the delta plain contracted towards the provenance direction. The boundary between delta plain and delta front is roughly located near Huanglong 4 and 5 Wells. Floodplains developed in the study area during this period. The sand body is mainly channel sand body and distributary channel sand body. The quantity and thickness of distributary channel sand body decrease, and fluvial sedimentation becomes weaker. During the deposition of xu6 Member, the lake basin shrank, the delta plain advanced to the southwest direction, and the river energy increased. Distributary channel sandbodies were generally developed in the study area during this period. The sand body mainly consists of channel sand body and distributary channel sand body, the number and thickness of channel sand body increase greatly, and the fluvial sedimentation becomes stronger.

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Session T8-1: Surface dynamic and stratigraphic development of fluvio-deltaic systems: Autogenesis and allogenesis
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Sedimentary characteristics and development model of sublacustrine fan in the third member of Paleogene Dongying Formation in Liaozhong Sag

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Keywords: sedimentary characteristics,development models,sublacustrine fan,Dongying Formation,Liaozhong Sag

Based on the observation, description and analysis of cores, combined with the analysis of petrology, logging response and seismic response, it is concluded that sublacustrine fan deposits were developed in the third member of Paleogene Dongying Formation in liaozhong Sag, and the sedimentary structure types are rich and the characteristics are obvious. Sublacustrine fan sedimentary in compositional maturity of medium and high textural maturity of sandy conglomerate, sandstone is given priority to, can identify horizontal bedding, mudstone tear, slump deformation structure, surface of discontinuity, bedding and other sedimentary structure, show the typical characteristics of the underwater gravity flow deposits, and has obvious slump, secondary handling characteristics, Natural gamma ray and electrical resistivity curve of the micro gear box, a bell and finger and their combination is given priority to, the more performance for the low frequency seismic reflection features, in - good continuity, high amplitude, as a whole has a certain strong reflection configuration, and the lacustrine facies mudstone weak amplitude blank reflection exists obvious difference, from the middle to thinning until pinchout on both sides. Based on the above analysis, the sublacustrine fan in the study area can be divided into three sedimentary subfacies including inner fan, middle fan and outer fan, and several microfacies including main channel and braided channel. The inner fan subfacies is mainly developed at the root of the sublacustrine fan, which is mainly deposited by gravity clastic flow. At the bottom, scour surface, parallel bedding and slump deformation structure are developed. The debris of mudstone can be seen. The middle fan subfacies vertically presents a positive cycle consisting of multiple periods of positive rhythm superposition, which is coarse-grained, reflecting the characteristics of gravity flow deposition. There is a scour surface between the bottom of the cycle and the underlying mudstone, and cross-bedding and mudstone tearing debris can be seen locally. Horizontal bedding and deformation bedding are developed in the outer fan subfacies. A longitudinally incomplete bauma sequence is BCD or CDE. The sedimentary characteristics of sublacustrine fan are controlled by provenance supply, paleogeomorphology and distribution of slope break zone, and the distant delta is the prerequisite for sublacustrine fan development. The paleogeomorphology provided accommodation space and controlled the location and scale of sublacustrine fan. The slop-break zone controls the deposition rate of sediments and the regulation and redistribution of sublacustrine fans.

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Lithofacies types and characteristics of typical channel sandbodies in Jinqiu Gas Field, Sichuan Basin

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Keywords: Sichuan Basin,Jinqiu gas field, Shaximiao Formation,Single sand body,Lithofacies

Tight sandstones from the Jurassic Shaximiao Formation in the Jinqiu Gas Field of Sichuan Basin are rich in natural gas and distributed along channels. The complex internal structure and strong heterogeneity of the channel single sand bodies of the Shaximiao Formation in the study area restrict the production and gas development. This study aims to reveal the lithofacies types and characteristics of channel single sandbodies of the J2S2 member of the Jurassic Shaximiao Formation. Based on the drilling cores, well logging, analysis and testing, nine types of lithofacies are divided, using the bedding, grain size and composition characteristics. The lithofacies types include massive medium-grained sandstones, massive fine-grained sandstones, large cross-bedding medium-grained sandstones, small cross-bedding fine-grained sandstones, parallel bedding medium-grained sandstones, parallel bedding fine-grained sandstones, horizontal bedding argillaceous siltstones, massive mudstones, horizontal bedding mudstones. The vertical assemblage types of lithofacies in the single sand bodies include massive + cross-bedding lithofacies assemblage, cross-bedding + parallel-bedding + horizontal-bedding lithofacies assemblage, cross-bedding + parallel-bedding lithofacies assemblage. Based on the differences of physical properties and logging response characteristics of lithofacies types, the lithofacies assemblages of channel single sandbodies in the study area are divided into three categories, e.g. class I-homogeneous, class II- weakly heterogeneous and class III-strongly heterogeneous. Among them, the physical properties of sand bodies with classI-homogeneous are best. According to the logging values of three types of lithofacies assemblages, the logging identification standards of various lithofacies assemblages are established. This study provides a geological basis for the prediction of high quality reservoir of the Shaximiao Formation in the Jinqiu Gas Field, and improves the development of the tight gas from the Jurassic Shaximiao Formation.

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Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-1: Surface dynamic and stratigraphic development of fluvio-deltaic systems: Autogenesis and allogenesis
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Anthropogenic effects on the Danube delta front deposits throughout the last 150 years

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Keywords: delta lobe, river engineering, sedimentation rate, depocenter

The majority of world river deltas are at present intensely affected by anthropogenic activities. One of the most damaging effects is the reduction of sediment supply due to damming in the river catchment and channelization inside the delta plain, which causes coastal erosion and thus ultimately endangering settlements on the delta plain. For this study we look at how Danube delta front responds to change from a natural to an anthropogenic regime by investigating the sedimentation rates reflected in bathymetric changes.

We analyzed decadal bathymetric changes for six time intervals spanning the last approximately 150 years (between 1865 and present). For each interval a sediment thickness map was made. Before 1900, the Danube delta front records a net positive sediment budget outlined by a rapid shoreline progradation (> 50 m/year) of the Chilia (northern) lobe and a high deposition rate (0.8 m/year in the deepest part) in front of the Sfantu Gheorghe (southern) lobe. After 1900, the natural regime of the delta was increasingly affected by anthropogenic influence on the Danube river catchment and changed delta sedimentation patterns. Consequently, Chilia lobe faced a gradual decrease in shoreline progradation rates reaching 20 m/year in the 1920s and erosion on the coast exposed to dominant waves, starting with the 1940s. The engineering works which started in the 1860s at the Sulina mouth extended the channel mouth jetties transforming the Sulina distributary in a shipping channel. The jetties extension enhanced erosion in the downdrift part of Sulina mouth due to local wave diffraction. Furthermore the Sulina jetties blocked the southward longshore sediment transport which deprived the southern Sf. Gheorghe lobe of the sediment supply generated by the Chilia mouths. This effect, together with the constantly decreasing overall river sediment input and increased storminess on the deltaic coast led to intensification of wave processes reworking Sfantu Gheorghe river mouth sediments and fast migration (0.2 km/year) of the depocenter toward the southern tip of its barrier island Sacalin. Sediment transported to the Danube delta decreased significantly after the 1940s when areas affected by coastal erosion expanded. Construction of river dams and embankments depleted the delta front of sediments while the intensification of delta plain channelization reduced the main distributaries water discharge. The effects of this human intervention is also reflected in the shrinkage of sediment depocenters identified on bathymetric maps and their migration towards south. Chilia and Sfantu Gheorghe depocenters record low rates of accumulation (0.15 to 0.3 m/year) and migrate southward with rates of 0.1 km/year suggesting stronger wave processes dominance over the river influence which previously controlled depocenter formation.

Scientific Themes: Theme 8. Modern Sedimentary Process
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Sedimentary characteristics of shallow-water Delta in chang 8 member of Yanchang Formation of the Upper Triassic in Yanchi area, Ordos Basin

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Keywords: shallow-water delta, sedimentary characteristic, Yanchi area,Ordos Basin

The shallow-water delta in lacustrine has become the focus of sedimentological research and oil and gas exploration. The rich oil and gas resources have been found in shallow-water deltaic sandstone reservoirs in lacustrine. Shallow-water deltas are one type of deltas developed in lacustrine with shallow water and relatively tectonically stable tableland, gentle topography and slow overall subsidence, featuring stable sedimentary thickness, continuous sedimentary sequence and large scale development of delta front facies belts.

Chang 8 member of Yanchang Formation is a typical deltaic delta front facies sedimentation in the Yanchi area of Ordos Basin. Core observation shows that coal lines, leaves and roots of plant, wormholes, sedimentary structures and other shallow water environmental markers are widely developed, and a large number of small cross-stratification, trough cross bedding stratification, wavy cross-stratification and depressional cross-stratification are developed, and the sedimentary sequence shows normal rhythmic characteristics. The sedimentary microfacies mainly including the underwater distributary channelthe underwater natural levee and the interdistributary microfacies, and its underwater distributary channel have characteristics of meandering river with low sinuosity. Under the control of the basin depression background, the sedimentation and sandbodies distribution of shallow-water delta are influenced by the raise and fall of the lake level, climate and supply of sources, which are as follows: In the periods of high water levels, the shoreline of the lake is rapidly moved towards the sources area and strip-shaped or birdfoot shaped subaqueous distributary channel sandbodies developed. In the periods of low water levels, the delta plain is mainly developed. The sandbodies is distributed in a strip-like form.

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Session T8-1: Surface dynamic and stratigraphic development of fluvio-deltaic systems: Autogenesis and allogenesis
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Sedimentary facies and sedimentary model for the Chang-6 oil measuresof the Triassic Yanchang Formation in the Qilicun Oil FieldOrdos Basin

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Keywords: Ordos Basin,shallow-water delta,sedimentary facies,Yanchang Formation,Qilicun Oil Field

Sedimentary facies and sedimentary model are constructed according to well logs and section examinationof the Chang-6 oil measures of the Triassic Yanchang Formation in the Qilicun Oil FieldOrdos BasinThe study shows that the target layer in the study area develops delta front subfacies deposition, and it does not have the three-layer structure of topsets, foresets and bottom sets of the Gilbert-type delta model.From the perspective of sedimentary structure, the delta has thin monomer and is widely distributed with the characteristics of “blanket” sedimentary structure and the dominant development of sand body of underwater distributary river course.The development of sedimentary microfacies takes the sand body of distributary river course as the skeleton, the mouth bar is generally not developed, and the distributary river course is subject to different degrees of sheeting transformation.On the one hand, when the river channel expands rapidly after entering the lake, it forms a plane flow to the center of the lake basin, and the sediment in the early stage is scoured and reformed after the river channel expands in the later stage.On the other hand, the transformation of lake water waves makes it difficult to preserve the estuary dam sediments formed at the estuary.Sedimentary microfacies consists of the subaqueous distributary channel and interdistributary bay microfacies in the delta front subfaciesThe controlling factors include tectonic evolutionclimateslake-level changes and sediment supply systemsDuring the deposition of the Chang-6 oil measures of the Triassic Yanchang Formationthe broad channels facilitated the wide spreading of water-carried fine-grained sediments and progradation toward the center of the basinand resulted in the formation of the“blanket”structure composed of the sandstone-mudstone couplets in the subaqueous distributary channel faciesGenerally, it is an interbedding development of sandbody and mudstone of underwater distributary river course.

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Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-1: Surface dynamic and stratigraphic development of fluvio-deltaic systems: Autogenesis and allogenesis
Presentation Preference: Oral Preferred

Does the effect of sediment retention and bottomset accumulation lead the linearly prograding deltaic shoreline?

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Keywords: shoreline progradation, retention rate, delta

Deltas are formed at the mouth of rivers as rivers lose their confinement and develop alluvium. Traditionally, the A/S (accommodation/sediment supply) ratio is considered for a main control on the shoreline migration. A delta progrades basinward (shoreline regression) when the S is greater than the A. The progradation rate decreases as the delta expands because the subaerial delta surface increases. However, interestingly, the Lafourche Delta is known to prograde at a steady rate even with the expanding delta surface and compaction hindering the progradation. Previous studies presented several hypotheses to explain this deviation. In this study, we investigate the effect of 1) bottomset aggradation and 2) retention rate increase on maintaining shoreline progradation rate. We integrated bottomset and compaction module into the delta building model to test these two hypotheses in the Lafourche Delta. The modeling results demonstrate that when the bottomset aggradation increases, the shoreline progradation tends to be linear, yet it is insufficient to explain the constant shoreline progradation rate of Lafourche Delta. On the other hand, the increased retention rate resulted in an almost constant progradation rate

Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-1: Surface dynamic and stratigraphic development of fluvio-deltaic systems: Autogenesis and allogenesis
Presentation Preference: Oral Preferred

The problems and solutions of the Sr/Ba ratio for salinity recovery of terrigenous clastic sediments

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Keywords: salinity recovery ,the Sr/Ba ratio , selective extraction, Distinguishing of the marine and terrestrial sedimentary environment, terrigenous clastic sediments

The salinity recovery of sedimentary environmen during the deposition of terrigenous clastic sediments is one of the main contents of sedimentology. The Sr/Ba ratio is one of the commonly used proxy for the salinity recovery of terrigenous clastic sediments. It is generally believed that the Sr/Ba ratio of marine sediments is greater than 1.0 and the Sr/Ba ratio of terrigenous sediments is less than 1.0, but the effect of practical application is often not satisfactory. The existing data show that most of the terrigenous clastic loose sediments (or terrigenous clastic sedimentary rocks), whether salty water or fresh water, generally have a total Sr content of 100 ~ 300 mg/kg and a total Ba content of 300 ~ 700 mg/kg, Therefore, under normal circumstances, their Sr/Ba ratio is generally less than 1.0. So, Is the Sr/Ba ratio not suitable for distinguishing the terrestrial and marine sedimentary environment?

The results of strontium and barium by Sequential extraction analysis from natural sediments of different salinity series in the modern Yangtze River Delta show that about 62% of the total strontium and 93% of the total barium in terrigenous clastic sediments exist in clastic silicate minerals. Their content has nothing to do with salinity, but only with hydrodynamic force and mineral composition of clastic sediments. This explains why the Sr/Ba ratio of most terrigenous clastic sediments (rocks) are less than 1.0 whether deposited in fresh water environment or salt water environment.

The results by sequential extraction analysis also showed that the content of exchangeable and carbonate-bound Sr and Ba were mainly related to the changes of salinity environment, and other Occurrence mode of Sr and Ba had no good correlation with salinity. Therefore, we can distinguish the marine and terrestrial sedimentary environment of terrigenous clastic sediments by selectively extracted Sr/Ba ratio of exchangeable & carbonate-bound Sr and Ba.The Sr/Ba ratio extracted by 1M NH4Ac and 10% HAc from the clastic sediments of the modern Yangtze River Delta shows that if the Sr/Ba ratio is less than 1.0, it indicates that the sediments are deposited in the river or upper delta plain environment of fresh water; If the Sr/Ba ratio is between 1~5, it will be deposited in the delta front environment of brackish water; if the Sr/Ba ratio is between 5~8, it will be deposited in the prodelta environment of salt water; if the Sr/Ba ratio is greater than 8, it will be deposited in the normal seawater environment. Obviously, analysis method by selective extraction is the only way to solve the poor application effect of trace element sedimentary geochemistry.

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Session T8-2: Linking surface dynamics to the stratigraphic record

ID: T8-20067

Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-2: Linking surface dynamics to the stratigraphic record
Presentation Preference: Oral Preferred

A review of the mismatch in grain size between modern and ancient tide-dominated deltas: does the rock record need to be reinterpreted?

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Keywords: tide-dominated delta, grain size, ancient units, modern systems

Modern tide-dominated and mixed-energy tide-dominated deltas are heterolithic and relatively fine grained, yet units considered to be their ancient counterparts are sandstone prone and coarser grained. This study reviews and provides semi-quantitative data from 13 modern tide-dominated deltas and 31 interpreted ancient counterparts, highlighting the mismatch in grain size and additional incongruities.

The studies of modern and ancient systems are potentially complementary as they provide different insights on the depositional system (e.g., short term processes vs. long-term evolution); however, it is not rare that models based entirely on interpretations (or also modeling simulations) would contrast with well-known and measured dynamics from modern systems where certainties are obviously much greater. Although other reasons (e.g., preservation) might exist, comprehensive and supported explanations for these mismatches are rarely provided, and a misinterpretation of the ancient remains the most reasonable justification.

This review study questions nearly four decades of research on ancient (mixed-energy) tide-dominated deltas and suggests that a change in direction for interpreting ancient coastal to shallow-marine successions is urgently required. The knowledge gap between modern and ancient systems is likely destined to remain wide if geoscientists will persist underestimating the knowledge gained from modern systems when interpreting the rock record

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Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-2: Linking surface dynamics to the stratigraphic record
Presentation Preference: Oral Preferred

Driving the salt or carried by the salt: a sedimentary wedge on a moving salt canopy

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Keywords: salt canopy ,extrusion rate ,sedimentary wedge,numerical simulation

Salt canopies are thick allochthonous salt presented in the deepwater area of salt-bearing passive margins. In the salt canopy region, two dominant mechanisms driving salt tectonic deformation are the contraction controlled by the gravity failure of the margin and the sedimentary loading associated with deepwater sedimentation. However, how the sedimentary loading interacts with the contraction is not well understood. We use numerical simulation to systematically investigate the interaction between deepwater sedimentation and an advancing salt canopy by varying the extrusion rate of salt and sedimentation patterns. The results show that the extrusion rate of the salt canopy has a first order control on the deformation pattern of the supra-salt sediment wedges. Increasing the extrusion rate directly increases the length of the deformation belt and allows the development of more contractional structures. In contrast, the sedimentary wedge can only dominate the deformation style when the extrusion rate is very slow. This study suggests that, the relative contribution between salt extrusion and sediment-differential loading in a salt canopy is closely linked to the extrusion rate of the system. Consequently, various styles of sediment-salt interaction may exist depending on the speed and nature of canopy advancement.

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Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-2: Linking surface dynamics to the stratigraphic record
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Alluvial fan evolution in response to glacial-interglacial climate cycles: A case study from Daihai Lake Basin, North China

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Keywords: Alluvial fan, debris flows processes, sheetflood processes, East Asian summer monsoon, colluvial slope failures

Understanding climate changes and resulting catchment-alluvial fans dynamics is helpful to reveal paleoclimate system by means of terrestrial archives, especially for during the interglacial-glacial cycles. However, it is debatable whether the alluvial fan deposits are capable of recording the orbital-scale climate fluctuations because the response time (10^6yr) of terrestrial landscapes for the climate changes are far longer than the cyclicality (~10^4-10^5yr) of high-frequency Milankovitch-period oscillations. Based on the detailed field survey, the sedimentary facies and the sedimentary processes of the late Quaternary Bantanzi (BTZ) fan in the Daihai Lake basin within the northern margin of the East Asian summer monsoon (EASM) is investigated. Meanwhile, a reliable interglacial-glacial chronology framework can be constructed utilizing the interfingering and interstratified relationship between fan deposits and loess-paleosol sequences and other chronological evidences. We find that the BTZ fan is constituted by the last interglacial debris-flow-dominated unit (DFU) and overlying the last glacial sheetflood-dominated unit (SFU). In consideration of the tectonically quiescent setting, the abrupt transition from debris-flow to sheetflood sedimentary processes over the last interglacial-glacial cycle is ascribed to the orbital-scale climate oscillations, which determine the enormous differences in precipitation and sediment supply within BTZ drainage basins. Compared with glacial periods, stronger extreme rainfall and more precipitation totals may surpass the threshold of catchment colluvial slopes failures to trigger widespread debris-flow processes due to the combination of global warming and northward migrating of the EASM rainfall belt during the interglacial. The study confirms the coupling response between the alluvial fan deposits and Milankovitch climate variations.

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Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-2: Linking surface dynamics to the stratigraphic record
Presentation Preference: Oral Preferred

Deep-water sedimentary systems on the tectonically active Antarctic margin

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Keywords: submarine canyons, plastered contourite drifts, the active high-latitude continental margin, the Antarctic Peninsula

The active continental margins are sites of tectonics and complex sedimentary processes (Fisher, 1974; Miller and Kuehl, 2010; Harris et al., 2014). Tectono-sedimentary interactions occur through geological time and determine the modern morphology of the margin (Ranero and Sallarès, 2004; Gamberi et al., 2015; Bailey et al., 2020). Such interactions, however, are poorly documented in high-latitude regions. This study focuses on the deep-water sedimentary systems on the South Shetland margin, the only remaining active continental margin in Antarctica. Analysis of bathymetric and seismic datasets allows the recognition of numerous gullies, 20 canyons, and a plastered contourite drift. Mineral contents and grain size derived from the gravity core indicate the main sediment input from the South Shetland Islands. Sediment transport is dominated by turbidity currents, while weak bottom currents further rework the sediments on flat terrace and the lower continental slope. Although the evolution stages of canyons and gullies can hardly be determined because of the lack of chronographic control, incision-infill features in seismic unit 1 and 2 shows the long-term influence of turbidity currents. Sedimentary features on the South Shetland margin are profoundly controlled by tectonic-resulted slope morphology and marginal compression. Gullies only shown on steep (slope>7°) and rugged slopes where tectonic compression is significant. The thalweg profiles and sinuosity of canyons are controlled by variations in the slope gradient. The plastered contourite drift is restricted to the fault-generated terrace. Frequently occurred earthquakes and the convex geometry of the drift influence the slope instability and might trigger the sliding. Two types of deep-water sedimentary models are suggested for the Antarctic continental margin. Type I is the most common hybrid turbidite-contourite depositional system. Type II represents separated systems of canyons and contourite drifts. The former is generated on the gentle slope (slope<2°), while the latter occurs on steep ones (slope>9°). Sedimentary features on the South Shetland margin and similar island arc systems have no latitudinal variations and are comparable in size. Tectonics exert a first-order control on the sedimentary systems. The results provide a deeper understanding of tectono-sedimentary interactions on the active continental margins.

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Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-2: Linking surface dynamics to the stratigraphic record
Presentation Preference: Oral Preferred

Architectural characteristics, evolutionary stages, and sedimentary models of clastic beach bars

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Keywords: architectural units, sedimentary models, evolutionary stages, beach bars, machine recognitionShandong Penisula

Beach bars are important reservoirs and have good exploration potential in several petroliferous basins globally. However, most of the models used for understanding the architecture of beach bars are macro-patterns of source-to-sink. They have imprisoned the further development of this territory, and we need new attempts to break through the current bottlenecks.

Our study areas were the Binhai Park of Rongcheng, Moon Bay and the Fenghe Estuary of Qingdao. These places are all distributed along the coast of the Shandong Peninsula in China. We also analyzed a beach bar of the fourth member in the Shahejie Formation of the Paleogene deposits found in Dongying Sag (Bohai Bay basin). We studied hydrodynamic zoning and the sedimentary environment and established fine-scale architectural units using field surveys, fine-scale scanning with unmanned aerial vehicles (UAVs), cores, grain size analysis, X-ray diffraction analysis, X-ray fluorescence analysis and conventional and image logging. Automatic identification of beach bar architectural units was conducted through principal component analysis and Bayesian discrimination.

The results indicated that the beach bars could be divided into shore beaches, submerged shoals and bars, based on different lithological and sedimentary characteristics. The architectural units of beach bars were divided into five subtypes, corresponding to four evolutionary stages based on hydrodynamic traits and the sedimentary environment. The evolutionary stages include the weak wave action stage, turbulent current - swash backwash stage, aeolian stage and swamping stage. Additionally, a discrimination standard was established based on principal component analysis and Bayesian discrimination while using fine-scale recognition to verify the units. The coincidence between manual recognition and machine recognition results was 94.8%. The discrepancy among the evolutionary stages of beach bars was compared based on the characteristics of architectural units, and the different sedimentary models for shore beach, submerged shoal and bar were established.

We hope that our methodology and models will help address the limitations in previous studies on beach bar reservoirs and will help promote improvements in the related theories and optimization of their exploration and development. Meanwhile, based on the research mentioned above, the finer description and dynamic simulation of beach bars can be continued in further studies.

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Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-2: Linking surface dynamics to the stratigraphic record
Presentation Preference: Oral Preferred

Quantitatively distinguishing the factors driving sediment flux variations in the Daling River Basin, North China

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Keywords: Small mountainous river, Vegetation coverage, Extreme climate, pollen, OSL

Understanding the riverine sediment load regime is crucial to sustainably managing fluvial-deltaic ecosystem restoration. However, in studies on global river sediment transport characteristics, small mountainous rivers (SMRs), transporting 45% of the global sediment flux into the sea, have been largely ignored. Furthermore, SMRs have hydrologic characteristics of instantaneous enormous fluxes under extreme climate, but the research on their driving factors affecting sediment transport is insufficient, not only the modern, but also the late Holocene time scales. Partial derivation method and multiple double mass curves were applied to a small mountainous river in North China, the Daling River to study how the three most variable factors—precipitation, vegetation coverage, and reservoirs—have quantitatively controlled sediment flux in the basin and its subregions in the last 50 years. The OSL (Optically Stimulated Luminescence) and 14C dating method were both used to establish the age framework, additionly, pollen and phytolith proxies were used to reconstruct paleoclimate via WA-PLS model, including the precipitation, temperature, and vegetation coverage of Daling River Basin in the Late Holocene. From 1961–1979 to 1980–2015, the 78.55% reduction in sediment flux was due primarily to restored vegetation coverage (50.42%-61.11%), followed by reservoirs (18.13–44.09%) and precipitation (5.49–22.34%) in the Daling River Basin (DRB) and its subregions. The restored vegetation in the DRB has intercepted a large amount of sediment, reducing the sediment flux transported to the reservoirs. Besides, the Daling River releases enormous amounts of sediment during heavy rainfalls. However, increasing vegetation coverage in recent years has changed the transport characteristics of sediment into temperate changes in runoff and sediment flux under extreme climatic conditions; thus this river provides a useful example of studying the characteristics of sediment transport controlled by nature and human activities against extreme climate conditions. In the DRB, topography, lithology, and vegetation density are the motivators for the differences in sediment flux and its change rates, from upstream to downstream. While in the Late Holocene, sedimentary rates in the Daling River estuary increased abruptly from 0.14 cm/a (~2-3ka) to 0.87 cm/a (~1-2ka), then decreased to 0.32 cm/a (~1ka), meanwhile, average vegetation coverage (NDVI: normalized difference vegetation index) decreased from 0.72 to 0.69, again reduced to 0.66. Annual mean precipitation and temperature were 615.12 mm and 13.23℃; 615.79 mm and 10.52℃; 640.13 mm and 14.06℃ in the three periods. From 2-3ka to 1-2ka, the lower temperature has promoted vegetation decline, besides, the slight increase of precipitation has sped up the water and soil loss. However, since 1 ka, higher amplitude precipitation and lower vegetation density, coupling with bulk sediment accumulation, caused the river channel to transform from southwest to northwest, therefore, the sedimentary rates decreased in the southwest of the Daling River estuary. These findings emphasize the crucial role of vegetation in driving sediment transport from source to sink in temperate SMRs.

Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-2: Linking surface dynamics to the stratigraphic record
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Provenance and Tectonic Setting of Sandstones from the Late Paleozoic Shihezi Formation, East Central of Ordos Basin, China

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Keywords: eastern central of Ordos basin,Shihezi Formation, provenance, tectonic setting

Petrography, major, trace, and rare earth element compositions of sandstones from the Late Paleozoic Shihezi Formation, East central of Ordos basin, in China, have been investigated to determine their provenances and tectonic settings. Petrologic studies demonstrate that all sandstone samples from Shihezi Formation are highly enriched in quartz (Q) but poor in lithic fragments and feldspar (F). The sandstone samples consist mainly of lithic quartz sandstone and litharenite with abundant metamorphic and volcanic fragments. On Q-F-L plots sandstones fall into the field of recycled-orogenic source. Chondrite-normalized Rare earth element (REE) patterns of Shihezi Formation samples with LREE enrichment, flat HREE, and negative Eu anomaly are attributed to felsic source-rock characteristics for Shihezi Formation sandstones. REE patterns of samples from study area are very similar to those of Archeozoic and Proterozoic metamorphotic rocks, such as granitic gneiss, monzonitic gneiss, diorite gneiss, biotite plagioclase gneiss, biotitequartz schist, granulite, mixed granite, etc, from Daqing Mountain, Wula Mountain, and Yin Mountain. Major element geochemistry of samples demonstrates that the most were derived from an active continental margin and passive continental margin, but some from an island arc of passive continental margin. Trace element geochemistry favors a continental-arc provenance mostly from felsic rocks. The major, trace element geochemistry of samples indicate that the source area have experienced complex tectonic settings, which related to combinating tectonic settings with active continental margin, passive continental margin, and continental arc, which correspond to the tectonic setting of northern source area. At the northern edge of the basin, the north margin of Ordos plate collision with Yin Mountain during 1.8~2.0Ga, which result in the collision belt towards continent, the tectonic setting have both active continental margin, passive continental margin, and continental arc. This deduction demonstrates that the uplift of the northern sourc area during late Paleozoic was the major source of Shihezi Formation clastic debris in the East central of Ordos basin.

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Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-2: Linking surface dynamics to the stratigraphic record
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Textures, provenances, and transport patterns of sediment on the inner shelf of the East China Sea

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Keywords: Provenance, Surface sediments, East China Sea, Yangtze river, Zhejiang-Fujian small rivers

Although many studies have been carried out on the mud wedge in the inner shelf of the East China Sea (ECS), the sediment sources and seismic textures of the mud wedge are still unclear and remain controversial. Therefore, this study utilizes grain size and clay mineral analyses of surficial sediment samples and high-resolution subbottom seismic profile interpretation to identify the provenance and texture of these mud wedge sediments. The results show that sediment sources on the inner shelf of the East China Sea are mixed by the Yangtze River, small mountainous rivers along the Zhejiang-Fujian, and western Taiwan coasts. The sediments derived from the Ou and Min rivers are mainly concentrated in the shallowest shelf area within a water depth of 20 m which is located north of the Min River Estuary. Their contribution to the estuaries and coastal areas reflects the different sediment transport patterns of the two small mountainous rivers. The thickness of the Holocene mud wedge between Hangzhou Bay and Taizhou Bay is greater than 20 m at a water depth of approximately 10 m. The cause of this phenomenon is possibly related to the presence of the Zhoushan Islands, which are distributed along the Zhejiang coast and appear to effectively trap sediments from the Yangtze River, facilitating sediment accumulation. The findings of this study will help improve our understanding of the sediment transport and deposition mechanism of deposition on the inner shelf of the East China Sea.

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Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-2: Linking surface dynamics to the stratigraphic record
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Sequence stratigraphic and geochemical records of paleo-sea-level changes in the Upper Carboniferous mixed clastic-carbonate successions in the eastern Qaidam Basin, China

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Keywords: eastern Qaidam Basin, Upper Carboniferous strata, mixed clastic-carbonate succession, sequence stratigraphic and geochemical characteristics, paleo-sea-level changes

The Upper Carboniferous strata in the eastern Qaidam Basin, China, constituted by several hundreds of meters thick mixed clastic-carbonate successions provides an excellent geological record of paleoenvironmental and paleo-sea-level changes during the Late Carboniferous icehouse period. Based on detailed outcrop observation and interpretation, five facies assemblages (fluvial channel, tide-dominated estuary, wave-dominated shoreface, tide-influenced delta, and carbonate-dominated marine offshore) are identified in cyclical stacking patterns. Correspondingly, four 3rd-order sequences were recognized and each 3rd-order sequence is composed by lowstand, transgressive and highstand system tracts. The lowstand system tract is generally dominated by fluvial channels as a result of river rejuvenation when sea-level falls. The transgressive system tract is characterized by tide-dominated estuary and retrogradational carbonated-dominated marine deposits formed during sea-level rise. The highstand system tract is dominated by aggradational marine and wave-dominated shoreface or tide-influenced delta deposits caused by sea-level fall and an increased debris supply. Sequence stratigraphy evolution and geochemical records from carbon and oxygen isotopes and trace elements suggest that four significant high-amplitude sea-level fluctuation events took place, and an overall long-term sea-level rise, which were primarily driven by Gondwana glacio eustasy. Assessing the result of the glacio-eustasy driven sea-level changes history in the eastern Qaidam Basin is useful in predicting the distribution and evolution of mixed cyclic successions in and around the Tibetan Plateau.

Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-2: Linking surface dynamics to the stratigraphic record
Presentation Preference: Oral Preferred

When and how are progradational coastlines actually prograding?

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Keywords: Coastal dynamics, erosion, progradation, distributary fluvial system, Queensland, Digital Earth Australia Coastlines

The long-term development of ancient and modern coastal distributary fluvial systems (DFS) during periods of relative sea-level highstand or fall has often been associated with an overall progradational shoreline. However, the study of modern marginal-marine systems has demonstrated that the spatial and temporal distribution of sediment supply and the combination of depositional processes at the shoreline play an important role in the along-strike coastal dynamics of DFSs. In this context, can we assess when and how much of the coastline is actually prograding at a given time? To address this question, the yearly movements of a 654.63 km segment of the Queensland coastline along the Gulf of Carpentaria were calculated using the Digital Earth Australia Coastlines data between 1988 and 2019, which includes geographical information of the coastline position every 30 m along it.

Preliminary results of this study show that, over 31 years, only 46.86% of the coastline had a net progradation, whereas 53.14% of the coastline was eroded. On the other hand, 50.60% of the studied coastline is characterised by a positive average yearly rate of coastal progradation, which only occasionally exceeds 2 m/year (average yearly erosion rates follow similar trends). The difference between the 1988-2019 net coastal behaviour and the average yearly rates of coastal progradation/erosion indicates that parts of the system are more impacted by out-of-the-ordinary events than others, where ordinary environmental conditions seem to be able to overprint such events. Finally, even if the spatial distribution of coastal erosion VS coastal progradation between 1988-2019 is very discontinuous along the studied coastline, data suggest that the yearly coastal behaviour is overall homogeneous and cyclical, with most of the coastline experiencing alternately erosion or progradation at a yearly to 5-years scale. Although still unresolved, the exact nature of these cycles could potentially be explained with events such as El Niño/La Niña, or variations in tropical-cyclone frequency.

Along-strike variations in coastal behaviour occurring at short spatial and temporal scales, like the ones documented in this study, would surely influence the development, preservation, and trajectory of facies belts and associated key sequence-stratigraphic surfaces in marginal-marine settings. These variations would notably include: what processes are involved in the genesis of such surfaces, their timing, extent, and degree of amalgamation, even if the overall and long-term behaviour of the DFS seems to have generated a uniform coastal progradation. The implementation of short-term coastal dynamics in longer-term basin-development models of modern and ancient marginal-marine systems could refine their predictive power, but the increased uncertainty might limit their spatial and temporal relevance.

Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-2: Linking surface dynamics to the stratigraphic record
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Stratigraphic record reveals contrasting roles of overflows and underflows over glacial cycles in the Dead Sea

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Keywords: Sediment density flows, Geological record, Flood plume, Turbidites, Sediment transport processes

In lakes and oceans, links between modern sediment density flow processes and deposits preserved in long-term geological records are poorly understood. Consequently, it is unclear whether, and if so how, long-term climate changes affect the magnitude/frequency of sediment density flows. One approach to answering this question is to analyze a comprehensive geological record that comprises deposits that can be reliably linked to modern sediment flow processes. To address this question, we investigated the unique ICDP Core 5017-1 from the Dead Sea (the largest and deepest hypersaline lake on the Earth) depocenter covering MIS 7-1.

We report a large dataset of sediment flow deposits (N >5,000) from the ICDP Core 5017-1. Based on an understanding of modern sediment density flow processes in the lake, we link homogeneous muds in the core to overflows (surface flood plumes, $\rho_{flow}<\rho_{water}$), and link graded turbidites and debrites to underflows ($\rho_{flow}>\rho_{water}$). Our dataset reveals (1) overflows are more prominent during interglacials, while underflows are more prominent during glacials; (2) orbital-scale climate changes affected the flow magnitude/frequency via changing salinity and density profile of lake brine, lake-level, and source materials; (3) regarding the generating of turbidity currents, the hyperpycnal plunging mechanism is more dominant during glacials, while the plume settling mechanism is more dominant during interglacials.

The current research bridges the gap between our understanding of modern sediment density flow processes and deposits preserved in a long-term geological record in the Dead Sea, a tectonically active subaqueous environment. It has wider implications for turbidite paleoseismology and implies that to develop prehistoric turbidites as a reliable paleoearthquake indicator, comprehensive modern sediment flow monitoring is essential. It also has wider implications for paleoclimate research in a tectonically active subaqueous environment. A sedimentary archive is filtered to remove significant instantaneous event deposits such as turbidites and debrites could help paleoclimatologists to better reconstruct paleoclimate change.

ID: T8-21563

Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-2: Linking surface dynamics to the stratigraphic record
Presentation Preference: Oral Preferred

Nature's laboratory of sedimentology: Zealandia as a host region of the ISC 2026

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Keywords: source-to-sink, plate margin, volcaniclastic, uplift, erosion

Zealandia is a small, 4.9 Mkm2 region of continental crust in the South Pacific that was once part of Gondwana. As a result of widespread Late Cretaceous crustal thinning, preceding supercontinent breakup, most of Zealandia became submerged. New Zealand constitutes the subaerially exposed part of Zealandia astride the Pacific and Australian plate boundary. The combination of tectonic movement along the boundary and erosion has resulted in a young, rugged, dissected landscape. This means New Zealand has spectacular and varied scenery that displays a diverse range of Cambrian to modern depositional and diagenetic systems in a relatively small geographic area. Fully terrestrial to deep marine deposits can be viewed, in some places close to their modern analogues. The interplay between tectonics, and volcanism and erosion can locally be tracked from source to sink. Many sedimentological localities are globally significant (e.g., Taranaki coast, East Coast), superbly exposed, with high geoheritage values and geodiversity. In the short human history of New Zealand, from the early Polynesian settlers to more recent immigrants, this geology has had a profound effect on New Zealanders, determining how we live in such a highly dynamic, and diverse environment. Understanding the sedimentary environment, modern and ancient, is a fundamental component to planning our future in the face of factors such as climate change, seismicity, volcanism, and their associated hazards. All these things are what this small part of the 8th continent of the world, Zealandia, will attempt to demonstrate hosting the ISC 2026 Congress.

ID: T8-21598

Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-2: Linking surface dynamics to the stratigraphic record
Presentation Preference: Oral Preferred

Sedimentary record associated with atoll growth: exploratory modeling approach

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Keywords: reef platform, submarine terrace, sediment supply, annual layers, event deposits, environmental changes

The general characteristics of the sedimentary record of atoll systems depend on the biological material supply from the reef platform and the subsequent allocation of the materials. An exploratory model (EMASS. Exploratory Modeling of Atoll Sedimentary System) is used to investigate the sedimentary patterns of the atoll proper and the submarine terrace, based on budgeting analysis and geometric assumptions. The definition domains of reef sediment productivity, background water depth, initial atoll magnitude, and a material allocation ratio of atoll retention to submarine terrace accumulation are incorporated to generate the various outcomes representing the deposition product. A synthesis of the outcome spectrum indicates that annual layers of fine-grained sediment escaping from the platform may heave a thickness of up to 10^{-1} mm/yr, and the event layers related to sediment gravity flow due to the self-organization process of reef growth may reach 10^{2} mm in thickness. Furthermore, the reef platform contains well-defined information on sea-level changes. The assumption that any large atoll system results from the growth of a small atoll is not supported by the simulation, since the temporal scale of the sedimentary record often does not fit into the scale of atoll growth with such an assumption. These observations should be taken into account when interpreting environmental changes in the past.

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Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-2: Linking surface dynamics to the stratigraphic record
Presentation Preference: Oral Preferred

Grain-size and compositional variability of Yarlung Tsangpo sand (upper Brahmaputra River, Xigaze cross section; southern Tibet)result from random mixing depositional progress of water and wind

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Keywords: Modern fluvial sediments, Sand petrography, Heavy minerals, Hydraulic processes, End-member numerical modeling, Lhasa and Himalaya

Studying the grain-size dependent compositional variability in modern river sediments provides us with a key to decipher the information stored in the sedimentary archive and reconstruct the evolution of the Earth's surface in the past. Bedload sand along the Xigaze cross section of Yarlung Tsangpo mainstem ranges in mean grain size from 0.5Φ to 3 Φ and displays a marked variability in the relative abundances of detrital components. Such variability does not depend only on hydrodynamic progress, but is controlled as well by the mineralogy of parent rocks in source areas, by the seasonal migration of the rainfall belt, wind reworking, and hydraulic-sorting processes. End-member numerical modeling suggested that the random mixing of wind or river dynamic processes took charge of the random variation of sediments from the Xigaze cross section of Yarlung Tsangpo.

ID: T8-21677

Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-2: Linking surface dynamics to the stratigraphic record
Presentation Preference: Oral Preferred

Revisiting the concept of wave base: a marine sediment dynamic approach

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Keywords: wave base, marine sedimentary dynamics, wavelength, critical wave orbital velocity of motion

Wave base is an important concept in sedimentology. It is classically defined as the maximum depth at which bottom sediments are stirred by the wave motion and distinguished into fair-weather wave base (FWWB) and storm wave base (SWB), the latter being deeper than the former. In some textbooks, SWB refers to the upper boundary of muddy deposition, FWWB indicates the lower boundary of sandy deposition, and the area between them is associated with mixed sediment deposition. This concept of wave base has been widely applied in analyses of sedimentary environment and stratigraphy, and becomes a powerful tool to recover ancient water depth from the sedimentary rocks and strata.

It has been perceived for a long time that the depth of wave base is equal to half of the wavelength. The theoretical basis for which is that, when the water depth is smaller than half of the wavelength, waves change from deep water waves to shallow water waves and begin to be influenced by the bed. Contradict to the original definition, the wave base refers to the depth from which waves start to stir up the bottom sediments, but not where the bed begin to influnce the waves. Thus, it is incorrect to use half of the wavelength as the depth of the wave base.

From the perspective of marine sedimentary dynamics, this study provides another approach to calculate the wave base. Firstly, the relationship between sand particle size and critical wave orbital velocity is established. Thereafter, the probabilities of sand movement driven by ocean waves in 10 representative shelf sea regions around the world were calculated. The results show that the calculated wave bases are approximately 40% of those estimated by the trational method in the textbooks. The trational method which defines the wave base as half of the wavelengh brings great overestimations, which will cause considerable errors in field applications.

ID: T8-21686

Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-2: Linking surface dynamics to the stratigraphic record
Presentation Preference: Oral Preferred

On the complexity of the structural arrangement of channelized and floodplain features on a deltaic surface

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Keywords: Stratigraphy, dynamics, complexity

Deltas are intricate landforms that contain distributary channel networks, which transport water, sediment, and nutrients to coastal or inland water bodies. The dynamics of such networks are complex and can result in highly variable and nonlinear spatio-temporal erosional and depositional patterns. In this study, we quantify how the probabilistic structure of these erosional and depositional patterns relate to the probabilistic structure of the temporally preserved stratigraphic record. The data used in this study are obtained from the large-scale experiments conducted at the National Center of Earth-surface Dynamics, University of Minnesota. Based on a statistical framework that quantifies scale-dependent variability and intrinsic nonlinearity in the elevation fluctuations, we show a transition in the surface dynamics and complexity from a channel-dominated regime to a floodplain-dominated regime. In particular, we show two distinct regimes in the power spectral density, which characterizes variability across a range of scales, of elevation transects at different time instants. We further show that channelized features introduce more complexity (higher nonlinearity) to the structural arrangement of elevation fluctuations on a topographic surface. These observations indicate that scale-dependent processes governing channel and floodplain dynamics require different time scales to create surface topography and the resulting heterogeneity seen in associated strata.

Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-2: Linking surface dynamics to the stratigraphic record
Presentation Preference: Oral Preferred

Where and Why Do Submarine Canyons Remain Connected to the Shore During Sea-level Rise? – Insights from Global Topographic Analysis and Bayesian Regression

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Keywords: submarine canyons, Erosion, Bayesian regression, marine geomorphology

Since the last glaciation, sea level has risen by about 120 meters. As a consequence, most coastlines have migrated landward, inundating large shelf areas. Some of these areas are now dissected by submarine canyons. However, with only 4% of the world's submarine canyons reaching todays coastline, these canyons remain the exception. This has important consequences as the efficiency of sediment routing from land to the ocean largely depends on the position of submarine canyon heads with regard to terrestrial sediment sources. Here, we aim to identify the environmental factors and Earth surface processes that control whether rates of headward submarine canyon incision can keep pace with landward migration of the coastline during the Holocene.

Globally, we identified 798 submarine canyon heads that are currently located at the 120m-depth contour (the Last Glacial Maximum shoreline) and 183 canyon heads that are connected to the shore (within a distance of 6km) during present-day highstand. Regional hotspots of shore-connected canyons are the Mediterranean active margin and the Pacific coast of Central and South America. We used 34 terrestrial and marine predictor variables to predict shore-connected canyon occurrence using Bayesian regression. Our analysis shows that steep and narrow shelves facilitate canyon-head connectivity to the shore. Moreover, our analysis supports the occurrence of such submarine canyons offshore river basins, that are characterized by resistant bedrock and high water discharge. Such rivers deliver coarse-grained sediment to submarine canyons, which can erode the canyon head and floor. To this end, our analysis offers new insights into the formation and maintenance of submarine canyons that are required to efficiently transport sediments, pollutants and organic carbon from rivers to the ocean floor.

Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-2: Linking surface dynamics to the stratigraphic record
Presentation Preference: Oral Preferred

Multiple Time-scales Ocean Front Variations in the Yellow Sea

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Keywords: Yellow Sea, Ocean Front, Big Data, Deep Learning

Ocean fronts are an important barrier to material exchange between nearshore and deep oceans, and its variations in strength exert significant role in the terrestrial material transport and global material cycle. Affected by winter storm, ocean temperature fronts are formed between the branches of West Pacific Boundary Current and the coastal current during the winter and spring seasons in the eastern shelf of China (ESC). Therefore, in order to investigate the terrestrial material transport and cycle in the ECS, it is necessary to understand the relationship between winter storm and temperature ocean fronts.

Deep learning and Signal decomposition are new technologies to process big data. On the weather scale, we investigate the coupling of low-latitude driven circulation systems and high-latitude driven winter storms on frontal variability with the moethods of deep learning. On the decadal (20 years) scale, we analyze how the frontal strength response to the Yellow Sea Warm Current (YSWC), using EOFs and EEMD to analyze potential temperature data in Yellow Sea.

The results indicate that only one mode of EOF dominates the sea surface temperature changes in the Yellow Sea, and its corresponding spatial pattern is significantly characterized by the YSWC and coastal currents. The time series of this mode is highly correlated with the inter-annual variability (derived from EEMD). In addition, the decadal mode of the YSWC is strongly correlated with the ENSO3 index, which dominates the low frequency variations of sea surface temperature pattern. These two results further reveal that, although the inter-decadal frontal variation was predominated by the strength of the YSWC, the strength of fronts positively correlated with that of YSWC in the southern part of the Liaoning Peninsula, while the front intensity increases and then decreases with the YSWC enhancing in Northern Shandong Peninsula and Western Korean Peninsula.

On the weather scale, in order to get the output of Sea Surface Temperature, a CNN-LSTM model is trained through inputting sea surface height and flow field at a water depth of 20 metres. Subsequently, the integrated gradient method is used to explore the dominating influence factor of ocean frontal variations triggered by winter storms. The results show that, in windless conditions, the strength of ocean front is maintained by the combination of pressure gradient forces resulted from sea surface height and Coriolis forces caused by flow field. However, in the storm conditions, influenced by Kelvin wave propagation and shear front fragmentation, the flow field is responsible for the ocean front variation.

The above results show that big data is a valuable tool to investigate climate change and the response of ocean system from different time scales. In practical cognition, our conclusion demonstrate that climate change will significantly influence the process of material cycle through altering ocean front intensity. Therefore, under the condition of future climate changes, the strength of material transport between near-shore and deep sea, together with its impact on ocean system is worth of further attention.

Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-2: Linking surface dynamics to the stratigraphic record
Presentation Preference: Oral Preferred

20,000 years of oscillating landscape response to abrupt climate change

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Keywords: quaternary climate, earth surface dynamics, inverse modeling, XRF, dynamical systems

Climate is one of the dominant controls shaping landscapes on interglacial time scales and has a long-term and non-linear impact on landscape dynamics. However, stratigraphic records of landscapes store information on both, past climates and the adjustment of landscapes to new climatic boundary conditions in the same sedimentary archive. The superposition of climate forcing and landscape response signals in sediment records challenge straightforward climatic interpretations. Here, we combine independent records of precipitation, sediment accumulation rates and composition offshore Western Sumatra to reconstruct landscape adjustment to climate over the past ~ 13 ka.

Using an inverse modeling approach, we show that an abrupt precipitation increase following the last deglaciation approximately 12 ka ago initiated a trajectory of landscape processes. The abrupt shift in climatic boundary conditions led to cyclic variations of enhanced deposition of terrestrial particulates and marine authigenic sediment. The landscape trajectory acts as an ongoing memory of landscape adjustment processes that will eventually fade out approximately 20 ka after the initial precipitation increase (~ 8 ka from now). These findings call for extending the conceptual models of landscape adjustment times and processes and to incorporate landscape trajectories as long-term feedback processes into landscape evolution models to predict future landscape adjustment to climate change.

Session T8-3: Calibration and application limitation of sediment-based proxies

ID: T8-30288

Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-3: Calibration and application limitation of sediment-based proxies
Presentation Preference: Oral Preferred

Reconciling inconsistent trends of environmental magnetic, Li isotope and elemental records from East Asian sediments based on modern calibration and paleoclimate analysis

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Keywords: Magnetic parameters, Li isotope, elemental weathering proxy, Qilian Shan

Accurately reconstructing the evolution of the Asian monsoon is predicated on understanding the impact of temperature, precipitation, and tectonic paleogeography on silicate weathering and environmental magnetic proxies over million year timescales. Here we present transfer functions between precipitation/temperature and magnetic parameters, Li isotopes, and element-based chemical weathering proxies, from an elevation transect from the Qilian Shan. The results show that all of these parameters are more sensitive to precipitation than temperature. However, when applying them to Neogene strata of the Qaidam Basin, strikingly different trends are observed. We compare the generated records with established temperature and CO_2 records in order to reconcile the different trends. The comparison reveals that variations of the elemental weathering proxy records in the Qaidam Basin were likely controlled by temperature, whereas magnetic parameter variations were mostly controlled by precipitation amount which is in turn determined by CO_2 and tectonic paleogeography conditions. Interestingly, the Li isotopes in the Qaidam Basin indicate low degree of chemical weathering intensity over well-established warm periods, which we interpret as a result of intensified congruent weathering. This case demonstrates the advantages of combining geochemical and magnetic proxies in terrestrial paleoclimate reconstruction and we conclude that an integrated approach is the best one to reconstruct temperature and precipitation history from terrestrial records.

Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-3: Calibration and application limitation of sediment-based proxies
Presentation Preference: Oral Preferred

Effects of wave-current interactions on sediment dynamics in Hangzhou Bay during Typhoon Mitag

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Keywords: sediment dynamics, wave-current interactions, Typhoon Mitag, Hangzhou Bay

The hydrodynamics and sediment characteristics of muddy estuaries and coasts during typhoons are closely related to geomorphic evolution, ecological environment, and economic development of coastal zones. Taking the macro-tidal turbid Hangzhou Bay (HZB) as an example, the sediment characteristics and the effects of wave-current interactions on sediment dynamics during Typhoon Mitag were studied using a well-calibrated numerical model. The model considers tides-wave-sediment interactions and the reconstructed typhoon wind field. The net sediment fluxes were controlled by residual currents and SSC. The combined interactions of currents and waves led to high SSC during the typhoon. In calm conditions, the impact of wave-current interactions was small except for the combined bottom stresses. The combined bottom stress was the primary wave-current interaction changing the sediment resuspension and increasing SSC, especially in shallow waters or during storms. The advection term, which played an essential role in reducing the SSC in HZB, mainly affected the SSC by enlarging the velocity. The wave dissipation term enhanced the vertical mixing, which involved the vertical exchange of suspended sediment and the currents. In the shallow waters of the southern bay, the wave dissipation term mostly led to the decrease of bottom stresses, the increase of currents, and the decrease of SSC, while the rise of SSC in the deep waters. The effects of the form drag, wave radiation stress, and refraction terms on suspended sediment dynamics were relatively small. The findings provide the theoretical foundations for the study of dynamics geomorphology in macro-tidal estuaries.

ID: T8-31090

Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-3: Calibration and application limitation of sediment-based proxies
Presentation Preference: Oral Preferred

A tsunami event sedimentary record from volcanic Emao Island, Vanuatu

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Keywords: tsunami, sedimentary, lagoon, volcanic, Kuwae

Both tropical cyclones and tsunamis have been causing significant damages and loss of human lives and resources in heavily populated coastal regions, and they have gained extensive attention. Their frequent occurrence in the South Pacific highlights the necessity of distinguishing their event deposition. In this study, a sediment core was recovered from Marou Lagoon in Emao Island, Vanuatu. A special event bed with multiple stacking sub-layers (total thickness, 36 cm) was identified. According to the sedimentary characteristics and material source analysis of the sub-layers, this bed was confirmed to be left by a tsunami event rather than a storm landfall. The dynamic process of its formation was deduced based on material source information and the local environment settings. Considering the radiocarbon results and volcano eruption records in this area, it probably points to the tsunami caused by Kuwae's explosive eruption in 1452 CE. Because of the peculiar sedimentary facies of this event bed compared to previous studies in similar environments, it is more substantial to use dynamic methods rather than merely rely on sedimentary characteristics.

ID: T8-31169

Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-3: Calibration and application limitation of sediment-based proxies
Presentation Preference: Oral Preferred

Impacts of sediments on dissolved oxygen concentration in macro-tidal turbid Hangzhou Bay

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Keywords: Hangzhou Bay,Numerical simulation,Dissolved oxygen,Sediment

Estuaries and coastal areas connect the terrestrial and oceanic environments, and are essential for both marine economy and ecosystem. Hangzhou Bay located in the east coast of China and is known as its macro-tides and high turbidity. In this study, a three-dimensional numerical model, coupling tide-wave-sediment-ecology, is established and validated using field data in both calm and extreme weather conditions. The impacts of sediment on the key parameters of ecosystem are studied using the numerical model and field data. The results show that the dissolved oxygen concentration (DOC) near the surface decreases from the north to the south, and the DOC near the bottom decreases from the northwest to the southeast. The bottom DOC is higher in the open sea than in the coastal waters. The DOC in the southeast of Zhoushan sea area is lower than the surrounding areas, and the bottom seawater tends to hypoxia. The DOC changes periodically with the flood-ebb and spring-neap tidal cycles. There are seasonal changes in the DOC, with higher values occur in winter. Water stratification is obvious in summer, and the pycnocline of DOC is obvious. The winds enhance the mixing of surface and bottom seawater, causing the bottom DOC rise. The temperature has an important influence on the distribution of DOC.

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Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-3: Calibration and application limitation of sediment-based proxies
Presentation Preference: Oral Preferred

Boundary exchange impacts lead (Pb) isotope composition in the ocean: implications from the Southeast Asia

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Keywords: lead, particulate exchange, boundary exchange

Material fluxes at the land-ocean interface modulate seawater composition and the global cycling of elements. Lead (Pb), for example, tends to have fluvial particulate fluxes into the ocean that are two orders of magnitude higher than the dissolved counterpart. However, the role of particulates as a source of seawater Pb is not understood thoroughly, limiting our interpretation for sedimentary records. Here, using field measurements of Pb concentration and isotope in seawater around Peninsular Malaysia, together with model simulations, we show that particulate-dissolved exchange an important mechanism controlling the concentration and isotopic composition of Pb in the dissolved pool. This particulate exchange can deliver much of the Pb to the ocean, especially before the Anthropocene. Our model indicate that particulate-exchange flux is larger than, or at least comparable to, other natural Pb sources to the ocean. Our work demonstrates the need for further investigations on particulate-dissolved element exchanges to better interpret the weathering-climate feedback in sedimentary records.

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Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-3: Calibration and application limitation of sediment-based proxies
Presentation Preference: Oral Preferred

Surface oxygen isotope seasonality of the South China Sea revealed by individual foraminifers collected in a sediment trap

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Keywords: Oxygen isotope, Individual foraminifer analysis, Seasonality, Sediment trap, South China Sea

Most paleoceanographic studies using planktic foraminifera (PF) are based on multi-shell analyses, but seasonal signals buried by the measurements of lumped specimens are very valuable. Oxygen isotope measurements on individual PF shells could potentially reveal seasonal changes in density and stratification, which is controlled by temperature and precipitation-evaporation imbalance. However, verification of this application is still missing. Based on foraminifers collected by a sediment trap in the northern South China Sea, we show that oxygen isotope data of individual PF shells faithfully record the seasonality of density in the surface ocean, and the seasonal stratification strength when data from species dwelling at different depths are combined. Flux data of the sediment trap suggest that most of the PF shells calcify in winter, so individual shell analyses of sediment samples downcore are needed to reconstruct paleo surface ocean processes of the summer and the annual mean in the northern South China Sea.

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Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-3: Calibration and application limitation of sediment-based proxies
Presentation Preference: Oral Preferred

Pyrite sulfur content and isotope reveal marine transgressions of the east coast of China since MIS5

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Keywords: Pyrite, Sulfur isotope, C/S ratio, Climate change, Marine transgression

Sea-level history reconstruction of the coastal area during geological history is the key to understanding how these areas respond to marine transgression. Here we attempt to use pyrite sulfur contents and its isotopic compositions to trace the marine transgression of the east coast of China since MIS5 (Liu et al., 2019; 2020; 2021). Our results suggest that the ratio of total organic carbon and pyrite sulfur contents (C/S) could distinguish between freshwater and marine environments, which are represented by high and low C/S ratios. In addition, pyrite production in sediments deposited at the beginning of the sea-level rise might be limited by sulfate supply as reflected by more positive values of $\delta^{34}S_{pyr}$. Therefore, our new findings provide a new perspective for identifying the marine transgression in stratigraphic records, especially when the sedimentary strata lack obvious lithologic and paleontological differences.

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Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-3: Calibration and application limitation of sediment-based proxies
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Episodic erosions on the Changjiang River subaqueous delta clinoform since mid-Holocene: sub-bottom stratigraphic evidences

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Keywords: erosion, subaqueous delta, sub-bottom seismic profile, Changjiang River, clinoform

In recent years, under the dual pressure of climate change and human activities, the estuarine delta regions have faced a significant systemic state transition, as well as the risks of erosion and saltwater invasion have intensified. The erosion of estuarine deltas on short- and medium-term time scales (seasonal, annual, decadal scales) has attracted much attention worldwide. However, the sedimentary system of the estuarine delta is formed at a longer time scale, and the clinoform of the subaqueous delta is generally considered to be a stable sedimentary environment, which is heavily used for the acquisition and study of sedimentary records. Through sub-bottom seismic profiles, boreholes and gravity cores studies, we found that under the condition of stable sea-level since the Middle-Holocene (about 7 ka B.P.), there has been episodic large-scale erosions of the Changjiang River subaqueous delta. The upper strata of the erosion interface present a downlap, and the clinoforms appears to be truncated, which area is huge, and extends tens to hundreds of kilometers from north to south of the subaqueous delta. Simultaneously, the truncation is relatively flat, which seems to be a long-term and continuous erosion process. The age of the borehole shows that the older erosion interface was formed between 5-3 ka B.P., while the overlying sediments is eroded between 3-1.7 ka B.P., and there is a diachronous between the north and south subaqueous delta, and a time-lag in the south. This erosion phenomenon may be due to the narrowing of the estuary of the Changjiang River, resulting in a decrease of sediments to the sea. Meanwhile, it might due to the Changjiang River Delta has been in a stable of accumulation, forming a U-shaped terrain during the stacking process, which leads to changes in coastal flow, resulting in erosion of the clinoforms.

Session T8-5: Particle flux in the oceans: Recent progress and future perspective

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Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-5: Particle flux in the oceans: Recent progress and future perspectives
Presentation Preference: Oral Preferred

Observation and Study on the Initiation of Sand-muddy Sediments Influenced by Coastal Constructions

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Keywords: Initiation velocity, Resuspended flux, Sedimentary environment, Sediment resuspension

The construction of large-scale inshore projects such as reclamation and channel dredging will inevitably change the composition of seabed sediments around the project area, which will have a huge impact on the nearshore ecosystem, especially the protected areas with important ecological value. The seabed surface of such areas affected by engineering construction is often settled with suspended particles of abnormal origin, which are quite different from the original natural sediments in terms of sediment source and sedimentary dynamic characteristics. To study the differences of sedimen between natural and influenced by the offshore engineering construction and the possibility of benthic environments restoration, a submarine tripod observation system, with OBS, ADCP and ADV was deployed for near bottom currents and suspended sediment, and with the collection and analysis of surface sediment samples, the initiation velocity and re-suspension flux of seabed sediment were studied in west of Dadeng Island in the Xiamen Bay, which is close to reclamation area of the Xiamen New Airport. The observed results show that (1) there is a significant re-suspension phenomenon in the study area, and the measured initiation velocity is between the value calculated by the existing initiation velocity formula for viscous sand and non-viscous sand. (2) During the spring tide, the sediment eroded flux near the observation point is greater than the sedimentation flux, and the sedimentary environment is mainly in eroded condition. (3) The fine particles in the surface of seabed sediment will be carried away by the tide during the spring tide, which is beneficial to the reconstruction of the benthic environment in the future.

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Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-5: Particle flux in the oceans: Recent progress and future perspectives
Presentation Preference: Oral Preferred

Zooplankton fecal pellet characteristics and contribution to the deep-sea carbon export in the southern South China Sea

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Keywords: Zooplankton fecal pellet, Carbon flux, Carbon export, South China Sea

Zooplankton fecal pellets sinking from the sea surface and water column constitute an important component of the marine biological pump and play a significant role in particulate organic carbon (POC) export, which has been widely reported in different ocean regions. However, fecal pellet carbon flux in the tropical marginal seas and its contribution to the total POC flux has not been deeply explored yet. Here, for the first time we studied zooplankton fecal pellet carbon flux in the South China Sea via one mooring with two sediment traps deployed at 500 m and 2190 m in the Nansha area from June 2020 to May 2021. Zooplankton fecal pellets were identified, counted, and measured according to three shapes: ellipsoidal, cylindrical, and spherical, which are most likely produced by various zooplankton communities including copepod, appendicularia, pteropod, euphausiid, amphipod, ostracod, and crustacean nauplii. Average fecal pellet numerical flux was $2.30*10^4$ and $4.22*10^4$ pellets m^{-2} d^{-1} at 500 m and 2190 m respectively, corresponding to average fecal pellet carbon fluxes from 0.31 to 0.71 mg C m^{-2} d^{-1}. Small ellipsoidal and spherical pellets accounted for more than 90% of the total numerical flux, while larger cylindrical pellets, although relatively rare (6%), accounted for almost 15% of the overall pellet carbon flux. Both fecal pellet numerical and carbon fluxes were lower in summer and higher in winter, with highest values showing up in December to early January, when the strong northeast winds and heavy rainfall increased the marine productivity and promoted the growth of zooplankton communities. Higher fecal pellet fluxes combining with the presence of extra-large pellets at 2190 m compared to those at 500 m suggested the in-situ repackaging of deep-dwelling communities as well as the zooplankton diel vertical migration in mesopelagic and bathypelagic zones. Contribution of identifiable fecal pellets to total POC flux in the southern South China Sea ranged from 0.4% to 30.0% (averaging 9.0%), with higher values occurring during winter monsoon, at which time fecal pellets became a critical conveyor of carbon to the deep sea. Our study confirms the significant role of zooplankton fecal pellet in local carbon export and provides new insight into the processes controlling the marine carbon cycle.

Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-5: Particle flux in the oceans: Recent progress and future perspectives
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Spatiotemporal distribution of diatom-derived oxylipins in coastal oceans: Implications for coastal hypoxia and carbon export

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Keywords: Diatoms, Oxylipins, Coastal ocean, Hypoxia, Particle export

The biological pump is driven by the interaction of biological processes, which is of great significance to carbon sink and global climate change. Diatoms play an important role in the export flux of particles through vertical sinking in benthic and pelagic food webs [1], accounting for 20-40% of the total primary production of the earth. Marine diatoms respond to environmental stress by producing bioactive oxylipins, which are the enzyme-catalyzed oxidation products of membrane lipids and can reflect the environmental conditions of their biosynthesis. Polyunsaturated aldehydes (PUAs) are very important and well studied components in diatom oxylipins. Although PUAs account for only a small proportion of biogenic organic carbon, they serve as allelochemicals to potentially influence the behavior of diatom grazers and competitive phytoplankton, as well as microbial remineralization of phytoplankton-derived sinking particles [2, 3].

Due to the influence of large river input, the coastal ocean has high primary productivity and export flux of particles. There are intense phytoplankton blooms outside the Pearl River Estuary (PRE) with the predominant species being PUAs-producing diatoms. We preliminarily report the high-resolution spatiotemporal distribution patterns of PUAs, their physical and biological controlling factors, and their potential biogeochemical effects, including those related to particulate matters in the PRE [3, 4]. The spatial distribution change of PUAs composition percentage at the surface frontal zone is consistent with the cross-front shift of the dominant PUAs-producing diatoms population. In addition, the particulate PUAs were significantly correlated with the turbidity in the bottom boundary of the front during the cross-front transect, which indicated a biological source of a sedimentary source of bottom PUAs. Biogeochemical implications of PUAs on the coastal ecosystem include not only the deleterious restriction of high PUAs-producing diatom bloom on copepod population and particulate carbon transfer but also the profound influence of particulate PUAs on the microbial cycling of organic carbon in the PRE [3, 4]. The particle-adsorbed PUAs (micromolar level) associated with sinking or suspended particles retrieved from hypoxic waters have been found to have the potential to affect the growth, metabolism, and community structure of particle-attached bacteria. The change in bacterial activity and composition could lead to an enhancement of oxygen utilization during the remineralization of particulate organic matter. Therefore, the export of particles will decrease, the consumption of dissolved oxygen in the water will increase, and thus the formation of coastal hypoxia may be aggravated [5].

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Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-5: Particle flux in the oceans: Recent progress and future perspectives
Presentation Preference: Oral Preferred

Carbon isotopic constraints on basin-scale vertical and lateral particulate organic carbon dynamics in the northern South China Sea

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Keywords: sinking POC, radiocarbon, stable carbon isotopes, source assessment, lateral transport

Lateral particle transport in shelf/slope settings of marginal sea systems have been reported as a widespread phenomenon, and may potentially supply allochthonous particulate organic carbon (POC) to the ocean interior. The magnitude and prevalence of such processes has implications for our understanding of the functioning and efficiency of modern biological carbon pump (BCP) processes, as well as for interpretation of deep ocean sediment records. Yet, ages, and relative contribution of POC from different sources to deep ocean basins are much less understood than those in the shallower regions. Here, based on radiocarbon (F_m, fraction modern), stable carbon ($\delta^{13}C_{org}$) and other geochemical analysis of particles intercepted by time-series sediment traps deployed at three different depths (1000 m, 2150 m, 3200 m), we constrain the source of the sinking POC in the deep basin of northern South China Sea (SCS). POC fluxes at the study site range from 1.3~12.5 mg m^{-2} d^{-1} (n=59) with significant temporal variations in each depths, while the C/N mole ratios, δ13Corg values and Fm values of sinking POC range from 6.6~9.6 (n=59), −23.2‰~−22.1‰ (n=59), 0.90~1.04 (n=59), respectively, indicating relatively constant characteristics dominated by modern marine productivity. Employing a Fm-LM/POC binary mixing model, we find that the modern POC derived from surface ocean productivity, acting as the vertical vector, accounts for 86.7±3.6% of sinking POC on average, while the lateral vector (aged POC hosted on resuspended sediment) comprises the remainder (13.3%), suggesting that sinking POC in the mesopelagic and bathypelagic realm of the northern SCS basin (1000~3200 m) predominantly derives from vertical export via the BCP. The contribution of laterally-supplied POC increases with depth, and is comprised of aged POC derived from several sources. The majority stems from sediment resuspension of the northeastern SCS slope, that entrains aged marine POC (dominant), fossil OC, and soil OC (least significant). The diminished proportion of fossil OC relative to deep basin sinking POC in Taiwan-proximal areas is likely due to its dispersion via resuspension-deposition loops and dilution by POC stemming from modern surface ocean productivity during the delivery. These results, which represent a first assessment on the age and source of sinking POC in the deep northern SCS basin, indicates that laterally supplied aged POC has minimal impact on the strength and temporal dynamics of BCP processes in the mesopelagic ocean. However, the importance of laterally supplied POC and complexity of POC sources increases with depth, underlining the importance of considering sedimentary OC resuspension and dispersion in bathypelagic and sedimentary records of these dynamic marginal sea systems.

Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-5: Particle flux in the oceans: Recent progress and future perspectives
Presentation Preference: Oral Preferred

Source and degradation of sinking particulate organic matter in the northern South China Sea: Insight from amino acids and carbon isotopes

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Keywords: Sinking particulate organic matter, Compound specific amino acid isotope, Sediment trap, Degradation

The sources and undergoing biogeochemical processes of sinking particulate organic carbon in the marginal seas are crucial to the budget of global. Yet, the provenance and dynamic particle processes in the northern South China Sea remain poorly understood. In this paper, based on particulate organic carbon (POC), amino acid (AA), total carbon isotopes ($\delta^{13}C_{bulk}$) and amino acid carbon isotopes ($\delta^{13}C_{AA}$) in the sinking particles intercepted by a sediment trap deployed at the mesopelagic layer of the northern South China Sea (SCS) from June 2009 to May 2010, as well as contemporaneous remote sensing data, we identify that the significant seasonal changes of POC flux and AA flux reflect the dynamic controls of multi-physical processes in the upper layer. The AA contents (% in POC) during the periods of winter monsoon and summer monsoon are 7.20 and 6.49, respectively. The relative fresh organic matter (OM) in winter is likely due to the higher productivity and subsequent faster POC export. Compound-specific $\delta^{13}C$ values of AA indicate that: (1) non-essential amino acid $\delta^{13}C$ values ($\delta^{13}C_{NEAA}$) reflect the effect of bacterial degradation, the significant relationships between $\delta^{13}C_{NEAA}$ and $\delta^{13}C_{bulk}$ values ($r = 0.67$, $p<0.05$), as well as the degradation indicator (Asp/β-Ala ratio) ($r = 0.54$, $p<0.05$), suggest that the sinking OM in the mesopelagic layer of northern SCS endures strong microbial alteration; (2) The normalizing measured pattern of essential amino acid $\delta^{13}C$ values ($\delta^{13}C_{EAA}$) in the sinking OM are consistent with those in phytoplankton, show a weak relationship with Asp/β-Ala and Glu/γ-Aba ratios, indicating that the EAA is mainly produced by primary production and the bio-modification of microbial is small during its vertical settling processes. Additionally, by combined analyzing of $\delta^{13}C_{EAA}$ linear discrimination and the bivariate scatter plot of the normalized $\delta^{13}C$ values of leucine and isoleucine, we find that the sinking POC is predominantly from picoplankton and diatom, while cyanobacteria, coccolithophore, dinoflagellate and chrysophyceae make a minor contribution.

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Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-5: Particle flux in the oceans: Recent progress and future perspectives
Presentation Preference: Oral Preferred

Trace metal fluxes in mesopelagic sinking particles from the northern South China Sea: The importance of anthropogenic aerosol deposition

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Keywords: Anthropogenic aerosol, trace metal, sinking particles, the northern South China Sea

Anthropogenic aerosol deposition has become the dominant source of the particulate trace metal in the surface layer of South China Sea (SCS). However, it remains unclear that if the trace metals from anthropogenic aerosol can be transported into the ocean interior. In this study, time-series samples intercepted by three synchronized moored sediment traps deployed at 1000 m, 2150 m and 3200 m in the northern SCS during June 2009-May 2010 were analyzed to quantify the mesopelagic particulate trace metal fluxes and investigate their sources. The ratios of Fe, Ti, V, Cr to Al in sinking particles were very close to their continental crustal ratios, indicating that they were originated from a lithogenic source. Whereas the ratios of Mn, Co, Ni, Cu, Zn, Mo, Cd and Pb to Al showed various degrees of enrichment over their continental crustal ratios (enrichment factor, i.e. EF>2). Meanwhile, the characteristics of these trace metals were consistent with the high EF values in the surface layer, which is likely due to the influences of natural and anthropogenic processes. Using a mass balance approach, anthropogenic aerosol Zn was estimated to account for 63±16%, 65±10%, 56±11% of the total Zn in the sinking particles at three depths, respectively, while anthropogenic aerosol Co was responsible for 27±10%, 42±8%, 52±5%, respectively. These results suggest that trace metals input from anthropogenic aerosols as an important source can be transported from surface to the deep waters via sinking particles. Further investigations are needed to elucidate how anthropogenic aerosol deposition affect trace metal fluxes and cycling.

Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-5: Particle flux in the oceans: Recent progress and future perspectives
Presentation Preference: Oral Preferred

Long-term (10 years) time series variations in flux and source of particulate organic carbon in the South China Sea

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Keywords: Sinking flux, Particulate organic carbon, South China Sea

The settling processes of organic carbon in the ocean comprise a major component of the global carbon cycle. However, studies on long-term time series change in the sinking flux and nature of particulate organic carbon (POC) in the deep ocean remain scarce and is required to better understand the ocean carbon cycle. Here, we present a 10-year (2011-2021) sediment-trap mooring observation on the flux and source of POC at water depths of 500 and 1960 m in the northern South China Sea. The POC fluxes at 500 and 1960 m showed considerable seasonal and interannual variations, ranging from 0.19 to 18.93 mg m-2 d-1 and from 0.75 to 63.59 mg m-2 d-1, respectively, with increased fluxes in the winter. Higher fluxes of POC also occurred occasionally in the spring (2014 and 2017) and the summer (2012) at 500 m and in most of the summer at 1960 m. The POC fluxes were higher at the 1960 m than those at 500 m (10.29±9.14 vs. 3.79±3.43 mg m-2 d-1), indicating additional inputs from mesopelagic/bathypelagic zones and/or horizontal advection in this region. δ13C values of POC showed no seasonal and interannual changes, ranging from –24.1 to –19.6‰ (–22.4±0.06‰) at 500 m and from –22.8 to –21.3‰ (–22.3±0.2‰) at 1960 m, respectively. The Fm values (14C activity) of POC with a mean of 1.04±0.01 (n=3) at 500 m in 2015 indicate a source of newly formed primary production from the euphotic zone above, while slightly lower Fm values (0.89–0.97) found at 1960 m during 2014–2016 were attributed to horizonal addition of terrestrial materials (Blattmann et al., 2018). The mixing model shows that primary productivity-sourced POC played a key role in the significant increase of organic carbon flux in the mesopelagic/bathypelagic deep ocean.

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Scientific Themes: Theme 8. Modern Sedimentary Process
Session T8-5: Particle flux in the oceans: Recent progress and future perspectives
Presentation Preference: Oral Preferred

Coupling regulation of surface mixing and thermocline on the biological pump in the Asian monsoonal marginal seas

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Keywords: biological carbon pump, Asian monsoon areas, sediment traps, mixed layer depth, thermocline

East Asian monsoon is regarded as the primary driver of seasonal fluctuations in the biological pump strength of the tropical marginal seas, such as Arabian Sea (AS), Bay of Bengal (BoB), and South China Sea (SCS). However, biogeochemical similarities and differences among the three areas, as well as the mechanisms of physical forcings on the seasonality in the fluxes and characteristics of sinking particles remain poorly understood. In this study, compiled time series sediment trap data (sinking particle fluxes and components) from three stations at central AS, BoB and SCS, respectively, were used in combination with climatological data from remote sensing and models to evaluate the combined effect of mixing and thermocline variation on the strength and efficiency of biological pump. The results showed that seasonal monsoon produces a distinct seasonality in the vertical fluxes of sinking particles, the fluxes during monsoon periods were generally higher than those during inter-monsoon periods. Significant relationships between the fluxes (fluxes anomaly as well) of sinking particles and the depths-difference (differences calculated between mixing layer depth and thermocline depth) were also observed, indicating that seasonally enhanced mixing and shoaled thermocline (nutricline) would replenish more nutrient into the euphotic layer, and therefore trigger higher primary production and subsequent higher sinking particle fluxes in the marginal seas. However, the efficiency of biological pump in the central BoB was relative higher than those in the central AS and central SCS, which is likely due to the stronger ballast effects, resulted by the dominant species of diatom and chlorophyte clades and the extremely high lithogenic matter fluxes.

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Time-series variations of zooplankton fecal pellet flux in the western South China Sea

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Keywords: Zooplankton fecal pellects, Particulate organic carbon, Seasonal variation, Western South China Sea, Sediment trap

Zooplankton fecal pellets are important vehicles for the transfer of particulate organic carbon to the deep sea, acting as a key contributor to the marine biological pump. Here, we studied time-series variation of zooplankton fecal pellet flux via one mooring with two sediment traps deployed at 500 m and 1170 m water depth from June 2020 to May 2021 in the western South China Sea. By counting, measuring, and biovolume calculating, we obtained numerical and carbon fluxes of fecal pellets of these sediment-trap samples. The numerical flux of fecal pellets was averagely 2.04 and $1.52*10^4$ m^{-2} d^{-1} at 500 m and 1170 m, respectively, and the carbon flux of fecal pellets was averagely 0.18 and 0.26 mg C m^{-2} d^{-1}, respectively. Both numerical and carbon fluxes varied greatly through time, exhibiting clear seasonal variations, with a primary peak in the spring at both depths and a secondary peak in the winter at 1170 m water depth. Distinct morphological types of fecal pellets contribute differently to the numerical and carbon fluxes. Ellipsoidal and spherical pellets accounted for 96% of the numerical flux at both water depths. Cylindrical pellets were rare in abundance (4%), but accounted for more than 10% of the total fecal pellet carbon flux. During the sampling period, the proportion of particulate organic carbon flux attributed to zooplankton fecal pellets ranged from 1.7 to 10.9%, with higher values occurring during periods when the water column was vertically mixed and the phytoplankton bloomed. Multiple mechanisms may be responsible for the production and fate of fecal pellets as well as their contribution to settling particulate organic carbon.

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Mineralogical composition quantified by Rietveld refinement of X-ray diffraction patterns of deep-sea sinking sediment in the South China Sea: Exploring the potential of this tool for geosciences

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Keywords: Rietveld, sediment trap, mineralogy, XRD, X-ray diffraction, mooring

Sediment represents a complex mixture of minerals and organic matter including products of physical and chemical weathering, biomineralization, and others. The mineral fraction typically comprises the majority of sediment mass and frequently includes crystalline minerals such as phyllosilicates, tectosilicates, carbonates, and others as well as amorphous minerals. These minerals differ greatly in their properties and genetic origin (e.g., lithosphere, pedosphere, ocean). Furthermore, they carry and record distinctly separate signatures of Earth's lithosphere, biosphere, climate, ocean chemistry, etc. By conducting Rietveld refinement of X-ray diffraction patterns, fully quantitative mineralogical composition of a mineral matrix can be disentangled. Using this tool, we report on a one-year time series of sedimentary particles intercepted by sediment traps between 1900 and 3800 m water depth in the northeastern South China Sea. We obtain quantitative contents of major mineral species such as calcite, chlorite, kaolinite, muscovite, plagioclase, quartz, and smectite, quantify contents of minor mineral species such as clinoptilolite, hornblende, laumontite, magnetite, and rutile, and also quantitatively constrain the content of X-ray amorphous material. We find that the mineralogical compositions are strongly correlated with the surface properties (surface area and cation exchange capacity) of the bulk sediment and are systematically related to the provenance of associated sedimentary organic matter. We will report on our progress in this congress. The application of Rietveld refinement for computing mineralogical composition is relatively new in geosciences and it is leading to intriguing new insights related to sediments on Earth (Blattmann et al., 2019) and Mars (Rampe et al., 2020).

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Testing the impact of organic matter coating on grain density and thresholds of sediment motion

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Keywords: SLOB hypothesis, sediment threshold of motion, organic matter, EROMES erosion chamber

The onset of sediment erosion in is governed by sediment properties such as grain size, density, and environmental controls such as current strength. Investigating the relevance of each of these parameters has been an ongoing part of experimental sedimentology, resulting in several empirical threshold of motion curves [1,2]. These are used for different geotechnical applications, but so far, none of these include the effects of organic matter (OM) on particle motion, a draw-back that has been identified early on and limits the applicability in natural systems [e.g., 3]. We perform sediment erosion experiments on natural, untreated OM-rich sediments to investigate the impact of high OM concentrations on the sediment threshold of motion. Six sediment cores from Swiss lakes were inserted to EROMES, a resuspension chamber using a propeller to produce and control shear stress [4,5]. By incrementally increasing propeller rotation rates, the first and second erosion thresholds were identified. Measuring OC (%) revealed the fluff eroded at er I has higher concentrations than the suspended particles at er II and consists of labile aggregates and free OM (e.g., leaves). Moreover, the presence of benthic organisms (tube worms) resulted in a measurable strengthening of the sediment surface. The measurements of er I and II are plotted against calibration measurements performed with standardized (quartz) grains of known grain size distribution, which reveals the lower threshold of motion of particles associated with OM. Consequently, we argue for the recalibration of threshold motion curves to include low-density, OM-rich particles and the stabilising effects of benthic organisms [6].

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Theme9

Resource Sedimentology

Session T9-2: Hydrocarbon quantitative sedimentology

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Sedimentary Evolution Characteristics of Different Type Basins — A Quantitative Evaluation Using Stratigraphic Forward Modelling

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Keywords: sedimentary evolution characteristics, controlling factors, quantitative evaluation, different basin types, stratigraphic forward modelling

Passive continental margin basins, rift basins, and cratonic basins are three major types of petroliferous basins in mid-east China. The sedimentary filling processes and the stratigraphic configurations produced are unique for each basin type and the main controlling geological factors may differ significantly. Adequate understanding of the temporal and spatial differences in the stratigraphic architecture and sedimentation filling process of different types of basin, as well as the main controlling geological factors that cause the differences, will help revealing the evolution of the sequence formation and changes in the sedimentary filling patterns in the basins. and thus has important theoretical and practical significances on petroleum exploration.

The Pearl River Mouth Basin, the Bohai Bay Basin, and the Ordos Basin were selected as three representative basin types to investigate their sedimentary and sequence characteristics based on the data accumulated during scientific research and exploration practice over the past decades. Three-dimensional stratigraphic architectures and sedimentary facies of these basins are established using a quantitative stratigraphic modelling program. The temporal and spatial differences of sedimentary filling characteristics of the three types of basin are also comparatively modelled and quantitative evaluated. By varying the input geological parameters, the characteristics of the sequence stratigraphic development and sedimentary evolution are quantitatively evaluated. The main controlling factors are also determined by a quantitative examination of responses of the sedimentation and filling process to various controlling factors.

The research results show that the filling of the Pearl River Mouth Basin is mainly controlled by the supply of sediments and the fluctuations of sea level. The steep slope segment (side) and the gentle slope segment of the Dongying Sag in the Bohai Bay Basin have different sedimentation filling characteristics and are controlled by different factors. For the gentle slope segment, sequence development is mainly determined by the amount of the accommodating space formed by the fluctuations of the lake level and the sediment supply. The sediment filling of the steep slope segment is mainly controlled by the rate of tectonic subsidence, in contrasting to the gentle slope segment, and its sedimentary filling is less sensitive to lake level fluctuations. In the Ordos Basin, the changes in lake level and sediment supply are equally important parameters that affect the filling of the basin. The filling pattern of the basin is exceptionally sensitive to the changes of the lake level due to its very gentle topography. Fluctuations of the lake level can affect a wide range areally.

Comparative simulations and quantitative evaluation of the sedimentary filling and evolution characteristics of the three-type basins under the control of tectonics, sea (lake) level changes, and provenance supply indicate: (1) rift basins appear to be most significantly affected by the tectonic subsidence/uplift; (2) The fluctuation amplitudes and frequencies of sea (lake) levels have obvious impacts on the sedimentary facies variabilities of the cratonic basin and the passive continental margin basins; (3) Rift basins are most significantly impacted by changes in sediment supply, followed by cratonic basins, the passive continental margin basins are leastly affected.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-2: Hydrocarbon quantitative sedimentology
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Illizi – Ghadames basin diagenetic evolution modeling

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Keywords: Diagenesis, Modeling, Evolution, Oil and gas, Illizi-Ghadames basin

Reservoir quality prediction and the reconstruction of the history of the pore network is an important feature for the study and comprehension of a hydrocarbon region and its potential. It controls the storage, distribution, and flow of fluids within a reservoir, and depends upon rock texture, depositional setting, burial, and thermal history of the basin. These characteristics affect diagenesis that may either improve or degrade original reservoir quality through geologic time.

Unfortunately, the exact reconstruction of this evolution is not easy to achieve, as it needs to constrain several key factors, with regional heat-flow through time probably being the trickiest constraint to challenge.

The Illizi-Ghadames basin (IGB) is one of the most prolific hydrocarbons regions in North Africa. Even if it has been widely studied, the possible thermal effect on the petroleum system of the Tertiary magmatic activity occurred in the region in two major cycles, Paleocene-Eocene and Miocene-Quaternary in age, is still debated (Di Giulio et al., 2021).

In this work, the modelling of the diagenetic evolution of Devonian reservoir rocks in a sector of the Illizi-Gadames Basin is used to check which thermal scenario can be considered more likely, because better reproduces experimental data; based on this, the impact on the time evolution of the petrophysical features of the studied reservoir rocks is investigated, and a detailed history of reservoir petrophysics due to the combined effects of compaction, cement precipitation and grain dissolution since Devonian time to present day is obtained.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-2: Hydrocarbon quantitative sedimentology
Presentation Preference: Oral Preferred

Study on the genesis and main controlling factors of low resistivity reservoirs in Bohai Bay Basin

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Keywords: low resistivity reservoirs, parent rock, diagenetic evolution, paleoclimate, Bohai Bay Basin

A large number of low resistivity reservoirs are intensively developed in Neogene strata in the west of Bohai Bay Basin, which has great exploration and development potential. In order to improve the exploration and development effect of low resistivity reservoir, this study analyzes the genesis and main controlling factors of low resistivity reservoir in this area from the perspectives of the microstructure of the rock, sedimentation, parent rock and diagenetic evolution. The study shows that high shale content, fine lithology, additional conductivity of clay minerals and complex pore structure are the main causes of low resistivity reservoirs in this area. Due to weak tectonic activity, dry climate and poor material supply capacity, the sedimentary types of low resistivity reservoirs are mainly edge beach and flood plain, and this is the main controlling factor for the formation of regional stable low resistivity oil reservoir. For the formation of low resistivity reservoirs with high content of illite mixed layers, it is mainly controlled by the rock type of acidic extrusive volcanic rock and weak hydrodynamic facies. The cementation type is mainly argillaceous cementation, which produces a large number of micro-pores and micro-throats, thus complicates the pore structure and further reduces the resistivity. In recent years, under the guidance of the main control factors of low resistivity reservoir, more than 100 million tons of high-quality geological reserves have been successfully found in Bohai oilfield, and excellent development results have been achieved.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-2: Hydrocarbon quantitative sedimentology
Presentation Preference: Oral Preferred

Diagenesis and the authigenic minerals occupying the pores of the sandstone reservoirs of the Coastal Swamp Depobelt, Niger Delta Basin

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Keywords: Diagenetic reactions, authigenic, kaolinization, pore sizes, enhancement, reduction

Earlier researchers have designated the Niger Delta sandstone as quartz arenites and also stated that diagenesis rarely occurred owing to early calcite cementation at depth shallower than 2500 meters. This study focused on diagenesis and identification of authigenic minerals occupying the pores of the sandstone reservoirs of the Coastal Swamp Depobelt, Niger Delta Basin in order to determine the reservoir quality.

Core samples were collected from depth between 2500 to about 3500 meters from two wells situated in coastal swamp depobelt of Niger Delta. End trim samples were cut into thin sections, later polished for advanced microscopic study and Scan Electron Microscopy (SEM). The remnants from thin sections were milled for X-Ray Diffractometry (XRD) and bulk mineral quantification using Reference Intensity Ratio.

The Niger Delta sandstone compositions from both microscopic counts and XRD revealed both quartz arenites and feldspathic arenites, with compositions; Q: 83 to 95%, F: 5 to 20%, RF: 0 to 5%. Different diagenetic reactions had taken place, such as feldspar dissolution, kaolinitization, sericitization, albitization and quartz cementation. These reactions had shape the pore sizes and pore throat of the sandstone reservoir. The dissolution voids created by partial and complete dissolution of feldspar minerals increased the pore sizes as much as 2 to >100µm leading to secondary porosities. The resultant authigenic clays from kaolinitization and sericitization such as kaolinites and its polymorphs; dickite and nacrite are resident in the pore grains and occur as book-form and stacked platelets. Mechanical compaction is minimized by framework grains (quartz and feldspar). Moderate chemical compaction resulted in tangential contacts, convex-concave contacts relationship between the grains. Authigenic albite rhombs float in many pores of the massive sandstone facies of delta plain to delta front deposit. The authigenic anhydrite/albite crystals act as interlocking cements and also displacing the feldspar minerals of delta front-mouthbar deposits at the deeper depth. The existence of quartz overgrowth is proven by euhedral extension into dissolution voids. Pore destructive authigenic illite is only identified in SEM as fibrous and membranous textured crystals in the quartz-deficient heterolithic facies of delta front facies. The abundant micro-fracture porosity observed in quartz grains showed a preferred orientation that suggests an impact force possibly from the growth faulting episodes in Niger Delta. Pore enhancement diagenetic reactions had exceeded the poor reduction ones leading to good reservoir quality sandstones with permeability values ranging from 0.26 to 6647mD.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-2: Hydrocarbon quantitative sedimentology
Presentation Preference: Oral Preferred

An optimized hydrocarbon generation potential method for evaluating both conventional and unconventional hydrocarbon resources: Implication for the Paleogene Shahejie Formation in the Niuxintuo area, Liaohe Western Depression

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Keywords: Optimized hydrocarbon generation potential method, Resource evaluation, low mature source rock, the Niuxintuo area

The hydrocarbon generation potential method is vital to estimate hydrocarbon resources. However, the method is susceptible to subjective influence, and the determination of hydrocarbon generation threshold (HGT) fails to consider the low-mature source rock. This study uses a data-driven approach to optimize the method by multiple nonlinear fitting, which greatly enhances the accuracy of resources assessment, especially for low-mature source rock. This method was applied to the low mature source rocks from the Member 4 of the Shahejie Formation (Es4) in the Niuxintuo area, Liaohe Western Depression, which can be subdivided into the Es4d, Es4g, and Es4n submembers from top to bottom. Results indicate that the Es4 source rocks were thick (>250 m) and mainly in the low-mature to mature stage (Ro=0.26% ~ 0.63%). The TOC was high (>3%). The kerogen was mainly types II and I. The crude oil shows typical characteristics of low mature oil, which exhibits an excellent genetic relationship with the Es4g and Es4n source rocks. The HGT was 0.3%Ro. The hydrocarbon expulsion threshold (HET) was 0.42%Ro. The Es4g source rock had the largest hydrocarbon generation amount (Qg = 13.94 × 10^8 t), but an extremely limited hydrocarbon expulsion amount (Qe = 0.94 × 10^8 t) and range. By contrast, the Qg and Qe from the Es4n source rock were 11.44 × 10^8 t and 3.28 × 10^8 t. The Ro value corresponding to the buoyancy-driven hydrocarbon accumulation depth (BHAD) in the Niuxintuo area was determined as 0.49%. In the Es4n submember, considering the accumulation coefficients of different types of reservoirs, the conventional oil resource which is formed above the BHAD was 0.35 × 10^8 t. The unconventional tight oil resource formed below the BHAD was 0.95 × 10^8 t. The shale oil resource was 4.41 × 10^8 t. Therefore, exploration in the Niuxintuo area should be dominated by tight oil and shale oil exploration.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-2: Hydrocarbon quantitative sedimentology
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Saline lacustrine formation overpressure and its origin mechanism of the Paleogene and Neogene in the Western Qaidam Basin, NW China

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Keywords: Saline lacustrine basin, overpressure, disequilibrium compaction, hydrocarbon generation, Qaidam

Previous research has shown that the origin and distribution of formation overpressure are governed by several dominant factors including disequilibrium compaction, hydrocarbon generation, tectonic compression, and diagenesis. These factors are influenced by salt components and their concentration in saline lacustrine basins, but it is unclear how salts affect formation overpressure via these factors. This paper investigates the effect of salts on formation overpressure based on organic geochemistry, rock mineralogy, and other analyses. The top surface of the overpressure ranges from 2300 to 2500 meters in depth, and the proportion of abnormal high pressures increases from the Paleogene to Neogene in the Western Qaidam Basin. The centers of the overpressure migrate from west to east, consistent with the migration of the basin's subsidence and sedimentary centers. Strong overpressure with a pressure coefficient of 1.82.0 mainly occurs in the upper Oligocene, where deep and semi-deep lacks are developed. Disequilibrium compaction is the most important controlling factor, with a contribution rate of more than 60% in the intersalt and subsalt strata, followed by tectonic compression, with a contribution rate of 20-30%. The contribution of organic matter to hydrocarbon generation is greater in the subsalt strata. Fracture reducing by salt filling and fluid volume expanding by gypsum dehydration increase the fluid volume in the formation, which promotes formation overpressure. The gypsum salt rocks also have strong plasticity and sealing effect, thus providing a good sealing condition for the formation of overpressure.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-2: Hydrocarbon quantitative sedimentology
Presentation Preference: Oral Preferred

3D Quantitative In-situ Modeling of Deep Shale Poroperm Characteristics

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Keywords: deep shale, poroperm characteristics, heterogeneity, in-situ modeling, 3D characterization

With the increase of the buried depth, the reservoir temperature and pressure, and the strength of the reservoir diagenesis evolution in deep shale, the poroperm control mechanism become more complex, the poroperm heterogeneity is more strong, the 3D quantitative in-situ modeling of deep shale poroperm characteristics faces huge challenges. The oil / gas storage and production capacity commonly relies on TOC, porosity and permeability, that come from the development and construction of natural or artificial pore and fracture system in deep shale. Therefore, how to accurately and reliably implement 3D quantitative in-situ modeling of deep shale poroperm characteristics, has become the breakthrough to solve the problem of efficient exploration and development of deep shale oil / gas.

The 3D quantitative in-situ modeling of deep shale poroperm characteristics can not be achieved by a single theory and technique. to this end, by fully absorbing the theoretical nutrients of fine-grain sedimentology and shale reservoir geology, integrating the advantages of existing shale geology, well logging and seismic interpretation technique, and exercising the poroperm heterogeneity of typical deep shale oil / gas example areas in Sichuan Basin, Junggar Basin, Ordos Basin and Qaidam Basin, the 3D in-situ modeling technique with heterogeneous rock-well-seismic coupling in deep shale was established. Specifically include: (1) shale lithofacies classification and logging quantitative identification method; (2) 3D visual discrete network modeling technique of bedding fractures, structural fractures and artificial fractures in deep shale ; (3) in-situ interpretation method of shale poroperm characteristics based on rock-rock-well coupling; (4) 3D in-situ modeling technique of shale poroperm characteristics relying on well-seismic coupling and genetic inversion; (5) Shale layer correlation and 3D visual structure characterization; (6) 3D quantitative in-situ poroperm characterization relying on seismic-lithofacies-fracture constraints.

Relying on the technique of 3D quantitative in-situ poroperm modeling, many 3D quantitative in-situ poroperm models distributed in the Jiaoshiba and the Weiyuan shale gas production area in Sichuan Basin, the Jimusar shale oil production area in Junggar Basin, the Xiasiwan shale gas exploration area in Ordos Basin, and the Fengxi shale oil production area in Qaidam Basin, have been gradually built, which verified the reliability and applicability of the present technique.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-2: Hydrocarbon quantitative sedimentology
Presentation Preference: Oral Preferred

Sedimentary Evolution and Petroleum Potential of the Cretaceous to Paleogene in Linhe depression, Hetao Basin, western China

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Keywords: sedimentary facies, petroleum reservoir, Cretaceous-Paleogene, Linhe depression, Hetao Basin, western China

Hetao Basin is a Mesozoic-Cenozoic superimposed sedimentary basin developed in the northwestern margin of the North China Plate. Depite a great sheer of studies, the sedimentary evolution of the Cretaceous and Paleogene strata in the basin, which has important oil and gas exploration potential, is poorly understood. In this study, we present a interated dataset in terms of sedimentology, mineralogy, petrology and geochemistry on the Cretaceous to Paleogene strata in the Linhe Depression, Hetao Basin. Using these data, we determined the sedimentary facies where the strata deposited, constrained the temporal-spatial distribution and evolution of individual facies in the sequence stratigraphic framework, and explore its petroleum significance. The results show that: 1) The Cretaceous to Paleogene sedimentation in Linhe Depression, Hetao Basin was characterized by sub-tropical arid and semi-arid climate. The sedimentary water was oxygen-rich as a whole but locally anaerobic, and fresh water and brackish water appeared alternately. 2) There are five types of sedimentary facies where the Cretaceous to Paleogene sedimentation happened, including alluvial fan, braided river, braided river delta, fan delta, and lacustrine facies, which can be further divided into 12 types of sedimentary subfacies and 22 types of sedimentary microfacies. In the northwestern margion of the depression, the fault activity was strong, the topographic height difference was large, and the alluvial fan-delta-lacustrine sedimentary system was developed. In the southeastern margin of the depression, the tectonic activity was weak, the topographic height difference was gentle, and the braided river-braided river delta-lacustrine sedimentary system was developed. The sedimentary pattern of each period is similar as a whole, only showing variations in the scale of fan body at the basin margin relative to the lacustrine facies in the basin. 3) The Cretaceous to Paleogene sedimentation of Linhe Formation was characterized by arid and semi-arid, shallow water, dual provenances controlled by weak episodic tectonic activity. In the early stage of basin development, the tectonic activity was strong, but the basin was small and shallow. The clastic materials on both sides rapidly advanced into the basin, and even converged in the center of the basin, forming a situation of "full basin sands". With the weakening of tectonic activity and the rapid rise of lake water, the supply of clastic materials was insufficient, and the lacustrine deposition began to dominate, thus forming a sedimentary pattern dominated by lake facies. 4) Sedimentary facies zones in the depression controlled the development scales and architectures of sand bodies, and further determined the spatial distribution characteristics of effective petroleum reservoirs. Under the dual controlling factors of sedimentary facies and faulting, the favorable reservoirs in the Cretaceous to Paleogene strata in the Linhe Depression of the Hetao Basin are mainly distributed in the central tectonic belt, where the shore-shallow lake deposits and normal faults are dominated.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-2: Hydrocarbon quantitative sedimentology
Presentation Preference: Oral Preferred

Study on Early Hydrocarbon Generation Characteristics of the Dongying Formation Source Rock in the Bozhong Sag, Bohai Bay

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Keywords: Bozhong Sag, Dongying Formation, Early hydrocarbon generation, Low-maturity oil

The Bozhong sag is the largest hydrocarbon-rich sag in the Bohai Sea in the eastern Bohai Bay Basin, and the Dongying Formation is a typical high-quality source rock of freshwater lacustrine facies. However, the hydrocarbon generation evolution of this set of source rocks has not been systematically studied by previous researchers, resulting in insufficient evaluation of its hydrocarbon generation contribution rate. In this paper, through scanning electron microscopy, XRD characterization, maceral identification, palynological analysis, combined with rock pyrolysis evaluation, TOC determination, gold tube thermal simulation, chromatography-mass spectrometry analysis and other methods, the hydrocarbon evolution characteristics of the Dongying Formation source rocks were studied, and the hydrocarbon generation mechanism of the Dongying Formation source rocks was discussed. The results show that the lithology of the Dongying Formation in the Bozhong Sag is mainly grey and black shale, and the content of pine pollen in paleontology is large. The benthic algae in the exinite account for a large proportion, which is an important part of the hydrocarbon generating parent materials. The organic matter type is mainly II_1 ~ II_2, and the whole source rock reaches good quality. The source rock of the Dongying Formation has two hydrocarbon generation peaks of low maturity stage and mature stage. The first hydrocarbon generation peak corresponds to about 0.6% of Ro, generating low maturity oil. The second hydrocarbon generation peak corresponds to about 1.0 % Ro, generating mature oil. The comprehensive analyses show that the reasons for the formation of low-mature oil in the source rocks of the Dongying Formation are as follows: (1) The benthic algae content has good matching with the bimodal evolution of source rocks, which is conducive to early hydrocarbon generation; (2) the protoplasm (pollen and lipids) in pine pollen participates in early hydrocarbon generation and forms low-mature oil; (3) the catalytic effect of carbonate at low temperature is conducive to the formation of low-mature oil; (4) overpressure is widely developed in mudstone of the Dongying Formation. The pressure coefficient of a strong overpressure zone can reach 1.5 ~ 1.7, which inhibits the thermal evolution of organic matter significantly. The overpressure extends the hydrocarbon generation period of the Dongying Formation. The understanding of the hydrocarbon generation mechanism of the Dongying Formation enriches the hydrocarbon generation theory of organic matter and contributes to the assessment of hydrocarbon generation contribution rate and potential of the Dongying Formation source rocks in the Bozhong Sag.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-2: Hydrocarbon quantitative sedimentology
Presentation Preference: Oral Preferred

Characteristics of Miocene source rocks and mechanism of organic matter enrichment in Yinggehai Basin

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Keywords: source rock, sedimentary environment, Yinggehai Basin

The Yinggehai Basin is a passive continental margin basin located in the northwestern part of the South China Sea. It is a typical Cenozoic strike-slip extensional basin with a diamond-shaped distribution in the NNW direction and is rich in natural gas. In this study, Miocene mudstone samples from the Yinggehai Basin were selected for testing and analysis, and the characteristics of source rocks and organic matter enrichment factors were comprehensively analyzed in combination with previous research results.

In this study, Miocene mudstone samples from different areas of the Yinggehai Basin were selected, and the organic carbon content (TOC), pyrolysis hydrocarbon generation potential (Pg), hydrogen index (HI), carbon-hydrogen-oxygen ratio (H/C, O/C), vitrinite reflectance (R_o) and pyrolysis peak temperature (T_{max}) comprehensively evaluate the characteristics of source rocks in the Meishan Formation and Sanya Formation in the study area. Based on the sporopollen assemblage, saturated hydrocarbon light-weight ratio $(C_{21}+C_{22})/(C_{28}+C_{29})$, Sr/Ba ratio, pristane/phytan and kaolinite content and other parameters, the paleoclimate environment, The source of organic matter, paleo-salinity, redox conditions and changes in paleo-sea level and other organic matter enrichment factors.

The research results show that the Miocene marine source rocks in the Yinggehai Basin are generally low in organic matter abundance and low in maturity, all of which have entered the hydrocarbon generation threshold and have good hydrocarbon generation potential. The organic matter types are mainly II_2-III types. Mainly, the type of natural gas is mainly coal-derived gas. On the plane, the abundance of organic matter in the Ledong and Dongfang areas located in the central depression is significantly higher than that in the Yingdong slope belt. Vertically, the organic matter abundance in the Meishan Formation was significantly higher than that in the Sanya Formation. The Meishan Formation was generally warm and humid during its development, while the Sanya Formation was generally dry and low temperature. The paleo-water environment in the Meishan and Sanya periods was salt water, the salinity in the eastern area was higher than that in the Yingdong slope area, and in the Meishan period was higher than that in the Sanya period. The sources of organic matter in the Meishan Formation and Sanya Formation in the Central Sag are both from aquatic organisms and from terrestrial higher plants, which are typical dual-source inputs. During the period of Meishan Formation and Sanya Formation, the sea level gradually increased from Yingdong slope to Ledong District to Dongfang District, and the sea level of Meishan Formation was higher than that of Sanya Formation vertically.Although the source rock characteristics and organic matter enrichment factors have been reported, the input ratio of terrestrial and endogenous organic matter, the main controlling factors of organic matter enrichment and the development of high-quality marine dual-source source rock area still require further research.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-2: Hydrocarbon quantitative sedimentology
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Quantitive analysis and evaluation of source-to-sink system of a low uplift area in Bohai Bay Basin: Insights for further hydrocarbon exploration

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Keywords: Source-to-sink,Analytic network process analysis, Chengbei Low Uplift, BoHai Bay Basin

The source-to-sink (S2S) system analysis of rifted lacustrine basins is one of the focus content of hydrocarbon exploration and development. Currently, most S2S studies are conducted based on statistical calculations of the parameters of S2S systems. However, few studies focused on the S2S system evaluation. Located in the western Bohai Bay basin, the Chengbei low uplift (CBLU) was an integrated S2S system, which provides a natural experimental condition for exploring the relationship between provenance system, transportation system, and sedimentary system. The results show that the eastern CBLU can be divided into three sub-level S2S systems, including one first-level system, two second-level systems and ten third-level systems. There are two types of sediment dispersion patterns in the study area: 1) the proximal-fan-delta sedimentary pattern and 2) the distal-braided-delta sedimentary pattern. Furthermore, we constructed a multivariate quantitative relationship between the influencing factors of source and sink. Additionally, utilizing the analytic network process analysis, the S2S systems can be quantified and ranked. Finally, based on the tectonic activity, sediment migration trajectory, and sediment dispersion pattern, we established two coupling models of S2S system. This study proposes a quantitative method to analyze and evaluate the S2S system, which not only deepens our understanding of the structure and sedimentary evolution on the temporal and spatial scales, but also generates positive significance for the prediction of favorable reservoir and stratigraphic-lithologic traps.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-2: Hydrocarbon quantitative sedimentology
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Sedimentary genesis and distribution of high argillaceous sandstone

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Keywords: Hanjiang Formation,high argillaceous sandstone,Genesis,Distribution

Area A is located in the east of Yangjiang Sag in Zhusan Depression, Pearl River Mouth Basin. The Neogene Hanjiang Formation in this area has deposited a large number of sand, silt and mud mixed clastic sediments, with different particle sizes and complex composition. Predecessors have done some research on lithology, sedimentation and reservoir of this Formation, but the understanding of genesis and distribution of high argillaceous sandstone is not clear. In this paper, the genesis and vertical distribution of high argillaceous sandstone in Hanjiang Formation are analyzed by core, logging and analytical test data. Combined with high resolution seismic data, the density and seismic elastic parameters inversion method are used to clarify the plane distribution characteristics. The results show that high argillaceous sandstone is mainly distributed in deltaic front underwater distributary channel, interdistributary bay and distal bar. Sediment deposition rate of deltaic front underwater distributary channel is fast, low energy hydrodynamic can not be fully scoured sediment screening, resulting in high mud content. The hydrodynamic conditions of deltaic front interdistributary bay and distal bar are weak, and fine-grained and argillaceous sediments are deposited in large quantities, so the argillaceous content of sandstone is high.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-2: Hydrocarbon quantitative sedimentology
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Genesis and distribution prediction of high-calcium and low-permeability sandstone

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Keywords: high-calcium and low-permeability sandstone,genesis,distribution,seismic inversion,Zhujiang Formation

The reservoir-caprock assemblage of Zhujiang Formation in A Oilfield of Yangjiang Sag, Pearl River Mouth Basin is superior and has excellent reservoir formation conditions. However, the process of oil and gas exploration is restricted due to the frequent drilling of high-calcium and low-permeability sandstones, and the unclear understanding of the causes of high-calcium and low-permeability sandstones and the distribution of sand bodies. In this paper, the causes and vertical distribution of high-calcium and low-permeability sandstones are studied by using rock cores, logging, analysis and testing data combined with the sedimentary background of the region. And the reservoir seismic inversion is carried out by using seismic data combined with permeability, so as to realize the plane distribution prediction of high-calcium and low-permeability sandstones. The study shows that the Zhujiang Formation in the study area mostly develops underwater distributary bay microfacies, which provides abundant carbonate provenance conditions for high calcium content of sand bodies. And the sand bodies in the microfacies of underwater distributary channel are closely embedded with the mudstone rich in calcium at the top and bottom, and the migration and related chemical reactions of carbonate from mudstone to sandstone occur at the junction, which further increases the calcium content of sand body. Combined with the study of permeability inversion model, it is considered that high-calcium and low-permeability sandstones are mainly distributed in the underwater distributary channel near the provenance region in the northern part of the study area.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-2: Hydrocarbon quantitative sedimentology
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Origin and evolution of overpressure in upper Member of Xiaganchaigou Formation, western Qaidam Basin

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Keywords: Abnormal pressure, Overpressure characteristics, Origin of overpressure, Overpressure evolution, Western Qaidam Basin

This research analyzes the distribution and causes of overpressure in the upper segment of the Xiaganchaigou Formation (E32) from the western Qaidam Basin through pressure test data, well logging data, and geological conditions of the area. Different causes of overpressure are quantified in this research.According to the deposition rate, organic matter abundance, organic matter type, organic matter maturity, tectonic compression stress, geothermal gradient, and clay mineral characteristics of the upper lower Ganchaigou Formation in three secondary structural belts in the western Qaidam Basin. It is considered that the main controlling factors of overpressure in the western Qaidam Basin are disequilibrium compaction, hydrocarbon generation and tectonic extrusion. This view is further verified by the analysis results of the combination of logging curves and the acoustic velocity-density cross plot. The residual pressure evolution in the western Qaidam basin is reconstructed by basin simulation. The results show that part E32 can be divided into five evolution stages: Normal compaction stage (before 25Ma), Weak overpressure stage (25-12Ma), Mixed pressurization stage (12-5Ma), Rapid pressurization stage (5-1.5Ma), Pressure release stage (1.5Ma-present).

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-2: Hydrocarbon quantitative sedimentology
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Analysis of Oil and Gas Source and Reservoir Forming Evolution History of Maokou Formation of Middle Permian in Center-North of Sichuan Basin

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Keywords: Sichuan Basin,Source of Oil and Gas,Hydrocarbon Accumulation Stages,Fluid Inclusion

Abstract: There is a common gas-bearing phenomenon in Maokou Formation of Middle Permian in the center-north of Sichuan Basin. Vertically, source rocks like those of Cambrian, Silurian and Permian are mainly developed in the study area. Hydrocarbon source faults and unconformities are relatively developed, which have superior reservoir forming conditions. However, due to the different structural characteristics and reservoir development degree in different areas of the basin, there are some differences in natural gas sources and oil and gas accumulation periods. At present, the source of natural gas in Maokou Formation in the study area is not sufficiently understood, and the contribution of Cambrian, Silurian and Permian source rocks to different gas reservoirs needs to be further studied. Based on the analysis of natural gas composition, stable isotope and biomarker characteristics of asphalt, and combined with the previous understanding of hydrocarbon source rocks of various strata in Sichuan Basin, the gas sources of Gaoshiti Moxi, longnusi, Yuanba and Jiulongshan Maokou Formation in the study area are analyzed in detail; At the same time, fluid inclusion analysis and other means are used to determine the hydrocarbon charging period and hydrocarbon accumulation history.

In this study, the differences in natural gas accumulation in the Middle Permian Maokou Formation in different structures in the central and northern Sichuan regions were taken as the research object. Through a large number of core observations and field outcrop sampling, combined with drilling, logging, seismic and organic geochemical data, the source and accumulation period of natural gas in the Maokou Formation of different structures in the study area were studied. On this basis, the law of oil and gas enrichment is analyzed, and favorable target areas are predicted. It provides an important theoretical basis and direction for the next exploration and development.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-2: Hydrocarbon quantitative sedimentology
Presentation Preference: Oral Preferred

Main controlling factors of petroleum differential distribution in the onshore area of the Niger Delta

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Keywords: Niger Delta, Petroleum distribution, Control factors, Source rock, Organic matter maturity

In order to prove the influence of source rocks in the Niger Delta on the differential distribution of oil and gas, we take "source control theory" as the theoretical guide, and then use drilling and geochemical data to analyze the characteristics of source rocks, the distribution characteristics of petroleum fields (reservoirs) and the influence of source rocks on petroleum distribution. The results show that: (1) The petroleum distribution in the study area can be divided into five petroleum accumulation areas and four gas accumulation areas, which are shaped like a belt; The source rock development area corresponds well with petroleum accumulation area and gas accumulation area on the plane. (2) The organic matter abundance of source rocks in the study area is high, and the organic matter types are mainly II and III, which came from both land and sea, and the maturity is mature to over mature. (3) The main controlling factors of petroleum differential distribution have obvious segmentation. The differential distribution of petroleum in the study area is mainly controlled by three factors: the type of organic matter, organic matter preservation conditions, and the maturity of organic matter. The distribution of petroleum reservoirs (fields) in the northwest section is mainly controlled by two factors: organic matter maturity and organic matter preservation conditions; The middle section is mainly controlled by the maturity of organic matter; The distribution of petroleum reservoirs (fields) in the southeast section is mainly controlled by the type of organic matter. The results of this study can provide a theoretical basis for petroleum exploration and development in the study area and other areas with similar geological background.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-2: Hydrocarbon quantitative sedimentology
Presentation Preference: Oral Preferred

Reservoir Modeling Research Based On Convolution-Recurrent Neural Network

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Keywords: Deep Learning, Reservoir Modeling, Convolution Neural Network, Recurrent Neural Network

Traditional reservoir stochastic modeling methods mainly use two-point geostatistics or multi-point geostatistics. Two-point geostatistics cannot use existing model data, and multi-point geostatistics is difficult to use because of the complicated generation process of training images. Recently, deep learning has made an excellent achievement in many fields, but it is rarely used by researchers in the field of reservoir modeling. The successful application of deep learning to reservoir modeling requires consideration of both the model data structure for input and the structure of the algorithm model. We proposed a combined algorithm model of convolution-recurrent neural network to mine the features of existing model data. The convolution part can effectively extract the spatial features of the model data, while the recurrent part can effectively extract the sequential features of the model data. We also compared the performance of the algorithm models under different hyperparameters, and selected a better model to train and predict the reservoir model of an oilfield in Qinghai. The prediction results are compared with the result generated by a commercial modeling software, and the comparison results effectively prove the feasibility of deep learning reservoir modeling.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-2: Hydrocarbon quantitative sedimentology
Presentation Preference: Oral Preferred

Quantitatively identify sedimentary microfacies of the Ng3-4 sand group in Bo61 fault block, southern area of Gudao Oilfield

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Keywords: South area of Gudao Oilfield, Ng3-4 sand group, Quantitatively identifySedimentary microfacies, reservoir characteristics

The work area is located in the Bohai 61 block in the northwestern part of Gudao oilfield, which is a key development block. In recent years, a batch of new well has been drilled. However, there are not enough studies on the division, contrast, sedimentary microfacies and reservoir characteristics of the key stratum such as Ng3-4 sand group, which affects the whole development effect to a certain extent. Based on the theories and methods of sedimentology, oil and gas field underground geology and logging geology, combined with core, logging, analysis and laboratory data, the sedimentary microfacies and reservoir characteristics of the Ng3-4 sand group in the working area are studied in depth to provide a reliable geological basis for further tapping the potential of oil fields.

In this study,the high-precision stratigraphic framework of the work area is established; the sedimentary microfacies types and vertical evolution rules of the study interval in the area are determined through the systematic analysis of single well facies, profile facies and flat facies. In addition, the Bayes discriminant method is used to quantitatively identify sedimentary microfacies, and a multi parameter discriminant model for 6 main sedimentary microfacies in the area is established.

In view of the limited log data of cores and cuttings, it is difficult to meet the fine characterization of sedimentary microfacies in the development block. Logging curves have various types, rich geological information, high vertical resolution, and can meet quantitative analysis. Therefore, in oilfield exploration and development, it is important to make full use of logging data to accurately and comprehensively divide sedimentary microfacies. Based on the above knowledge, in order to maximize the use of logging data and quantitatively characterize the sedimentary microfacies, the Bayes discriminant method was used to quantitatively identify the upper sedimentary microfacies of the Guantao Formation in Gudao Oilfield, laying a solid geological foundation for the fine development of the oilfield. In this paper, representative well sections with sedimentary microfacies in 3 coring wells in the study area and the corresponding 58 sets of logging data are used to establish the Bayes discriminant model. SP, COND, and AC logging curves are selected and optimized. Normalize and extract feature parameters, and use them as the input set for Bayes discrimination, and use the interpretation of sedimentary microfacies as the output to establish the Bayes discrimination model. The cross-validation method is used to verify the established model. The results show that: The accuracy of the training results is 98.3%, the accuracy of the cross-validation is 96.6%, and the accuracy of the prediction results is 93.3%, which indicates that the model has a good application effect on the identification of microfacies of river facies and sediments in the upper part of the Guantao Formation in Gudao Oilfield.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-2: Hydrocarbon quantitative sedimentology
Presentation Preference: Oral Preferred

An integrated workflow for diagenetic facies, microfacies analysis and petrophysical characterization of Zhuhai Formation tight sandstone from Zhu-III sag, Pearl River Mouth Basin, South China Sea

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Keywords: Petrophysics, Reservoir quality, Diagenetic facies, Pearl River Mouth Basin

Zhu-III sag is a key area of resources exploration with great potential of resources in the Pearl River Mouth Basin. Reservoir in Zhuhai Formation (Oligocene) is a typical tight sandstone reservoir. These exposed Zhuhai Formation outcrops, of the intercalated continental and marine sediments, allow us to conduct more detailed and integrated studies on the various depositional settings with diverse lithologies as analogous for the subsurface reservoirs. The proposed workflow allowed the extension of our knowledge to Zhuhai Formation in Zhu-III sag into some hydraulic fluid flow units and reservoir rock types. The present stud enabled developing a static model for the Zhuhai Formation reservoirs in Zhu-III sag which exhibits heterogeneities in the fluid flow and microfacies at micro and macro scales. The present study concerns the implication of the mineralogical components and the diagenetic controls on the petrophysical properties and the reservoir characteristics. Diagenetic facies are a significant tool to indicate the key parameters of tight sandstone reservoir properties. In this work, diagenesis of tight sandstone reservoir of Zhuhai Formation is investigated by multiple experiments of borehole core, thin section, scanning electron microscope, X-ray diffract ion and conventional rock analysis to discuss the influence of main diagenesis and minerals. Four diagenetic facies are identified as strong compaction facies, medium compaction facies, carbonate cemented facies and clay mineral filling facies. We quantitatively determine the correlation between diagenetic facies with well logging and petrophysical parameters. The strong compaction and cements are the primary reason for the development of low-quality reservoirs. Cementation and compaction are the main reservoir quality-reducing factors, as dissolution and fracturing enhanced its quality. We establish the facies prediction system and predict the favorable reservoir via well logs. The relationship between porosity and permeability is controlled by diagenetic facies. A further correlation between the Zhuhai Formation outcrop data and the analogous subsurface reservoirs is critical for modeling and simulating the Zhuhai Formation reservoirs, which will improve the reservoir behavior and prediction during the appraisal, development, and production phases. The findings of this study point to the presence of some prospective flow units that should be traced in the nearby analogous subsurface reservoirs in the Pearl River Mouth Basin.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-2: Hydrocarbon quantitative sedimentology
Presentation Preference: Oral Preferred

Analysis of hydrocarbon generation characteristics based on S2 parameter correction of Rock-Eval-Taking the first member of Qingshankou Formation in Gulong sag, Songliao Basin as an example

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Keywords: hydrocarbon generation, S2 correction, Qingshankou Formation

Shale oil and gas is an important part of future energy pattern, quantitative characterization of its formation process is of great scientific significance. As one of the effective methods to quantitatively characterize the hydrocarbon generation of shale organic matter, the hydrocarbon generation potential method is affected by the high boiling point of heavy components and the difficulty of volatilization at 300 °C in the Rock-Eval experiment. Therefore, the measured S2 before extraction can not accurately reflect the pyrolysis hydrocarbon content of solid organic matter, so it directly affects the applicability of this method. In this study, taking the first member of Qingshankou Formation in Gulong Sag, Songliao Basin as an example, the hydrocarbon generation potential method is further improved by establishing the heavy components correction model of pyrolysis hydrocarbon content S2. By selecting shale samples with different maturities to carry out Rock-Eval experiments, the heavy hydrocarbon correction model is established based on the ratio evolution of pyrolysis hydrocarbon difference ΔS2 before and after extraction to pyrolysis hydrocarbon S2' after extraction. The experimental data of Rock-Eval in the target layer of study area are corrected and restored, and then the hydrocarbon generation model of organic matter in the first member of Qingshankou formation is analyzed and revealed. The results show that: the difference of pyrolysis hydrocarbons before and after correction is obvious. The proportion of adsorbed heavy components ΔS2 / S2' increases with increasing maturity, showing an exponential growth trend; ΔS2 content is controlled by the evolution stage of hydrocarbon generation, showing a trend of "first increasing, then stabilizing and finally decreasing", which is related to the adsorption capacity of organic matter; The corrected evolution model of hydrocarbon generation in the first member of Qingshankou Formation shows that the organic matter begins to generate hydrocarbon at the maturity of Ro ~ 0.5%, reaches the peak of hydrocarbon generation at about Ro ~ 0.9%, and the pyrolysis of soild organic matter basically ends at Ro ~ 1.3%; The heavy components begin to crack at maturity of Ro ~ 1.2%, with a large number of nano organic pores formed.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-2: Hydrocarbon quantitative sedimentology
Presentation Preference: Oral Preferred

Establishment of retrograde fan delta sedimentary model of Upper Urho Formation in Junggar Basin and discovery of large stratigraphic lithologic traps

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Keywords: Fan delta, Sedimentary model, lithologic traps, Upper Urho Formation, Junggra Basin

In recent years, major oil and gas discoveries have been archived in the Upper Permian Upper Urho Formation (P3w) in major petroliferous sag of Junggar Basin, including Mahu Sag, Fukang sag and Shawan Sag. The sedimentary system and sedimentary evolution of Upper Urho Formation are studied through field outcrop, core, drilling and logging data. The results show that: Upper Urho Formation mainly developed fan delta sedimentary system. The lithology gradually becomes thinner from bottom to top, reflecting the sedimentary characteristics of lake transgression. The sand body regress and overlap each other to provenance area. The distribution of fan body is controlled by sedimentary paleo-channel and paleo-provenance, and the fan body is divided by paleo-uplift. Ten fan delta sedimentary bodies are developed in the Upper Urho Formation of the Junggar Basin. The sedimentary model of retrograde fan delta of Upper Urho Formation is established. This mode has revealed following geological lawsslope break control sand distribution; fan delta plain dense conglomerate and lacustrine mudstone control the forming of the lithologic trap. Conglomerate with poor mud matrix developed in fan delta front control good reservoir. It is pointed out that the sand body developed in the channel between paleo-uplift can form effective lithologic traps. The sedimentary model of retrograde fan delta can provide geological basis for further oil and gas exploration and reference for oil and gas exploration in areas with similar background.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-2: Hydrocarbon quantitative sedimentology
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

The role of quantitative characterization of small source and sink system sand bodies in oil and gas exploration -- Taking Huilu low uplift in Pearl River Mouth Basin as an example

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Keywords: small source-to-sink system, quantitative characterization of sand body, Huilu low uplift, restoration of ancient landscape, sand body scale

At present, oil and gas exploration in the Pearl River Mouth Basin is gradually turning to the deep layer, the Paleogene, when terrestrial source-to-sink system was mainly developed. With the deepening of the exploration process, such source-to-sink systems in the peripheral low uplift area also show great exploration potential. Compared with marine material source, the material source of low uplift area is proximal and unstable, which is called small source-to-sink system. Besides, complex evolutionary process leads to strong denudation and transformation of the source area, then leads to differentiated transportation systems and complex sedimentary systems, thus the scale of sand bodies is difficult to predict.

According to the characteristics of small source-to-sink system, the research quantitatively characterizes the whole process of source-to-sink system in Huilu low uplift by integrating three-dimensional full coverage seismic data and drilled wells, combined with logging data, core data, and laboratory data. Firstly, according to the different restoration technologies of denudation area and super stripping zone, the research restores the ancient landscape before denudation. The denudation area of upper Wenchang Formation is nearly 1700km2 and the denudation thickness is up to 300m. Then, the research finely traces various source-rock combinations and the provenance systems by the comprehensive analysis method of genesis, morphology and age of clastic zircon, thus finely characterize the dynamic source supplies of different uplift groups. Secondly, based on comprehensive analysis of the ancient valleys, slope-break belts and fault systems, the research quantitatively characterizes each transport channel's scale of multi-source differential supplies, thus optimizes the transport channels by seismic sedimentology method. Finally, the research refines the boundary and inside description of sedimentary bodies, and establishes the identification mode, response characteristics and temporal and spatial evolution law of typical sedimentary sand bodies in high-frequency sequence units, thus precisely depicts and quantitative characterizes the scale of sedimentary sand bodies under the coupling of source-to-sink system in Huilu low uplift area.

After the quantitative prediction of sand bodies, the catchment area(mainly sand bodies) of upper Wenchang formation is three times larger than before, which reveals great exploration potential of this stratum. Soon afterwards the preliminary well LF-A and evaluation wells encountered nearly 100 meters medium-coarse sandstones rich in oil and gas after drilling. This greatly increases exploration confidence of Huilu low uplift area while nearly all the original drillings nearby encountered mudstones in upper Wenchang formation. This technological innovation has a good guiding role for the exploration of small source-to-sink system in the Pearl River Mouth Basin, which opens up a new exploration direction and shows great exploration prospect.

Key words: small source-to-sink system; quantitative characterization of sand body; Huilu low uplift; restoration of ancient landscape; sand body scale.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-2: Hydrocarbon quantitative sedimentology
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

3D modeling of oil saturation in lacustrine mixed shale reservoirs based on the control of seismic inversion and fluid classification phase

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Keywords: oil saturation,seismic inversion,fluid classification facies,geological modeling

Lacustrine mixed shale reservoirs are widely distributed in global sedimentary basins, such as the Western Siberia Basin, Newark Rift Basin, Junggar Basin, Songliao Basin, Ordos Basin, etc. Although the shale oil in many basins has entered the stage of industrial development,there are many technical difficulties restricted the development.Firstly, the traditional methods (Logging data method and Seismic data method) cannot satisfied the accuracy of characterization due to the variable structure, complexed oil-water relationship and Strong heterogeneity of lacustrine mixed shale oil reservoir.Secondly, the number of exploration wells and production wells is small, and the sparse well pattern also seriously affects the prediction accuracy between wells. There are still many difficulties in the fine quantitative characterization of oil saturation.

To solve the problems above, a “three-stage”modeling method based on dual control of seismic inversion and fluid classification phase is proposed:(1)Using log data to invert the formation, and using the “horizontal trend” method to overcome the variable structure problem of Lacustrine mixed shale oil reservoir ,which cannot be representated by log data alone,improve lateral resolution, and ensure the accuracy of horizontal extension;(2)Controlling Reservoirs with Fluid Classified Phasesusing the "vertical trend" technology to overcome problems that thin layer and strong heterogeneity of lacustrine mixed shale reservoir and improve the vertical resolution;(3) Through the dual control of seismic inversion and fluid classification phase, integrating the log data, the seismic data , the fluid classification phase and physical property parameters together.By “three-stage” modeling method, we can make full use of the advantages of "seismic control" which have a high lateral resolution and"horizontal trend" which have a high vertical resolution. The advantages of this method improve the quantitative characterization accuracy of the oil saturation model in an all-round way.

The method is used to study the oil saturation of a saltwater lacustrine reservoir in western China, the results show that the calculation is fast, the accuracy is high, and the error is small.Under the dual constraints of seismic inversion and fluid classification phase, the entire technical system can found optimal solutions for different problems quickly. It has strong advantages in the analysis of oil saturation in the reservoir, which provides better data support for the refined study of the reservoir.The 3D modeling method which has high application value and and can provide a reference for describe the distribution regulations of oil saturation in lacustrine mixed shale reservoirs quantitatively in similar areas.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-2: Hydrocarbon quantitative sedimentology
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Characterization Of Heterogeneous 3D Distribution Of Oil and Water In Thin Interbedded Sandstone Reservoirs Under Complex Structural Systems

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Keywords: Sedimentary Sand Body,Complex Structure, Thin Interbeds, Spatial Distribution of Oil and Water, Heterogeneity

Thin interbedded sandstone reservoirs are one of the key points for unconventional reservoirs in the world; for example, the Berkin Basin in Algeria, the Oriente Basin in Ecuador, the Qaidam Basin and the Bohai Bay Basin in China all have typical thin interbeds Sandstone oil reservoirs, The number of vertical layers is large, the thickness of the single layer is thin, and the plane distribution is wide, highly developed faults, extremely complex tectonic systems, and the diverse sedimentary sand bodies and the influence of diagenesis factors, resulting in strong spatial distribution of oil and water heterogeneity and The distribution law is unclear, which brings great difficulties to the subsequent efficient development of such reservoirs. Therefore, a set of effective technical methods for characterizing the heterogeneous distribution of oil and water in thin interbedded sandstone reservoirs is urgently needed.

In order to solve the above problems, this paper proposes a technical process for the characterization of the heterogeneous three-dimensional distribution of oil and water in thin interbedded sandstone reservoirs under complex structural systems. It mainly includes: (1)Detailed description of complex tectonic systems, proposed technical methods for classification and analysis of complex fault systems, and completed stratigraphic division and comparison of target areas and detailed structural interpretation; (2) described the distribution characteristics of complex sedimentary sand bodies, proposed a set of technical methods for the characterization and modeling of the microfacies distribution of complex sand bodies, and completed the deposition of the target area. The vertical, horizontal and plane distribution characteristics of sand bodies are described; (3) Oil-water identification and heterogeneous three-dimensional distribution characterization, in-depth analysis of the control effects of complex structures, sedimentary sand bodies and gravity differentiation on oil-water spatial distribution, and a set of technical and method flow for single well oil-water characteristic analysis-longitudinal analysis of multi-well oil-water profiles in sub-wells and sub-blocks-analysis of distribution law of layered oil level in the whole region is proposed; completed the vertical, horizontal and plane distribution characteristics of oil and water under the control of complex structures and sedimentary systems, three-dimensional The distribution law of oil-water space heterogeneity is revealed.

The above-mentioned technical process has effectively completed the heterogeneous distribution and Characterization of oil and water in the upper and lower Youshashan Formation of Yingdong Oilfield, Qaidam Basin, aiming at the characteristics of thin interbedded sandstone reservoirs, such as many and thin layers, large plane distribution, diverse sedimentary sand bodies and developed faults. and achieved good results; thus providing a reliable theoretical basis for a series of production processes such as follow-up injection and production.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-2: Hydrocarbon quantitative sedimentology
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Quantitative identification and analysis of lithology in shale reservoirs in Lucaogou Formation, Junggar Basin

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Keywords: Lucaogou Formation,shale reservoirs,quantitative identification of lithology

As the shale oil reservoirs of Lucaogou Formation in the Junggar Basin belong to lacustrine mixing, the petrology is characterized as diverse lithology, varied minerals, and multiple transitional rock categories, resulting in the increasing inconsistency of lithology reflected by conventional logging. The identification of sweet spots is of great significance to the exploration and development of shale oil reservoirs in this area. Previous studies have analyzed the genetic mode of the dessert reservoir, but the lithographic classification and identification have not been studied before, thus it is urgent to study it.

According to the lithology of the well above and below the dessert, the lithology of the area is divided into three categories: mud shale, dolomite and sandstone. On this basis, it is further divided into six subcategories, namely silty mud shale, dolomitic mud shale, sandy dolomite, dolomicrite, silty sandstone and dolomitic-argillaceous siltstone. All the six subtypes of lithology exist in the upper desserts, and no dolomicrite exist in the lower desserts. Based on lithology division and conventional logging sensitivity analysis, the top and the bottom desserts are quite different.

By analyzing the curve values of lithologies, GR and RT curves of lithology with high sensitivity were selected for research. The first step is the logging curve data processing to determine the effective cut-off value of logging curve data; the second step is the single core curve reading; the third step establishes the sensitive curve GR-RT crossplots; the fourth step is to confirm the identification rules of lithological logging boundary parameters. In the upper sweet spot, the identified GR range of dolomicrite and sandy dolomite is less than or equal to 75API, and the RT ranges of them are larger than 190Ω.m and from 60 to 190Ω.m. The rules for dolomitic mud shale is GR greater than 75API and RT greater than 60Ω.m. For silty sandstone, dolomitic-argillaceous

siltstone and silty mud shale, the GR values are less than or equal to 60API, between 60API and 80API, and larger than 80API, while the RT range of these three subtypes is less than or equal to 60Ω.m. In the lower sweet spot, the RT ranges of silty muddy shale and sandy dolomite are both greater than 55Ω.m, while the GR for them are greater than and less than or equal to 75API. The RT values for silty sandstone, dolomitic-argillaceous siltstone and silty mud shale are all less than or equal to 55Ω.m, and GR values are less than or equal to 60API, from 60 to 80API and greater than 80API. Finally, compared with SPSS lithology identification rule, lithology analysis analysis, the recognition rate of dessert area was 92.58% and that of dessert area was 94.43%.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-2: Hydrocarbon quantitative sedimentology
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Quantitative characterization of gypsum heterogeneous distribution and its controls on the reservoir in Feixianguan Formation in Tieshanpo area

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Keywords: Feixianguan Formation in Tieshanpo area,Gypsum layer; Control on the reservoir,Heterogeneous distribution,Quantitative characterization

Tieshanpo is located in the Huangjinkou structural belt at the front of the Daba Mountains, Sichuan Basin, and the Feixianguan Formation in the area is developed on the edge of the carbonate platform in the east of the Kaijiang-Liangping Trough. Affected by both the paleogeomorphology of the ocean trough and the depositional environment, the Feixianguan Formation in Tieshanpo area is rich in natural gas resources, but the reservoir formation mechanism, and its temporal and spatial distribution characteristics are unclear, which seriously affects the development prospects of the gas reservoir.

On the basis of abundant core, well log, logging and 3D seismic data in Tieshanpo area, a large amount of evidence of paleosedimentary environment evolution was found by core description and thin section analysis. Combined with previous achievements, a geological model of sedimentary microfacies was established. Based on the geological model calibration logging and well log data, the longitudinal evolution sequence of sedimentary microfacies was established. Furthermore, genetic inversion method is used to obtain the distribution of interwell sedimentary microfacies by logging constrained seismic.

The results of the above geology-log-seismic integrated interpretation and analysis show that :(1) the gypsum layer produced by heavy brine reflects the arid and low-lying gypsum lagoon sedimentary microenvironment near the surface, with shallow seawater and high salinity; (2) The vertical and horizontal heterogeneous distribution of gypsum layer indicates that the sedimentary microenvironment of gypsum lagoon changes rapidly, resulting in the rapid change of seawater energy, which makes gypsum lagoon coexist with oolitic beach at the edge of platform, forming the interbedded structure of gypsum layer and oolitic beach vertically and horizontally. (3) Based on the significant response of gypsum layer logging and seismic, a three-dimensional model of gypsum layer and oolitic beach of Feixianguan Formation was established by sequential indicator simulation, revealing the distribution law of gypsum layer and oolitic beach, quantitatively characterizing the favorable reservoir-cap assemblage of gas reservoir in three-dimensional space, indicating the direction of efficient development of gas reservoir.

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Session T9-2: Hydrocarbon quantitative sedimentology
Presentation Preference: Oral Preferred

Molecular simulation of the interaction behaviors between different gases and the nanopore system

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Keywords: CO2-enhanced shale gas, adsorption behaviors, kerogen and minerals, CH4 and CO2

Recently, CO_2-enhanced shale gas development technology has received more and more attention since it can realize CO_2 sequestration while increasing the recovery of shale gas. However, the adsorption behaviors between different gases and the nanopore system in shales are still poorly understood. In this study, different kerogen models as well as clay minerals were built by the molecular dynamic method. The adsorption behaviors of CH_4, CO_2 as well as their mixtures on these models with different water saturation were examined by the grand canonical Monte Carlo simulation. Excess adsorption curves were achieved and fitted by the DRk model. The result show that the adsorption of CH_4 and CO_2 in shale components belongs to physical adsorption and the adsorption capacity of kerogen increases with the increasing maturity. The interaction between CO_2 and kerogen is stronger than that of CH_4, indicating that CO_2 can effectively replace CH_4 in kerogen. A similar phenomenon can be seen in the interaction of clay minerals and CO_2. Furthermore, it is found that kaolinite has the strongest adsorption capacity for CH_4, while montmorillonite is more inclined to adsorb CO_2. Moisture significantly reduce the adsorption capacity of the gases on kerogen and minerals since the water molecules crowd out the adsorption sites as well as storage space for the gases. These findings will provide theoretical evidence for further assessment of the mechanisms for CO_2 geological sequestration with enhanced shale gas recovery.

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Two-stage classification and evaluation technology of CUS and CS for low porosity and ultra-low permeability reservoirs

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Keywords: CUS and CS,Low porosity and ultra-low permeability reservoirs,Hierarchical classification evaluation,Classification facies modeling,Facies control attribute modeling

At present, the world is facing serious challenges of the greenhouse effect. my country is in the critical period and window period of "carbon peak". Carbon capture, utilization and storage technology (CCUS) is the most widely used frontier in the oil and gas industry. The technology can effectively and economically realize CO_2 sequestration while exploiting the potential of oil reservoirs, and solve the pressing environmental problems. However, at present, there is no complete set of supporting technologies at home and abroad to realize the CCUS classification and evaluation of reservoirs, so that there is no sufficient technical reference for CCUS operations in oilfields.

Based on this urgent need, this paper proposes a complete set of reservoir CUS and CS classification and evaluation techniques. (1) Relying on basic data such as logging interpretation data to understand the basic geological characteristics of the oil reservoir, formulate a set of scientific and reasonable classification standards for the classification of reservoir facies and oil layers, and divide the strata into reservoirs and interlayers. According to the pros and cons of reservoir capacity and flow capacity, it is further divided into good reservoir C1, reservoir C2, and poor reservoir C3, and the barrier and interlayer are divided into barrier and interlayer G1 and good barrier and interlayer G2 according to the tightness and plugging capacity of the formation. The oil saturation of the fluid in the layer divides the reservoir fluid into three types: oil layer, oil-water layer and water layer. (2) Establish a single well classified facies model and the corresponding classified facies model. On this basis, a facies-controlled attribute model of porosity, permeability and saturation is established. (3) Considering the effective thickness and caprock factors on the basis of the existing model, establish a corresponding model according to the two-stage classification standard of CUS and CS, and calculate the reserves of crude oil and the storage amount of CO_2.

In this paper, a two-stage classification and evaluation of CUS and CS is carried out for a low-porosity and ultra-low permeability reservoir in central my country. The crude oil output of the reservoir is about 9.16 million tons, the CO_2 storage in the CUS stage is about 22.66 million tons, the CO_2 storage in the CS stage is about 70,000 tons, and the total CO_2 storage in the CUS and CS stages is about 22.73 million tons. The results are scientific, valid, reliable, economical, and quantifiable.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-2: Hydrocarbon quantitative sedimentology
Presentation Preference: Oral Preferred

AI-based Quantification of Sedimentary Facies and 3D Reservoir Architecture of Fan Delta Front in the Du66 Block in the Lacustrine Liaohe Sub-Basin, Bohai Bay Basin

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Keywords: Sedimentary Facies, Reservoir Architecture, AI-based Quantification, Sandbody Connectivity

The sandstone in the upper 4th member of the Paleogene Shahejie Formation in the Du66 Block in the Liaohe Sub-Basin, Bohai Bay Basin is a shallow heavy oil reservoir. Previous studies indicated this reservoir is lacustrine fan delta front sandstones. The heterogeneity of the reservoir needs to be characterized for the identification of permeable reservoirs and barriers for a better development plan using in-situ combustion. According to the well-logs motifs corresponding to the sedimentary facies, acoustic log (AC), shallow resistivity (RS), and deep resistivity (RT) are selected as supervised logs to predict the facies using the neural network method. Then the six seismic attributes including original seismic reflection, coherence, RMS, signal envelope, 40 HZ spectral decomposition, and dip near the wellbore are selected to predict the lithofacies based on the neural network training of seismic attribute waves tied to the logs with frequency reduction. The 3D lithological bodies are then reconstructed based on the artificial intelligence with deep learning, which is way faster than the traditional geostatistics method. The fine-grained, medium-grained, coarse-grained, and sandy gravel sandstone bodies, structure, and thickness can then be rendered from the seismic attributes, clearly showing the connectivity and trap volume of reservoirs. The accuracy of the prediction ranges from 76% to 96%. The results reveal that the thick fine to medium-grained sandstone is very heterogenous and could be a channel for the steam breakthrough, the thick connected sandy gravel is a primary permeable channel for heavy oil flow.

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Session T9-2: Hydrocarbon quantitative sedimentology
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Sequence-lithofacies paleogeographic characteristics and geological significance of Lower Permian Chihsia stage in upper Yangtze region

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Keywords: upper Yangtze region, Sichuan Basin, Lower Permian, Chihsia stage, Sequence-lithofacies paleogeography

The dolomite reservoir of Permian Chihsia Formation in Sichuan Basin located in the Upper Yangtze region is a hot spot of exploration and has been making breakthroughs in recent years. In the early Permian, The area is in the extension-compression transition period of Hercynian tectonic cycle. The tectonic-sedimentary process is complex, and there exist differences in regional lithofacies and paleogeography, which greatly limited the large-scale exploration of Chihsia Formation. Through the massive collection of logging, field outcrops, core and isotope geochemical data, based on the study of the relationship among sea-level change, sequence filling, paleogeomorphology and lithofacies, the lithofacies paleogeography and evolution of Liangshan-Chihsia Formation of lower Permian in Sichuan Basin and its periphery were restored, and its sedimentary tectonic dynamic process was revealed. The results show that the periphery of Sichuan Basin is characterized by "four uplifts and four depressions", which is characterized by four paleo-uplifts (or paleo-lands) of Kangdian, Hannan, Shennongjia and Xuefeng mountain, and four depressions of Chengdu-Mianyang, Kangdian front, Xuefeng mountain front and Yichang, while inside the basin, it is a paleogeographic pattern of "alternating sub-convex and sub-concave". Under the influence of continuous and gradual transgression and overlap in Hercynian period, there are three third-order sequences (SQ0, SQ1 and SQ2) developed in the depression area, while only two third-order sequences (SQ1 and SQ2) in the uplift area. The continuous development of the uplift-depression reflected by the strata in each sequence filling period generally presents different degrees of stratigraphic thickness differentiation in the northeast and northwest directions in different stages, which indicates that the NE and NW extensional structures developed simultaneously in the Sichuan Basin control the paleo-geomorphic pattern and sequence filling mode of the basin under the background of the oblique subduction of the Jinshajiang-Ailaoshan ocean and the North-South expansion of the Mianlue ocean. Meanwhile, SQ2, as the main development period of mound-shoals of Chihsia Formation, the distribution of dolomitic reservoirs (dolomite, calcareous dolomite and dolomitic limestone) has a good correlation with the concave-convex conversion slope break zone of sedimentary landform. On the basis of this, a new understanding was put forward that the favorable mound-shoals and dolomitic reservoirs are distributed in the scale of "platform-margin surrounded by the depression and sags surrounded by uplands in the basin", and it was pointed out that the platform-margin area in western Sichuan is still the focus for exploration at present, while Chengdu-Mianyang and Guangwang depressions within the platform and central Sichuan-southern Sichuan are favorable exploration areas for dolomite reservoirs of Chihsia Formation in the next step. The research results redefine the tectonic paleogeographic framework of the key tectonic transformation period of the lower Permian, which has important reference significance for re understanding the tectonic and sedimentary evolution of the upper Yangtze Permian. By using the four elements “sea-level change, sequence filling, paleogeomorphology and lithofacies" obtained from the study, a mapping method of oil and gas lithofacies paleogeography could be used for effectively predicting the distribution of favorable reservoir zones, which greatly expands the exploration field of Chihsia Formation.

Session T9-3: Sedimentary mineral deposits in the deep ocean: Mineralization, genetic models, and environmental issues

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-3: Sedimentary mineral deposits in the deep ocean: Mineralization, genetic models, and environmental issues
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Influence of the Emeishan basalt eruption on hydrocarbon generation and expulsion characteristics of Sinian algal dolomite in Sichuan Basin

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Keywords: Oil and gas resources, Emeishan mantle plume, Geothermal effect, Hydrocarbon generation and expulsion, Sichuan Bsin

The Sichuan Basin is rich in marine oil and gas resources, and the amount of resources is affected by source rocks (Zou et al., 2014; Dai et al., 2018; Hu et al., 2019). The Emeishan mantle plume is an important tectonic thermal event in the Sichuan Basin, which has an important influence on the source rocks under the Middle-Lower Permian in the Sichuan Basin (Zhu et al., 2007; Aarnes et al., 2011; Agirrezabala et al., 2014; Li et al., 2016). Therefore, the better understanding of the effect of Emeishan basalt eruption on source rock is vital for the exploration of marine oil and gas resources. Based on the thermal history study of the Sichuan Basin (Cao et al., 2015; Jiang et al., 2018; Liu et al., 2018; Qiu et al., 2021), this study restored the thermal maturity of the algal dolomite of the Dengying Formation in the Sichuan Basin to the maturity of normal evolution. The hydrocarbon generation and expulsion characteristics of normally evolved algal dolomite and algal dolomite affected by basalt eruption were calculated by the hydrocarbon generation potential method (Jiang et al., 2016; Li et al., 2020). Through comparison, the influence of the Emeishan mantle plume on the algal dolomite of the Sinian Dengying Formation is analyzed. The research indicates that the Emeishan mantle plume has an important influence on the algal dolomites of the Sinian Dengying Formation. The thermal effect of the Emeishan mantle plume promotes the maturation of algal dolomite, which leads to the shortening of the oil generation period and the early arrival of the gas generation peak. The main hydrocarbon expulsion period of the normally evolved algal dolomite should be from the end of the Triassic to the end of the Jurassic, while the main hydrocarbon expulsion period of the algal dolomite affected to basalt eruption was advanced to the end of Silurian to the end of Triassic. In the current period, due to the high maturity of algal dolomite, the Emeishan mantle plume has little impact on the total resources.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-3: Sedimentary mineral deposits in the deep ocean: Mineralization, genetic models, and environmental issues
Presentation Preference: Oral Preferred

Variation of Precambrian seawater environments and related microbial hydrocarbon source – reservoir assemblage system

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Keywords: Microorganism, seawater environment, Ediacaran, hydrocarbon source-reservoir assemblage, Sichuan Basin

Several commercial Precambrian petroleum systems have been discovered worldwide. Various types of microorganisms have been identified in Precambrian successions contributing to the development of high-quality hydrocarbon source rocks and microbialites with high reservoir porosity. However, there are still some key issues which need to be thoroughly explored. For example, what is the role of microbes and which oceanic conditions lead to the development of organic-rich hydrocarbon source rocks and microbialite reservoirs? And, how did the microbial source rock and reservoir constitute an effective hydrocarbon source-reservoir assemblage system. Fortunately, widespread black shale source rocks in the Edicaran Doushantuo Formation, and the directly overlying Dengying Formation microbialite reservoirs in the Sichuan Basin (China), provide the ideal material to address these key issues. During the Edicaran Doushantuo Formation period, high-quality black shale source rocks were widely developed, and the organic matter in the source rocks was mainly derived from microbes including filamentous bacteria and planktonic algae. The thickness of the source rocks is up to 200 m, and the total organic carbon (TOC) value is ~17.9%. During the Dengying Formation period, thick-layered microbialites, including microbial stromatolite, thrombolite, and botryoidal dolomite were developed extensively, with the abundant primary framework and secondary dissolution pores. The transition of the seawater environment controlled the development of microbial source rocks or microbialite reservoirs. In a deep, euxinic reducing seawater conditions, microbial organic matter was well preserved and accumulated in fine-grain sediments, thus forming the high-quality microbial source rocks. Meanwhile, under such a reducing condition, a large amount of layered, nodular, granular, and strawberry pyrites were precipitated due to the effect of BSR reaction with extremely positive δ34S values (up to 39.0‰). Meanwhile, in a shallow turbulent high-energy oxidized seawater conditions, especially in the intermittent "Dolomite Sea" environment, microbial dolomitization promoted the massive development of microbial dolomite mound/shoal frameworks, constituting the matrix for the development of large-scale microbialite reservoirs. During the later burial evolution process, oil and gas generated from the Doushantuo Formation microbial source rocks migrated along faults and accumulated into the overlying Dengying Formation microbialite reservoirs, and was sealed by the Lower Cambrian mudstone caprocks, thus forming an effective microbial source-reservoir assemblage system. The areas surrounding the Mianyang, west side of the Chengkou, and northwest side of the western Hubei troughs are considered as favorable areas for the microbial source-reservoir system. The black shales of the Mesoproterozoic Xiamaling Formation and the overlying microbial stromatolites in North China, and the source rocks of the Ara Group and the overlying microbialites in the Salt Basin of South Oman also constitute a similar potential effective microbial source-reservoir system.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-3: Sedimentary mineral deposits in the deep ocean: Mineralization, genetic models, and environmental issues
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Terminal Ediacaran Microbial Carbonates in a High-frequency Sequence Stratigraphic Framework — A Case Study of the 4th Member of Dengying Formation, Central Sichuan Basin, SW China

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Keywords: Terminal Ediacaran, fourth-order depositional sequence, thrombolite, stromatolite, depositional environment

Objectives

Because of their significance in earth's biological and environment co-evolution and reservoir potential, the terminal Ediacaran shallow marine microbial carbonates have been paid great attention in sedimentological research as well as oil and gas exploration. Current study is largely focused on the general depositional environment and paleooceanography of the microbial carbonates, while the lithofacies association and environmental transition during higher-frequency sea level fluctuation deserve further investigation. A series of wells from the 4th member of Dengying Formation in Gaoshiti-Moxi area, Sichuan Basin, SW China enables us to conduct research on terminal Ediacaran microbial carbonate lithofacies and related environmental characteristics and evaluate their reservoir potential within a fourth-order depositional sequence.

Methods and Procedures

1 Through detailed core and thin section observation, the lithology and lithofacies association modes of microbial carbonates and non-microbial carbonates are identified.

2Combining the lithofacies characteristics with logging data interpretation, we divide fourth-order depostional sequences of the 4th Member of Dengying Formation and conclude the lithofacies distribution in a fourth-order sequence. The spatial lithofaices association modes in the study area are also compared.

3According to lithofacies distribution, typical samples are selected to conduct in-situ trace elements analysis to explore the corresponding environmental features. Trace element content, ratio and REE+Y normalized patterns are applied to characterize salinity and redox variation in during the fourth-order sea level change.

4Combining the lithofacies and environmental characteristics, we establish a depositonal and environmental model during fourth-order sea-level fluctuations for terminal Ediacaran microbial carbonates of the study area. Additionally, by matching the collected porosity and permeability of with typical lithofacies associations, the reservoir potential of the typical lithofacies associations are summarized.

Results and Conclusions

(1) Clotted thrombolite, planar thrombolite and wavy stromatolite are three types of microbial carbonates in the 4th member of the Dengying Formation in Gaoshiti-Moxi area, Sichuan Basin. The microbial carbonates and non-microbial carbonates (mainly including mudstone and grainstone) were developed on a carbonate platform in a shallow subtidal - intertidal environment during terminal Ediacaran.

(2) In a fourth-order depositional sequence, during late TST - early HST, thin-layered mudstone - clotted thrombolite association dominates the platform margin, while thin-layered mudstone - wavy stromatolite association dominates the platform interior. From late HST of the last sequence to early TST of the next, the platform margin develops thick-layered clotted thrombolite - grainstone association, while the carbonate interior develops thin-layered planar thrombolite - wavy stromatolite association.

(3) Variation occurs in salinity and redox during fourth-order sea level change. Specifically, during late HST, the platform margin is characterized by low-salinity and with high less reduced environment, where clotted

thrombolites dominate. The platform interior develops several high-salinity and more reduced areas, where planar thrombolites and wavy stromatolites dominate. Overall, the carbonate platform became more oxygenated during terminal Ediacaran.

(4) In a fourth-order depositional sequence during terminal Ediacaran, the late HST platform margin clotted thrombolite - grainstone association and platform interior planar thrombolite - wavy stromatolite association contribute the most reservoir potential. late TST - early HST microbial carbonates deserve further study for potential favorable reservoirs.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-3: Sedimentary mineral deposits in the deep ocean: Mineralization, genetic models, and environmental issues
Presentation Preference: Oral Preferred

Petroleum geological conditions and exploration direction of Neoproterozoic in Tarim Basin

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Keywords: tectono-sedimentary sequence, petroleum system, Exploration direction, Neoproterozoic, Tarim Basin

The investigation shows that the Neoproterozoic to Early Cambrian source rocks are widely distributed in the world, forming many large oil and gas fields. On the Precambrian basement, the Neoproterozoic Cryogenian-Ediacaran tectono-sedimentary layers are widely developed in the Tarim Basin. After rifting-depression evolution, a huge thickness of moraine-shelf slop-shore and carbonate platform sedimentary system is formed, accompanied by the multiple-phase igneous facies. The early deep water shelf facies and late carbonate platform facies can form high-quality ancient source rocks and reservoirs and form a good combination of source, reservoir and cap rocks with the mudstones and shales distributed widely in the early Cambrian shelf facies. According to the comprehensive evaluation of basin evolution and petroleum geological conditions, well LT1, LT3 and TS5 in the structural high of Tabei Uplift encountered good oil and gas shows in the Ediacaran System. The Ediacaran Qigebrak Formation and Lower Cambrian Yuertusi Formation form a good reservoir-cap assemblies in northeast part of ancient Tabei uplift. In the eastern part of the area Cryogenian System Aulacogen is developed, which may be able to form two types of reservoirs. The high part of platform in the reef-shoal facies belt of platform margin and the slope area is a favorable exploration area and targets.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-3: Sedimentary mineral deposits in the deep ocean: Mineralization, genetic models, and environmental issues
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Genesis of various ooids in the Qigebulake formation of the Upper Sinian of Neoproterozoic in northern Tarim

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Keywords: various ooids, nucleation via microbial mineralization,storm turbulencediagenetic alterationQigebulake formation in Upper Sinian

Ooid in carbonate rocks is one of the important carriers to reconstruct the ancient depositional environment. The co-occurrence of various ooids have been found in the microbial mat and shoal bar of lagoon, Qigebulake formation in Upper Sinian at Xinghuo 1 well area, northern Tarim Basin. Ooids can be divided into 12 sub-types, including bacteria (algae) complex ooids, thin-skinned heteromorphic micritic giant ooids , thin-skinned micritic giant ooids , cerebroid ooids, coniatoid ooids (oval to irregular large) , radial-cerebroid giant complex ooids, broken and regenerated thin-skinned eccentric complex ooids, selective dolomitization ooids, radial micritic (envelope) ooids, concentric radial ooids, spiny radial-concentric ooids, recrystallization ooids, in which the bacterial (algae) complex ooids , micritic giant ooids, spiny radial-concentric ooids are dominated. This paper elaborates the structure of the cortex and core, as well as cement, matrix and formation condition of the above ooids, and discusses the effects of nucleation induced by microbial mediation, tidal-current or storm surges in a warm, alkaline saline lagoons environment and diagenetic overprint on their symbiosis and evolution. The nucleation via microbial mineralization occurs extensively. The tidal current and the storm turbulence caused aragonite- and organic matter-riched micrite limestone which precipitated in low-energy and anoxia bottom water to tear, roll or grind into debris, and further promoted the formation of large and giant micritic ooids and other associated ooids. Marine cementation, metabolic activities (colonization), meteoric water dissolution, quasi contemporaneous dolomitization of the aragonite or high-Mg calcite are widely developed in the aragonite sea through accretion processes and diagenetic reformation, which play an important role in the formation and evolution of ooids. Therefore, the main factors controlling the origins of multiple types of ooids are nucleation induced by microbial mediation or biofilm calcification, the suspension and accretion process under certain marine hydrodynamic conditions, and a variety of diagenetic alteration. Moreover, mold pores, intergranular (intragranular) solution pores, intergranular pores and organic micropores presented in the above ooids have certain reservoir significances for the petroleum explore.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-3: Sedimentary mineral deposits in the deep ocean: Mineralization, genetic models, and environmental issues
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Source environment and hydrocarbon source quality during Ediacaran - Cambrian transition period: A case study of Qinglinkou outcrop in Zigui, western Hubei, China

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Keywords: Ediacaran - Cambrian, Qinglinkou outcrop, Hydrocarbon-Forming Organism, mineral assemblage, sedimentary environment

The paleomarine environment and biomes changed significantly during the Ediacaran-Cambrian transition period. Varied studies have been carried out on environmental evolution, biometric identification, accurate correlation of stratigraphic chronology, palaeogeographic pattern and development environment of source rocks. However, the controlling factors of sedimentary environment evolution on the development of source rocks during the E-C transition period remains to be systematically studied. In this paper, the Qinglinkou outcrop in Zigui, which continuously exposes the lower Ediacaran-Lower Cambrian strata in the Middle Yangtze region, is selected. On the basis of field observation and sedimentary facies analysis, combined with microscopic section analysis, X-ray diffraction, SEM and other experimental methods, the relationship between sedimentary environment changes and source rock quality of Doushantuo Formation in the Upper Ediacaran- Yanjiahe Formation of the Lower Cambrian was studied systematically. The results show that the content of clay is less than 30% in all source rocks, the content of carbonate (mainly dolomite) is more than 40%, and the Doushantuo formation and the Yanjiahe Formation both show a high level of silicon content. The organic carbon content of source rocks is positively correlated with the silicon content, but when the silicon content exceeds 70%, it reverses, showing a Parabolic pattern which deviating to the right. The hydrocarbon-forming organisms of Doushantuo Fm., Dengying Fm. and Yanjiahe Fm. were found to contain planktonic algae, benthic algae, radiolarians and acritarchs. In the source rock of Doushantuo Fm., there are a large number of characteristic large spiny acritarchs, which can be found only in the lower member of Dengying Fm. Large spiny acritarchs disappear completely in the Lower Cambrian in this outcrop. The vertical variation of sedimentary environment in Qinglinkou area was analyzed based on the characteristics of hydrocarbon forming organism assemblages and mineral assemblage in different layers, indicating that the sedimentary environments contains shallow water shelf, tidal flat, deep water shelf and open platform developed successively from bottom to top. The internal relationship between the sedimentary environment and the quality of source rocks is also discussed tentatively based on this research.

Scientific Themes: Theme 9. Resource Sedimentology
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Seabed mineral deposits as a sustainable resource for rare earth elements

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Keywords: crusts, nodules, placer deposits, rare earth elements, seafloor minerals, sustainable blue economy.

By 2050, the global economy and population are expected to grow significantly, requiring more food, energy, and raw materials that will put great pressure on the environment. To limit global warming and the climate crisis, modern society is focusing on “net-zero emissions” targets based on the use of clean-energy technologies, which will require new sources of rare earth elements (REEs) and other E-metals. Promising new sources for these essential REEs are seafloor minerals, especially ferromanganese crusts (crusts), polymetallic nodules (nodules), phosphorite, and placer deposits [1].

The Clarion Clipperton fracture zone (CCZ) in the northeast Pacific Ocean was the first extensive nodule field discovered, followed by crusts rich in cobalt on seamounts in the Pacific Ocean. Thirty International Seabed Authority contractors signed 15-year contracts for the exploration of nodules, crusts, and polymetallic sulphides in the international seabed area of the Atlantic, Pacific, and Indian oceans [2].

The most extensive nodule fields occur in the CCZ, the Penrhyn Basin (South Pacific), Peru Basin, Central Indian Ocean basin, and NW Pacific. REE-rich deep-sea muds occur in many places in the Pacific Ocean and have been well studied near Minamitorishima Island in the western North Pacific Ocean [3]. Potential targets for crust exploration occur in the NW equatorial Pacific Prime Crust Zone, the NE Atlantic, Arctic and Indian oceans [4, 5, 6].

The major concern associated with deep-sea mining is the extent and nature of environmental impacts. Mining strategies should incorporate activities to support the restoration of disturbed ecosystems, like the setting of un-mined biological corridors, larval dispersal routes, and the positioning of artificial substrates in the case of nodules [7]. Collecting biological baseline data and further progress in restoration science, technology, and training will reduce the potential ecological impacts of REE mining.

Placer deposits composed of heavy and weathering-resistant minerals are distributed in numerous sites along continental shelves. Potential areas for exploitation of REE-rich placer deposits occur along the SE coast of Madagascar, on beaches and offshore China, coastal areas of India, at Aksu Diamas in Turkey, Atlantic coasts of Galicia in Spain and the Nea Peramos shallow-marine environment in Greece [8]. High concentrations of thorium and uranium make monazite a restricted ‘atomic’ mineral for the exploration of many beach placers.

Seabed mineral resources have relatively low TREO grades and significant TREO yields compared to the large terrestrial LREE-rich carbonatite-hosted deposits and are comparable to the terrestrial HREE-rich ion-adsorption clay deposits. These marine deposits offer a promising alternative to the land-based REE-rich deposits even though extracting minerals from the deep ocean presents a technological challenge. However, two advantages of the deep-ocean deposits are their polymetallic nature, and the relative ease of extracting the REEs from the ore compared to the complex processing of carbonatites for their REE content.

The achievement of the Sustainable Blue Economy objectives, where environmental protection and economic activities go hand in hand, demands the formal establishment of regulations and practices for ocean mining and the effective management and exploitation of deep-sea mineral resources.

Reference

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Session T9-3: Sedimentary mineral deposits in the deep ocean: Mineralization, genetic models, and environmental issues
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Enhanced Bottom Currents Promoted the Enrichment of Rare Earth Elements (REYs) in Pelagic Sediments from the Northwestern Pacific Ocean at ~11.5–9.5 Ma

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Keywords: Deep-sea REY-rich sediments, Bottom currents, Abyssal ventilation, Northwestern Pacific Ocean

Pelagic sediments enriched in rare earth elements (REY) widely distributed in the Pacific Ocean (e.g., Kato et al., 2011; Shi et al., 2021), which have gained extensive attention as economically valuable resources. However, the REY enrichment mechanisms in pelagic sediments remain controversial. An active bottom current and a low sedimentation accumulation rate (SAR) seem to be important for the formation of REY-rich sediment (e.g., Ohta et al., 2020; Bi et al., 2021; Shi et al., 2021), but related studies on such links are still lacking, partly related to the difficulty in obtaining reliable geochronology for the slowly accumulating, essentially carbonate-free sediments. Here, we present refined chronostratigraphic framework for a sediment core taken from the pelagic environment of the western North Pacific Ocean combing authigenic $^{10}Be/^{9}Be$ dating, $^{230}Th_{ex}$ dating, and magnetostratigraphy. Furthermore, neodymium isotopic signal of the authigenic Fe–Mn oxyhydroxide fraction together with the Mn/Al and Mn/Ti ratios and grain sizes of bulk sediments, were used to reconstruct the variability of deep ocean currents. Multiple lines of evidences from Nd isotopic values, the Mn/Al and Mn/Ti ratios, and grain sizes consistently indicated that distinct enhancement of bottom currents occurred in the study area between 11.5 Ma and 9.5 Ma, presumably resulting in intensified deep-water ventilation. Our results thus established the link between enhanced bottom current and enrichment of REY in the pelagic sediments of the study area. We suggest that intensified abyssal ventilation and the associated increase in primary productivity around seamounts might increase the flux of micronodules and fish debris into the pelagic sediments, promoting the scavenge of REY from bottom seawater.

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Scientific Themes: Theme 9. Resource Sedimentology
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Presentation Preference: Oral Preferred

Studies on Specific Surface Area of Polymetallic Nodules: Pretreatment for Analysis and Control from Genesis

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Keywords: Polymetallic nodules, Specific surface area, hydrogenetic nodules

Polymetallic nodules (nodules) are predominant deep sea sedimentary mineral resources due to the enrichment of critical metals. Polymetallic nodules are loose and porous, which is the critical material feature that contributes the adsorption and then enrichment and mineralization of trace metals from seawater and pore water. Furthermore, this feature has potential to be utilized in industrial water disposal by adsorption. Therefore, specific surface area (SSA) is one of key factors deserved further study. At present, the technology and methods for analyzing SSA are well-developed. However, it is less applied in the analysis of the specific surface of polymetallic nodules, and the pretreatment conditions are various according to various research targets. Consequently, the researches on controls of SSA of nodules are still needs to be investigated. In order to achieve the SSA of nodules and to investigate controls, this study explored the pretreatment conditions for the BET SSA analysis of polymetallic nodules, and analyzed the mineralogy and geochemistry of nodules from various areas. The polymetallic nodules from the Atlantic, Indian, and Pacific oceans were recovered for this research. The pretreatment conditions including temperature, duration, and particle size for SSA analysis of polymetallic nodules were studies by applying temperature programming, heating accumulating, and particle size comparing methods. Mineralogical compositions of nodules were analyzed by XRD, and geochemical concentrations were determined by ICP-MS and ICP-OES. The results show that the analysis values of SSA reach plateau when the heating temperature is above 210℃ till 350 ℃; The analysis values of SSA keep consistent after heating for 3 hours by a step of 1 hour at 210℃. The SSA values of samples with a size of several millimeters are 1.027~28.535 m2/g higher compared with those of the same samples crushed into microns. The SSA of nodules correlated positively Co, δCe, and LREEs, and negatively with intensity of XRD 10Å peak, Ni, and Cu. The SSA of nodules from the western Pacific is 329.440~418.711 m2/g, comparable to the SSA of Co-rich crusts. We suggest that consistent SSA values can be obtained when the polymetallic nodules with sizes of several millimeters are heated in vacuum system for 3 hours at 210℃, which is the pretreatment condition to analyze SSA of polymetallic nodules for the research of the mineralization. We proposed that SSA of nodules is controlled by its genesis, and hydrogenetic nodules have higher SSA.

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Presentation Preference: Oral Preferred

Clay mineral distribution characteristics of surface sediments in the South Mid-Atlantic Ridge

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Keywords: Metalliferous Sediment (MS), South Mid-Atlantic Ridge (SMAR), clay mineral, smectite

Abstract: Clay minerals are usually considered as important indicators to identify sources in both terrigenous and marine sediments. In particular, clay minerals in metalliferous sediments (MS) have long been researched in global oceans except in South Mid-Atlantic Ridge (SMAR) due to few explorations arrived there before. Thus, thirty-two MS and thirty-four non-MS (NMS) were studied to shed light on the distribution characteristics and mineral compositions of clay minerals. All the sediments were collected along the SMAR between 10 °S and 27 °S. After removal of organic matter and carbonate, clay fractions (<2 μ m) were investigated by X-ray diffraction (XRD) analysis. The results show that clay mineral assemblages of surface MS consist dominantly of smectite, less abundant illite, chlorite and kaolinite, with average weight percentages of 30%,21%,18% and 16%, respectively. On the other hand, clay mineral assemblages in the NMS consist mainly of illite, less abundant kaolinite, chlorite and very scarce smectite, with the average weight percentages of 47%, 29%, 24% and 0.2%, respectively. The clay fraction in MS comprise amorphous or poorly crystallized Fe/Mn oxyhydroxides, clay mineral, quartz and plagioclase. However, the counterparts in the NMS are mainly composed of well crystallized clay minerals, quartz and plagioclase without the presence of Fe/Mn oxyhydroxides. It is suggested that most of the illite, kaolinite, and chlorite in both MS and NMS are likely belong to aeolian dust originated from South Africa continent. In addition, the abundance of kaolinite dominates the clay mineral assemblage at low latitudes, where the intensive chemical weathering of continental source rocks facilitate the formation of kaolinite. In terms of smectite, it is indicated of authigenic origin with consideration of only smectite is available in several MS and the very scarce in NMS. Moreover, the MS samples with only smectite available are always accompanied by goethite. Therefore, it is believed that most of smectite occurred in studied area is the results of interaction between hydrothermal Fe-oxyhydroxide, silica, and seawater.

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Geological setting and seafloor features of the Tongguan field discovered on the Southern Mid-Atlantic Ridge

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Keywords: Southern Mid-Atlantic Ridge, Tongguan field, new volcanic zone

Tongguan field is the southernmost field discovered in the SMAR to date. This field is located in a continuous new volcanic zone within a deep and wide rift valley. The ridge segment is approximately 380 km long and has developed a continuous rift valley with an average width of approximately 30 km. The Tongguan hydrothermal field is located in the rift valley which has a full spreading rate (based on the NUVEL-1 model) of 35.98 mm/yr (V-lat=-7.3 mm/yr, V-lon=-35.2 mm/yr) and is located at an azimuth of N258.3E (DeMets et al.,1990, http://www.ldeo.columbia.edu/ ~menke/plates.html). Meanwhile, two prominent pseudo-fault scarps have been identified on the non-transform offsets at both tips of this segment; such morphological characteristics suggest that along-axis propagation has occurred toward each tip.

The rift valley is characterized by a graben-like structure with an inner valley that is controlled by a series of normal bounding faults; at least three major steep normal fault walls were identified between each flank crest. The height of the rift valley walls, which corresponds to the average height of the two walls between the inner floor and the flank crests (Thibaud et al., 1998), is ~1000m. Meanwhile, the distance between the summits of the first steep walls on both sides is ~18 km. The symmetrical development of three steep walls on each rift valley wall, in conjunction with the presence of flanked abyssal hills that are parallel to the axis on both sides, reflects a symmetrically accreting ridge section. Furthermore, at the center of the inner floor of the rift, a continuous axial ridge rising to a height of 220 m above the inner floor is undergoing accretion.

Guided by the signature of the water temperature anomaly, we performed a surveying line using a towed deep-sea camera body. From this seafloor observation, we found that the new volcanic zone where the Tongguan field was located mainly comprised fresh pillow lava, along with some rifts/fissures that probably developed due to crustal cooling. No significant structural faults were seen, nor were large areas of rock breccia. The unique feature of the Tongguan field, which has a lateral extent of ~200 m, is that it directly overlies pillow lavas, and there is no significant transition zone between them. Through this surveying line, massive sulfide accumulations, altered sulfides, hydrothermal sediments and hydrothermal biota were identified; however, neither vents nor chimneys were observed. Massive sulfide accumulations, mainly comprising breccia deposits, extend for ~100 m through the surveying line, and they show lithological mutation contact relations with their surrounding rocks. A large area (~100 m) of hydrothermal yellowish-brown sediments was also observed along the surveying line; these sediments overlie sulfides, altered sulfides and pillow lavas, and they vary widely in thickness, generally becoming thinner moving away from the direction of the sulfides. Additionally, large populations of hydrothermal biota, particularly blind shrimp, were continuously observed in the water above the hydrothermal sediments and pillow lavas, thus implying that active hydrothermal venting is occurring nearby.

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Constraints on fluid evolution and growth processes of black smoker chimneys by pyrite geochemistry: A case study of the Tongguan hydrothermal field, South Mid-Atlantic Ridge

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Keywords: Pyrite, Trace element, Black smoker chimney, Tongguan hydrothermal field, South Mid-Atlantic Ridge

The Tongguan hydrothermal field is a modern submarine massive sulfide discovered on the South Mid-Atlantic Ridge. A well-preserved black smoker chimney was collected from the active vent field. Pyrite represents the most abundant sulfide phase, and amorphous silica is the dominant non-sulfide phase in the black smoker chimney. Sulfide phases are commonly rimmed by amorphous silica.

Based on the mineral associations and morphology, the black smoker chimney can be broadly divided into three different concentric zones from the outer wall to the axial hydrothermal flow conduit. The external outer wall of the chimney contains mainly pyrite with minor sphalerite, chalcopyrite and galena. The sulfides within the internal middle layer consist of predominant pyrite, with lesser amounts of marcasite. The axial conduit is dominated by chalcopyrite, with minor pyrite. Seven types of pyrite: framboidal, relict, colloform, dendritic, massive, euhedral and lined pyrites, are identified from exterior to interior of the chimney.

Previous studies have shown that framboidal and colloform pyrites are generally considered to form during the early stage of chimney growth, while massive and euhedral pyrites as well as massive chalcopyrite commonly precipitate during the mature stage of black smoker chimney growth indicating higher fluid temperatures and less fluid-seawater mixing during precipitation (Keith et al., 2016).

As shown by the results of LA-ICPMS, geochemical compositions of pyrite vary across the chimney. Generally, low-temperature elements (Mg, V, Mn, Pb, Zn, Ag and Tl) are enriched in pyrite in the outer wall of the chimney and decrease toward the interior zones. Elements indicative of high temperature conditions, such as Se and Te, show opposite trends and are enriched in pyrite within the inner zones of the chimney. Framboidal, relict, colloform and dendritic pyrites precipitate from low to mid temperature fluids, while massive and euhedral pyrites are products of ore-forming fluids characterized by mid to high temperature (Hannington et al., 2005). The observed patterns are resulted from the changes in temperature and fluid chemistry caused by interactions of between seawater and hydrothermal fluids with each other in the chimney.

Previous studies revealed that Co concentration in hydrothermal pyrite was largely dependent on its contents in parental fluids. Liu et al. (2011) proposed that a drop in temperature and/or a small drop in salinity could result in the decrease of stability of CoCl in low-saline fluids, leading to the precipitation of Co. During the formation of the black smoker chimney, the fluid temperatures increase from rim to core, while the Co concentration in pyrite decrease gradually, which can be explained by drop in salinity of the parental fluids. The extremely low Co contents in the pyrite in our study indicates that the hydrothermal fluids vented from the black smoker chimney are significantly depleted in Cl- compared to seawater, which is generally attributed to phase separation.

The systematic variations in geochemistry and morphology of the pyrite across the chimney reflect multiple stages of mineralization. Different degrees of fluid-seawater mixing and phase separation are the main controlling factors during the chimney formation.

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Metallogeny of Xunmei hydrothermal field (26°S), South Mid-Atlantic Ridge: Constraint from in-situ sulfur isotope of sulfides

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Keywords: Sulfur isotope, Xunmei hydrothermal field, South Mid-Atlantic Ridge

Demand for mineral raw materials is increasing as a result of population growth, rising living standards, urbanization and, more recently, the transition to a low-carbon economy (Zepf et al., 2014). Yet the mining industry faces numerous challenges including rising costs, reducing ore grades and declining discovery rates of new deposits (Calvo et al., 2016). As a result, alternative sources of these minerals are being considered, including the deep-ocean (Murton et al., 2019). Modern seafloor hydrothermal sulfides are rich in Cu, Pb, Zn, Au, Ag, Co, etc. which show good prospecting potential, important economic values and strategic significance. More than ten submarine hydrothermal fields were discovered in South Mid-Atlantic Ridge (SMAR) by China. Up to now, Xunmei (26°S) is one of largest hydrothermal fields in SMAR. In order to tracing the metallogenetic process, *in-situ* sulfur isotopes of 118 spots/minerals (pyrite, chalcopyrite, sphalerite) from 8 sulfide samples, including 3 well-preserved sulfide chimneys, 3 massive sulfides and 2 disseminated sulfides, were ananlysed by laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS). The results exhibit a range of $\delta^{34}S$ values from 2.1 to 8.2‰ (mostly range from 4 to 5‰), with an average value of 4.4‰ (n = 118), falling between the $\delta^{34}S$ values for basalt ($\delta^{34}S = +0.3 \pm 0.5$‰) and seawater ($\delta^{34}S = +20.99$‰), and within overall range of $\delta^{34}S$ values for sulfide samples from other seafloor hydrothermal field (from 1 to 9‰; n = 1841). Pyrites from one of the typical sulfide chimney sample display a relatively large variation in $\delta^{34}S$ values (2.98.2‰, average = 4.3‰, n=26), while chalcopyrites show narrow variation (4.65.1‰, average = 4.5‰, n=21). Variation of sphalerite (4.06.0‰, average = 4.6‰, n=17) are between pyrites and chalcopyrites. This phenomenon is consistent with the distribution of sulfide minerals, of which pyrites commonly occur from low to moderate to high temperature stage, chalcopyrite mainly growth in high temperature stage, sphalerite mainly deposited at (low to) medium (to high) temperature stage. Therefore, the variations of $\delta^{34}S$ value are similar to the temperature ranges of sulfide mineral from the Xunmei hydrothermal field. Two component mixing model was utilized to reveal the contribution of reduced seawater sulfate and basalt (Ono et al., 2007). We can estimate the varying proportions of sulfur derived from seawater in the sulfide chimney, massive sulfide, and disseminated sulfide (1238%, 927%, and 1119%, respectively) and from basalt (6288%, 7391%, and 8189%, respectively), indicating the source of sulfur is mainly derived from magma with little contribution from seawater.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-3: Sedimentary mineral deposits in the deep ocean: Mineralization, genetic models, and environmental issues
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

The extremely enrichment mechanism of REY for REY-rich sediments from Central Indian Ocean Basin

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Keywords: REY-rich sediments, Early diagenesis, Formation models, Central Indian Ocean Basin, Antarctic bottom water

Rare earth element and yttrium (REY)-rich deep-sea sediments are recently discovered potential undersea rare earth element (REE) resources. Here, we present the results of the mineralogical and geochemical characterization of REY-rich sediments collected from the Central Indian Ocean Basin (CIOB). These data were used to discuss the formation mechanism of REY-rich sediments. The research results show that the REY-rich sediments distributed in the CIOB mainly consist of phillipsite-bearing pelagic clay and pelagic clay, and are characterized by enrichments in middle REEs (MREEs) and heavy REEs (HREEs), negative Ce anomalies and positive Y anomalies. The REY in these sediments are mainly captured dirtcely from overlying seawater by bioapatite and micronodules at the water-sediment interface. After burial, driven by the redox reaction between organic matter and an oxidizer (free O2 and Mn and Fe oxides), the REY-rich sediments experienced weak early diagenesis, and the REY released from hydrogenetic micronodules were captured by the bioapatite (the final host mineral). The REY absorbing mechanism of bioapatite suggest that the post-mortem bioapatites need a long time to keep in touch with seawater, so the low sedimentation rate is the basic condition for the formation of REY-rich sediments. In the low sedimentation rate deep-sea basin (below the sedimentation rate threshold: about 1.5mm/ka), the variation of AABW could affected the contents of REY in REY-rich sediments by controlling the contents of bioapatite.

Scientific Themes: Theme 9. Resource Sedimentology
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Mineralogical and geochemical characteristics of near-vent metalliferous sediments along the southern Mid-Atlantic Ridge (12°S–28°S)

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Keywords: Metalliferous sediments, Southern Mid-Atlantic Ridge (12°S–28°S), Mineralogy, Rare earth elements, Hydrothermal mineralization

Mineral and geochemical compositions of surface sediments at 50 sites collected from six hydrothermal fields along the southern Mid-Atlantic Ridge (SMAR) 12°S–28°S were analyzed. The study area can be divided into two segments with Zouyu, Taij, Caifan, and Deyin hydrothermal fields in the northern segment and Xunmei, Tongguan hydrothermal fields in the southern segment. Mineral composition shows that MS in the southern segment contain large amounts of metallic minerals. The features of the sulfides show that a stable high temperature mineralization environment in the Xunmei field and an unstable ore-forming environment in the Tongguan field. Major and trace element geochemistry indicates that hydrothermal materials, terrestrial and volcanic materials are the major sources in these sediments along the SMAR. Rare earth element geochemistry shows that the sulfide-rich MS (metalliferous sediments) have a similar sulfide composition. However, some sulfide-rich MS samples in the Xunmei field show clear positive Eu anomalies, indicating that the rare earth elements (REEs) concentrations in these samples are derived directly from the hydrothermal fluids with high temperature. The other sulfide-rich MS samples in the Xunmei and Tongguan field show nearly "flat" REE patterns with an absence of Eu anomalies. The change in conditions including decreased temperature and increased fO2 when the sulfides precipitate from the hydrothermal fluids can be used to explain the absent Eu anomalies. The Si-Fe-Mn oxide-rich MS have positive Eu anomalies, which also indicate that these oxides are derived from hydrothermal fluids with high temperature. When the oxides precipitate, although the temperature and composition may change, the low-temperature fluids still produce the REE patterns of the high-temperature endmember black smoker fluid and exhibit a clear positive Eu anomalies. The chlorite-rich MS show nearly “flat” REE patterns similar to the volcanic material-rich sample and MORB, which reflects the origin of the hydrothermal alteration of volcanic materials. In the southern segment of SMAR, the geochemical and mineralogical characteristics indicate that the MS are mainly derived from the collapse of sulfide and Si-Fe-Mn chimneys. In the northern segment, most of the MS are derived from plume fall-out particles that have been in contact with large volumes of seawater. In addition, the chlorite-rich MS in the Taiji field are derived from hydrothermal alteration.

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Significance of chronology for exploration and evaluation of hydrothermal sulfides on Mid-Atlantic Ridge

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Keywords: hydrothermal sulfide, chronology, mid-ocean ridge, Atlantic ridge, sulfide deposit, mineral resources

The Mid-Atlantic ridge(MAR) is the most potential area for modern seafloor sulfides mineral resource. Since 2009, COMRA has carried out a series of hydrothermal activity survey cruises in the South Atlantic, and 10 hydrothermal sites have been found there. By far, more than 100 hydrothermal sites have been found on MAR. Among these hydrothermal points, which have more resource prospects has always been a question explored by ore deposit scientists. Cherkshov (2017) proposed that the geochronology of sulfide deposits in ultramafic environment has a positive correlation with the outcrop area, which has certain significance for resource potential. However, the resource potential of sulfide deposits in basaltic environment cannot be judged. In this study, we firstly analyzes the geological controlling factors of hydrothermal systems on MAR, and divides them into four geological controlling types: detachment fault-related type, high dip normal fault-related type on the valley wall, dot magmatic dome-related type in the axis rift and linear magmatic neovolcanic ridge-related type in the axis rift. On this basis, the exposure characteristics and U-Th chronological characteristics of different types of the hydrothermal sulfide deposits are studied. The results show that:

The longer the maximum cumulative metallogenic time of the detachment fault-related deposits, the larger the outcrop area (e.g. pebeda-2). This is related to the fact that the heat source of this kind of hydrothermal system is directly under the OCC. Because most of these deposits are active, the exploration can mainly focus on the water column detection.

The older the high angle normal fault-related deposits on the valley wall, the smaller the outcrop area (e.g. Peterburgskoe). The mechanism for this relationship is related to the distance between the initial ore-forming position and the heat source which is under the ridge axis. The farther the initial ore-forming location, the smaller the heat source support, then is the worse the metallogenic sustainability and the smaller outcrop scale. Most of these deposits are inactive, so the exploration of these deposits can be dominated by electromagnetic method & geochemical exploration.

Dot magmatic dome-related deposits in the middle valley may have an unexpected outcrop scale(e.g. Xunmei hydrothermal field, which is located on 26°S MAR), while linear magmatism neovolcanic-related deposits generally have a very small size. This is mainly related to the stability of heat source and fault for the fluid passway. Most of these deposits are active, the water column anomaly may be the mainly objectives.

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Scientific Themes: Theme 9. Resource Sedimentology
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Electrical Structure of Seafloor Massive Sulfide Deposits in the South Mid-Atlantic Ridge Based on Marine Transient Electromagnetic Method

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Keywords: seafloor massive sulfide deposit, South Mid-Atlantic, transient electromagnetic method, resource assessment

The Mid-Atlantic Ridge is a typical slow spreading ridge, with great potential for the formation of seafloor massive sulfide deposits. At present, the international investigation and research on hydrothermal activities in the Mid-Atlantic Ridge is mainly concentrated in the North Mid-Atlantic Ridge, while the research on the South Mid-Atlantic Ridge is a few. In addition, the traditional methods mainly used can only detect the surface characteristics of the deposit, and its morphology, scale and occurrence state still need to be solved. Marine transient electromagnetic method (MTEM) has become one of the emerging methods for the detection and evaluation of seafloor massive sulfide deposits because of its sensitivity to shallow conductivity. In order to study the submarine hydrothermal system in the South Atlantic, China has carried out several cruises in the South Atlantic. We have conducted a transient electromagnetic survey in the South Atlantic Ridge during cruise DY52 segment 2, using a central loop method towed by a ship. The Occam method is used for inversion. The results show that the shallow resistivity of the survey area is low, while the deep resistivity is higher. The conductivity in the shallow is distributed along the line, while the deep resistivity varies unevenly. Between No. 840-880 and No. 1060-1080, there are two continuous low-resistance anomalies ranging from shallow to deep, and the corresponding secondary field response is relatively strong, which is speculated to be seafloor massive sulfide deposits. The seafloor massive sulfide deposit has a tubular shape, extending down about 30m. It proves that the marine transient electromagnetic method can be used to locate hydrothermal sulfide ore, delineate the scope of sulfide ore, study the spatial structure of sulfide ore, etc., and finally serve the evaluation of seafloor massive sulfide deposits.

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Scientific Themes: Theme 9. Resource Sedimentology
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Genesis of REY-rich deep-sea sediments in the Tiki Basin, eastern South Pacific Ocean: Evidence from geochemistry, mineralogy and isotope systematics

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Keywords: REY-rich sediment, Bioapatite fossi, Sedimentation rate, Tiki basin

Deep-sea sediments in the eastern South Pacific Ocean were recently found to contain high concentrations of rare-earth elements and yttrium (REY). To understand the genesis of REY enrichment in the sediments, we performed detailed element and isotope geochemical analyses on samples from gravity core S028GC23 recovered from the Tiki Basin in the eastern South Pacific Ocean.

The REY-rich sediments in core S028GC23 are dark-brown to black zeolite clays, with REY (∑REY) contents of 1136–2213 ppm (average of 1857 ppm). The ∑REY contents in the sediments are positively correlated with P2O5 and negatively correlated with Ce anomalies. The REY-rich sediments display obvious Ce depletion and positive Y anomalies in the post-Archean Australian shale (PAAS)-normalized REY diagrams. Bioapatite fossils contain the highest REY concentrations (average of 8921 ppm) among the constituents, indicating that they are the primary hosts of REY. The REY enter through the roots and diffuse to the tops in the bioapatite fossils. Fe–Mn micronodules are divided into two different types based on Ce and Y anomalies in the PAAS-normalized REY patterns, and they have average REY concentrations of 781 ppm and 937 ppm, respectively. The phillipsite has low REY contents (average of 106 ppm) and is associated with a low sedimentation rate. REY patterns and Sr-Nd isotopic signatures show that seawater was the main ore-forming fluids during the formation of REY-rich sediments. The average sedimentation rate of the sediments in the core (0-41 cm) obtained by the best fit exponential regression line based on 230Thex data versus depth profiles was 0.8 mm/Ka, which provided sufficient exposure time for co-precipitated materials to scavenge REY from seawater. The REY accumulation process can be explained by two-stage fluid-bioapatite fossil interactions and small contributions of Fe-Mn micronodules in an oxidized environment with slow sedimentation rate. The strong absorption capacities of bioapatite fossils, the two-stage of fluids effects, and the low sedimentation rate are the key factors in the formation of REY-rich sediments in the Tiki Basin.

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Presentation Preference: Oral Preferred

Formation mechanism of ocean anoxic environments driven by global ocean current circulation

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Keywords: Anoxic environments, Dissolved oxygen, Temperature gradients, Current circulation, Transport dynamics, Global ocean

It is of great significance to understand the distribution of ocean anoxic environments and its formation mechanism for predicting organic carbon and other mineral enrichment in ocean sediment. Nowdays, there has been only formed a conceptual model of global ocean current circulation, since few data are available on the global ocean deep currents. Therefore, there is still a lack of sufficient ocean current data to reflect the replenishing detail of dissolved oxygen in deep ocean. In this study, the plane and profile concentrations of dissolved oxygen in the global oceans, have been found to match well with seawater temperature gradient, indicating that the later indirectly controls the supply and diffusion of dissolved oxygen by driving ocean current circulation. Meanwhile, the seafloor topographical tendency and the earth's rotation also have impacts on deep ocean currents. These can also be revealed by the diffusion paths of dissolved oxygen. This study might have further clarified the dynamics of global ocean deep currents, and uncovered the formation mechanism of ocean anoxic environments.

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Influence of Quaternary MTDs on hydrate system in Qiongdongnan Basin, South China Sea

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Keywords: Gas hydrate, mass transport deposits, Qiongdongnan Basin, global carbon cycle

The hydrate system discovered in recent years are spatially related to mass transport deposits (MTDs), which are common gravity flow deposits in deep-water basins on the continental margin(Brooks, 2020; Festa et al., 2018; León et al., 2019). However, the hydrate system affected by MTDs is still unconstrained. In this study, the analysis of integrated cores, well logs and seismic data were used to study the influence mechanism of MTDs on hydrate system. Results show that hydrates reduce sediment permeability and cause build-up of overpressure at the base of the gas hydrate stability zone. Resulting hydro-fracturing forms pathways for overpressured fluids to migrate upward (so-called pipe structures)(Elger et al., 2018). However, seismic data and logging data show that the pipeline structure terminates in the underlying strata of the MTDs. The MTDs have lower porosity and permeability and higher density than in-situ seafloor sediments, and MTDs compress and shear the underlying strata during transportation. The MTDs leads to the inversion of porosity gradient of underlying sediments, and prevents the further migration of overpressured natural gas. The capping effect of Quaternary MTDs on natural gas contributes to the formation of high saturation hydrate, and limits the escape of natural gas to the ocean and even the atmosphere, especially in the hydrate system with active fluid activity. Given the wide distribution of MTDs, we believe that the impact of MTDs on carbon release in the marine environment and the global carbon cycle is underestimated.

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Evaluation Method of Cobalt-rich Crusts Thickness in Seamount

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Keywords: ME Seamount, Cobalt-rich Crusts, Thickness, comprehensive assessment method

Seamount crusts are rich in cobalt resources and have attracted worldwide attention. The thickness of crusts is an important parameter for the resource assessment of cobalt-rich crusts in seamounts. There are two major problems in the evaluation of crust thickness. First, the most effective geological sampling method in seamount exploration is used to obtain data, which is expensive, sparse and insufficient. Second, the use of a single thickness assessment method, such as Inverse Distance Weighted (IDW) and Kriging statistical method, has its own advantages and disadvantages, which cannot make full use of their advantages to give the most appropriate assessment under the current exploration and research level, resulting in the estimation results cannot express the thickness distribution more precisely. For example, the most accurate thickness data can be obtained according to station survey, but due to limited conditions and sparse conditions, it is difficult to comprehensively estimate the thickness of the whole research area. The “Distance-Slope” Kriging interpolation method (Dewen Du,et al.,2017) estimates the crust thickness according to the terrain Slope and the Distance between stations, which provides a larger prediction range, however, in the case of insufficient stations, the estimation accuracy is limited, and the farther away from the known information point, the lower the accuracy is. According to the restrictive mechanism of Cobalt-rich crust deposition and mineralization (Dewen Du, et al., 2020), the expected value of thickness data of stations collected in different topographic classification features has statistical significance for the estimation of crust thickness in the study area, but the local specificity of crust distribution cannot be reflected, so it is suitable for use in large-scale studies. In this paper, the evaluation scheme of crust thickness is developed comprehensively based on several methods of station survey thickness, mathematical statistical calculation of crust thickness expectation of terrain classification, and Kriging interpolation statistics. Firstly, the station buffer method was used to calculate the crust thickness in the 1km area around the station, and then the Thiessen polygon method was used to calculate the crust thickness covering the whole research area according to the station position, and then the optimal crust thickness within 1km was estimated by combining the two methods. Secondly, the “Slope-Distance” Kriging interpolation method is used to calculate the estimation of the crust thickness in the study area, and the optimal crust thickness within the effective radius is given to make up for the gap in the previous estimation results. Thirdly, the mathematical expectation method mentioned above is used to estimate crust thickness of the remaining unassigned regional. This method has been applied to the evaluation of ME seamount crusts thickness and achieved good results. It shows that this method is suitable for the evaluation of seamount crusts thickness under the condition of incomplete investigation.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-3: Sedimentary mineral deposits in the deep ocean: Mineralization, genetic models, and environmental issues
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

A location and correction method of near-bottom camera data in volcanogenic massive sulphide ore deposits surveys

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Keywords: volcanogenic massive sulphide ore deposits, near-bottom camera, topographic profile matching, location and correction method

The submarine camera system is one of the most effective detection methods for the detection of volcanogenic massive sulphide ore deposits. The positioning of camera equipment is generally achieved by ultra-short baseline(USBL) positioning systems. Affected by the dynamic changes in the marine environment and the loss of acoustic signals, there are a large number of abnormal points in the USBL positioning data. The existing technical means cannot perform positioning correction for USBL positioning data with a large number of scattered abnormal points, which affects the accurate positioning of the camera data. In this paper, Dynamic Time Warping algorithm (DTW) is used to match the water depth profile of the camera to the high-precision terrain profile in the target area to solve this problem. Therefore, the location of the topographic profile with the greatest similarity to the camera's water depth profile can realize the positioning correction of the camera data, which is convenient to find the exact location of the volcanogenic massive sulphide ore deposits. The experimental research area of this paper is located in the Xunmei hydrothermal field, Southern Atlantic Ridge. In the near-bottom survey operation in this area, the Submarine camera is used to carry out the near-bottom tow-type operation. At the same time, the submarine camera is bound with a pressure sensor, so we can obtain a high-precision water depth profile of the camera. Using the seabed high-precision terrain data with a resolution of 1m * 1m obtained by the "Qianlong No.3" Autonomous Underwater Vehicle (AUV), by matching the water depth profile of the camera with the profiles extracted from the high-precision terrain data, we can finally find the location of the terrain profile that is the most similar to the water depth profile of the camera, to locate and correct the location and data of the submarine camera. Based on the Python language and ArcGIS technical environment, this paper extracts a total of 97469 topographic profiles in the target area, matches a terrain profile with a similarity of 95.9% to the water depth profile of the camera in the target area, and proves the reliability of the positioning correction results was verified through the record report of this voyage. The test results of the algorithm application show that this algorithm is fast and effective, and can solve the problem of the inability to accurately locate the underwater detection equipment when the USBL data is abnormal. It is expected to provide services for the accurate positioning of the underwater equipment in the international seabed resources survey.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-3: Sedimentary mineral deposits in the deep ocean: Mineralization, genetic models, and environmental issues
Presentation Preference: Oral Preferred

The role of clay minerals in enriching rare earth elements (REYs) in deep-sea sediments from the Wharton Basin, Indian Ocean

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Keywords: Rare-earth elements, enrichment mechanism, clay minerals, Wharton Basin

Recently, as the pelagic sediments enriched in rare-earth elements (REYs: including La-Lu and Y) being found in the Pacific and Indian oceans (Kato et al., 2011; Shi et al., 2021), the REYs in deep-sea sediments has been widely regarded as a potential mineral resource. However, their enrichment mechanism remains uncertain, and the role of clay minerals was remains controversial. In this study, we selected one sediment core (core S035GC26, 258 cm in length) obtained at a water depth of 4307 m in the Wharton basin of the Indian Ocean. The major and trace elements and clay minerals compositions of the bulk sediments and the clay components (< 2 μm) were analyzed, and the role of clay minerals played in the enrichment process of REYs was furthermore assessed.

The total concentration of REYs (∑REY) in the deep-sea sediments of core S035GC26 ranged from 86.1 ppm to 1036.8 ppm, with an average of 717.4 ppm. The good positive correlations between REY and Al_2O_3 (R^2=0.97) and between $REY_{bulk\text{-}sediment}$ and REY_{clay} (R^2=0.56) indicate that the enrichment of REYs in these deep-sea sediments is related to clay components. Our results show that montmorillonite and illite are the main clay minerals in these sediments, followed by chlorite and kaolinite. The ∑REY of these sediments gradually increase with the increase of montmorillonite content. Piper (1974) believed that the montmorillonite in deep-sea sediments played a positive role in the enrichment of REYs. Previous studies have confirmed that REYs are mainly hosted in bioapatite and micronodule, clay minerals are not the main REY-host minerals in deep-sea sediments (Yu et al., 2021; Zhou et al., 2021; Bi et al., 2021). However, the clay minerals may as a kind of "pre-carrier" in the enrichment process of REYs, due to their strong adsorption capacity. We speculate that the clay minerals may adsorbed the REYs in seawater at first, then the adsorbed REYs were released and transferred into the final REY-host minerals (e.g., bioapatite and micronodule) during the diagenetic process, although further studies are needed.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-3: Sedimentary mineral deposits in the deep ocean: Mineralization, genetic models, and environmental issues
Presentation Preference: Oral Preferred

SEM and coupled systems: A powerful tool to characterize REE minerals

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Keywords: REE mineral, Scanning Electron Microscopy, Energy Dispersive X-ray Spectrometer, microstructure and micromorphology, chemical composition, crystal structure

Scanning Electron Microscopy (SEM) and related analyses are particularly suited to the complexity and very fine grained nature of the rare earth element (REE) mineral assemblages.

1. Microscopic morphological characteristics

Imaging with secondary electrons provides information about morphology and surface topography of REE minerals, especially of those tiny particles, which are difficulty to characterize under ordinary optical microscope. Results from this analysis include micro-inclusions, growth rings, exsolution structures, reactive boundaries, metasomatic textures, alteration edges, etc., reflect the environments and conditions of REE mineral formation and transformation.

2. Rare earth elements mineral phases

Back-scattered electron imaging quickly groups the REE minerals and non- REE minerals, and gives out the shape, size, location, and distribution of REE minerals, also relative content under a corresponding image analysis software, thus, REE-bearing situations, such as main mineral form, REE mineral assemblages, close associations, growing matrix, host complexes, filling constituents, precipitation periods, etc., are exhibited in details.

3. Elements distribution patterns

X-ray Energy Dispersive Spectrometer (EDS) mounted on the SEM is a useful method to assess the chemical composition of minerals. There are three ways of EDS analysis: point spectrum, line scanning and area mapping, provide effective solutions for relative elemental contents in or between particles, then direct the different stages of REE mineralization and segregation degrees of ore-forming fluid according to the abundance variation.

4. Crystal structure parameters

Electron Back-Scattered Diffraction(EBSD) or Cathodoluminescence (CL) in the SEM can be used to obtain crystallographic data of REE minerals, with which we can learn the mineral internal structures, lattice defects and impurity contents, deduce the physical chemistry environment conditions when the lattices were formed, and establish genetic relations between REE minerals and their sources and the types of hosting deposits.

5. Automated identification and characterization

Configured with automated quantitative software such as MLA, TIMA, AMICS, BPMA, SEM can finish the scan and analysis of samples automatically, quickly show the mineral composition and content, particle size, dissociation, particle morphology, embedding levels, and other structural characteristics of REE minerals, indicate the occurrences, developments, associations, aggregations and alterations of them.

In a word, the SEM and combined analyses provide important evidences to test, support, and constrain various theories and processes proposed for the origin of the REE mineralization in the earth.

Scientific Themes: Theme 9. Resource Sedimentology
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Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Sediment Fe/Mn: An Effective Parameter of REY Enrichment in Deep-sea Sediments of Western North Pacific Ocean

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Keywords: deep-sea sediment, REY resource, parameter

As a great-potential rare earth elements (REY) resource, deep-sea sediments have attracted extensive attention. Component of deep-sea sediment is complex, including authigenic minerals, terrigenous detrital and volcanic materials. Authigenic bioapatite and Fe-Mn micronodules are the REY hosts in deep-sea sediments. Finding effective parameters to distinguishing them from the other components is critical for revealing mechanism of REY enrichment in deep-sea sediment. To search parameters of REY enrichment, we recompiled the published data of deep-sea sediments surrounding Minamitorishima Island in western North Pacific Ocean. We find that Fe/Mn ratios of sediments show good performance in indicating sediment REY enrichment. In the diagram of REY vs. Fe/Mn, REY contents of deep-sea sediments are higher than 500 ppm in the range of Fe/Mn < 5.0; by contrast, if Fe/Mn ratios are greater than 5.0, REY contents are rarely higher than 600 ppm. According to simulation with different endmembers, the results suggest that Fe-Mn micronodules control the sediment Fe/Mn. The simulation also shows that in the range of sediment REY contents < 3000 ppm, less than 20% of bioapatite are in the deep-sea sediments; while, more than 50% of bioapatite can exist in the deep-sea sediment when the bulk REY contents are extremely high, > 8000 ppm. Thus, the Fe/Mn ratio is an effective parameter in indicating the REY enrichment of the deep-sea sediment and may have potential in studying the enrichment mechanism.

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Scientific Themes: Theme 9. Resource Sedimentology
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Presentation Preference: Oral Preferred

Deep-sea REY resource: global distribution, metallogenesis, and exploitation perspective

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Keywords: deep-sea REY-rich resource, metallogenic belts, metallogenesis, exploitation perspective

In recent years, the REY-rich (rare earth elements (REE) and Yttrium (Y)) sediment discovered in the deep-sea is a new type of marine mineral resources, which is characterized by considerably higher concentrations of middle and heavy rare-earth elements. The quantity of deep-sea REY resource is far more than the land reserves, which makes it highly important as a potential resource for future usage. Since 2011, large areas of REY-rich sediments have been discovered by Chinese scientists in the central India Basin, the southeastern and western Pacific Basins. Overall, four metallogenic belts are preliminarily identified in the Open Ocean: the western Pacific Ocean metallogenic belt, the central and eastern Pacific Ocean metallogenic belt, the southeastern Pacific Ocean metallogenic belt, and the central Indian Ocean-Wharton basin metallogenic belt. The REY-rich sediments are mainly zeolite clay and pelagic clay developed in the deep-sea basin, which is autogenetic, and some of them are developed near the mid-ocean ridge and affected by the hydrothermal processes. The research shows that bioapatite is the most important host phase of REY in the deep-sea sediments, which takes up the REY from ambient seawater and porewater. The REY is transferred from its original binding phase and eventually redistributed into the bioapatite. It is suggested that the deep (beneath the Carbonate Compensation Depth) water depth, low sedimentation rate, and strong bottom currents are principal controlling factors leading to large-scale enrichment of the REY in deep-sea sediments. Considering the similar water depth and ecological environment during mining, deep-sea REY-rich sediments would be mined together with polymetallic nodules as the first commercially-exploited deep sea minerals.

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Scientific Themes: Theme 9. Resource Sedimentology
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Presentation Preference: Oral Preferred

International Legal Regime for the Mining in the International Seabed Area

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Keywords: the Area, Deep Seabed Mining Regime, International Seabed Authority

The discovery of strategic metals (such as cobalt) and metals used in clean energy infrastructure and technologies in the deep seabed (such as manganese, nickel and copper) has led to a surge of interest in mining in the area in the past decade. Unlike mineral resources on land or nearshore that are under the control of a State, mineral resources in the international seabed area (the Area) are designated as the common heritage of mankind, which means no State may claim or exercise sovereignty or sovereign rights over the Area or its resources which are vested in mankind as a whole and the rights of those resources may not be alienated. That being said, marine scientific research and exploration or exploitation of the mineral resources in the Area are subject to international law, inter alia, the United Nations Convention on the Law of the Sea (UNCLOS). UNCLOS establishes a comprehensive and complicated regime for activities in the Area and an international organization, namely, the International Seabed Authority (ISA), to control and manage activities in the Area on behalf of human beings as a whole. There exists a threshold of financial, technological, and environmental capabilities of the applicants accessing to mineral resources in the Area. Persons and entities who are willing to conduct activities in the Area must be assessed by the ISA. After getting permission from the ISA, persons and entities are legally allowed to do so. Moreover, the UNCLOS stipulates an array of obligations for the operators of different activities, breaches of which may incur individual liability, and even state responsibility. This lecture aims to provide a whole picture of the deep seabed mining regime and introduce the requirements, obligations, and liabilities for activities in the Area.

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Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

In situ geochemical characteristics in the microlayers of the polymetallic nodules from the Clarion-Clipperton Zone (CCZ) in the Eastern Pacific Ocean: implication for its genetic types

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Keywords: Polymetallic nodules, Microlayers, Genetic type, In situ geochemical analysis, East Pacific Ocean

Polymetallic nodules enriched in metals of economic interest (e.g., Mn, Co, Ni, and Cu) from the Clarion-Clipperton Zone (CCZ) in the Eastern Pacific Ocean is one of the most important potential mineral resources on the seabed. We present in-situ elements distribution and correlation in microlayers of polymetallic nodules using X-ray diffraction, electron microprobe, and laser ablation inductively coupled plasma mass spectrometry to clarify the genetic types and element enrichment mechanism of nodules. The results show that nodules are characterized by significant rhythmic microlayers varying different geochemical characteristics. The inner microlayers of the nodule are mainly composed of vernadite and present columnar and laminated microstructure and dense microlayers, which features high Fe and Co contents, low Mn/Fe values, and positive δCe anomaly. Whereas the outer microlayers are mainly composed of 10 Å manganese with dendritic microstructure and loose microlayers, which presents high Mn, Ni, Cu, and Mn/Fe values and negative δCe anomaly. According to Mn-Fe-(Ni+Cu+Co) × 10 triangle diagram and rare earth element covariance discrimination diagram, the inner microlayers of the nodules are of hydrogenic origin, while the outer microlayers are of diagenetic origin. Element correlation analysis shows that Mn phase minerals have a high capacity for Ni and Cu, but Fe would inhibit Ni and Cu enrichment. Both Mn and Fe phase minerals are enriched in Co.

The CCZ is located near the equator and its high level of surface biological productivity favors the decomposition of marine surface organisms and producing abundant metals for nodules growth. The Antarctic Bottom Water (AABW) that enriched oxygen and flows through the CCZ is likely to be the reason for the difference in the genetic types of the inner and outer microlayers of the nodule. The strong AABW creates an oxidation environment conducive to the formation and growth of nodule water, while the weak oxidation environment caused by the decline of AABW leads to the transformation of nodules into diagenetic growth. The Mn phase minerals adsorb Ni, Cu, and Co through surface electrostatic force, of which Ni and Cu are further substituted by Mn^{2+} ions. The combination of Fe and Mn phase minerals occupies a certain amount of negative charge, which inhibits the Ni and Cu enrichment, while Co^{3+} replaces part of Fe^{3+} in the Fe phase minerals. The "dark" mineral microlayers indicate that the specific internal microenvironment formed by the infiltration of seawater into the pores of nodules may lead to the secondary metasomatism of minerals in nodules.

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Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Material Source and Rare Earth Elements Enrichments of Sediments in the Northwest Pacific: Evidence from Clay Minerals and Sr-Nd Isotope Compositions

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Keywords: Northwest Pacific, deep-sea sediments, material source,sedimentary environment, REY enrichments

Recently lots of rare earth elements and yttrium (REY)-rich sediments were discovered in the sea area of Minamitorishima Island, Northwest Pacific. In order to understand the material source and REY enrichments of sediments in this area. Clay minerals and Sr-Nd isotopes analyses on gravity core GC1601 gained in the Southeast Sea area of Minamitorishima Island were performed. The results show clay mineral compositions of the core is very similar to that of terrigenous materials, and its montmorillonite/illite (M/I) ratio ranges from 0.09 to 0.20 with an average of 0.15, suggesting that the sediments in the study area should be mainly dominated by terrestrial sources, which corresponds to the results of Sr-Nd isotope study. Considering that the study area is far away from the mainland and in the downwind direction of the East Asian monsoon, it is proposed that the terrigenous material of the sediments in the study area is likely East Asian dust. The εNd values of GC1601 show a positive correlation with P2O5, Co, Ni, and Cu, and have an increasing trend with increasing depth, approaching that of the seawater, indicating that the sedimentary environment in the area is relatively stable. Unlike the sediments in the South Sea area of Minamitorishima Island, the sediments in study area receive small influence of Lower Circumpolar Deep Water (LCDW), combining with the large supply of terrigenous materials for the sediments, it is difficult for the study area to form high-grade REY-rich muds.

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Scientific Themes: Theme 9. Resource Sedimentology
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Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Enrichments of Platinum Group Elements in Marine Ferromanganese Nodules and Crusts and Their Resource Implications

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Keywords: Northwest Pacific, deep-sea sediments, material source, sedimentary environment, REY enrichments

Recently, lots of rare earth elements and yttrium (REY)-rich sediments were discovered in the sea area of Minamitorishima Island, Northwest Pacific. In order to understand the material source and REY enrichments of sediments in this area. Clay minerals and Sr-Nd isotopes analyses on gravity core GC1601 gained in the Southeast Sea area of Minamitorishima Island were performed. The results show clay mineral compositions of the core is very similar to that of terrigenous materials, and its montmorillonite/illite (M/I) ratio ranges from 0.09 to 0.20 with an average of 0.15, suggesting that the sediments in the study area should be mainly dominated by terrestrial sources, which corresponds to the results of Sr-Nd isotope study. Considering that the study area is far away from the mainland and in the downwind direction of the East Asian monsoon, it is proposed that the terrigenous material of the sediments in the study area is likely East Asian dust. The εNd values of GC1601 show a positive correlation with P2O5, Co, Ni, and Cu, and have an increasing trend with increasing depth, approaching that of the seawater, indicating that the sedimentary environment in the area is relatively stable. Unlike the sediments in the South Sea area of Minamitorishima Island, the sediments in study area receive small influence of Lower Circumpolar Deep Water (LCDW), combining with the large supply of terrigenous materials for the sediments, it is difficult for the study area to form high-grade REY-rich muds.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-3: Sedimentary mineral deposits in the deep ocean: Mineralization, genetic models, and environmental issues
Presentation Preference: Plenary Talk

Perspectives on the hydrothermal system of the Southwest Indian Ridge

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Keywords: Ultra-slow spreading, Southwest Indian ridge, Hydrothermal circulation model, Driving mechanism, Ore-controlling mechanism

The ultra-slow spreading mid-ocean ridge has unique magmatic-tectonic activity characteristics, which leads to its hydrothermal circulation model is different from other types of ridges. Its hydrothermal system may circulate deeper, last longer and have a greater probability of producing Cu-Au-rich deposits. Due to the limitation of regional location and investigation degree, the hydrothermal circulation mechanism of ultra-slow spreading ridge is still unclear, which limits the understanding of the distribution mechanism of sulfide resources at the southwest Indian ridge. Relying on China's self-developed deep-sea manned / unmanned carrier and exploration platform and the 10000 km2 sulfide exploration contract area in the southwest Indian Ocean, the research team studies the hydrothermal circulation system of ultra-slow spreading from four aspects: the spatial structure of hydrothermal channel and heat source driving mechanism, the deep process of local magma supply and its metallogenic effect, the evolution process of detachment fault and its control mechanism on hydrothermal circulation system, and the biomineralization effect of thermal radiation light from hydrothermal vents. This study reveals the hydrothermal channel structure of the ultra-slow spreading ridge and establishes the driving model of mantle heat conduction; A new causal model of ultra-slow spreading ridge and ultra-thick oceanic crust is proposed, which reveals the deep magmatic process of tectonic and magmatic ridge; The development and evolution mechanism of detachment faults with different spreading rates and magma supply conditions are clarified, and the ore-controlling geological model of detachment faults of ultra-slow expansion ridge is established. Through this study, the hydrothermal cycle model of ultra-slow spreading ridge is finally established, which improves the understanding of the hydrothermal circulation mechanism of ultra-slow spreading ridge. The research results provide key support for sulfide contract exploration in the southwest Indian Ocean of China.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-3: Sedimentary mineral deposits in the deep ocean: Mineralization, genetic models, and environmental issues
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Contribution of microbial processes to the enrichment of Middle Permian manganese deposits in northern Guizhou, South China

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Keywords: Geomicrobiology, Maokou Formation, Mn-metasomatism

Economically important manganese deposits are hosted in the Middle Permian Maokou Formation of Zunyi, northern Guizhou, South China. During the Middle Permian, the intense rifting related to the initial stage of the Emeishan Large Igneous Province (ELIP) led to the development of carbonate platforms and inter-platform troughs. The manganese deposits occur in the transitional zone between carbonate platforms and troughs. Previous studies emphasized that the hydrothermal activities at the bottom of the trough basin controlled the formation of manganese deposits. In this study, new sedimentary, mineralogical, and stable isotope evidence are acquired from this manganese deposit, indicating that the microbially-mediated metallogenic mechanism also made an important contribution for the Middle Permian manganese deposition. The metallogenesis of this manganese deposit is highly like the combination of hydrothermal and microbial processes. Manganese ores in Zunyi are manganese carbonate, showing massive and clastic structures, no macroscopic nor microscopic lamination are found, samples are coarse-grained, diagenetically recrystallized with abundant mineralized microbial and microfossil biosignatures. FTIR, EPMA, and Raman analyses recognize micrometer-scale cyclic mineralogical assembly and help reconstruct the proposed new model of microbial manganese metallogenesis. Hydrothermal activity in the basin provided dissolved Mn2+ ions into the anoxic basal watermass. In the syngenetic stage, microbial systems could be subdivided into three categories: (1) cyanobacterial system, (2) Mn-biomat system and (3) Fe-biomat system. Cyanobacterial activity led to the precipitation of calcite, and it could be partially affected by Mn-metasomatism and transformed to Mn-bearing calcite. Mn-oxidizing microbes led to the precipitation of manganese bio-oxide (δ-MnO2) near the redoxcline of the basin. Fe-biomat system was responsible for the precipitation of Fe-oxides (hematite) and Fe-hydroxides (ferrihydrite and lepidocrocite). After burial, manganese oxides reacted with the organic matter in the sediments through the microbially-mediated processes during the early diagenesis and the Mn-metasomatism of the cyanobacterial carbonate jointly contributed to formation of early diagenetic manganese carbonate ore. The redox fluctuations between oxic/suboxic and anoxic zones led to the re-oxidation process and resulted in cyclic marcasite. Anatase cycles observed in samples were interpreted as the diagenetic product of Fe-biomat system.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-3: Sedimentary mineral deposits in the deep ocean: Mineralization, genetic models, and environmental issues
Presentation Preference: Oral Preferred

Origin and evolution of carbonates and clay minerals in the Bakchar marine ironstone deposit (Western Siberia)

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Keywords: Siderite, clay minerals, ooidal ironstones, marine deposit, iron ores

The metal source and processes of iron mobilization in Phanerozoic ooidal ironstone deposits remain controversial (Kimberley, 1994). In Phanerozoic ooidal ironstones, siderite is the main cement in association with a clay matrix. The genesis of siderite is poorly examined for tracking sources of carbon and metals and for understanding processes of mobilization and transportation. Clay minerals are an essential component of ooidal ironstones, occurring forming various mineral phases and associations. However, little is known about their modification, evolution and/or transformation during the formation of marine iron-rich deposits.

A detailed study of the cement and matrix of ooidal ironstones of the Bakchar deposit (Western Siberia) was carried out to assess the factors influencing ore-forming processes within the sedimentary sequence. Siderite is one of the main cementing minerals in ironstones, which is of two varieties that differ in morphology, chemical and isotopic composition, and fluid inclusions. The first variety of siderite appears either veinlet or anhedral cement with the following stable isotopes composition: $\delta^{13}C$ from -39.5 to -29.7‰ and $\delta^{18}O$ from -15.2 to -5.1‰. Fluid inclusions of the first variety of siderite show a relatively high homogenization temperature (170–320°C) and methane in the gas phase suggesting formation by methane-bearing hydrothermal fluids. The second variety of siderite occurs as individual grains or concretions in the ironstone matrix and is relatively enriched in ^{13}C and ^{18}O ($\delta^{13}C$ from -28.1 to -12.2‰ and $\delta^{18}O$ from -28.4 to -2.1‰), suggesting its formation on the seafloor under the combined influence of methane flux and seawater. The authigenic mineral associations of ooidal ironstones reflect the transition from methanic (sulfate-methane transition zone) to ferruginous (iron reduction zone) through sulfidic zone across thin intervals. Such intervals are accompanied by the different mineral association. The proximal zone of the ore deposit is marked by the first variety of siderite, with rare authigenic minerals, and a low clay content (kaolinite, chlorite, nontronite) within ooidal ironstones deposit. This zone is an area of intense diffusion of metals- and carbon-bearing fluids through marine sediments. The clay in the proximal zone of this ore-forming process characteristically shows an increase in kaolinite and Fe contents of the smectites. The intermediate zone is montmorillonite-illite-saponite-nontronite with the second variety of siderite, and the distal zone is illite-montmorillonite (illite-smectite) with rare inclusions of siderite of the second variety. The ratio of 1M phyllosilicates (kaolinite) to the main swelling 2M phyllosilicates in the clay fraction (K/M mineral index) varies within the spatial zones. A coastal-marine environment possibly contributed to the accumulation of montmorillonite and illite contents within sediments, which was transformed into nontronite and saponite during diffusion of methanic fluid solutions through marine deposits.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-3: Sedimentary mineral deposits in the deep ocean: Mineralization, genetic models, and environmental issues
Presentation Preference: Oral Preferred

Periodic enrichment of critical metal elements in Late Permian coal-bearing series in western Guizhou —the astronomical forcing of volcanic activity

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Keywords: Critical metal elements, Volcanic activity, Long eccentricity cycle, Mineralization, Development regularity, Late Permian

A series of critical metal elements enrichment layers are distributed in the Late Permian coal-bearing strata in western Guizhou and eastern Yunnan, and the content of some layers reached the exploitable content[1-8]. The distribution of these critical metal elements enrichment layers in the sequence framework has obvious regularity. According to the distribution in the vertical direction, both the sequence stratigraphic framework and the development regularity of critical metal elements enrichment layers are discussed. The results show that the critical metal enrichment layer is well related to the astronomical orbit period changes. The Lopingian has well-preserved astronomical orbital cycles[9-10]. Among them, 11 long eccentricity cycles were preserved in the Longtan Formation, and 5 were preserved in the Changxing Formation. According to the calculation results of geochemical data, the weathering parameters have obvious periodic variation in the vertical direction, which are well related to long eccentricity cycles and the critical metal enrichment layers. The ages of critical metal element enrichment layers in the sequence framework were roughly similar, which may indicate the periodicity of volcanic activity during the period of the Later Permian. It is likely that volcanic activity is affected by the period of the astronomical orbit. Periodic orbital changes forced volcanic activity and formed rhythmic distribution characteristics. Therefore, a variety of parameters reflecting periodic changes is related. The preservation of critical metal elements is affected by the sedimentary environment. Hydrostatic and sealing conditions can better preserve critical metals and mineralization.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-3: Sedimentary mineral deposits in the deep ocean: Mineralization, genetic models, and environmental issues
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Metallogenic process of the “Datangpo-type” manganese deposits limited by environmental factors in the Cryogenian Nanhua Basin, South China

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Keywords: Neoproterozoic, Metallogenesis, Manganese deposits, Paloclimate, Redox

The Neoproterozoic Era witnessed two global glaciations, i.e., the Sturtian Glaciation (~ 720-663 Ma) and the Marinoan Glaciation (~ 654-635 Ma)(Kennedy et al., 1998; Macdonald et al., 2010; Shields-Zhou et al., 2012; Lan et al., 2014; Rooney et al., 2015) in the Earth history. Large amounts of Mn-carbonates precipitated in the post-Sturtian Datangpo Formation of the Nanhua Basin, South China, which are known as “Datangpo-type” manganese deposits. The metallogenic process of the sedimentary manganese deposits in the Nanhua Basin consists of two stages. Firstly, the dissolved Mn^{2+} was oxidized to Mn oxides/oxyhydroxides and then precipitated in the sediments. Secondly, Mn oxides/oxyhydroxides were reduced by organic matter and then preserved as Mn-carbonates. The evidences of Fe speciations, Fe isotope compositions and Corg:P (Feng et al., 2010; Li et al., 2012; Zhang et al., 2013, 2015; Yu et al., 2016; Ma et al., 2019) indicate that deep Nanhua Basin was mainly in anoxic conditions, but interrupted by episodic oxic intervals, which can provide oxygen for the Mn^{2+} oxidation. In this study, we report high-resolution chemical index of alteration (CIA) values to reconstruct paleoclimate variation from the syn-Sturtian Tiesi’ao Foramtion to the postglacial Datangpo Formation. The CIA profile of drillcore ZK2115, which shows no relationship to core lithology, exhibits a progressive upsection increase, from values of 45-67 (mean 58) in the upper Tiesi’ao Formation to 60-72 (mean 67) in the Mn-carbonate unit and to 64-70 (mean 68) in the overlying black shale unit of the Datangpo Formation. This pattern reflects a slowly warming climate during the final stage of the Sturtian Glaciation and the subsequent deglacial/early interglacial intervals. Co-fluctuations in CIA and Mn-carbonate precipitation during the deglacial interval can be interpreted as evidence of stepwise disintegration of the Sturtian icesheet, releasing pulses of cold, dense, well-oxygenated waters that episodically ventilated the deeper parts of the Nanhua Basin. The episodic ventilation promoted the Mn-carbonates precipitation through the redox variations in the deep basin. This model explains the influences of paleoclimate and redox factors on the metallogenetic process of the “Datangpo-type” manganese deposits. The episodic high-density flows caused by slowly warming paleoclimate transferred oxygen to the deep basin resulting in the redox condition variations. Then the dissolved Mn^{2+} was oxidized to form Mn oxides/oxyhydroxides which can facilitate the metallogenesis in the Cryogenian Nanhua Basin. This study explains the relationship between environmental factors and the metallogenesis of the “Datangpo-type” manganese deposits.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-3: Sedimentary mineral deposits in the deep ocean: Mineralization, genetic models, and environmental issues
Presentation Preference: Oral Preferred

Sediment-hosted High-grade Iron Ore Deposits

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Keywords: Iron ore, Sedimentary, BIF, Hypogene, Supergene

Iron ore deposits with Fe-wt% >45% are in general mined for the iron and steel industry. The deposits can be associated with magmatic processes or more commonly within sedimentary host successions with Fe-enrichment either by hypogene hydrothermal or by supergene weathering processes or a combination of both (Barley et al., 1999; Beukes et al., 2003, Dalstra et al., 2004). The most important sedimentary Fe-ore deposits are mostly restricted to the BIF host rock in the Archean-Proterozoic sedimentary/volcano-sedimentary successions. Besides these BIF-hosted Fe-mineralization, detrital channel iron ore deposits also constitute important resources. The BIF-hosted deposits supply over 95% of the world's production. These deposits are commonly high-grade with Fe-wt % reaching >65% in many world-class deposits of Brazil, Australia, India and South Africa. Mineralogically the high-grade Fe-ore deposits are overwhelmingly enriched in hematite with martite, magnetite and goethite constituting subordinate components. The hypogene hydrothermal deposits replacing the host BIF mother rock might include magnetite/martite-rich orebodies at depth and profuse carbonate alteration. The best candidates for the hypogene hydrothermal orebodies from the Kaapvaal, Pilbara cratons of South Africa and Australia, respectively, and the Iron Quadrangle of Brazil, where iron formations developed on top of or within carbonate platforms and the orebodies show profuse carbonate alteration at depth. Similar carbonate alterations are yet to be described from the Indian high-grade ore deposits. The supergene ores on the other hand are monotonously hematitic. The grade of ore in supergene deposits decreases with depth. The hypogene orebodies with martite-magnetite components at a deeper profile, when exposed to the surface, undergo extensive supergene alteration. The supergene alteration leads to dissolution and porosity development in the hypogene orebodies. Such alteration leads to the development of porous to dusty ores (Beukes et al., 2008, Mukhopadhyay et al., 2008). The Mineralogical, textural, and chemical compositions provide important clues for the genesis of BIF-hosted high-grade iron ore deposits.

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Session T9-4: Characterization of subsurface sedimentary architectures

ID: T9-40002

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Oral Preferred

Development of a methodological approach to better assess the aquifer potential of a glacial deposit environment

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Keywords: Saint-Narcisse Moraine, stratigraphy, TEM, sediments, aquifer, regional piezometry

Geological contexts that lack minimal stratigraphic and piezometric information can be challenging to produce an initial hydrogeological map in remote territories. This study proposes an approach to characterize a regional aquifer using transient electromagnetic (TEM) surveys. Given the presence of randomly dispersed boreholes, the Saint-Narcisse moraine in the Mauricie region of Quebec (Canada) is an appropriate site for collecting the required geophysical data, correlating the stratigraphic and piezometric information, and characterizing regional granular aquifers in terms of stratigraphy, geometry, thickness, and extent. In order to use all TEM results (i.e., 47 stations) acquired in the moraine area, we also correlated 13 TEM stations, 7 boreholes, and 6 stratigraphic cross-sections to derive an empirical and local petrophysical relationship and to establish a calibration chart of the sediments. Our TEM data, combined with piezometric mapping and the sedimentary records from boreholes and stratigraphic cross-sections, revealed the compartmentalization of a multi-kilometer morainic system and indicated the presence of two large unconfined granular aquifers overlying the bedrock. These aquifers extend more than 12 km east to west across the study area and are between 25 and >94 m thick. The TEM method provides critical information on groundwater at a regional scale by acquiring information from multiple stations within a short time span to a degree not possible with other existing methodologies.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Single sandbody architecture of sublacustrine fan in middle sub-member of 3rd member, Shahejie Formation in Shishen 100 area of Dongying Depression

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Keywords: Dongying Depression, Shahejie Formation, Sublacustrine fan, Quantitive scale, Three-dimensional architecture model

Sublacustrine fan deposition is one of the hot research directions of lacustrine deep-water gravity flow in China. This kind of tight reservoir usually has the characteristics of rapid planar changes and high heterogeneity. There are few studies on the single sandbody architecture of sublacustrine fan in lacustrine rift basin. As a result, a reasonable and unified architecture model has not been established. Taking the turbidite sandstone reservoirs in the middle sub-member of 3rd member of Shahejie Formation in Shishen 100 area of Dongying Depression as an example, based on the integrated analysis of the core, seismic, logging and dynamic production data, the analysis of architecture was investigated, and the geometric characteristics and spatial superposition relationship of single sandbody in each layer were determined. This study indicates that the sublacustrine fan deposits with feeder channels are developed in the target section, which includes channel system and lobe system. 7 different sedimentary microfacies were identified in sublacustrine fan, including main channel, branch channel, overbank lobe, lobe edge, slip block, semi-deep and deep lacustrine. For a single channel, the average thickness is 8.3 meters, the width ranges from 215 meters to 1040 meters, and the aspect ratio ranges from 37 to 99. The main channel in the shape of wide strip is near the provenance, which bifurcates continuously and becomes smaller scale along the provenance direction. At the end of main channel eventually evolve into branch channel and lobe. The branch channels are narrow stripe-shaped, and located at the upper part of the lobe, downcutting the lobe sandbodies. The lobe composite sandbody in the shape of lobe and fan is composed by multiple tongue-shaped lobes, and narrower in the proximal region while wider in the distal region. The lobes are mainly as the laterally compensational superposition pattern across the provenance direction. While along the provenance direction, they are progradational or retrogradational. The compensational superposition pattern is related to the ultra-short term base-level changing. For the single lobe with convex top and flat bottom vertically, the maximum width ranges from 355 meters to 1260 meters, the maximum thickness ranges from 3.3 meters to 10.2 meters, and the aspect ratio ranges from 84 to 152. The composite sandbodies dominated by channel deposits develop small-scale lobes, and are mostly isolated. For this kind of sandbody, the maximum width is 592 meters and average aspect ratio is 85. In comparison, the scale of composite sandbodies dominated by lobe deposits are larger and they develop more continuously. For this kind of sandbody, the maximum width is 895 meters and average aspect ratio is 145. Moreover, the slip blocks are isolated lenticular in front of the lobes. Ultimately, according to the results, the three-dimensional architecture model of sublacustrine fan in the study area was established. Meanwhile, these results seek to enrich the reservoir architecture theory of sublacustrine fan in lacustrine rift basin, and provide geological bases for the deployment of well pattern and optimization of injection-production parameters.

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Sedimentary Model-constrained Prediction of Sandy Conglomerates Distribution in Provenance Area

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Keywords: provenance area, sandy conglomerates, prototype sedimentary model, paleogeomorphology, reservoir prediction

The sedimentary regularity of sandy conglomerates in buried hill provenance area is complex, and predicting its distribution is of great significance to the development of buried hill reservoirs. Based on the prediction idea of medium-deep sandy conglomerates in offshore oil and gas fields and guided by the prototype sedimentary model, the technical process of sandy conglomerates reservoir prediction in provenance area is established and applied to the Archaean buried hill of Bohai A Oilfield. The following understandings are obtained: Through the investigation of modern deposition in the western mountainous area of Karamay City, Junggar Basin, 3 prototype sedimentary models of sandy conglomerates in provenance area are established according to the geomorphic background mainly controlling deposition. Using impressing method and differential amplification technology based on slope attribute to restore the paleogeomorphology of buried hill in oilfield A, its sandy conglomerates deposition conforms to the type of ‘intermountain erosion channel–piedmont alluvial fan’. Based on the principle of seismic sedimentology, the low-frequency seismic data are optimized to predict sandy conglomerates distribution in provenance area of oilfield A. The sandy conglomerates thickness in the geomorphic unit of intermountain gully is large and is distributed in continuous strips. The sandy conglomerates development degree in the ridge area of mountain peak is low and is distributed in discontinuous patches. The sandy conglomerates thickness in the geomorphic unit of piedmont slope changes greatly and is distributed in contiguous areas.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
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Reservoir Classification and Evaluation Based on Fractal Theory and Factor Analysis

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Keywords: Fractal Theory,Factor Analysis,High-pressure Mercury Injection Test,Reservoir Classification and Evaluation

With the development of exploration and development of oil and gas resources, the early reservoir description methods based on physical parameters can no longer meet the requirements of guiding the development and production of modern oil and gas fields. The pore structure of the reservoir is an important factor affecting reservoir properties and seepage properties, and its fine characterization has gradually become an important content of reservoir description. The reservoir pore structure is complex and affected by many factors, so it is difficult to describe quantitatively. Katz, Wong, and Pfeifer later discovered and confirmed that the pore structure of sedimentary rocks has fractal characteristics, which can be used as an effective means to characterize reservoir physical properties, pore structure, and heterogeneity.

The concept of fractal was put forward by Mandelbrot in 1977, which is a mathematical-statistical theory to study the self-similarity of objects. It is a more accurate quantitative representation of the inhomogeneity of the distribution of the basic properties of the stratum in three-dimensional space. The theory has been mature and widely used in architecture, physics, geology, and other industries. In geology, it is mainly used in the quantitative characterization of reservoir pore structure, joint or fracture, microscopic image observation, etc., and is mostly used to describe geological body structure. It can also be used as a measure of the irregularity of complex geologic bodies at the microscopic scale, reflecting the order and complexity of geologic body microscopic morphology.

1. Fractal Theory

In this paper, the fractal dimension of the reservoir is obtained by calculating the experimental data of high-pressure mercury injection of rock samples. The fractal formula of the capillary bundle was used to process the experimental data.

2. Factor Analysis

Factor analysis combined R-type analysis of variable correlation analysis with Q-type analysis of sample correlation analysis. The R-type and Q-type factor matrices were calculated respectively, and then the R-type factor load of the variable and the sample was formed. On this basis, the correlation statistics and analysis between variables, samples, and samples were carried out to obtain the objective classification results of samples.

3. Comprehensive Analysis

Based on the principal factor analysis of reservoir parameters, the correlation between the fractal dimension and the key parameters in the principal factor analysis is further verified to clarify the accuracy of the fractal dimension in the characterization of the overall reservoir properties. By comparing the fractal dimension with the physical property and pore structure of the strata, the relationship between the fractal dimension of different types of rocks and the influence of rock properties on the fractal dimension are discussed. It provides

a reference for quantitative characterization of rock mass structure and rock type discrimination in the study area.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
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Pore-throat characteristic response of different sedimentary microfacies of shallow-water braided river delta reservoirs in Guantao Formation, Bohai Bay Basin, China

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Keywords: Pore structure, Sedimentary microfacies, Loose sandstone,Bohai Bay

Abstract: The Guantao Formation Reservoir in the Penglai Oilfield is a loose sandstone with high porosity and high permeability. The reservoir diagenesis is weak and is dominated by compaction diagenesis. However, insufficient research into the relationship relationship between sedimentary microfacies and pore structure characteristics, which restricts the prediction of favorable reservoir distribution and the scientific implementation of development plans. In this paper, the loose sandstone reservoir of Neogene Guantao Formation in Penglai Oilfield are targeted to clarify and estimate the sensitivity of pore structure characteristics to sedimentary microfacies and the main controlling factors affecting the microscopic pore structure of the reservoir are quantitatively analyzed by grey correlation analysis. Firstly, the main sedimentary microfacies types of Guantao formation reservoir are identified based on core and logging data. Then, the reservoir characteristics of different sedimentary microfacies, such as reservoir space types, pore size distribution, fractal dimension, grain size characteristics and mineral distribution were revealed by means of high-pressure mercury injection, laser grain size analysis, core analysis and scanning electron microscopy. Finally, after the above parameters are extracted, grey correlation analysis is applied to quantitatively analyze the main controlling factors affecting the pore structure characteristics. The results show that the pore structure of various sedimentary microfacies is comprehensively influenced by the sedimentary texture and differences in mineral distribution. Characterized by more abundant hard siliceous minerals, positive skewness, and lower pore sorting coefficients, the arenaceous microfacies possess larger pore-throat radius and lower pore fractal dimensions than argillaceous microfacies. Using the grey correlation method, it is clarified that the order of importance affecting the pore structure characteristics is the mean grain size> median grain size> potassium feldspar> plagioclase> kaolinite> sorting> mix-layer illite/smectite > skewness> quartz> chlorite >illite. These results provide new insights for studying the control mechanism of microfacies controls on reservoir quality.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
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Multiple-point geostatistical simulation of outcrop based on UAV oblique photographic data:A case study of Shihezi Formation in Pingtou Township, Lüliang City, Shanxi

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Keywords: UAV,oblique photography, digital outcrop,three-dimensional outcrop modeling,multiple-point geostatistics,training image

Aiming at shortcomings in the traditional research methods of outcrops, using the agility, overall perspective and high-degree quantification of UAV oblique photography, the authors have completed the collection, processing and geological interpretation of delta outcrops, and established the three-dimensional digitized outcrop model and quantitative geological knowledge database of reservoirs. Through the fine analysis and comparative study of multiple outcrop sections, and the use of such methods as lithofacies combination, hierarchical interface , interaction of plane and section, sequential indicator stochastic simulation and multiple-point geostatistical simulation, this study establishes the three-dimensional multiple-point statistical model of the outcrop area. The study shows that: (1) The three-dimensional coordinate system of the oblique photographic data collected by UAV after processing is fully coupled with the information of high-precision images, realizing the three-dimensional digitalization, visualization and quantification of the geological information of outcrops. Under the setting of well points, in combination with the lithofacies constraints of well point, this paper carries out a comparison of outcrops with cross-well base-level cycles and the tracking of substrata, and establishes the spatial stratigraphic framework and quantitative reservoir geological knowledge database of the outcrop area. (2) Combining the analysis of traditional outcrop sections and the quantitative reservoir geological knowledge database of modern UAV oblique photography is a complementary means of establishing the spatial distribution of geological attributes and geological models in the study area, which improves the rationality of research results. Three types of genetic sandbodies with great differences in architecture is developed from bottom to top in the outcrop area, i.e., crossed-superimposed distributary channels, distributary channels superimposed with sheet sand bars, and skeletal sandbodies such as thin sheet sandbody or isolated distributary channels. (3) UAV oblique photography model expands the study of two-dimensional irregular outcrop sections into three-dimensional space, and establishes a three-dimensional sequential indicator stochastic simulation model, which not only enhances the correlation between the sections, but also provides strong support for studying the plane sedimentary microfacies of outcrops, and finely describing the distribution of sandbody architecture by the interaction of plane and section. (4) Based on the interaction of plane and section, as well as data from the quantitative reservoir geological knowledge database, this paper determines the structure model of three-dimensional training images, finally conducts three-dimensional multiple-point statistical simulation, and explores the facies-controlling porosity parameters and "sweet spot" distribution rules. The results show that there are small differences in the realization of the multiple-point model, the distribution of sand bodies in each layer, the quantitative reservoir geological knowledge database, and also the statistical data values of various models; the model achieved by multiple-point 3D simulation is highly reliable.

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Effects of basinal water depth on bar finger architecture in the deltaic environment

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Keywords: Bar finger, Basinal water depth, Architecture, Delft3D simulation

Bar finger is the significant sand body in the digitate delta, consisting of mouth bar, distributary channel and levee deposits. It is common seen in modern deposits, as well as ancient hydrocarbon reservoirs, formed by fine-grained, cohesive river. Bar finger could be developed in both shallow-water and deep-water deltas, which exhibits distinctive architectures. Basinal water depth play critical roles on their architecture. However, it is still unclear that effects of basinal water depth. We utilize Delft3D simulations and model deposits to quantify the effects of basinal water depth on bar finger geometric and internal architectures, and recognize criteria for shallow-water and deep-water deltas. The results show that (1) bar finger is almost straight if basinal water depth is larger than distributary channel depth, otherwise, bar finger is sinuous, and the sinuosity of bar finger positively scales to the basinal water depth; (2) bar finger width and length is negatively related to the basinal water depth; (3) basinal water depth determines distributaries-mouth bar combination style, high basinal water depth accompanies with thin mouth bars and relatively deep distributaries, low basinal water depth accompanies with thick mouth bars and relatively shallow distributaries with many avulsed distributaries; (4) basinal water depth influence the existence of point bar, if basinal water depth is smaller than distributary channel depth, sinuous bar finger could develop point bars at inner bank of distributary channel, resulting in distinct internal archtecture with straight bar finger. As results, the ratio of basinal water depth to distributary channel depth is a crucial parameter to determine whether shallow-water or deep-water delta. And three morphologic criteria for digitate shallow-water and deep-water delta is recognized: Sinuosity, the ratio of distributary channel depth to mouth bar thickness, the existence of avulsed distributaries, the existence of point bars. This work provides insights into natural and artificial digitate delta growth and provides new quantitative facies models for shallow-water digitate delta reservoirs.

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Session T9-4: Characterization of subsurface sedimentary architectures
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Characteristics and Origin of Conglomerate Diagenetic Traps in the Junggar Basin

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Keywords: Diagenetic trap, Conglomerate, Baikouquan Formation, Junggar Basin

The reservoir lithology of Trassic Baikouquan Formation is primarily fan delta conglomerate with low porosity, permeability, and compositional and structural maturity. The properties of the distributary channel conglomerate of the fan delta front are better than those of the distributary channel of the fan delta plain, and reserviors in delta front have strong heterogeneity. So far, there is still controversy over the types of hydrocarbon trap in the fan delta front, which has led to the different understanding of hydrocarbon accumulation[Lei et al., 2015; Zhi, 2017]. In this study, 225 samples were collected from 31 wells for reservoir characteristics and diagenetic research. Based on reservoir characteristics and diagenesis of reservoirs and dense layers at different burial depths, the relationship between every single factor and secondary pore development was analyzed according to differences in sedimentary facies, detrital feldspar content, formation temperature, and formation water characteristics. These parameters define the formation mechanism of the traps. The reservoirs underwent a series of diagenetic events during the burial process, accompanied by changes in reservoir structures and properties. Influencing factors, including rock composition, structure, and diagenetic environment, i.e., temperature, pressure, fluid, and tectonics, created strong heterogeneities during the processes changing reservoir quality. Microscopic observations of the Baikouquan Formation reservoirs in the Mahu sag show that the reservoir qualities are mainly related to diagenesis. Diagenetic differences are primarily due to rock composition, paleogeothermal environment, and formation fluids during burial. Reservoir qualities of the Baikouquan Formation were improved during deep burial due to the formation of secondary pores from feldspar dissolution. The detrital feldspar in the front reservoirs dissolved and secondary pores formed when the formation temperature was in the correct range for a weakly acidic fluid environment. Feldspar dissolution mainly depends on feldspar concentrations, weak acid formation, and paleo-temperatures. When all three conditions are not satisfied, i.e., low feldspar concentrations, non-acidic water, or inappropriate paleo-temperatures, the reservoir quality cannot be effectively improved and instead becomes a diagenetic dense layer that acts as a barrier to oil and gas.

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A Study on the Single Sand Body Architecture Model of Gravity Flow Channel in Ban 1 Oil Formation in Banqiao Oilfield

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Keywords: Banqiao Oilfield, Shahejie Formation, Gravity Flow, Single sand body; Architecture Model

The Ban 1 oil group is the main oil-bearing of the second member of the Shahejie Formation in Banqiao Oilfield. This layer is a lacustrine gravity flow deposition, and is mainly composed of channel deposition. In this paper, through the in-depth study of the gravity flow channel in the Ban 1 oil group, the sedimentary architecture characteristics of the gravity flow channel under different influencing factors such as channel stage, scale and swing stability are analyzed, and different channel architecture patterns are summarized, which provides model guidance for the subsequent development of reservoirs in the area. Combined with coring data, the sedimentary background and sand body distribution characteristics of the study area were analyzed, and it was determined that the study area developed lake bottom gravity flow channel deposits. In this paper, by selecting key blocks with dense well net and high development level, combined with dynamic information such as tracers and injection-production relationship, the channel architecture boundary is determined, and the results of the thin layer-level single water channel division are obtained, and finally the scale of the waterway is quantitatively analyzed. The research results show that there are two complex channels in the study area, and there are multiple single water channels in each complex. The water channel complex is mainly developed in the north area of Banqiao, and the water channel gradually bifurcates into the lobe in the middle area of Banqiao. The average thickness of a single channel is 7.2m, the plane width of the channel is 664m, and the width-thickness ratio is between 120:1 and 172:1. Statistical analysis of the size of a single sand body shows that the width and thickness are positively correlated (w = 182.79hmax-237.7). On the basis of studying the single sand body configuration and geometric characteristics of the gravity flow channel in the study area, the three-dimensional architecture of the gravity flow channel in this area is summarized according to the channel stage, channel size and swing stability. The model provides a geological basis for the subsequent determination of the remaining oil distribution and well location deployment.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
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Characterization of pore structure of deep shale based on shape coefficient

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Keywords: Sichuan Basin, Longmaxi formation, deep shale, scanning electron microscope, shape coefficient, pore structure

Abstract: Deep shale gas is gradually becoming the key exploration and development object in Sichuan Basin, China. The corresponding nano pore characterization technology and method of deep shale gas also need to be further developed and innovated. Field emission scanning electron microscope was used to observe and extract the minimum ferite diameter of micropores, mesopores and macropores. The elliptical shape coefficient of organic pores was obtained through calculation. The pore structure of deep organic-rich siliceous shales of the Longmaxi Formation in the Luzhou area of the southern Sichuan Basin was characterised quantitatively by shape factors. According to the ideal (oval) organic pore shape coefficient, micropores (0.93) are the least affected by compaction, followed by mesopores (0.85), while macropores are the largest (0.61). Their shape gradually tends to be flat from circle. According to the true shape coefficient of organic pores, in the deep shale section with organic pores of about 4000 m, the shape of macropores was the worst preserved, common complex irregular ellipses are densely and disorderly distributed in organic matter, and the true shape coefficient was about 0.3~0.6; The mesoporous shape was well preserved, the common approximate regular ellipse is sparse and disorderly distributed in organic matter, and its true shape coefficient was about 0.6~0.9; The shape of micropores was the best preserved. They are usually approximately regular circles, which are densely and evenly distributed in organic matter, and their true shape coefficient was about 0.9~1.0. The preservation and distribution of full pore organic pores are characterized by shape coefficient, and the heterogeneity of pore structure decreases from macropores to micropores. Therefore, micropores and mesopores are the main enrichment sites of adsorbed gas and free gas.

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Sandbody Architecture and Reservoir Heterogeneity of Sandy Braided River: An Insight from Outcrop and Subsurface Data

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Keywords: Sandy Braided River, Sandbody Architecture, Remaining Oil Distribution, Sedimentologic Genesis-based Mudstone Types, Crude Oil Distribution

As an important oil/gas reservoir, sandy braided river sandstone is characterized by thick thickness, well continuity and good physical properties. However, muddy barrier-intercalation is developed inside the sandy braided river, there are few systematical study have been carried out on reservoir heterogeneity of this type of reservoir. On the basis of outcrops in Yungang Formation of Datong Basin, Shanxi and study in sandy braided river in Jimidi Formation of Melut Basin, according to fine observation of outcrops and cores, measurement for outcrops, inter-well correlation, experimental analysis, and logging interpretation, the results show that sandy braided river deposit is dominated by seven typical litho-facies and five litho-facies assemblages, where three types of muddy barrier-intercalations with different sedimentologic genesis were recognized, flooding mud (Fm) with large thickness and wide distribution, and lateral accretion draping mud (Lm) and abandoned-channel filling mud (Am and Em) with restricted distribution inside single channel. Four typical sandbody architecture units are common to be found, including channel (CH), Channel bar (CB), Point bar (PB) and overfall deposits (OF), where distribution frequency of channel and channel bar is the highest and reservoir quality of channel bar is the best. According to the case study in Jimidi Formation in Ruman area of Melut Basin, channel and channel bar architecture units that are characterized with high porosity and permeability controlled the enrichment of heavy oil, especially the channel bar architecture units, with higher charging of heavy oil, is the major reservoir type for remaining oil.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Architecture analysis of shallow water braided river delta reservoirs_Taking Enping 420 oil group in Lufeng A oilfield, Pearl River Mouth Basin as an example

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Keywords: Shallow water braided river delta, composite sand body, seismic sedimentology,seismic edge detection, channelization characteristics

Braided river delta sand bodies are widely developed in Enping formation of Eocene in Lufeng sag, Pearl River Mouth Basin, which is the key target area for CNOOC's 14th Five-Year Plan.The unclear relationship between reservoirs and the complex internal structure are the bottlenecks restricting the planning of such oilfields. Combining well-seismic and carrying out the anatomy of composite sand body is the key to solving the problem. Taking the Enping 420 Oil Group in Lufeng A Oilfield as an example, under the guidance of the theory of sequence stratigraphy, seismic sedimentology and regional big data pattern, combined with core-logging facies, paleogeomorphology analysis and seismic inversion volume edge detection technology , clarified the internal structural characteristics of the sand body. The results show that: (1) the geomorphology of the Enping 420 oil group was relatively flat during the depositional period, but there were structural slope breaks in some parts, which was the shallow-water braided river delta deposition dominated by the channel; (2) it was subdivided into three periods vertically, among which the early sand The sand body is small in scale, poor in physical properties, and limited in distribution; in the middle stage, the sand body is large in scale and is the concentrated section of the main oil layer; in the late stage, the sand body is in limited distribution. (3) On the plane, it is characterized by divergent interweaving channels, the width of the main channel is 300m~600m, with good connectivity. The above achievements have effectively guided the well pattern deployment and well type selection of Lufeng A Oilfield, and promoted the rapid production of the oilfield.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Oral Preferred

Configuration characterization of underground deep-sea channel reservoir driven by geological model

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Keywords: deep-sea channel, Sedimentary configuration, Configuration characterization, Well-seismic combination

Deep sea channel is the migration channel of terrigenous debris to deep-sea plain. It is also one of the main oil and gas reservoir units in deep-sea sedimentary environment. It has important value and significance of oil and gas resources exploration and development. Studies have confirmed that although the deep-sea channel reservoir often has high porosity and permeability, its plane flow path and internal building structure are complex and changeable. Even in a very short lateral distance, the reservoir thickness and connectivity will change greatly, which greatly increases the drilling risk and reduces the design quality of development scheme. In addition, due to the limitation of marine sedimentary environment and operation cost, deep-sea oil and gas fields often have "few wells, large well spacing and thin well pattern". The traditional reservoir configuration characterization method suitable for onshore dense well pattern is difficult to adapt to deep-sea oil and gas fields. In addition, the complex superposition relationship of channel reservoir itself brings challenges to the high-precision prediction of underground deep-sea channel reservoir, which affects the efficient development of deep-sea channel reservoir. Therefore, this paper proposes a geological model driven characterization method of underground deep-sea channel reservoir configuration. The specific process is as follows:

Construction of development scale channel configuration mode: on the development scale, the deep-sea channel is divided into four levels: channel system, complex channel set, complex channel and single channel. Then, based on the shallow high-frequency 3D seismic data, the vertical superposition mode and plane migration mode of four levels of deep-sea channel are established.

Analysis of core-logging-seismic response characteristics of interfaces with different orders of architecture: According to the characteristics of small scour or lithofacies abrupt change in the bottom interface of a single channel, the structural interface of a single channel order is identified on the core; The interface characteristics of a single channel level structure are determined on the logging curve, and the logging response characteristics of the interface of a compound channel level structure are identified through the combination of a single channel, medium-sized scour surface and lithofacies change characteristics; Through the analysis of profile shape and style, the seismic response characteristics of the interface of single channel and complex channel structure are determined, and the well-seismic response characteristics of the interface of the complex channel series and the hierarchical structure of the channel system are identified through the complex channel combination and seismic profile structure analysis.

The above method completes the fine characterization of channel sedimentary bodies of different sedimentary scales through step-by-step constraints. While proving the sedimentary characteristics of large-scale underground channel reservoir sand bodies, it can also clarify the sedimentary distribution characteristics of impermeable geological bodies such as small-scale sand-mud interlayers. , has important geological significance for the exploration and efficient development of deep channel type reservoirs.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
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Quantitative characterization of clastic reservoir architecture based on envelope surface: a case study of P oilfield in Bohai Sea

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Keywords: reservoir architecture, geological modeling,envelope surface ,equivalent characterization, bohai oilfield

In order to solve the problems existing in conventional grid-based clastic reservoir architecture modeling methods, such as low model accuracy and non-convergence of reservoir numerical simulation, a quantitative characterization method of clastic reservoir architecture based on envelope surface was proposed. This method achieves the fine geology modeling and reservoir numerical simulation of clastic reservoir architecture through the prototype modeling of reservoir architecture envelope surface, envelope surface reconstruction based on discrete architecture data and equivalent characterization of envelope surface. In P oilfield of Bohai Sea, this method was applied to quantitatively characterize the braided river reservoir architecture units.Firstly, the 3D surface-based prototype model of braided river architecture units was established based on the geological knowledge base. Then, under the constraints of the prototype model, the envelope surfaces of each level architecture units were constructed by using the reservoir architecture data of different dimensions,such as 1D well point data,2D boundary data, etc. Finally, an equivalent characterization method based on the conductivity of grid interface was used to realize the quantitative characterization of the envelope surface in conventional grid-based reservoir numerical simulation, which provided a model basis for fine remaining oil prediction and potential exploitation in the middle and late stage of oilfield development. Reservoir numerical simulation results of P oilfield show that the historical fitting coincidence rate of the new model based on the proposed method is 12 percent higher than that of the old model, and the overall prediction accuracy of remaining oil is more than 85%.In addition, this method has been successfully applied in many meandering river and delta oilfields in Bohai Sea, showing a good application prospect.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

A Multi-point Stochastic Based Turbidite Lobe Architecture Modeling of L Oilfield, Lower Congo Basin, West Africa

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Keywords: Deep-water Turbidites, Lobe Reservoir Architecture, Multi-point Stochastic Modeling

Deep-water turbidite is a specific field of current exploration and development because of its considerable petroleum potential. As a significant composite of turbidite deposition system, internal architectural and 3D characterization of turbidite lobe has been technical tacking difficulty as consequence of its complex depositional environment and strong heterogeneity. Based on a large number of cores, logging, field outcrop and high-frequency three-dimensional seismic data, using the research ideas of well-seismic combination and progressive constraint, taking Miocene reservoir developed turbidite lobe of L Oilfield in the Lower Congo Basin of West Africa as an example, detailed architecture analysis and three-dimensional geological modeling were carried out. Firstly, the standard of lobe architecture level was clarified and the three-dimensional architecture model was established based on multi-dimensional and multi-scale data. Secondly, according to the middle-high frequency seismic data of the target layer in the study area and the high frequency seismic data of shallow layer, seismic RMS attribute slices were used to obtain the lobe deposition samples. The length, width and thickness of the turbidite lobe system were quantitatively analyzed to establish empirical function of geometric parameters and as a quantitative knowledge base to provide parameter guidance for multi-point statistical simulation. Lastly, the lobe training image is established by means of seismic multi-attribute and seismic volume carving technology, and 3D architecture model of turbidite lobe in the target layer M8 sand group is established by multi-point geostatistics method. The simulation results generally followed the lobe architecture model and were highly consistent with the actual drilling inspection well. This study has formed a set of detailed modeling technology for deep-water turbidite lobes, and enriched the geological knowledge base of deep-water turbidite lobes, which has practical significance for efficient development of lobe reservoirs.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Oral Preferred

Sedimentary Architecture Models of Fluvial Successions in Responsible for Variable Accommodation to Sediment Supply Ratio

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Keywords: Accommodation, Sediment supply, Sedimentary architecture; Fluvial succession, Datong basin

Fluvial rivers are common landforms of continental environments, and sedimentary architecture models of their successions are variable with the change of accommodation to sediment supply ratio (A/S ratio). However, few published research documents proposed variable sedimentary architecture models of fluvial successions in responsible for conditions of A/S ratio. Therefore, this work aims to establish variable sedimentary architecture models of fluvial successions that are responsible for the conditions of A/S ratio, based on the outcropping fluvial successions located in the Datong Basin, China. The used fluvial outcrop is composed of 8 outcrop sections, and the used dataset mainly includes (i) outcrop photomosaics, (ii) data obtained from analyses of rock samples, consisting of measurements of grain size, porosity, and bulk and skeletal density, (iii) impregnated thin sections. Outcrop fluvial strata is divided into 9 short-term and 2 medium-term depositional (A/S ratio) cycles based on mudstone (sandstone) percent, paleosol maturity, and ancient river depth. The results indicate that fluvial rivers transit between different patterns following the sequence, i.e., braided rivers, wandering rivers, transiting rivers between braiding and meandering, and to meandering rivers. Sedimentary architecture models are different significantly for their succession in different river pattern or conditions of A/S ratio. For example, erosion/incise surfaces and chutes show a heavy density in braided river successions whereas decrease sharply in wandering river successions. Also, mid-channel bars in wandering rivers are commonly composed of a set of vertical accretion sandbodies, which are separated by thin silt layers. Generally, variable sedimentary architecture models that are responsible for different conditions of A/S ratios are proposed in this work.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
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Depositional architectures of tectonically forced deep marine channel bends: Niger Delta offshore

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Keywords: submarine channel, depositional architectures, deflected bend, tectonic forcing, autogenic processes, Niger Delta

Throughout the past decades, submarine channels have been one of the most relevant hydrocarbon prospects in continental slopes. The detailed descriptions of channel architectures and the connectivity of sand bodies have aided hydrocarbon production in terms of reservoir heterogeneity and connected oil. Nevertheless, the ranges of these stacked channels within tectonically complex slopes remain poorly understood, in part because their sedimentary records diverge. Two submarine channel systems have been investigated in the Agbada formation, within the southern Niger Delta offshore, to help understand and depict the distribution of submarine channel architectures around growing structures. A critical examination of these channels including stratigraphic subdivision has led to the identification of several vertically-stacked channel complexes, revealing a number of channel bends around structural reliefs. These latter have been mapped using seismic attributes, including variance, RMS, and spectral decomposition. The cross sections analysed along these bends, have permitted the characterization of channel stacking patterns, consisting of lateral offsets, vertical amalgamations, and oblique amalgamations. The integrated seismic profiles and planforms, have been further used to assess several parameters around the bends, such as channel TWT-thickness, width, sinuosity, bend amplitudes, and channel shift distances. This has allowed the classification of the deflected bends throughout the opposition of tectonic forcing against channel autogenic processes.

The tectonic forcing reflects the high amplitude bends growing with dominantly lateral offsets. In addition, the seismically-defined channel chute cut-offs are as well believed to form on stepwise tilting of channel floor. Where the channel encounters orthogonal ridge, the deflected bend has been associated to overwhelming sands 'swept' into structural lows making up 'ladle-shaped' architectures with bars and channel cuts, and significant amounts of upstream sediment reflections. While, the opposite autogenic influence is shown by levee confinements, which dramatically restricted the bend growth and were favorable to downstream translation of channel pathways. These channel relief constrictions have comprehensively resulted oblique and vertical channel trajectories within bend apices. Besides, where channel sedimentation is dominantly mud-rich debrites, the deflected bends were particularly kinked, showing up a poor development of channel lateral shifting. Such architecture is believed to emerge under the influence of downstream surge flows surpassing the tectonic drift. These observations demonstrate the pivotal role of channel sedimentary processes altering the architectures of tectonically influenced bends, establishing a new outlook for future investigations on structurally controlled submarine channels.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Oral Preferred

Outcrop Modeling of Flow Units and Reductant within a Sandstone Uranium Reservoir in the Zhiluo Formation, Eastern Ordos Basin: Implications for the Uranium Mineralization Mechanism

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Keywords: architecture, flow unit, carbonaceous debris; outcrop modeling; Ordos Basin

The spatial distribution of flow units and reductant within a sandstone uranium reservoir is very beneficial for exploring the uranium mineralization mechanism; however, such studies have been almost neglected. As such, this paper aims to provide the sedimentological interpretation and heterogeneity models of the sandstone of the Middle Jurassic Zhiluo Formation at Shiwan outcrop area, in the eastern Ordos Basin. The outcrops are sandstone-dominated subaqueous distributary channel successions, in which five distinct architectural elements are identified and interpreted: channel units (CU), downstream accretion elements (DA), lateral accretion elements (LA), sandy bedforms (SB) and no-channelized fine-grained sediments (NFS). Within the sandstone succession, six flow units are present in the middle and lower parts of CU, or the lower parts of DA and SB elements, with their geometry to be controlled by the fourth- or third-order bounding surfaces. Moreover, the carbonaceous debris-rich zones (CDZ) are places with the highest abundance of reductant and preserve exclusively upon the basal erosional surfaces of CU and DA elements. Based on those results, a prediction model is established and shows that the formation of interlayer oxidation zone is strongly selective and confined within the CU and DA elements. The favorable sites of uranium mineralization are preferentially distributed in the transition zone between the front of flow unit and the CDZ.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
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Architecture of deep marine and deep lacustrine turbidite lobe deposits

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Keywords: turbidite lobe, deep-marine, deep-lacustrine, architecture, thickening-upward cycle

Deepwater (deep-marine and deep-lacustrine) turbidites are sedimentary sand-bodies with good physical properties, and their complex internal structures and heterogeneities directly control the distribution of residual oil. In recent years, significant progress has been made in the exploration and development of deep-marine turbidities, and a series of giant oil and gas fields have been discovered, making deepwater domain an important strategic replacement area for future global oil and gas resources. Architectural characteristics of deepwater turbidite channels have been extensively studied, whereas works on the architecture hierarchy and anatomy of the turbidite lobes are less. In this study, three turbidite lobe analogues are investigated and correlated: the deep-marine Carboniferous Ross Sandstone Formation outcrops in western Ireland, the deep-marine Silurian Longmaxi Formation cores in the Sichuan Basin, and the deep-lacustrine Triassic Yanchang Formation outcrops in southeast Ordos Basin. Based on detailed anatomy, deep-marine and deep-lacustrine turbidite lobes can be comparable in many aspects: 1) three genetic units are recognized: turbidite lobe, turbidite channel, and slump-slide; 2) turbidite lobes can be classified into a similar four-fold hierarchy from bed, lobe element, lobe, to lobe complex. The architecture units at each hierarchical level and the corresponding architecture interfaces have completely different characteristics, among which the lobes show characteristics of evident compensational stacking, and the lobe elements display a thickening-upward pattern; 3) typical thickening-upward cycles consist of, from bottom to top: laminated shales/shales with interbedded siltstone beds; interbedded sandstones/siltstones and mudstones; structureless massive sandstones with a strong degree of amalgamation and load structures at bases. In general, the turbidite lobe deposits appear as tabular, parallel/sub-parallel sandstone with mudstone interbeds. Turbidite lobe deposits transit from thick, massive sandstones with high net-to-gross ratio and high degree of amalgamation at the proximal region into thin sandstones interbedded with mudstones with low net-to-gross ratio and degree of amalgamation towards distal fringes both laterally and longitudinally. By detailed anatomy of hierarchy and lateral tracing of architectural units, this study suggests that, despite less extent and shallower water depth, deep-lacustrine turbidite lobes have similar features with deep-marine turbidite lobes, in terms of depositional mechanism, genetic units, architecture hierarchy, and lateral distribution of facies associations. This could benefit future exploration and development of deepwater turbidite lobe reservoirs.

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Sedimentary characteristics and architecture model of river-dominated shallow water delta front

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Keywords: Shallow water delta front,Sedimentary model,Lake-level fluctuation,Sandbody Architecture,Huanghekou Sag

Based on the comprehensive application of modern sedimentary, core, logging and dynamic data, the sequence stratigraphy and sedimentary characteristics of oilfield A in Huanghekou Sag are studied in detail, and the architecture model of distal fine-grained shallow water delta is established. The study shows that the lower Ming member of Neogene in A oilfield in the Huanghekou sag is divided into two complete third-order sequences and seven fourth-order sequences, that is, the bottom third-order sequences composed of IV and V oil groups are dominated by low-stand and transgression domains, and the top third-order sequences composed of I, II and III oil groups are dominated by low-stand and high-stand domains. Slow slope and far away from provenance are necessary conditions for the development of fine-grained shallow-water deltas. Fine sedimentary particle size, scale of sedimentary structure and small thickness of single genetic unit sand body are obvious sedimentary characteristics. The high frequency fluctuation of lake level controls the sedimentary model of distal fine-grained shallow water delta. Flake shallow water deltas are mostly developed in the lowstand period, with underwater distributary channel sand body as the main body, and channel migration and swing frequently. Dendritic shallow water deltas are developed in the early stage of transgression and highstand, and underwater distributary channels are striped and isolated. In the late high-level region, lobed shallow water deltas were developed, overbank deposits are mostly developed between single distributary channels and some distributary channels were transformed into bar and sheet sand by lake waves in the distal. The research results provide a basis for the exploration and development of shallow water delta in the Huanghekou Sag.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Sedimentary sequence and architecture analysis by integrating multi-discipline data – An example of a sandy conglomerate reservoir in Qie12 block, Qaidam Basin, NW China

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Keywords: Sedimentary sequence, sedimentary architecture, sandy conglomerate reservoir, Qaidam Basin

Understanding the sedimentary sequence and architecture is important for planning the development strategy. We illustrate a case study of analyzing the sequence and architecture of a sandy conglomerate reservoir by integrating geology, petrophysics, seismic, and development data. The analysis indicates that the depostional environment of the target lower part of the Ganchaigou Formation is an alluvial fan. We defined eight lithofacies according to the core analysis and five sedimentary microfacies by integrating the core and petrophysical data. We next propose four sedimentary architectural models by integrating the lithofacies result, microfacies analysis, and high frequency sequence models. The four architecture models include the extensively connecting body sandwiched with intermittent channels, the composite channel formed by the overlapping and separation of stable channels, the lateral alternated braided channel and sheet flow sediment, and the runoff channel inlaid in flood plain mudstone. We finally build an architecture model for the alluvial fan. The model of the alluvial fan overall shows an upward-fining grain-size features and this feature indicates that the alluvial fan belongs to a retrograding sequence. The built model consists of six alluvial fan bodies that migrates from north.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Oral Preferred

Sedimentary architecture characteristics of submarine fan lobes under gravity flows and bottom currents ——Insights from a deep-water research in East Africa

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Keywords: Gravity flows, Bottom currents, Submarine fan, Lobe, Reservoir architecture, Connectivity feature

Submarine fan deposits have great potential for oil and gas resources, and the study of their sedimentary architecture is essential for the development of deep-water reservoirs. At present, the influence of bottom currents on submarine fan channel architecture has been widely recognized. Whereas, for submarine fan lobes, the current study only found that bottom currents can modify the entire lobe system distribution and deposit architecture under gravity flows and bottom currents, and no research has been carried out on the effect of bottom currents on different hierarchical lobe architecture under this deep-water environment. In this paper, we study on a deep-water area in East Africa under gravity flows and bottom currents, including architecture of the submarine lobe, and different stacking patterns and connectivity features of different hierarchy lobes by using well core, logging and seismic data. Then, the sedimentary architecture pattern of submarine lobes under gravity flows and bottom currents is established. The main conclusions include: 1) the lobe complex and the single lobe show unidirectional southward stacking pattern, which is opposite to the direction of bottom currents, and the single lobe presents an asymmetric shape with thicker lobe margin on bottom currents; the mudstone between the lobe complex is thick and continuous, and the mudstone between the single lobe is thin and discontinuous. 2) The lobe layers in a single lobe display vertical accumulation, which shows no obvious relationship with bottom currents; there are few mudstone interlayers in a single lobe, and the mudstone interlayers gradually increase from the proximal the distal of the lobe. 3) The influence of the bottom currents on the lobes is mainly manifested in the fact that the single lobe in the early stage deposited thicker vertically of the lobe margin along the bottom currents side, so that the followed single lobe deposit on the lower position of the previous topography, showing the migration opposing bottom currents. For the effects of the bottom current on the channel, their migration directions are all opposite to bottom currents. For the submarine lobe, there is no obvious asymmetry with large-scope horizontal drift deposits on the bottom currents side. Instead, the single lobe margin is thicker vertically on the bottom currents side, which shows the asymmetry that the main body of the lobe is biased to the bottom currents side. The research is of great significance to improve the theory of deep-water sedimentary architecture and development of reservoir.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Oral Preferred

Densification of the Lower Cretaceous tight sandstones, Sandaoqiao area, western Tabei uplift in the Tarim Basin: implications for paleo-uplift evolution

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Keywords: Paleo-uplift evolution, Tight sandstone, Densification mechanism, Tarim Basin

Previous practices proved that sandstone reservoir of Lower Cretaceous is partial tight in the Tabei uplift. And the petroleum accumulation is related to the paleo-uplift distribution. At the aid of seismic, core and drilling data, three stratigraphic sequences and sedimentary facies are identified. And using porosity and permeability, thin section, cathode luminescence and pore structure data describe the reservoir characteristics. Based results above to clarify the relation between reservoir densification and paleo-uplift evolution. The target layers are Lower Cretaceous Yageliemu Formation (K1y), Shushanhe Formation (K1s) and Baxigai Formation (K1b). The K1y and lower K1s are regarded as the first stratigraphic sequence of Lower Cretaceous (K1SQ1). And the upper K1s and K1b are considered to be K1SQ2 and K1SQ3, respectively. The K1SQ1 in the study area develops braided-river delta. Then rising sea level submerges the uplift and the study area develops bar. The provenance of K1SQ1 and K1SQ2 comes from the weathering products of northwest denuded zone. The K1SQ3 develops meandering river delta derived from southeast area. The results show the reservoir has an averaged porosity of 7.8% and an averaged permeability of 9.7 mD, indicating a low porosity and medium permeability reservoir. However, the physical properties of reservoirs in different sequences are different. The reservoir in K1SQ3 has the maximum averaged porosity (10.3%) and permeability (34.6mD), followed by K1SQ1(7.2%, 2.1mD) and K1SQ2 (6.7%, 0.29mD). Meanwhile, the results of mercury injection indicates that the pore structure of K1SQ3 is more connected. Sedimentation and diagenesis are main factors that controlling the partial densification of reservoir, which is closely related to the uplift evolution. (1) When the uplift was submerged, it inherited to form a bar. The grain size of bar within K1SQ2 is smaller which makes the primary porosity is limited. (2) Cathode luminescence results show that the calcite cements within reservoir of K1SQ2 are much more developed than that of K1SQ1 and K1SQ3. The cements block the pores and throats which significantly decreases the physical properties of reservoir. These cements in bar are developed because the bar is far away from the Terrigenous clastic. The settings of shallow lacustrine makes it is favorable for calcite cements formation. In summary, uplift evolution makes the sedimentary facies and diagenesis environments change, then they will affect the reservoir quality.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Oral Preferred

Characterization of the single sandbody architecture in the sublacustrine fan reservoir of Triassic Yanchang Formation in Heshui Area, Ordos Basin, China

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Keywords: Sublacustrine fan, single sandbody, architecture model, Triassic Yanchang Formation, Ordos Basin

In recent years, the research on the deep-water gravity-flow deposits has become a hot and difficult topic in the field of international academic research and petroleum exploration and development. Compared with marine gravity-flow reservoirs, the distribution of lacustrine gravity-flow reservoirs is more complex, which leads to greater petroleum development difficulty and poorer economic benefits. Taking the lacustrine gravity-flow reservoirs in the Chang 6 oil-bearing interval of the Triassic Yanchang Formation in the Heshui area, Ordos Basin, Chian as the research object, the distribution of the single sandbody architecture and the semi-quantitative to quantitative sedimentary architectural model of the sublacustrine fan reservoir was investigated by integrating the core, well logging and production data in this research. Six architecture elements were identified in the sublacustrine fan, namely, main channel, branch channel, lobe, lobe edge, inter-channel and inter-lobe, among which the lobe sandbodies are the most widely distributed. Based on the single sandbody boundary identification mark of exploration wells and horizontal wells, the boundary of single sandbody was divided. The lobe complex is composed by multiple individual lobes through different compensational superimposition pattern, including lateral, deintegration or prointegration pattern, which is related to the base-level changing. The single lobe is tongue-shaped on the plane and is slightly narrower in the proximal region as well as slightly wider in the distal region. There is an obvious linear positive correlation between the maximum width and the maximum thickness, with the aspect ratio ranging from 100 to 160. Ultimately, according to the analysis results of the single sandbody architecture in study area, a three-dimensional architecture model of the sublacustrine fan in the depression lacustrine basin was established. The research results can provide reference for the architecture analysis of the similar oilfields, and can facilitate hydrocarbon exploration and production in similar lacustrine deep-water gravity-flow reservoirs.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Oral Preferred

Study on sedimentary characteristics and main controlling factors of fluvial-dominated shoal lake delta ——Taking Yongjin area in the Hinterland of Junggar Basin as an example

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Keywords: Shoal water delta, Distributary channel, Sedimentary characteristics, Distribution characteristics, Qigu formation

Due to the great controversy over the influence of different main control factors such as water flow characteristics and provenance supply on the development and sedimentary characteristics of shoal water delta, in this paper studies the sedimentary characteristics of Jurassic Qigu formation in Yongjin area by comprehensively using core , well logging, seismic, experimental test and other data. It is found that the basin is mainly braided river delta in this period, which is different from that generally believed by predecessors, Typical fluvial-dominated shoal lake delta are developed in this area, and the sedimentary characteristics are quite different from braided river deltas. Combined with the characteristics of lithofacies, well logging facies, seismic facies, the sedimentary microfacies and water environment of shoal water delta are identified; The distribution characteristics of sand bodies are analyzed in combination with the changes of sea level rise and fal1, the distribution characteristics and evolution law of sedimentary microfacies, and the characteristics of seismic facies. The study shows that the sedimentary microfacies are mainly underwater distributary channels, lack of mouth bars, etc., and the phenomenon of scouring and cutting between channels in a single stage is obvious. The sediment is mainly fine sandstone with thin layer of mudstone, which often appears alternately in reddish brown and light gray, reflecting that the sedimentary water body is shal1ow and oscillatory. The shoal water delta in the study area extends far to the center of the lake basin. The vertical superposition mode of sand body can be divided into four types: thick at both ends, thin at the middle and thin at the lower part, thin at one end, thick at the middle and equal at one end, thin at both ends, thick at the middle and thick at the upper part, and nearly equal thickness; The stacking modes of sand bodies on the plane can be divided into three types: continuous type, cross cutting strip type and isolated strip type; The genesis is mainly controlled by six factors: gentle topographic conditions, changeable lake level fluctuation cycles, shallow water depth, sufficient material source supply, frequent climate change and stable basin tectonic activities.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Oral Preferred

Transport pathways of source to sink systems and Sand Controlling Mechanism of the Paleogene in Chengbei-Zhuanghai area.

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Keywords: source to sink system, palaeogeomorphology, Transport pathway, Chengdao-Zhuanghai area,

The source to sink system concerns with various components of sedimentary systemsfrom source areasthrough dispersal systemsthence to deposition in a number of potential sedimentary sinks. Chengbei-Zhuanghai area is taken as a whole source to sink system. utilizing logging,well logging,rock core and three-dimensional seismic data,we analayed the basement rock types of provenance transport system and sedimentary system types and features on the Chengbei-Zhuanghai area from the perspective of source to sink system,reconstructed the palaeogeomorphology,The palaeogeomorphology,and gully transport system, sedimentary results and distribution, the coupling relationship of source to sink system are clarified to guide the exploration and prediction of favorable zones in the study area and similar basins.The principle and method of high-precision paleogeomorphology restoration are adopted for paleogeomorphology restoration in Chengdao -Zhuanghai area. The analyzing processes include five steps:(1) correcting of apparent thickness;(2)recovering eroded thickness;(3)establishing of compaction equations;(4)restoring compaction of formations in each single drilling wel;(5)composing maps of thickness of original layer and paleo-geomorphology. Furthermore, the paleo-geomorphological maps of the EdIII1 Fomation and Es3 Fomation. When the Es3 Fomation time,One highland in the western and sag in the eastern in the Chengdao area , which is sandwiched between Chengbei low uplift and Chengbei 30 buried hill. One highland in the middle and two sags in the eastern and the western sides of the Zhuanghai area were recognized from the map.Three types of gully valleys (V-shape, U-shape, W- shape and composite shape), fault troughs (single fault trough and double fault trough) and structural transformation zones are usually developed by using the method of three-dimensional seismic data to identify the transport pathways. The sedimentary strata in the eastern depression of Chengdao low uplift in Chengdao area are well developed, and the uplift zone is overlain layer by layer. Multiple negative geomorphologic units can be seen in the uplift zone and the depression, and 25 transport channels are mainly developed, including 15 paleo-valleys and 10 fault troughs. Three types of sedimentary facies were observed in the main horizon of the catchment unit, namely, sublacustrine fan, nearshore subaqueous fan and fan delta. Sublacustrine fan and fan delta developed in gentle slope, semi-deep water or shallow water environment. The nearshore subaqueous fan is generally developed in the steep slope and deep water environment, which is featured with wide and continuous plane distribution and superimposed vertical distributionCoupling mode of the source-to-sink system suggests that effective source area controls the size of sedimentary system; sand transporting path controls sedimentary distribution direction and shape.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Oral Preferred

Influence of bottom currents on the hierarchical architecture of deep-water channels

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Keywords: bottom current, deep-water channel, architecture

Deep-water channels are important reservoir element in deep-marine setting that preserve complex internal architectures governed by both sediment gravity flows and bottom currents. The existing models for bottom current-influenced channel architecture fail to consider the effects of channel hierarchy and sinuosity, leading to two contradictory interpretations: lateral channel migration upstream or downstream of bottom currents. This study intends to unravel the complexity of bottom current-influenced channel architecture through 3D seismic-based analysis on several channel samples from offshore Mozambique where interaction of sediment gravity flows with bottom currents is representative. Results reveal the hierarchical variations in channel stacking patterns, rather than the previously assumed unidirectional migration regardless of architectural hierarchy. The multiple channel systems from different sequences migrated bidirectionally in a compensational stacking pattern, with rare influence by bottom currents. The multiple channel complexes within a channel system show unidirectional migration upstream of bottom currents, which suggests dominant influence by bottom currents in agreement with previous findings. The multiple individual channels within a channel complex show diverse stacking patterns involving lateral migration upstream or downstream of bottom currents, and longitudinal migration downstream of sediment gravity flows. These patterns vary according to bend orientation and sinuosity due to the combined effects from sediment gravity flows and bottom currents. A hierarchical model for bottom current-influenced channel architecture is finally developed highlighting the hierarchically variable interaction between the two important deep-marine sediment transport processes. These findings prompt reevaluation of the existing models and deeper digging into the interacting process regimes.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

The Electrofacies and Facies Model of the Eocene Lacustrine Carbonate Reservoir: a case analysis of the Fourth Member of Shahejie Formation, Dongying Depression, China

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Keywords: lacustrine carbonate, eletrofacies, facies model, reservoir heterogeneity

The fourth member of Shahejie (Es4) lacustrine carbonate in Dongying Depression is deeply concerned with the ultra-high production of about thousand-ton perday in single well, but the differential reserve between wells remains enigmatic. The traditional sedimentary analysis maintained the extended development of reefal buildups along the paleohighs located in rift margin, contributing framework pore space for prolific reserve. However, the recent core observations show the grainy facies are common, including carbonate sands, oolites and bioclasts, which provide good pore space. Based on new nine types of electrofacies, the facies model was built, illustrating reef facies with common frame of Cladosiphonia sinensis extended in limited coverage, with patchy deposits above grainy base. The result could not support the previous knowledge that the large extension of reefal facies and their dominant contributions to high production. The facies model further agrees with the humid and warm environments which are friendly for biological development happened in the Middle Eocene period of East Asia. The energy-driven heterogeneity of facies also illustrate the fluctuation of lake levels, especially the high energy settings above rift paleohighs, where bioclasts reworking commonly happens with deficient buildup left. The possibly shallow water conditions are favorable to experience the meteroric dissolutions happened in good reservoirs, as well as dolomitization within lacustrine carbonates. The lake expansion and contraction cycles recorded in the Es4 interval of the Middle Eocene rift lacustrine settings are probably dominant controls on facies characteristics, as well as the reservoir heterogeneity. As for the paleographic aspect, the favorable facies and reservoirs located in paleohighs of rift lake away from siliciclastic inputs in basin margins. The warm, shallow water environments and possibly surrounding hydrothermal fluids facilitate carbonate factories, contributing to the typically good reservoir for lacustrine hydrocarbon reserve.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

The Facies of the Cretaceous Cenomanian-Turonian Mishrif Carbonates: a case analysis of the southern margin in the Neo-Tethys

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Keywords: carbonate platform, Cretaceous, microfacies, OAE, carbonate reservoir

The Cretaceous Mishrif carbonates formed in the Cenomanian-Turonian period contain giant hydrocarbon reserve, which is known as the prolific resources in Tethys regions. The heterogeneous nature of carbonate rocks make the challenges in exploration and development activities, which make the facies models are in real need. This study introduces a case analysis of the Mishrif platform carbonate, applying the integrated method based on petrographic properties, core facies, and logging database (including conventional well logs, borehole images and downhole nuclear magnetism resonance data among 6 cored wells and over 150 open hole wells), establishing the facies models for the Mishrif carbonates. There are 14 typical microfacies developed in the Mishrif carbonates, mainly include the burrowed bioclastic wackestone (MF3), peloidal wackestone (MF4), planktonic pelagic mudstone (MF5), echinoderm bioclastic packstone (MF7), limestone conglomerates (MF10), foraminifera packstone (MF13), bioclastic grainstone(MF14), bioclastic floatstone (MF15), miliolid foraminifera wackestone (MF16), dasyclad green wackestone (MF17), benthic foraminifera bioclastic wackestone and packstone (MF20), fenestral bindstone (MF23), intraclast wackestone (MF24), various skeletal bioclastic grainstone and packstone (MF26). Based on microfacies and eletrofacies, the carbonate ramp facies model was established. The results show that the Mishrif ramp facies varies during the time of late Cenomanian and early Turonian. These facies evolution are deeply influenced by eustatic levels, which also reflecting the uplifts in regional event. The carbonate ramp settings of inner ramp bioclatic shoals, rudist biostromes are the good reserve for reservoirs. Both the petrographic and paleontological features illustrate the ramp shifting from inner sites to outer settings, with the organic mudstone deposits in the sea level rising. The facies and carbon isotope positive excursion also record the OAE2 characteritics with the recovery of coral and rudist deposits. The faceis models provide detailed measures to characterize the Mishrif carbonates. The facies/electrofacies models have the implications for reservoir architecture analysis, re-understanding the subsurface reservoir models, as well as production strategies, which provide comparisons for local reserves as well.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Genetic Analysis of Low Resistivity Reservoir: A Case Study

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Keywords: low resistivity reservoir, genetic Analysis, smectite content and morphology, rock framework, reservoir conductivity, micro-characteristics

A typical low resistivity reservoir is developed in the N_1gIII formation of C Oilfield Bohai Sea Areaand analyzing the influential factors of reservoir resistivity is of great significance to the efficient development.
In the research X-ray diffraction (XRD)scanning electron microscopy (SEM)cast thin sectionscation exchange capacity (CEC) testdigital core modeling were used to study the clay mineral content and morphology,rock framework grains contact relationship,reservoir conductivityand then reservoir micro-characteristics and the influential factors of reservoir resistivity were discussed.
The results showed that the reservoir resistivity is influenced by the combination of clay mineral contentmorphologyand rock framework grains contact relationship.
The content of smectite in clay minerals of normal resistance reservoir is 16 ~ 28%and the content of smectite in low resistance reservoir is 52 ~ 70%, which is positively related to the cation exchange capacity.
Smectite is distributed in two types. The first type is thin filmwhich wraps rock framework grainsleading to the formation of a conductive film on the surface of rock framework grainsand this type accounts for about 80%; A small amount of smectite exists between rock grains in flocculent and dispersed formand the smectite between grains accounts for about 20%this type is relatively dispersed and fails to form a continuous conductive structure.
Moreover the rock framework grains of N_1gIIIformation are in point contact to line contact due to compaction, which leads to the contact of smectite conductive film on the surface of rock framework grains and the formation of continuous conductive structure.
According to the digital core experiment, smectite is in film shape and rock framework grains are in contact with each other. Moreover, smectite is easy to form a continuous conductive structure while the content is greater than 45%, which is consistent with the understanding of the study area.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Thickness prediction and sedimentary architecture characterization by the combination of well logs and seismic data in lacustrine gravity flow deposits

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Keywords: Sedimentary architecture, Seismic attribute, Frequence-decomposed inversion, Lacustrine gravity flow, Qingcheng oilfield

The Chang 7 formation in Qingcheng Oilfield of Ordos Basin develops abundant hydrocarbon reservoirs, which were generally related to lacustrine gravity flow. And Chang 7 formation contains three sand-groups, each sand-groups can be divided into many of zones. The reservoirs of Chang 7 formation are tight sandbodies, and their geological structures are complex. This work aims to fully understand their distribution and features, mainly including predicting the thickness distribution and characterizing the sedimentary architecture of compound sandbodies by combining the well logs and seismic data. For Zhuang 214 block of Qingcheng Oilfield, the sedimentary architecture of gravity-flow deposition was characterized and a 3D lithological model was established, by combining the fusion of frequency-decomposed seismic attributes and intelligent seismic inversion. Firstly, the original seismic cube was decomposed into multiple seismic volumes with different dominant frequencies using the method of continuous wavelet transform, i.e., frequency-decomposed seismic volume (FDSV). These FDSVs and their seismic attributes were selected according to the thickness interpreted from well logs. Distribution and thickness of sandbodies at sand-groups were predicted by fusing the seismic attributes. Secondly, the frequency-decomposed inversion was performed on the original seismic data. A 3D lithological model was modelled with the algorithm of sequential collaborative indication Kriging based on the well logs and seismic inversion result, in which the seismic inversion result is the collaborative data. The radio of sand thickness to its related zone thickness can be extracted by the 3D lithological model and multiplied by its related zone thickness to obtain the sand thickness distribution of each zone. Finally, under the restriction of the thickness of sandbodies, the fine characterization of single sandbodies was completed. The results indicate that: (1) compared to the single attribute, the correlation between the fused seismic attributes and the sand thickness improves greatly. (2) The 3D lithological model modelled using the seismic inversion results can further improve the prediction accuracy of thickness, and sand thickness of all zones were predicted. (3) The sandbodies of three sand-groups show obvious progradational sedimentary characteristics. The high value area of sand thickness advances along the provenance direction. (4) Single lobes are distributed in tongue shape, and their scale is controlled by A/S ratio. The scale of single sandbodies decreases when A/S radio increase, but increases when A/S radio decrease. The thickness of single sandbodies is mainly less than 6m and the width between 300m and 2000m.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Oral Preferred

Depositional features and growth pattern of large shallow-water deltas in depression basin

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Keywords: depression basin, shallow-water delta, depositional feature, growth pattern, Poyang Lake

Large shallow-water deltas in depression basin contribute to the main potential increase of onshore lithologic reservoirs in China. The Baoqian delta of the Upper Cretaceous in southern Songliao Basin and the modern Ganjiang delta in Poyang Lake were analyzed. The particular focus was put on the paleo-environmentdepositional features and growth pattern of this type of delta.1Depression basins are favorable for large shallow[1]water deltas. Unconfined morphology results in the frequent rise and fall of lake-levelwhich controls the delta dimension in dip direction.2There are two different types of deltas in the Upper Cretaceous of southern Songliao Basin. One is deep-water delta characterized by lobe shape and easily-identified depositional faciesmainly including distributary channelsmouth barsand interdistributary bays. Another is shallow-water delta characterized by bird's foot shape and obscure boundaries between depositional faciesmainly including distribu[1]tary channels and interdistributary bayswith mouth bar less developed.3The remote sensing for modern sedimentary systems reveals the evolution of Ganjiang middle delta in Poyang Lake in recent 50 yearsshowing the transition from disperse branch shape to connective network shape.4Large shallow-water delta in depression basins is a complex consisting of several deltas formed in multi-scenarios. The sand-bodies of distributary channels are the most significant reservoir and carry massive lithologic reservoirs. They are distributed horizontally in a net pattern and control the distribution of lithologic reservoirs.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Oral Preferred

Reservoir Characteristics and Sedimentary Models of the Third Member of Dongying Formation on the Western Slope of Liaozhong Sag

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Keywords: sublacustrine fan, sediment gravity flow, seismic response characteristics, sedimentary model, reservoir prediction

With the increasing exploration degree in Bohai Oilfield, the lithologic trap related to sublacustrine fan has become a hot field with the Paleogene sandstone as its reservoirs, but the genetic types and subtly characterization of sand bodies are still unclear. Based on drilling, coring, logging, analytical testing and 3D seismic data and guided by theory about sediment gravity flow, this paper takes the third member of Dongying Formation of the western slope of Liaozhong Sag as the research object to strengthen the application of prediction technology of new reservoirs and provide theoretical support for oil and gas exploration in this area.

Braided river delta deposits are well developed on the slope, which can be uncemented under the trigger of slump and then transported into the lake floor and form the sublacustrine fan deposition. Four types of sediment gravity flow, including slides, slump, debris flow, and turbidity current are developed in this area. The sublacustrine fan sediments are divided into the inner fan subfacies dominated by slides-slump, the middle fan subfacies dominated by debris flow and the outer fan subfacies dominated by turbidity current. And the sedimentary model of the sublacustrine fan on the western slope of Liaozhong Sag is established. (Different subfacies of sublacustrine fans have obvious seismic response, which can be characterized by strong parallel reflection, imbricated reflection and weak discontinueous reflection. Reservoir inversion, slice and multi-attribute analysis are also used to track the envelope related to the top of the reservoir. Under the constraints of seismic attributes and formation thickness, these responses are used to subtly depicted the petroliferous fans. The study result shows that it is important for lithology oil and gas exploration in Bohai Sea Area to discover more sublacustrine fans by the established sedimentary model and seismic response. Due to the bulk freezing characteristics of slides-slump and debris flow, sand-rich bodies can also develop on the slope of lake floor. And due to the superposition of multiple gravity flow events, debris flow can form continuous sand bodies of medium fan and advance to the central basin, which has great significance to expand the exploration in the field of deep water.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Oral Preferred

Intelligent fluvial sand body prediction and architecture characterization of Guantao Formation in Chengdao oilfield, Bohai bay basin, China

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Keywords: Sand body prediction, Architecture characterization, Intelligent seismic attribute fusion, Frequency-decomposed genetic inversion, Fluvial reservoir

The study of the fluvial successions is the most important hydrocarbon clastic reservoirs in China, characterizing meander belts and point bars in fluvial reservoirs is significant for reducing drilling risks and improving the recovery of oil and gas. Although many valuable studies have been done in the past decades, the research on quantitative sand body prediction and fine architecture characterization combined with well and seismic data has been relatively weak. Therefore, a fluvial reservoir case in Chengdao oilfield is selected in this research, intelligent frequency-decomposed attributes fusion, fusing seismic attributes of target and neighboring zones, and frequency-decomposed genetic inversion are used to predict sand body and architecture distribution, the research results and conclusions are as follows.

Three intelligent methods for sand body prediction are proposed to improve the interpretation of seismic data during the characterization of fluvial reservoirs and the establishment of fluvial models. (1) The method is proposed, which combines the frequency decomposition, attribute optimization and machine learning, and can predict the sand thickness quantitively. (2) Frequency decomposition and genetic inversion are combined, forming a new inversion method, to predict sand body distribution effectively. (3) A novel method is proposed that combines multiple seismic attributes of the target interval and of its interfering neighboring zones, implemented by a supervised machine learning, which remarkedly reduces the interference of the neighboring zones.

On the basis of sand body prediction, combined with well logging response characteristics, the distribution of meander belt, point bar and abandoned channel are characterized. The three important symbols of point bar are composite positive rhythms, thick sand-bodies, and being adjacent to abandoned channels. Corresponding to these features, point bars show the characteristics of seismic response with high fusing seismic attributes and high genetic inversion properties, while abandoned channels show low fusing attributes and low genetic inversion properties with the characteristics of flat top and convex bottom. Based on the application of using fusing seismic attributes and inversion properties to predict the location of the point bar, the span of the point bar is calculated through empirical formula, the scale of point bar is recognized, and the identification of subsurface point bar is effectively guided. The constraint of dynamic data also provides a basis for point bar identification. This method proposed in this paper can provide implications to the oilfield with similar sedimentary characteristics and data condition.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Oral Preferred

Study of provenance, sedimentary environment and paleoclimate of Permian Jiamuhe Formation in Shawan Sag, Junggar Basin

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Keywords: provenance system, sedimentary environment, paleo climate, Jiamuhe Formation, Shawa Sag, Junggar Basin

many years of oil and gas exploration practice has proved that shawan sag in Junggar Basin has great potential, but its provenance is unknown, sedimentary system is not clear, sandbodies distribution are unknown, which restrict further oil and gas exploration. Based on detailed description of legalistic cores, comprehensive analysis of logging, seismic and outcrop data. This paper makes a thorough study of the study area by using grain size analysis, Q-type cluster aanlysis of heavy minerals, statistics of detrital particles and elemental geochemistry analysis. The provenance system, formation mechanism and distribution on law of sandbodies are clarified, and paleoclimate chages are summarized.

1) The provenance system of Permian Jiamuhe Formation in Shawa Sag is characterized by “a system of provenance, three provenance directions” and “a major provenance, three secondary provenances”. The REE distribution patterns of the samples all showed a right-leaning distribution patten, with negative Eu anomalies and a “V” type in the figure, indicating stable provenance in the study area. In the LREE(La~Eu) segment, the element distribution curve has a high slope and an obvious “right-leaning” degree, indicating a high degree of fractionation between LREE elements. On the contrary, the distribution curve of HREE(Dy~Lu) indicating a low degree of fractionation between HREE. In La/ Th-Hf, most of the samples fall on the acidic rocks in the acidic island arc region, which are dominated by granite and felsic volcanic rocks. The results of cluster analysis showed that the provenance of the south and the north had broad homology. According to multidimensional scale analysis of heavy minerals and REE, principal component analysis, the provenance of the study area can be divided into three types. The primary provenance in NW direction and secondary provenance in other directions.

2)“One provenance system and two kinds of sedimentary environment” developed in the study area. Jiamuhe Formation is mainly composed of coarsen gravelly sandstone, volcanic recks and poor structural maturity. Sedimentary structure is not developed, but scour surface, the reddish mudstone and “floating conglomerate” are mostly along the fault zone, indicating a near provenance and rapid sedimentary environment. Volcanic sedimentary facies, lithofacies of clastic rocks and their lithofacies assemblages were established. There are volcanic sedimentary facies dominated by tuff and andesite in the study area. the fluvial fan-delta facies, dominated by gravelly sandstone, was affected by provenance and hongche fault zone, and developed three fan bodies with different provenance directions.

3)Based on the determination of 25 elements in 40 samples from Jiamuhe Formation. The paleosedimenraty characteristics are reconstructed by analyzing the contents and ratios. Th/U values ranged from 0.67~8.33, with an average of 5.59. One δU is greater than 1, and the others are all less than1. V/(V+Ni) values range from 0.79-0.99, with an average of 0.88, indicating that H2S exists in stratified water and anaerobic environment in formation water. Sr/Ba ranges from 0.25-1.02, with an average of 0.57, and is mainly dry heat. Sr/Cu values range from 6.13 to 45.24, with an average of 21.55>. 10 indicates that the climate is relatively dry and hot.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Oral Preferred

A MPS-based novel method of reconstructing 3D reservoir models from 2D images using seismic constraints

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Keywords: two-dimensional images, three-dimensional reservoir modeling, Seismic constraint, Probability aggregation, multiple-point geostatistics

While multi-point geostatistics (MPS) be used to model complex underground reservoirs, this method relies heavily on high-quality three-dimensional (3D) training images that may be difficult to acquire in real field studies. Furthermore, the original MPS technique does not include seismic data, which may noticeably improve underground reservoir predictions. Our proposed model, Se3DRCS, is a novel method to reconstruct 3D geological models from two-dimensional (2D) images and seismic information. In Se3DRCS, we are able to perform MPS-based modeling using 2D training images, rather than 3D images. These 2D images are produced by analyzing well profiles and sedimentary facies planes. After using the Se3DRCS method to obtain an initial geological model, we then generate elastic parameters and synthetic seismograms via direct sampling and convolution with the extracted seismic wavelets, respectively. By comparing the observed and synthetic seismic records, we refine the simulation results using the adaptive sampling method. The initial geological model is then updated with conditional data after each subsequent simulation iteration. When the error between the observed and synthetic seismograms falls below a reasonable threshold value, we have arrived at the best-fitting geological model. Our results indicate that the Se3DRCS method is capable of predicting the data elicited from wells with an accuracy of up to 82.88%, providing constraints on the distribution of branch channels in a delta reservoir, and reproducing local complex non-stationary geological features.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Oral Preferred

Terminal Fan Analysis of the Paleogene Lower Fourth Member of the Shahejie Formation in the Bonan sag, Jiyang Depression, China

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Keywords: Terminal Fan, Lower Fourth Member, Shahejie Formation, Bonan sag.

The Lower 4th member of the Paleogene Shahejie Formation in Bonan sag, Bohai Bay Basin, East China was taken as the target for our study object to identify the potential and favorable reservoirs for further studies on a great scale. In Bonan down warping region, Paleogene stratona deposits are mainly terrigenous clastic materials that formed in arid or semi-arid regions. From a classical view, on the face of it, four depositional systems were developed in the Bonan sag. Among them, the fan delta developed in the central part of the study area, consisting of gray-white fine glutenite with poor sorting and rounding. The braided river delta is developed in the southern part with the lithology of light gray conglomerate, pebbly sandstone, and sandstone. Sedimentary structures like parallel bedding, cross-bedding and scour are visible. Floodplain sedimentary facies is mainly developed in the inundating plain that in some weather conditions has the characteristics of shallow lake facies. However, insufficiencies appeared, in the instance of presence explanation on multiple colors of mudstones, the relatively strong and low levels of total organic carbon (TOC) which are very disparate in the area. Consequently, given the conditions of deposits, the depositional system which occurs in the area suggests that it would rather be terminal fan deposits. Although some scholars have conducted studies on terminal fans abroad and in China, the concept remains unfamiliar and deserves to be more elucidated, that will be the case in this study. In that case, the study approach must be reviewed for oil exploration.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Oral Preferred

Characteristics of stratigraphic structure of nanhua-Sinian rift-depression sedimentary system and its control on source, reservoir and cap in Tarim Basin

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Keywords: Tarim basin, Rift-depression sedimentary system; Ancient source rocks; Control Source,, Control reservoir, Control trap

Based on outcrop, drilling and gravity, magneto-electric and seismic (2-3D) data, the wave group characteristics of Nanhua-Sinian were calibrated using virtual well synthetic record calibration method.Optimize the 2-3D seismic data, build the frame section, establish the sequence structure model, determine the stratigraphic interpretation scheme, and carry out geological series and mapping work of the whole basin.The stratigraphic structure and distribution range of The Nanhua-Cambrian system are analyzed in detail based on the framework section and basin map. It is concluded that the Nanhua-Sinian strata have obvious characteristics of rift basin and developed two structural backgrounds of rift and depression.The stratigraphic structure can be divided into four seismic reflection types corresponding to four sedimentary facies combinations according to the characteristics of internal wave group and the termination relation of reflection axis.The nanhua-Sinian system can be divided into three second-order sequences by identifying four large unconformities and three Marine flooding surfaces.According to the outcrop and drilling data, the paleo-rift has the characteristics of controlling source, controlling reservoir and controlling trap: controlling the development range of ancient source rocks of Sinian-Cambrian, controlling the development location of ancient reservoirs and ancient traps of paleo-slope and paleo-uplift.Based on the exploration practice of the ancient carbonate reservoirs in Anyue Gas field of Sichuan Basin, it is considered that the paleo-uplift surrounding the hydrocarbon generation depression is a favorable exploration area. The slope of the central margin of the Nanhua-Sinian rift, the uplift area and the Cambrian platform margin zone are surrounded by the tectonic sedimentary background with large-scale accumulation. It has laid a solid foundation for the search and evaluation of ancient traps in ultra-deep ancient carbonate rocks in Tarim Basin.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Oral Preferred

Influence of geomorphology and subaerial leaching process on the formation of bauxite deposits of the Early Carboniferous Jiujialu Formation in central Guizhou, south China

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Keywords: Jiujialu Formation, Central Guizhou, Paleogeomorphology, Bauxite

The Lower Carboniferous Jiujialu Formation bauxite deposits are widespread in central Guizhou, south China (Ling et al., 2015, 2017; Wang et al., 2018). We collected data from ~700 drillcores in central Guizhou to reconstruct geomorphological characteristics for the period of formation of those bauxite deposits, which indicates that thicker bauxite deposit are concentrated in relatively deep depressions. We undertook a petrological, mineralogical, and geochemical study of the Xiuwen deposit in drillcore ZK43-20 which is located within the karstic depression revealed on geomorphological reconstructions to gain insights into its formation history. Deposits of Jiujialu Formation within the drillcore of ZK43-20 contains Al-rich deposits in the upper member and Fe-rich deposits in the lower member. Bauxite ores are characterized by high Al_2O_3 and Al-mineral content, while low SiO_2 content. Bauxitic claystone is characterized by relatively lower Al_2O_3 and higher SiO_2, clay mineral (mostly illite and kaolinite) content. Geochemical characteristics of samples from the study drillcore indicates that leaching is the main control on quality of bauxite ore, while a low groundwater table and water-permeable underlying units contributed to the formation of high-grade bauxite ores in the study area. The formation of high-grade bauxite ores was accompanied by the further losses of most mobile elements (e.g., KNa, Ca, Mg, Si) and further relative enrichment of Al under intense chemical weathering and leaching processes. On the other hand, trace elements (particularly Li) and rare earth elements are relatively enriched in bauxitic claystones and Fe-rich claystones. Sedimentary features, geochemistry characteristics and paleosalinity analysis indicate Fe-rich deposits of Jiujialu Formation are residual, while Al-rich deposits are formed in the subaerial environment while the leaching process and geomorphology influence the formation.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Oral Preferred

Lacustrine shallow-water delta front formation processes and main controlling factors

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Keywords: shallow-water delta, inner delta front, outer delta front, fluviation, sediment supply, water-level oscillation

Although the shallow-water delta facies have been studied for decades, the formation process of this kind of delta remains poorly documented. Differences in the morphology and facies architecture are potentially significant for exploration and development of these kinds of reservoirs. In this article, facies analysis was applied to the Yanchang Formation exposed in the Ordos Basin of China, while the delta front formation process was studied by observation and description of the Ganjiang modern delta at Poyang Lake, China. We documented the shallow-water delta microfacies and their spatial arrangement and analyzed them in the context of formation processes under different fluvial and wave force conditions. Seasonal water-level oscillation separated the delta front into the delta inner front (DIF) and outer front (DOF), which differentiates the shallow-water delta from a traditional Gilbert delta. Three facies sets were recognized in the DIF: (i) distributary channel, (ii) preserved mouth bar, and (iii) interdistributary silt and mud; and four facies were recognized in the DOF (i) distal channel, (ii) mouth bar, (iii) fluxoturbidite, and (iv) sheet sand. Because of the seasonal submergence of the DIF, fluviation dominated during drawdown and wave action dominated when the water level was high. Channels at the DIF can be classified into the main channel, which is characterized by large scale and low width to depth (w/d) ratio, and the migration channel, which is characterized by high w/d ratios. The mouth bar also developed under shallow-water conditions. At the DIF, few mouth bar sand deposits are preserved because of the erosion by the migrating channels, but mouth bars are well preserved at the DOF. Because the DIF channels are the main reservoirs, we studied the physical property distribution within the different channels. The best porosity and permeability values were located in the core of the main channel; the flank, top, and bottom of the channel had lower porosity and permeability. The physical property distribution in the migration channels is similar to that of the main channel, but porosity and permeability decrease along with the lateral migration direction of channels as well.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Oral Preferred

Quantitative identification of the conglomerate diagenetic trap

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Keywords: diagenetic trap, critical physical property, quantitative identification, Junggar Basin

The lithology of the reservoir of conglomerate diagenetic trap is the same as that of the surrounding rock, and the physical property difference is small. It is very difficult to define the reservoir and non-reservoir. In order to describe diagenetic traps in detail and improve the identification accuracy of conglomerate diagenetic traps, we start with the analysis of oil and gas filling power and resistance, and confirm that the effectiveness of diagenetic traps is controlled by the pore structure characteristics of reservoir and surrounding rock, so as to establish the relationship between critical physical properties and depth. The sensitive parameters are optimized, the functional relationship between reservoir physical properties and small angle elastic impedance is established, and the quantitative identification of effective reservoirs under different depth conditions is solved by using seismic data volume, so as to realize the spatial characterization of variable depth of diagenetic traps. This method is applied to Triassic Baikouquan Formation of Mahu sag, Junggar basin. It is the first time to recognize that the reservoir critical physical properties of oil and gas filling in conglomerate diagenetic trap change with buried depth, and quantitatively characterize the differences of diagenetic trap formation conditions at different depths. The carefully identified conglomerate diagenetic trap provides an effective basis for drilling well deployment.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Sedimentological and Diagenetic control on the ASR viability in the Edwards aquifer (New Braunfels, Texas)

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Keywords: Aquifer storage and recovery, sustainable, water resources, sedimentology, diagenesis, storage zone

The Edwards aquifer is a sole source aquifer providing drinking water to over 2 million people in South-central Texas. It is a two-layered aquifer, the upper layer being the Pearson formation (storage zone 1), and the lower layer, the Kainer formation (storage zone 2) — both separated by the confining layer, the Regional Dense member (RDM). With increasing population and extreme climate conditions, the stress on freshwater availability has increased and annual water demand has been projected to surpass the maximum year supply by 2024 in New Braunfels (Texas). Aquifer storage and recovery (ASR) has proved successful in converting seasonally available water supplies to reliable, resilient, and sustainable water resources, even in brackish aquifers. It is a cost-effective engineered method for storing water during times when water is available and recovering it when needed. However, an efficient and successful ASR operation depends on site-specific hydrogeological and hydrogeochemical conditions. This study characterizes the sedimentology of the two-layered Edwards aquifer system by (1) describing the initial and diagenetic texture and fabric of the aquifer matrix, (2) placing diagenetic events into a paragenetic sequence, and (3) evaluating the abundance of porosity types by point counting and inferring their distribution pattern in enhancing the permeability. The objectives are to decipher the main diagenetic processes and porosity types to better guide ASR operations. This will help target storage zone(s) that would allow optimal ASR recovery efficiency with water quality meeting minimum requirements. Dolomitization, fracturing, and dissolution are late diagenetic processes and may play a major role in the aquifer's storativity and transmissivity. Due to their brittleness, dolomitic sections appear to have been readily fractured compared to micritic sections. In addition to intercrystalline porosity developed by dolomitization, fractures, and dissolution likely enhanced connectivity between pores. Intercrystalline porosity is abundant from 618 to 7111 ft depth (current ASR storage zone) and 756 to 825 ft depth. Well preserved compaction features observed in the confining unit (RDM) separating both aquifer zones probably contribute to its low permeability. However, partially cemented fractures in the Regional Dense Member present potential pathways connecting both aquifer zones. These cemented fractures may be weak zones likely to re-fracture due to an increased pumping induced gradient following recovery of water stored in one aquifer zone. This study suggests implementation of two ASR wells screened in dolomitic portions of the Kainer formation and Pearson formation of the Edwards aquifer in order to limit head pressure differential that would have been generated from pumping in only one storage aquifer zone.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Oral Preferred

Depositional Architecture of Mouth Bar in Lacustrine Fan Delta Front through unmanned aerial vehicle (UAV): Insights from the Lower Cretaceous Xiguayuan Formation of Sangyuan outcrop, Luanping Basin

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Keywords: Sangyuan outcrop, Fan delta front, Mouth bar, Development, Vertical garin-size trend

Fan delta, as an important sedimentary type at the margin of basin, is an important place for the enrichment of petroleum, natural gas and other geological resources. Although many studies about sedimentary characteristics of fan delta front in lacustrine basin have been done in the past decades, it is poorly understood that the depositional architecture of mouth bar. Unmanned aerial vehicle (UAV) observation was used to investigate the lacustrine fan delta of Sangyuan outcrop within Xiguayuan Formation of Lower Cretaceous in Luanping Basin, aiming to analyze the sedimentary characteristics of mouth bar and discuss the development degree. The mouth bar with flat bottom and convex top mainly consist of sandy and gravelly accretions. The sandy accretion shows an overall coarsening upward trend, and gravelly accretion shows the fining upward trend. The vertical grain-size trend of mouth bar is controlled by superposition patterns of the accretion bodies, which shows either coarsening upward trend or fining upward trend. The mouth bar is widely developed in study area, which accounts for 36.88% of glutenite bodies in Sangyuan outcrop. The distributary channels, tongue-shaped debris deposits and sheet sand account for 53.42%, 8.39% and 1.31%, respectively.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Oral Preferred

Configuration characterization of distributary channel-type shallow water delta reservoir: A case study of oil formation L60 in PL Oilfield, Bohai Sea

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Keywords: Seismic attribute optimization, shallow water delta, distributary channel, Reservoir configuration, Bohai Sea

The L60 oil formation of PL oilfield in Bohai Sea is composed of delta front subfacies, and the reservoir is mainly developed with distributary channel microfacies. The reservoir thickness changes rapidly and inter-bedded reservoirs are relatively developed. The commonly used amplitude seismic attribute cannot effectively identify this reservoir and find difficult to describe fine reservoirs. In this study, the seismic attributes are classified and optimized to improve the prediction accuracy of inter-well reservoirs. On this basis, combined with core and logging data, the reservoir configuration of offshore distributary channel-type shallow water delta sand body is studied, and the classification of sand body configuration, interface recognition standard and sand body superposition model are established. Through the optimization analysis of seismic attributes, the average instantaneous frequency attribute has a good correlation with the thickness of reservoir sand body of L60 oil formation in the study area, and the distribution characteristics of sand body are re-recognized based on this attribute. The shallow water delta sand bodies in the area can be divided into four configuration levels: delta body, delta front sedimentary body, composite channel and single distributary channel. The longitudinal interface of single distributary channel includes mudstone interface, siliceous interface and physical interface of erosion origin. Lateral interface recognition including river edge, thickness difference of channel sand body and interchannel discontinuous sand body. The sand body superposition model can be divided into four types: isolated type, docking type, lateral cut superposition type and lateral superposition type. Finally, the shallow water delta channel sand body configuration model in the study area is established, which provides a basis for pre-drilling well location optimization and horizontal well deployment.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-4: Characterization of subsurface sedimentary architectures
Presentation Preference: Oral Preferred

Configuration anatomy and application of composite sand body based on seismic attributes: Taking Guantao Formation in Well Block5 in Oilfield P of Bohai Bay Basin as an example

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Keywords: Composite sand body, forward modeling, seismic attributes, onfiguration

Well Block5 in Oilfield P of Bohai Bay Basin has entered a high water-cut period. The main reservoir of Guantao Formation is the L50 sand body, which is a composite channel bar sand body reservoir. Implementing horizontal wells to excavate the remaining oil, it is difficult to drill due to the impact of bottom water flooding, poor top reservoirs, and internal barrier interlayers. It is necessary to carry out the fine configuration anatomy of the L50 sand body to guide the deployment and implementation of horizontal wells. This topic is based on the high-resolution seismic data, combined with the understanding of reservoir stacking mode and forward modeling, it is proposed to use the root mean square amplitude attribute combined with the minimum curvature attribute to analyze the boundary and superposition relationship of main and secondary channels in the composite sand body, and complete the sedimentary model of L50 sand body and the characterization of the internal structure of composite channel bar sand body.The result was indicative that: The boundary channel and internal main channel in L50 sand body are relatively stable, the internal secondary channel migrates frequently, and the sand body has experienced three stages of development, maturity and decline. It is considered that the horizontal well should avoid the main channel on the plane and the top poor reservoir on the vertically. The research results guide the optimization of horizontal wells and the implementation while drilling, and contribute to the efficient tapping of oilfield potential.

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Session T9-5: Unconventional petroleum sedimentology

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Evolution mechanism of bedrock weathering crust and its control significance to reservoir in Dongying Sag, Bohai Bay Basin

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Keywords: bedrock weathering crust, evolution mechanism, main influencing factors, distribution characteristics, Dongying sag

The exploration potential of the bedrock reservoir is notably large, and clarifying the evolution mechanism and main influencing factors of bedrock weathering crust is the premise of predicting the distribution of favorable reservoirs. Based on cores and thin section observations, outcrop surveys, conventional logging data, image logging analysis and seismic interpretations, our study systematically explores the dynamic mechanism of the formation, transformation and preservation of bedrock weathering crust reservoirs in Dongying Sag, Bohai Bay Basin. The results indicate that the vertical structure of bedrock weathering crusts in the study area is a double layer composed of a top eluvium or dissolution layer (completely weathered layer) and a bottom disintegration layer (semiweathered layer) and the dissolution and eluvium layers are the products of different evolution stages on top of the disintegration layer. In the early evolution of the weathering crust, the disintegration layer began to develop into a dissolution layer, and a double layer with dissolution layer and disintegration layer appeared; in the middle-stage evolution of the weathering crust, the dissolution layer evolved into an eluvium, forming a double layer with eluvium and disintegration layer. In the late evolution of the weathering crust, only the disintegration layer was preserved. Bedrock weathering crust reservoir has undergone structural tilting, fracture destruction, fluvial abrasion and other transformation effects when it is formed, and it is believed that the preservation effect brought by the later stratigraphic coverage is crucial to the bedrock weathering crust. The earlier the later stratigraphic coverage occurs, the better it is for the preservation of bedrock weathering crust reservoirs. There is a huge difference in the types of weathering crust on different elevations, different slopes and different structural belts. Only disintegration layers are developed at the top of the structure, eluvia are developed in the marginal areas of the high structural part, and dissolution layers are developed in middle- low structural parts. The disintegration layer is widely distributed. The analysis of the formation, transformation and preservation evolution mechanism of bedrock weathering crust not only gives us a more comprehensive understanding of the evolution of bedrock reservoirs, but also provides new ideas and theoretical support for further exploration of bedrock reservoirs in other rift basins worldwide.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
Presentation Preference: Oral Preferred

Organic matter thermal maturation and organic pore development and preservation in black shales

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Keywords: Organic matter, maceral, thermal maturation, organic pores, solid bitumen, black shales

Organic matter (OM) quantity, quality, and thermal maturity are key parameters in source rock evaluation and shale reservoir characterization. OM-hosted pores are important constituents of the pore system in shale reservoirs, and they, to a large degree, control the gas content and porosity of shales. OM in black shales can be classified into four types of kerogens (kerogen type I, II, III, and IV) based on H/C and O/C atomic ratios and five maceral groups (vitrinite, inertinite, liptinite, zooclasts, and secondary organic matter) with each group consisting of multiple macerals. Different macerals have different origins, and varying potential of hydrocarbon generation and development of organic pores. Oil-prone macerals such as alginite and bituminite generally disappear after peak oil window maturity (Ro 0.8–1.0%) due to hydrocarbon generation. Organic pores in black shales can be primary or secondary, the latter of which is the dominant type. Primary pores are pores inherited from the biological structure of the original OM such as cellular pores in inertinite, but they are typically filled with diagenetic minerals. Secondary organic pores occur in solid bitumen or pyrobitumen, and their development is related to thermal maturation of oil-prone macerals. The development of secondary organic pores is controlled by OM type and thermal maturity, and their preservation depends on thermal maturity, OM content, mineralogical composition of shales, as well as pore pressure. When conducting source rock evaluation, the hydrocarbon generation potential of OM should be studied based on a good understanding of maceral types, composition, and their hydrocarbon generation potential. In order to accurately assess the contribution of organic pores to the pore system of shale reservoirs, the influence of OM type, content, and thermal maturity should be taken into consideration.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Sedimentary characteristics and sand body distribution law of Chang 81 reservoir in Heshui area, Ordos Basin

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Keywords: Heshui area, Shallow water delta front,Chang 81,Sand body structure,Distribution

Abstract: Shallow water delta deposits developed in the Chang 8 Member in the Ordos Basin. This paper takes the Chang 81 Member in the Heshui area as an example to study the structure and distribution of sand bodies. On the basis of previous studies, through the observation of core slices, combined with the analysis of logging and logging data, it is determined that the Chang 81 Member in the study area mainly develops shallow water delta front deposits, and underwater distributary channel sand bodies are the main reservoirs. The long 81 is divided into three sub-layers from top to bottom according to the deposition cycle. According to the response characteristics of sand body log curves and the relationship of vertical superposition, the sand bodies of Chang 81 Member are mainly divided into the following types: multi-phase channel superposition type, single-phase channel type, sand bar type and isolated type. body. The sand bodies are distributed in the NE-SW direction as a whole, and the sand bodies are multi-stage. The thickness of the sand bodies developed in each depositional stage and the location of the sand bodies fork or intersect are different. The distribution pattern is complex: the multi-stage superimposed sand bodies are mainly distributed in Chang 811, Chang 812 and partly in Chang 813; other types of sand bodies are partially distributed in each layer, and the main type is single-stage channel-type sand bodies. The overall distribution frequency of multi-stage superimposed sand bodies is low and the thickness is large, and they are high-quality reservoir sand bodies in the Chang 81 oil layer group in the study area. The sand bodies with better performance are the main reservoir sand bodies in the study area; the isolated sand bodies are less than 3m thick, with weak depositional energy, impure sand quality and poor reservoir physical properties, are invalid reservoir sand bodies and are widely distributed on the flanks of the main channel. On the whole, the sand body quality of Chang 811 period is better than that of Chang 812 period, and the sand body quality of Chang 813 period is the worst.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
Presentation Preference: Oral Preferred

Differential sedimentary response of coal seams in coal-bearing rock series and oil and gas exploration:A case study of J1b Formation in Mahu slope area

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Keywords: coal-bearing rock, J1b Formation, Stable thick coal seam,Limited thin coal seam,Coal humic acid

The coal-bearing rock in the different sedimentary response of different kinds of coal seam, and the effect of adjacent glutenite diagenetic into reservoir research is relatively weak at present, through the field outcrop, sporopollen combination, well - seismic profile, core phase sequence, logging response, such as scanning electron microscope, electron probe energy spectrum data, a stable thick coal seam in the studied area, limited thin coal seam are analyzed in different sedimentary response. The results showed that represented by thrust faults I and II of the basin edge the oscillation behavior of resurrection of boundary faults and the basin basement subsidence, provides the study area with thick layers of peat accumulation, wide wide slow - ancient slope cover lake invasion, hinder the swamp drainage to prevent the oxidation of the organic matter, reduce the river gradient - weakening terrigenous clastic interfere with the four aspects, such as favorable conditions, A large area of stable thick coal seam was formed near the first lake flood surface in the lacustrine basin, and the maceral indicates that the coal forming swamp has maintained a good hysteretic water reduction condition. The limited thin coal seams are scattered and have obvious phase-controlled characteristics, and are mostly distributed in the low energy facies zones such as interfan/interchannel with weak hydrodynamics. The maceral indicates that the coal forming swamp has a semi-oxidation stage with poor local hysteretic reduction conditions. In penecongenic-early diagenetic stage, humic acid in coal measures formed dissolution pores in feldspar grains of early diagenetic stage, and the dissolution particles were dominated by calcium-rich plagioclase. The occurrence of kaolinite cement products is mainly close to the inner ring edge of particles, and its purity is high. Complete kaolinite particles and partial kaolinite particles are formed by the process of dissolution of feldspar particles, kaolinite filling and collapse polycondensation. The former is of high purity and the latter is of low purity. In the middle diagenetic stage, organic carboxylic acid of hydrocarbon source forms dissolution pores in feldspar grains in the middle diagenetic stage, and the dissolution components are mainly potassium feldspar, and the dissolution residual components are mainly albite. The occurrence of cemented kaolinite is mainly the outer ring edge of particles or filling intergranular pores with low purity. The influence of humic acid in coal measures on the quality of adjacent conglomerate reservoir is mainly inhibition. The vertical radiation thickness of stable thick coal seam is 10-30m, the porosity of conglomerate in radiation zone decreases by 2.3%-5.2%, and the permeability decreases by 1.3-2.1mD. The vertical radiation thickness of limited thin coal seam is 3m-8m, the porosity of conglomerate in radiation zone decreases by 1.2%-3.5%, and the permeability decreases by 0.8-1.9md. The high content of rigid particles is the prerequisite for the effective preservation of the original intergranular pores, especially the humic acid solution pores in the penicsyngenetic and early diagenetic coal measures. The removal degree of dissolution products such as kaolinite and silica further restricts the effectiveness of the pores.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
Presentation Preference: Oral Preferred

Major geologic events affect organic matter enrichment in the upper Guadalupian in South China

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Keywords: Organic matter enrichment, Emeishan LIP, Kuhfeng Formation, Organic-carbon isotope, Hg concentration

Extraordinarily high organic matter enrichment occurs in the black shale/chert in the Kuhfeng Formation of South China. This OM-rich interval is one of the most interesting shale gas exploration targets in China. The formation process of this black rocks in the Guadalupian is the key for unconventional petroleum exploration in this field. My work presents a significant organic-carbon isotopic composition and Hg anomalies evidences for uplift of Emeishan large igneous province and its contribution to the extraordinarily high organic matter accumulation in the Kuhufeng Formation. OM burial responsed to the Emeishan LIP uplift via abrupt increasing of TOC content, suggesting that rapid crustal uplift and volcanism triggered the onset of extraordinarily high OM enrichment.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
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Characteristics and origin of calcite cementation in Ahe Formation sandstone reservoirs in Dibei area of Kuqa Depression

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Keywords: Calcite, Deep fluids, Coal measures strata, Jurassic, Kuqa depression

Calcite cements are widely developed in clastic rock reservoirs and are one of the key factors causing reservoir diagenetic heterogeneity. Taking tight sandstone reservoirs in Dibei area of Kuqa Depression as the research object, core observation, thin section identification, QEMSEM analysis, X-diffraction analysis, field emission scanning electron microscopy analysis, cathodoluminescence analysis (CL), electron probe analysis (EPMA), laser in-situ micro-element analysis, carbon and oxygen isotope testing and other technical methods, on the basis of systematic research on petrological characteristics of tight sandstone reservoirs, finely characterized the petrographic, geochemical and chemical properties of calcite cement in sandstone reservoirs. The spatial distribution and other characteristics indicate that the distribution of calcite cement is controlled by the coal-measure source rocks and the northern Yiqikelike Fault zone. The lithology of the sandstone in the study area is mainly coarse sandstone, and the rock composition is mainly lithic sandstone. In the reservoir close to the first-level fault, the deep fluid activity controls the calcite cementation; while the calcite development in the reservoir far from the first-level deep fault is mainly affected by the second- and third-level oil source faults communicate with the control of the coal measure strata. The calcite content near the deep and large faults is high, and the cementation methods are various, mainly porosity cementation, with the characteristics of high iron-magnesium, high iron/manganese, and light rare earth elements enrichment. And the calcite cement content increases with decreasing distance from the Yiqikelike Fault.the diagenetic fluid may be controlled by deep and large faults, and it is mainly bright-yellow luminescent under cathodoluminescence. The calcite content of reservoirs far from deep and large faults is low, and the formation of carbonate cements is controlled by the fluid during the evolution of coal-measure organic matter. The greater the influence of Yangxia formation coal seam, the lower the negative bias of carbon isotope of carbonate cement.

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Session T9-5: Unconventional petroleum sedimentology
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Unconventional Petroleum Sedimentology: A Key to Understanding Unconventional Hydrocarbon Accumulation

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Keywords: Deposition, Diagenesis, Black shales, Fine-grained sediments, Organic matter enrichment, Sweet spot

After two decades of revolutionary development, the commercial exploitation of unconventional hydrocarbon resources (e.g., shale oil/gas and tight oil/gas) has profoundly changed the global energy structure. The sweet spot, the most prolific intervals (areas) in unconventional hydrocarbon resources, generally consists of the most organic-rich deposits, or sandstones/carbonate rocks closely associated with them. Although the roles of diagenesis and hydrocarbon accumulation are indispensable, the formation of sweet-spot intervals (areas) is fundamentally controlled by their depositional settings, resulting from coupled global or regional geological events such as tectonic activity, sea-level change, climate change, bottom-water anoxia, volcanic eruption, and biotic mass extinction during certain geological time intervals. Mudstones with extraordinarily high organic matter content and their associated high-quality reservoir rocks resulting from the coupling of geological events not only provide a prerequisite for the massive generation of hydrocarbon but also abundant hydrocarbon storage space. Considering four typical unconventional hydrocarbon systems as case studies, i.e., the Ordovician–Silurian Wufeng–Longmaxi Formation of the Sichuan Basin, the Devonian Marcellus Shale of the Appalachian Basin, the Devonian–Carboniferous Bakken Formation of the Williston Basin, and the Triassic Yanchang Formation of the Ordos Basin, their formations were controlled by coupled geological events, resulting in the favorable environment for the production, preservation, and accumulation of organic matter, as well as hydrocarbon generation, migration, accumulation, and extraction. Unconventional petroleum sedimentology, which focuses on the coupling effect of geological events, is key to understanding the formation and distribution of sweet-spot intervals (areas) in unconventional petroleum systems.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
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Analysis of main controlling factors of deep marine shale reservoir of Wufeng-Longmaxi in southern Sichuan, China

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Keywords: Sichuan Basin, Wufeng-Longmaxi formation, deep marine shale, organic matter abundance, gas bearing property, reservoir

Abstract: The geological conditions for the formation of high-quality reservoirs of marine shale in China mainly include organic matter abundance, high thermal maturity, high brittleness and so on. The main controlling factors of deep marine shale reservoir of Wufeng-Longmaxi in Changning-Luzhou- Weiyuan-Dazu block in southern Sichuan were studied by comprehensively using core test data such as logging, geochemistry and XRD diffraction. It was shows that biological siliceous rock, siliceous shale and clay siliceous mixed shale facies were conducive to the development of organic pores, while carbonaceous silty shale facies was not conducive to the development of organic pores. The abundance of organic matter was controlled by redox environment at low deposition rate and paleo-productivity at high deposition rate. The limit was 10 m/MA: at low deposition rate, the higher the reduction degree, the faster the deposition rate, the higher the abundance of organic matter; At high deposition rate, the higher the paleo-productivity, the slower the deposition rate and the higher the abundance of organic matter. The redox environment and paleo-productivity further affected the total gas content through the control of TOC, and the relevant parameters were significantly positively correlated with the gas content. The face rate of shale organic matter increases with the increase of thermal evolution, and will not increase when Ro reached about 3.5%. Therefore, the relatively high thermal evolution was of certain constructive significance. The micropore volume and mesopore volume of shale are positively correlated with the gas content, and mesopore volume had a better linear relationship with the gas content, while the macropore volume had no obvious correlation with the gas content. In a word, lithofacies controls the content of brittle minerals and the development of micro pores in shale; Redox environment, paleo-productivity and sedimentation rate control the abundance of organic matter; Micro pore structure and pore water control the gas bearing property of shale; Thermal evolution controls organic matter pore development and reservoir effectiveness

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Scientific Themes: Theme 9. Resource Sedimentology
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Pore structure characteristics and evaluation of carbonate reservoir: a case study of the Lower Carboniferous in the Marsel exploration area, Chu-Saresu Basin

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Keywords: Chu-Saresu Basin, Carbonate reservoir, Pore structure, Fractal dimension

The pore structure of the carbonate reservoir determines the fluidity and storage characteristics of oil and gas, and it is vital for reservoir evaluation as well as oil and gas production. The Visean and Serpukhovian carbonate reservoirs in the Marsel exploration area of Chu-Saresu Basin possess a complex lithology and pore structure, which seriously affect the production efficiency. In this study, the pore structure of the reservoir was studied via X-ray diffraction, conventional petrophysical measurements, cast thin section analysis, scanning electron microscopy, and high pressure mercury injection. The results show that the lithology in this area mainly comprises fine-grained limestone, bioclastic limestone and silty limestone and that the mineral assemblage is quite different. The correlation between porosity and permeability is poor, and most cores are tight. The types of carbonate reservoir space are complex and diverse. The primary pores are mainly biological cavity pores. The secondary dissolution pores dominated by intergranular dissolution pores, intragranular dissolution pores and microfractures are the dominant storage spaces of the Carboniferous carbonate reservoir in this area. Structural fractures are relatively developed in this area, which can increase the percolation capacity of the reservoir. However, some structural fractures are filled with calcite, which destroys their effectiveness and reduces the percolation capacity of the reservoir. Based on the shape of capillary pressure curves and the relevant parameters obtained, the samples are divided into three types, of which the physical properties decrease from type-I, type-III through type-II. Based on the correlation between fractal dimension and pore structure parameters, it can be concluded that the pore structure becomes increasingly complex with increasing fractal dimension. Therefore, fractal dimension can characterize the complexity of reservoir micropore structures in the study area. Based on the results obtained via imaging logging, the fractures of well A2 include conductivity fractures, fissures, and resistive fractures. Finally, it is concluded that the formation of high-porosity and permeability zones is caused by quasi syngenetic dolomitization and syngenetic-quasi syngenetic dissolution.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
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Geochemical characteristics of Mesozoic source rocks from the northern tectonic belt in the Kuqa Depression, Tarim Basin, NW China: Implications for the depositional environment and organic matter accumulation

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Keywords: Source rocks, Depositional environment, Organic matter, Northern tectonic belt, Kuqa Depression

Five units of the Triassic-Jurassic are excellent hydrocarbon source rocks in the northern tectonic belt in the Kuqa Depression, Tarim Basin, NW China. These source rocks of the Triassic Huangshanjie and Taliqike and Jurassic Yangxia, Kezilenuer and Qiakemake formations (Fms) were studied to reveal vertical heterogeneities, environmental evolution, and depositional models using geochemical methods. Our study samples are thermally mature, and contain abundant organic matter (OM) within type II-III kerogens. Maceral are dominated vitrinite, and paleoclimates were relatively warm and humid. Multiple indicators imply suboxic brackish to freshwater conditions during the Huangshanjie Fm stage, freshwater swamps during the Taliqike Fm stage and suboxic to oxic deltaic plains and bays during the Yangxia Fm stage. After the drier climate, freshwater delta fronts with an unstable thermocline formed during the Kezilenuer Fm period, and brackish semi-deep lakes with dysoxic environments formed during the Qiakemake Fm period. The environmental changes are compatible with the variations in OM sources; that is, high water inflow and aquatic organisms supported moderate to high primary productivity during the Huangshanjie Fm stage, whereas mixed terrigenous and aquatic OM sources were dominant during the Taliqike Fm stage. Important contributions from terrigenous higher plants and algae occurred during the Yangxia Fm stage; higher contributions from terrigenous OM occurred during the Kezilenuer Fm period, and significant contributions from phytoplankton occurred during the Qiakemake Fm period. Subsidence-sedimentation led to changes in lake conditions, which caused changes in organisms and bioproductivity. The depositional environments affect the production, degradation and preservation of OM, while organisms consume, provide and disturb OM. The characteristics and interactions of environments and OM contributed to the development of source rocks. These synergistic models are beneficial to predict similar efficient source rocks in other lacustrine superimposed basins.

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Session T9-5: Unconventional petroleum sedimentology
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Organic matter of the Ordovician-Silurian transitional shales using scanning electron microscopy

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Keywords: Shale gas, Organic matter, SEM, Pyrobitumen, Organic pore

Fine-grained organic matter (OM) particles are commonly widely dispersed in shale deposits. However, carrying out investigations of pores hosted by OM particles and the nature of grain interactions of OM particles and associated detrital grains using optical microscopy is difficult at best. Scanning electron microscopy (SEM) is much better suited for characterizing the microstructure of dispersed OM particles and has found wide application in the study of unconventional oil and gas systems. Scanning electron microscopy was used to define the types of OM contained in marine shale deposits of the Wufeng and Longmaxi formations spanning the Ordovician-Silurian transition in South China. Of particular interest is the development of OM-hosted pores and identification of the factors that controlled their formation. The dominant OM type contained in the studied deposits is pyrobitumen with subordinate graptolitic OM and sparse OM of unknown origin. Pyrobitumen is present in four forms, including pore fillings among authigenic quartz grains, within framboidal pyrite, and between authigenic clay grains and massive material. Diagenetic alteration has given rise to OM pores of differing morphology, size, and time of formation. Common small, equisized circular or oval OM pores are most developed and appear to have formed in association with the generation of hydrocarbons. Shale deposits containing abundant pyrobitumen filling interparticle pores among authigenic quartz crystals display robust reservoir and fracturing capacity. Sedimentary environment appears to have been the main factor affecting the type of OM and the nature of its association with detrital and authigenic minerals. Results of this study demonstrate that a sedimentary environment is a primary requisite for the formation of highly prospective/high yielding hydrocarbon shale reservoir deposits.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
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Reconstructing Late Ordovician – early Silurian tectonic and sedimentary evolution of the western Sichuan basin

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Keywords: Late Ordovician – early Silurian, tectonic and sedimentary evolution, western Sichuan basin,temporal and spatial distribution,ancient uplift,Kwangsian orogeny

The Late Ordovician – early Silurian is one of the key time boundaries of major global geological events (Melchin et al., 2013). The marine black shale formed in this period has attracted much attention because it is the main horizon of global shale gas exploration (Zou et al., 2019), and its shale deposition mechanism has attracted much attention (e.g., Armstrong et al., 2009). However, previous studies have believed that the deposition of marine black shale at this stage mainly is controlled by the fluctuation of global sea level (Challands et al., 2008; Meinhold et al., 2013; Li et al., 2017). The Upper Ordovician – lower Silurian Wufeng – Longmaxi shale has been considered as the most potential for unconventional oil and gas development marine object. At the same time, the Sichuan Basin, being located in the western South China Plate and covered extensively by Wufeng – Longmaxi marine shale, had experienced tectonic effects of Kwangsian orogeny (Chen et al., 2014; Xu et al., 2016), which had caused the Wufeng – Longmaxi shale deposited into the area being restricted by the peripheral uplift or oldland (Chen et al., 2018). It is a pity, the study about shale depositional mechanism being affected by Kwangsian orogeny is relatively scarce. The most controversial is spatial-temporal uplift process of the western Sichuan basin which had cut off the connection with the Paleo-Tethys ocean and the Sichuan basin, because present field outcrop data could not provide convincing geological evidences. So the drilling wells being located into the Weiyuan – Zigong area have been chosen in order to explore the spatial – temporal evolution process of the western Sichuan basin during the Late Ordovician – early Silurian. Based on sedimentology, petrography, temporal and spatial distribution of sedimentary thickness and geochemical data, paleogeographic characteristics of Weiyuan – Neijiang area could be divided three depositional stages: (1) during the Wufeng stage, the study area was directly connecting with the Paleo-Tethys ocean without barrier from marignal ancient uplift, because the reef limestones and radiolarian cherts extensively were deposited into the western margins of the Sichuan Basin; (2) during Guangyinqiao stage, expansion of the Neijiang uplift was controlled by the global sea-level dramatic drop because of the Hirnantian Glaciation, but there was still without barrier from western marignal ancient uplift; (3) during the Longamxi stage (Normalograptus persculptus – Coronograptus cyphus), there was obvious transition from open marine to strongly restricted basin in the study area, being supported by anoxic geochemical index of the Longmaxi shale, which implies the western margin of the Weiyuan – Neijiang area should be uplifted which was caused by compression from eastern Kwangsian orogeny. The paleo-marine environment bounded by three uplift or arch is conducive to the enrichment of organic matter of the marine Longmaxi shale.

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Laminar structure and reservoir property evaluation of lacustrine shales in China

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Keywords: Unconventional petroleum, Heterogeneity, Micro-/nano-scaled pore system, Organic-rich shales, Fine-grained deposition

Lacustrine shale oil has become one of the major replacement areas of oil and gas exploration in China. The laminar structure, a unique fabric feature of shale, has attracted increasing attentions because it can significantly influence the evaluation of source rock quality, reservoir quality and engineering quality. In this paper, the organic-rich shales in fresh-brackish lake basins, saline lake basins and transgressive lake basins are taken as targets to analyze the laminar structure characteristics and discuss the influence of laminar structure on the selection of sweet spots. The results show that: (1) The laminar structure varies in different lake basin types, and is affected by the salinity. The carbonate laminar mainly develops in the saline lake basins, but less in the fresh-brackish lake basins. (2) Very fine segmentation at sub-millimeter level and heterogeneity of laminar structure is obtained; and the difference of TOC and pore structure between different laminae are identified. It is suggested that the quality of a certain laminae type changes in different basins. (3) Laminar structure determines the microscopic migration and accumulation characteristics of shale oil and the enrichment mode of "primary source and reservoir", affecting the retained hydrocarbon content, fluid mobility and fracturing. Fine evaluation of continental shale laminar structure and searching for the distribution area of high-quality shale lithofacies are the critical issues for oil and gas exploration from the outer-source to inner-source, which are the basis for the discovery of economic and effective resources within the source and have important significance for the optimization of shale oil "sweet spot" and "sweet spot section".

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Sedimentary environment characteristic of transitional shales in the lower member of Longtan Formation, Western Guizhou: Insights into the influence of Emeishan large igneous province and organic matter accumulation

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Keywords: Longtan Formation, transitional shale, sedimentary environment, Emeishan large igneous province, lagoonal shale

The marine-continental transitional shale in the upper Permian Longtan Formation is not only an important target of shale gas exploration and development, but also an important research object of extreme paleoenvironmental events in Middle-Late Permian. Based on X-ray diffraction (XRD), polished sections, scanning electron microscopy (SEM), total organic carbon content (TOC) and elemental geochemistry, the paleoenvironment characteristics of the transitional shale in the lower member of Longtan Formation in Western Guizhou were studied, including primary productivity, paleo-redox conditions, paleoclimate, provenance. The influence of Emeishan large igneous province on sedimentary environment and the organic matter enrichment mechanism of transitional shale are analyzed. The results show that in the Middle-Late Permian transition, with the Dongwu movement and the eruption of Emeishan basalt, the paleogeographic pattern of high in the west and low in the east was formed in the Upper Yangtze region. The Western Guizhou was in a marine and continental transitional environment, and the lower member of Longtan Formation was deposited in a marginal tidal flat-lagoon environment. Influenced by seawater and rivers, sand and mud were interbedded frequently, and the organic matter content in shale were generally more than 5%. Longtan shales were deposited in a complex environment with warm and humid paleoclimate, anoxic-reducing, brackish to saline bottom water, high terrigenous detrital input and high deposition rate. The weathering products of Emeishan basalt were the main source of longtan Formation. The mineral and element composition characteristics of shale are closely related to Emeishan basalt. In addition, transitional shale was accompanied by a small amount of volcanic ash and hydrothermal input, and the elements carried by the hydrothermal increased the salinity of water, and was conducive to the anoxic-reducing environment. In general, the organic matter enrichment in transitional shale of the lower member of Longtan Formation is closely related to sedimentary facies. The shale deposited in mire has the highest organic matter content (>20%), followed by the shale deposited in tidal flat (10%). The organic matter content in lagoonal shale is the lowest (5%). Lagoonal shales are dominant in the lower member of Longtan Formation, and their organic matter enrichment mechanism is mainly “preservation model”. The lagoonal shales were deposited in a warm and humid, brackish-saline water, anoxic-reducing environment, with good preservation conditions for organic matter. The primary productivity was low and organic matter mainly came from higher plants. However, hot and humid climate strengthened terrestrial weathering and increased terrigenous detritus, diluting the organic matter content in shale. Higher deposition rate reduced the decomposition time of organic matter and was beneficial to the preservation of organic matter.

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Laboratory evidences for the possible genesis of poor development of organic-pores in the Lower Cambrian organic-rich shale, South China

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Keywords: Paleozoic shales, shale gas, simulation experiment, system sealing capacity, OM carbonization.

Many comparative investigations on the different development of organic-pores (OPs) and gas-bearing characteristics in the Silurian and Cambrian organic-rich shales of southern China are presented, while the genesis of the poor OP development and lower gas content in the Cambrian shale is still controversial. Here, artificial experiments were performed to reveal the impacts of system sealing capacity and organic carbonization on OP development in shales at overmatured stage. Closed and semi-closed pyrolysis was conducted on a low-mature lacustrine shale sample using the same instrument characterized by lithostatic pressure and limited reactive space. The results suggested that the different gas contents of the Cambrian and Silurian shales in southern China may be associated with the differences in the system sealing capacities of shales, although the sedimentary environment of the studied sample is lacustrine, and the lower methane content of the Cambrian shale gas is probably ascribed to semi-closed system. However, variations in organic porosity based on mass balance calculations demonstrated that the organic porosity evolution is collectively affected by system sealing capacity and thermal maturity at lower matured stages, whereas that is independent of system sealing capacity at high- and overmatured stages. This provides direct evidence that the difference in system sealing capacity is not the predominant factor leading to different OP developments in the Silurian and Cambrian shales. A semi-closed pyrolysis of a high-mature marine shale may unravel the possible origins of the poor OP development in the Cambrian shale. The results showed that intense carbonization of organic matter (OM) occurs after 3.49% R_{mc} (Raman maturity). During OM carbonization, preexisting OPs become interconnected and coalesce to form organic cracks, leading to an increase in the average pore diameter of OP. When combining the burial characteristics of the Cambrian overmatured shale in South China, the coupling between OM carbonization and mechanical compaction is invoked to explain the common perception that poor OP development in the marine shale. This study provides a direct laboratory evidence for the different gas contents and OP developments in the two marine gas shales.

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Characteristics and Formation Mechanism of Chang 7 Tight Sandstone Oil in Ordos Basin, China

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Keywords: Chang 7 Member, Tight sandstone reservoirs, Formation mechanism, Unconventional tight sandstone, NMR

Tight sandstone reservoirs develop extensively in Chang 7 Member in Longdong area, Ordos Basin, China, and tight oil is abundant. Unconventional tight sandstone reservoirs need a special experimental techniques and analysis methods, which is different from the conventional reservoirs of high porosity and permeability. This study adopted tight rock analysis (TRA), nuclear magnetic resonance (NMR), core and thin section observation, and formation micro-Scanner image (FMI) materials, in order to characterize the reservoirs precisely. The formation mechanical of tight sandstone reservoirs were then analyzed on this basis.

The results of the experiments show that: (1). Destructive diagenesis is very strong and effective porosity, bound hydrocarbon (% of BV) decrease with depth. The physical property is poor due to high hydromica content, whose average value is 10.4%. (2). According to the centrifugal experiment, this study sets 0.1μm as the lower limit of pore throat of tight sandstone reservoirs, which is consistent with high pressure mercury data. (3). The movable fluid saturation is high, whose average value is 55%, and the correlation between movable fluid saturation and porosity and permeability is poor, whose correlation coefficient is 0.24 and 0.70, respectively. (4). Chang 7 tight sandstone reservoir is prone to be fractured and favorable for later recovery due to high content of quartz, whose average value is 40.4%, the micro-cracks develop widely and they greatly improve the oil and gas migration and accumulation capacity.

The formation mechanism of tight sandstone reservoirs are:mechanical compaction, pressure solution, cementation, metasomatism, the control of sedimentary micro-facies and interstitial material.

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Differential reservoir evolution controlled by sandstone particle size and composition: Eocene Pinghu Formation, West subsag of Xihu sag, the China East Sea Shelf Basin

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Keywords: Low permeability tight reservoir, Sedimentary and diagenetic factors, Differential diagenesis, Differential pore evolution

The reservoirs of the Pinghu Formation in the West Sub-sag of the Xihu Sag are deeply buried, mainly low-permeability-tight reservoirs, and there are certain differences in the physical properties of the reservoirs. Sandstone particle size and composition are key factors controlling reservoir quality. Particle size and composition are the basis for the evolution of the reservoir, resulting in the differential diagenetic evolution of the reservoir during the process of burial diagenesis, resulting in the formation of reservoirs with different physical properties: Reservoirs with coarser grained, more soluble components contain more dissolved porosity, and strong resistance to compaction, which in turn leads to better physical properties of the reservoir. Reservoirs with finer grained, less soluble components, and more argillaceous reservoirs contain low dissolved porosity, more carbonate rock cements, and weak resistance to compaction, which in turn leads to poorer physical properties of the reservoir. Therefore, feldspar-rich medium-sandstones with high feldspar content, such as medium-grained and medium-fine-grained detrital feldspar sandstones, have strong dissolution and relatively good reservoir physical properties, and the reservoirs are not yet tight. Strong compaction and weak dissolution are important reasons for the poor physical properties of feldspar-poor sandstones such as medium-grained, medium-fine-grained feldspar lithic sandstones, and tight reservoirs. Fine-very fine sandstone and very fine sandstone have high mud content, strong carbonate cementation, and generally tight reservoirs.

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Research progress of oil shale in situ conversion experiment

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Keywords: oil shale,catalyzer,In situ transformation technology,Underground water separation technology

With the continuous progress of global science and technology and the continuous development of economy, the demand for energy in the world's industry and people's life is also gradually increasing, and the importance of solving the energy problem is increasingly prominent. As one of the potential energy sources in the future, the exploitation and utilization of oil shale is the focus of current research. However, the development of oil shale is mainly ground distillation, which requires a lot of water resources and produces a lot of waste residue, which brings pressure to environmental protection work. Therefore, the in-situ conversion technology of oil shale gradually attracts people's attention, and the in-situ conversion technology is also the future trend of oil shale industry development under environmental protection conditions. However, there are many technologies, catalysts and auxiliary technologies for in-situ oil shale development, and the advantages and disadvantages of different technologies are not clear. Therefore, this paper conducts research on domestic and foreign research materials and data, and summarizes and analyzes the current mainstream oil shale in-situ conversion technology, catalyst and water-isolation auxiliary technology. Widely recognized shale in situ conversion technology at present stage has electric heating and convection heating, radiation heating and combustion underground four, has its advantages and disadvantages of various technologies: electric heating method research earlier but slow heat transfer, heat convection heating but high efficiency heat transfer process vulnerable, radiation heat penetrability strong but limited range of heating, underground combustion heating speed but not easy to control. In order to assist the higher rate conversion of oil shale, the catalysts and their principles, including $CoCl_2 \cdot 6H_2O$, $NiCl_2 \cdot 6H_2O$, calcium-modified HZSM-5 zeolite, SO_3H-APG, pyrite and corn straw, were also summarized in this paper, which can be classified into four categories: metal salts, clay, native minerals and biomass. In addition, in response to the oil shale in situ transformation of groundwater pollution, on the frozen wall, gas drive water and grouting closed three water assistive technology is summarized, and based on the general background of the our country to protect the environment and reduce the cost of industrial demand, reveal the type suitable for domestic oil shale in situ conversion technology for convection heating in situ conversion technology. Further analysis of the development trend of in-situ conversion of oil shale:1Using solar energy and other new energy, reasonable distribution of drilling spacing, reduce costs;2The research and application of underground sealing technology should be strengthened to reduce groundwater pollution caused by in-situ conversion. It provides reference and help for the future research and development of in-situ conversion of oil shale in China.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Pore structure characteristics and its relationship with diagenesis in sandstone reservoirs of Huagang Formation in Xihu Sag, East China Sea Basin

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Keywords: Pore structure characteristics, Diagenetic influence, Sandstone reservoir, Xihu Depression

The pore structure of sandstone reservoirs and its diagenetic influence of Pinghu Formation (E2p) and Huagang Formation (E3h) in Xihu Depression is comprehensively evaluated. The pores of sandstone samples mainly include primary intergranular pores, intergranular and intragranular dissolved pores, and micropores related to clay aggregates. Thin section and scanning electron microscope (SEM) observation results show that more intergranular solution pores, moldic pores and inter-crystalline pores of kaolinite are developed in E2p. Compared with E2p, E3h has smaller pores, narrower and more curved throats. A new parameter, pore structure index (PSI), is established for comprehensively evaluating the pore structure. The effects of three main kinds of diagenesis on pore structure are analyzed. Mechanical compaction is the main reason for the reduction of pores, which has serious damages to the pore structure by making the mineral particles arranged more closely and creating smaller pores and narrower throats. Different types of cement have different effects on reservoirs. The inter-crystalline pores of kaolinite can compensate for some pores reduced by compaction and cementation, which can improve the pore structure. The development of illite has a significant damage on reservoir quality by occupying the pore spaces and blocking the throats. The inhibition of chlorite on the quartz overgrowth and its blocking effects on throats are negligible, therefore having little effect on the reservoir quality. Carbonate cement and quartz overgrowth both occupy part of pores and throats, which can reduce pore connectivity thus damages the pore structure. Quartz overgrowth has a weaker impact compared to carbonate cementation. Dissolution is the key function to improve the reservoir. The proportion of dissolution pores in sandstone samples in the study area can reach 67.91% ~ 94.96%, which can increase the porosity and enhance pore connectivity. This work is of great application value in sandstone reservoir quality evaluation.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Characters and Genesis of Under-Compacted Sandstone- a case in Lenghu VII Tectonic Belt, Northern Qaidam Basin

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Keywords: deep buried reservoir, under-compacted sandstone, sedimentary environment, dissolution of calcite, Qaidam Basin

Based on recovering core observation and thin section identification, combined with scanning electron microscope images and statistics of physical property, XRD, trace elements and carbon and oxygen isotopes, the genesis of under-compacted sandstone of the Xiaganchaigou Formation(Fm) of the Paleogene in Lenghu VII structure in the northern Qaidam Basin has been confirmed through a detailed comparison with normal one on the aspects of sedimentary environment, petrological and diagenesis characters. The result show that the under-compacted sandstone developed in underwater distributary channel with less argillaceous matrix, and the particle size is medium to fine. The average porosity can reach 9.70%, and permeability reach to 1.89 mD, which is dominated by intergranular pore. The under-compacted sandstone formed because of the intrusion of organic acid fluid which lead to the dissolution of calcite cements and restoring of primary pores. The conclusion can be drawn from these aspects: Firstly, the total clay minerals content of under-compacted sandstone (6.6%~11.9%) is similar with normal one (7.9%~12.1%), however honeycomb-like chlorite grain-coatings is much abundant (33%~58% in total clays) in under-compacted sandstone, indicating transformation from I/S under intrusion of Mg-rich fluid; Secondly, the carbonate cements of under-compacted sandstone (5.7%~17.3%) and normal one (4.1%~20.3%) are both dominated by micrite calcite, and early calcite residues result from dissolution only could be found in under-compacted sandstone. The δ18O value (17.36‰ ~ -10.54‰) and the δ13C values (-5.12 to -3.51‰) indicate inorganic carbon, however, the little negative bias of δ13C of under-compacted sandstone indicate more organic carbon mixed compared to normal one; Thirdly, the minor changes of V/Zr, Ni/Zr, Co/Zr, Sr/Zr and Mo/Zr values suggest a similar and stable paleoenviroment in both sandstones. The weaker correlations among U/Zr, Ni/Zr and V/Zr indicate that U/Zr is affected not only by environment, but also by fluid intrusion. However, U/Zr is much large (3.6~23.9) in under-compacted sandstone comparing to normal ones (0.83~3.69), which indicates an acid fluid invasion originating from source rock.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
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Petrographic characteristics and gas-bearing evaluation of the shales of Dayuaba Formation, southern Guizhou

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Keywords: southern Guizhou, Dawuba Formation, petrographic characteristics, quantitative calculation of gas content, key controlling factors

The Dawuba Formation of Lower Carboniferous in southern Guizhou is an important marine shale series. As a key research area in the Dian-Qian-Gui Basin in southern China, there are still few studies on shale Petrographic characteristics and gas-bearing evaluation in this area. Taking Qianshuidi 1 well as the research object, based on the core description, thin section identification, X-ray diffraction analysis, scanning electron microscopy and methane isothermal adsorption, the shale lithofacies and gas-bearing properties of Dawuba Formation was systematically analyzed in this study. The shale of the Dawuba Formation in southern Guizhou is dominated by clay minerals and carbonate minerals, and the content of siliceous minerals is relatively small. According to the three-end lithofacies division scheme of siliceous minerals, carbonate minerals and clay minerals, the shale facies types of the Dabuba Formation are mainly included calcareous shale (C, C-2), argillaceous-rich calcareous shale (C-3), siliceous argillaceous shale (CM-1) and mixed shale (M-2, M-3), among which the argillaceous-rich calcareous shale is the most favorable lithofacies. The average shale gas content of the Dabuba Formation in the study area is 0.51 m^3/t, ranging from 0.21 to 1.13 m^3/t, which is generally low. The theoretical gas content calculated based on Langmuir model and Lewis model is significantly higher than the measured gas content. According to the geological conditions of southern Guizhou area, the parameters such as temperature, water content, porosity and TOC were optimized and modified to obtain a new characterization formula suitable for the study area, and their correlation index R reached 0.92. By analyzing the main controlling factors of shale gas content in the Dawuba Formation, it is found that the low measured gas content is mainly controlled by poor gas generation conditions (average organic carbon content is 0.82%) and poor preservation conditions (preservation index P < 0.3). The above research results can support the prediction of shale gas enrichment areas and provide suggestions for the subsequent shale gas exploration and development in the southern Guizhou Area.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
Presentation Preference: Oral Preferred

Study on the Differential Diagenesis and Effective Reservoir Formation Mechanism of Tight Sandstone Reservoir -A Case Study of the Lower Es3 in Jiangjiadian Area, Linnan Sag

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Keywords: Effective reservoirs, Formation mechanism, Differential diagenesis, Tight sandstone, Linnan Sag

Tight oil in Linnan Sag has great development potential. At present, it is unclear about the formation mechanism and distribution law of effective reservoirs, which is the direct reason for the difficulty of oil and gas exploration in the middle and deep layers. In this paper, the formation mechanism of effective tight sandstone reservoirs in the lower Es3 member of Jiangjiadian area in Linnan Sag was studied by comprehensive utilization of core, grain size analysis, casting thin section, X-ray diffraction, mercury injection, scanning electron microscopy, inclusions and isotopes. The results show that the study area is the delta front mouth bar and distal bar microfacies. The larger the particle size is, the better the sorting is, and the less the mud matrix is, the larger the porosity is. The reservoirs in the study area have undergone compaction, metasomatism, cementation and dissolution, and are mainly in the middle diagenetic stage A. The diagenetic evolution sequence is as follows: compaction action→early carbonate cementation under original alkaline formation water environment→dissolution of debris and feldspar in acidic environment + phase I quartz secondary enlargement + late carbonate cementation→late carbonate cementation in alkaline environment + dissolution of enlarged edge of quartz→re-dissolution of feldspar and lithic in weak acidic environment+ dissolution of carbonate cements + phase II quartz secondary enlargement→late pyrite cementation. According to quantitative calculation of diagenesis evolution process, the original porosity of sandstone is 34.2%-37.4%, the loss porosity of compaction is 33.0%-37.0%, the increased porosity of dissolution is 1.6%-23.0%, and the loss porosity of cementation is 0-39.3%. The strength of pore-increasing effect caused by corrosion and pore-reducing effect caused by cementation are the key factors for reservoir effectiveness in the study area. Dissolution siltstone and calcareous siltstone are mainly developed in the study area, and the difference comparison shows that the lower limit of effective reservoir porosity in the study area is about 7%, and the occurrence of micron-sized pores is closely related to the effectiveness. Based on the study of lithofacies and diagenesis, taking a group of 'mud-coated sand' combination as an example, the formation mechanism of effective reservoir is analyzed. Under the control of different lithofacies, the dissolved siltstone facies is affected by the release of organic acids from the thermal evolution of organic matter and the leaching of atmospheric freshwater. The feldspar cuttings are dissolved and the authigenic kaolinite and quartz are precipitated near. Calcareous cementation siltstone is affected by alkaline fluid environment, and its dissolution is weak. Late calcite and dolomite cementation mainly occur. Based on the analysis of effective reservoir formation mechanism, the effective reservoir genetic model of 'early atmospheric pressure open system→middle weak overpressure sealing system→late atmospheric pressure open system' is established. This paper can not only deepen the understanding of the formation mechanism of effective tight sandstone reservoirs, but also have guiding significance for the exploration deployment of tight oil in the study area and the scale increase of reserves and efficiency.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
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Analysis on Organic Matter Enrichment Law and Main Controlling Factors of Longmaxi Formation Shale in Changning Area of Southern Sichuan Basin

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Keywords: Shale, Organic matter, Longmaxi Formation,enrichment Law, Controlling Factors

Based on TOC test, XRD test, trace element and major element test data, organic matter enrichment rule and main control factors of Longmaxi formation shale in Changning area of southern Sichuan Basin were studied. The results show that:(1) the $S_1l_1^1$ shale TOC in the study area is between 0.46% and 8.35% (average value: 3.75%); Vertically, TOC shows a trend of decreasing first, then increasing and then decreasing from bottom to top, showing the characteristics of “sandwich cake”. On the plane, the TOC value of $S_1l_1^{1-1}$- $S_1l_1^{1-2}$ are the highest in the southeast and gradually decreases in the north and southwest; The high TOC value of $S_1l_1^{1-3}$-$S_1l_1^{1-4}$ has the enrichment rule of migration to the central X2 well area. (2) The TOC of $S_1l_1^1$ shale in the Changning area is logarithmically related to the sedimentary environment index; it is negatively correlated with terrigenous influx and a complex correlation with paleoproductivity. (3) The enrichment of organic matter of the $S_1l_1^1$ in the study area is mainly the coupled superposition of the paleoenvironment, palaeoproductivity, terrigenous input and other factors. when the paleoproductivity is less than 2200μg/g, the preservation conditions (ie. sedimentary environment) are the most important factors to control the enrichment of organic matter. When the paleoproductivity is greater than 2200μg/g, ultra-high paleoproductivity is the main controlling factor of organic matter enrichment. The moderately-strongly restriction environment and warm, humid paleoclimate conditions of $S_1l_1^1$ in the study area are conducive to the enrichment and preservation of organic matter. However, the two have little effect on the differential enrichment of organic matter in each sublayer of $S_1l_1^1$. (4) From $S_1l_1^{1-1}$ to the lower part of the $S_1l_1^{1-3}$ is anoxic depositional environment, which provides good preservation conditions for organic matter enrichment, and is the main controlling factor of organic matter enrichment, followed by paleoproductivity. Starting from $S_1l_1^{1-2}$, it shows the adverse effects of terrigenous influx on organic matter enrichment. The middle to the upper part of $S_1l_1^{1-3}$ is a dysoxic sedimentary environment. When the paleoproductivity is low, the enrichment of organic matter is mainly controlled by terrigenous input; but when the paleoproductivity is high, the organic matter enrichment is controlled by paleoproductivity and terrigenous input. The top of $S_1l_1^{1-3}$ is an oxygenic depositional environment, TOC is mainly controlled by paleoproductivity and sedimentary environment, followed by terrigenous input. The $S_1l_1^{1-4}$ is mostly oxygenic sedimentary conditions, when paleoproductivity is low (Babio<1100μg/g), the main controlling factor for organic matter enrichment is sedimentary environment. When paleoproductivity is high (1100μg/g$_{11}^2$

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
Presentation Preference: Oral Preferred

New understanding of Yanchang Formation sedimentation and isochronous stratigraphic division scheme in Ordos Basin

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Keywords: Progradation body, Stratigraphic correlation, U-Pb dating, Yanchang Formation, Ordos basin

Currently, the oil production in Yanchang Formation, Ordos Basin is more than 35 million tons per year. It is well known that chemostratigraphy correlation is significantly critical in oil production. Marker bed and equisection method are traditionally applied in define of oil formation. However, this kind of stratigraphy correlation approach has been increasingly questioned. With the constrain of drilling date, the high precision dating data in tuff from Chang 7 oil formation in various sedimentary systems and high precision seismic stratigraphic interpretation and stratigraphic isotope chronology are carried out respectively by using the high quality 3D seismic data newly collected from blocks to the north of Qingcheng. The diachronism is also supported by high-precision ziron dating from different sedimentary systems in Chang 7 period. It is the first time to identify 11 prograding bodies from the top of Chang 73 oil formation to the bottom of Chang 2 oil formation these blocks. 6 prograding bodies are described in Chang 7 oil formation, suggesting stratum diachronism in current stratigraphic correlation of Yanchang Formation. We proposed that high precision dating is urgently required to be a marker in Chang 7 oil formation from diverse provenance systems. Coupled with elevated frequency seismic data and thin-bed correlation by geophysical logging, a high sequence stratigraphic framework could be redefined and chemostratigraphy correlation could be established in Yanchang formation. This study could be in favor of refining reservoir distribution patterns in Yanchang Formation, and provide a valuable lesson for the study of deep-water sedimentary evolution and chemostratigraphy correlation in other lacustrine basins in the future.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
Presentation Preference: Oral Preferred

The organic matter accumulation of the Pliensbachian-Toarcian lacustrine shale in the Sichuan Basin, SW China

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Keywords: Organic matter accumulation, Lacustrine shale, T-OAE, Shale gas, Sichuan basin

Pliensbachian-Toarcian lacustrine shale in the Sichuan Basin is characterized by two organic matter-rich layers (Dongyuemiao and Da′anzhai members) interlayered with an organic matter-poor layer (Ma'anshan member). Both the organic-rich layers are promising target layers for shale oil and gas in China, meanwhile, they are a terrestrial sedimentary record for the Toarcian Oceanic Anoxic Event (T-OAE). What the factors dominated the enrichment of the organic matter in them? It is not only benefit to the exploration of shale gas and oil, but also to probing the way to carbon complement. Basing on the paleo-environment analysis and the correlation with organic matter accumulation in the Pliensbachian-Toarcian lacustrine shale on the subaqueous paleo-uplift in the Sichuan Basin according to lithofacies and geochemical proxies. We concluded that lake stratification and oxygen deficiency were gradually strengthened in an upward sequence from Pliensbachian Dongyuemiao member to late Toarcian Da′anzhai member. However, primary productivity was reduced. Chemical weathering was strongest during the early Toarcian stage (Ma'anshan member). The organic matter accumulation in these lacustrine shales is closely related to environmental changes caused by tectono-sedimentary evolution and depositional conditions of the Sichuan Basin. The Pliensbachian Dongyuemiao member was dominated by high primary productivity and low terrigenous detrital input. In the case of the deposition of early Toarcian Ma'anshan member, the organic matter was difficult to preserve due to the high sedimentation rate and the lack of anoxic water conditions. However, the late Toarcian Da'anzhai member was primarily composed of chemical precipitation that was closely correlated with the climate changes during T-OAE. The organic matter accumulation in this member was positively correlated with salinity-induced stratification and elevated CO_2 concentration.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Formation mechanism of rhythmic bedding in the Lower Silurian Longmaxi black shales on the Yangtze platform, South China

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Keywords: Mineralogical characteristics, Diagenesis, Shale deposition

Shales have long been considered as deposited under quiescent conditions. However, recent studies on silty laminated shales have emphasized the modification of sediments by bottom currents. The presence of laminae tends to induce rock damage and increase the brittleness of shales. A model for the formation of rhythmic bedding in black shales is proposed in this study on the basis of detailed sedimentological studies and geochemical characterization of the Lower Silurian Longmaxi Formation shales in southern China through scanning electron microscope with energy dispersive spectroscopy, X–ray diffraction, X–ray fluorescence spectrometry, and inductively coupled plasma mass spectrometry. Rhythmic laminations are mainly composed of argillaceous shale and siliceous shale. Argillaceous shale is mainly composed of terrestrial chlorite and albite enriched with U, Th, and light rare earth elements (LREEs). In comparison, siliceous shale is mainly composed of authigenic quartz and illite enriched with Si, P, Cu, and middle rare earth elements (MREEs). The preferential alignment of graptolites, sedimentary structures, and the higher Si/Al, Ti/Al, Ca/Al and Sr/Al values in siliceous shales indicate that the sediments were reworked by bottom currents through erosion and winnowing. Differences in bottom current activity result in significant differences in redox conditions, clastic input, and paleoproductivity between the two shales during their deposition. Intermittent bottom current activities play an important role in the formation of rhythmic bedding in the Longmaxi Formation shales of the Sichuan Basin. The synergistic effect of the complexation of residual organic matter and the physical charge adsorption of clay minerals results in the enrichment of LREEs in argillaceous shale; authigenic quartz and illite may capture MREEs in pore water during diagenesis, causing MREE enrichment in siliceous shale. Different authigenic minerals further enhanced the differences between the two shales during diagenesis. Bottom current mainly affects the Yichang and Fuling areas in the Sichuan Basin, and has less impact on the Changning area. Thermohaline–induced circulation and wind forces may be the main controlling factors responsible for the formation of bottom currents. Understanding the genesis of rhythmic bedding in shales can help clarify shale anisotropy and induced deformation during hydraulic fracturing.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

PETROLOGIC AND GEOCHEMICAL CHARACTERISTICS OF CARBONATE CEMENTS IN THE UPPER TRIASSIC XUJIAHE FORMATION TIGHT GAS SANDSTONE, WESTERN SICHUAN BASIN, CHINA

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Keywords: Sichuan Basin, carbonate cements, pore fluid, genesis model, reservoir quality

Early calcite, when dissolved by organic acids, can generate porosity in sandstones. Mineralogical, petrographic, and geochemical analyses determined the timing and origin of carbonate cements in the fourth sandstone member of the Upper Triassic Xujiahe Formation (Xu4 sandstone) in the western Sichuan Basin. Two phases of carbonate cement identified are the crystalline calcite and carbonate filling of secondary pores, which consists of calcite, dolomite, ankerite, and ferrocalcite. Early calcite precipitated during the Middle Jurassic period with low Na^+ and K^+ contents, the carbon isotope compositions show that early calcite precipitated from alkaline fluid after deposition. $\delta^{18}O$ values of the fluid indicate an involvement of meteoric and alkaline water. The burial history and fluid inclusions indicate that late calcite formed during the Late Jurassic. The relatively high Na^+ and K^+ contents and carbon isotope compositions suggest that organic acids participated in the formation; the $\delta^{18}O$ values of the fluid are slightly higher than that of early calcite due to the reduction in the influence of meteoric water as burial depth increased. Dolomite cement precipitated from Late Jurassic to Early Cretaceous and has the same carbon source as late calcite. The transformation of smectite to illite likely sourced the calcium and magnesium. Active water-rock interactions in an open diagenetic system are the leading cause of carbonate mineral precipitation.

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The Relationship between clay minerals and organic matter enrichment in lacustrine shale: A Case Study on Yanchang Formation of Triassic in Ordos Basin, China

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Keywords: lacustrine shale, Clay minerals, Abundance of organic matter, Hydrocarbon generation potential, Ordos Basin, Yanchang Formation

With the successful exploration and development of shale oil and gas, shale has become an important research object of oil and gas exploration. Clay minerals and organic matter, as the two main components of shale, have complex relationship with each other. In order to clarify the influence of the structure, type and quantity of clay minerals on the enrichment of organic matter, 536 gray black or black mudstone and shale core samples of well F75 and well D81 of Triassic Yanchang Formation in Ordos Basin were selected for clay mineral analysis, organic carbon determination and rock pyrolysis analysis. The test results show that the clay mineral content of the above samples is mainly concentrated in the range of 30% ~ 60%, with an average of 45.9%; The main types of clay minerals are Yimeng mixed layer, illite, kaolinite and chlorite; TOC is mainly concentrated between 2% ~ 6%, with an average of 3.90%. Hydrocarbon generation potential (S1 + S2) is mainly concentrated between 6.00 ~ 24.00mg/g, with an average of 13.58mg/g. It is a good and high-quality source rock. It is found that when the clay mineral content is less than 65%, the clay mineral content is positively correlated with TOC. With the increase of clay content, TOC also increases. For every 1% increase of clay mineral content, TOC increases by 0.05%, that is, the characteristics of rich organic matter with high clay content reflect the enrichment of clay minerals on organic matter; Different clay minerals have different enrichment of organic matter. The content of Yimeng mixed layer is about 30% and the content of chlorite is about 30%, which is the most conducive to the enrichment of organic matter. Too high or too low is unfavorable, while the higher the content of illite and kaolinite, the more conducive to the enrichment of organic matter; The hydrocarbon generation potential of shales is directly related to the enrichment of clay minerals on organic matter. The stronger the enrichment of clay minerals on organic matter, the higher the hydrocarbon generation potential, on the contrary, the lower the hydrocarbon generation potential. Generally speaking, to a certain extent, the content of clay minerals controls the enrichment of organic matter and its hydrocarbon generation potential. There are differences in the enrichment of organic matter by different types of clay minerals, which can provide reference for resource evaluation, exploration and development of shale oil and gas.

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The reservoir quality of favorable reservoirs and their controlling factors in saline lacustrine tight reservoirs of Middle Permian Lucaogou Formation, southeastern Junggar Basin, northwestern China

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Keywords: Favorable reservoirs, tight reservoirs, reservoir quality, sedimentary microfacies, diagenetic evolution

As a vital type of unconventional reservoirs, tight reservoirs are widely distributed in lacustrine basins in China. These reservoirs are featured by complex lithology, poor reservoir quality, nanoscale pore throats and strong heterogeneity of pore structures, which significantly impact the distribution of favorable reservoirs and hydrocarbon production. This study evaluated the tight reservoirs of the second member of Permian Lucaogou Formation and revealed the controlling factors of the favorable reservoirs based on fifty-one cores from seven wells in Jimsar Sag of Junggar Basin, northwestern China. Based on 1740 data of helium porosity, air permeability and movable fluid saturation measurement, the permeability of favorable reservoirs is higher than 0.01mD and the movable fluid saturation is higher than 14.6%. The porosity of favorable carbonate reservoirs is higher than 6.2% while that of clastic reservoirs is higher than 8.8%. According to the results of thin section analyses, scanning electron microscopy (SEM), pressure-controlled mercury injection (PMI), rate-controlled mercury injection (RMI) and X-ray computed tomography (CT), the favorable reservoirs are characterized by the development of dissolution pores and contracted or narrow sheeted throats with the average pore throat radius greater than 0.025μm and the connecting pore throat radius greater than 0.129μm. As the main lithofacies of favorable reservoirs, dolomitic siltstone and silty dolomite have great number of throats with the radius greater than 0.1μm and good pore throat connectivity. Deposited in a saline lacustrine environment, dolomitic siltstone mainly develops in sandy beach-bar, which distributes in shore-shallow lake zone. In the eogenetic A period, the chlorite-coatings in thick sandy beach-bar reservoirs resist strong compaction and preserve a wealth of primary intergranular pores. Although a number of pores are filled by later carbonate cements, during the eogenetic B and mesogenetic A period, organic acids released from the thermal evolution of organic matter are transported into sandy beach-bar reservoirs, resulting in extensive dissolution of carbonate cements, tuffaceous component and feldspar grains. The strong dissolution leads to the development of a large number of intergranular pores, wide throats and pore network with good connectivity, resulted in remarkable increase of porosity (ave 7.9%). In an evaporitic environment, silty dolomite widely develops in dolomitic sandy flat, which continuously distributes along the edge of lacustrine basin and near terrigenous provenance. Compared with sandy beach-bar reservoirs, compaction causes less damage to the porosity of dolomitic sandy flat reservoirs. Although fewer primary pores develop in dolomitic sandy flat reservoirs, fewer carbonate cements fill in intergranular pores and the reduction of porosity in dolomitic sandy flat reservoirs (ave 7.0%) is obviously lower than that in sandy beach-bar reservoirs (ave 14.3%). These research results are crucial to evaluation and predication of favorable reservoirs in similar continental tight reservoirs.

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Sedimentary characteristics of Late Carboniferous and Early Permian coal measures and its control on symbiotic gas reservoirs in Shouyang area

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Keywords: Late Carboniferous-Early Permian,Coal system gas,Sedimentary,symbiotic association

In recent years, the Ordos Basin has made a major breakthroughof coal-measure symbiotic gas reservoirs.However, the exploration target of Qinshui Basin, which is in the same structural unit, is still focused on coalbed methane.The late Carboniferous-Early Permian sedimentary environment in the Shouyang block in the northern Qinshui Basin is a transitional marine-land sedimentary environment. Among them, the Coal-3 in Shanxi Formation and the Coal-9 and Coal-15 in Taiyuan Formation which have a high degree of thermal evolution are good source rocks;The sea-land transitional phase is conducive to the development of various types of reservoir-cap combinations. These conditions indicate that this area has the basic geological conditions for the development of coal-system gas symbiotic gas reservoirs.Based on previous studies and the data of 108 CBM exploration wells, the sedimentary characteristics of the Late Carboniferous-Early Permian coal measures have been carefully studied.The Taiyuan Formation is divided into three subfacies and the Shanxi Formation is divided into one subfacies.Based on the above results, 8 typical lithofacies combinations are summarized, and 3 types and 4 types of coal gas storage cover are obtained through comprehensive analysis.Based on the above results, this paper summarizes 8 typical lithofacies combinations and defines 4 types of coal-based gas symbiotic gas reservoir combinations.Finally, the potential areas of various symbiotic gas reservoirs in Shouyang block are predicted.

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Study on the occurrence characteristics and main controlling factors of shale oil in Hassan area, Junggar Basin

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Keywords: shale lithofacies, occurrence state, main control factors, microscopic stepwise migration and accumulation model, Fengcheng Formation

As a substitute resource of conventional oil and gas resources, Continental shale oil has broad exploration and development prospects. The occurrence state of shale oil is very important to characterize the mobility of shale oil. However, the unclear occurrence characteristics and main controlling factors of shale oil in Fengcheng Formation shale in Hashan area of Junggar basin limit the evaluation of its shale oil resources. In this paper, by means of X-ray diffraction, TOC, rock pyrolysis, scanning electron microscope and two-dimensional nuclear magnetic resonance (NMR) experiments, combined with core observation and thin section identification, the occurrence characteristics of shale oil in Fengcheng Formation shale in Hashan area of Junggar basin is systematically studied. The results show that there are four types of lithofacies in Fengcheng Formation, which are limestone (dolomite) lithofacies, siltstone lithofacies, peperite lithofacies and tuff lithofacies. The free shale oil mainly occurs in fractures and dissolution pores (veins) and matrix pores with large pore size. Adsorbed shale oil mainly adsorbs kerogen and the surface of inorganic minerals. Lithofacies types, rock fabric, organic matter evolution and reservoir space are the main controlling factors of shale oil occurrence. Finally, the occurrence model of matrix type and fracture type shale oil in Fengcheng Formation and the microscopic stepwise migration and accumulation model of shale oil in different pore and fracture types are established. This paper provides a geological basis and reference for the evaluation of continental shale oil.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
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Sedimentary characteristics and shale quality in the first member of Cretaceous Qingshankou Formation, Songliao Basin, China

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Keywords: sedimentary characteristics, shale quality, lacustrine, Qingshankou Formation, Songliao Basin

The first member of the cretaceous Qingshankou Formation (K_2qn) was a representative type of Songliao Basin lacustrine shales. The typical characteristics of this lacustrine shale was its high clay contents (as much as 55% in some samples), which was quite different to marine siliclastic shales. Therefore, it is extremely significant to study the sedimentary characteristics and properties of lacustrine shale, as is the foundation for sweet spotting of shale oil in Songliao Basin. Based on core observation, thin section identification, high-density element scanning and organic geochemical analysis, the mineralogy, lithofacies and geochemical characteristics were dicussed in this research. The results indicated that four main lithofacies could be distinguished by their different mineral compositions, laminae assemblages and bioclastic compoments: (i) felsic shale (FS), (ii) clay shale (CS), (iii) bio-bearing shale (BS), and (iv) mixed shale (MS). The clay minerals content in the CS (average: 46.72 wt%) and MS (average: 41.11 wt%) was higher than that in FS (average: 39.97 wt%) and BS (average: 35.48 wt%). Furthermore, five types of lamination were defined: (1) Feldspar and Quartz Lamination (FQL), (2) Clay Lamination (CLL), (3) Siliceous Clay Lamination (SCL), (4) Ostracods Lamination (OSL), and (5) Organic Matter Lamination (OML). Pyrolysis and organic carbon measurements showed that the organic matter types mainly included type I and type II, and the lithofacies that had the highest TOC content was CS (average 2.22 wt%), which was followed by BS (average 1.78 wt%), MS (average 1.75 wt%), and FS (average 1.62 wt%). It was discovered that FS, CS, and MS samples had very high S_1 values, indicating that these rocks have larger free hydrocarbon contents. As to the hydrocarbon generation potential, CS was the best among these four lithofacies, and geochemical analysis showed that the micro-migration might exist within the source rocks. A new lithofacies scheme and laminae associations were defined in this study, and the mineralogy and source rock property varied among different lithofacies, which could throw light on E&D targeting for unconventional resources.

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The impact of laminae characteristics and types on Organic matter enrichment of Chang 73 sub-member in Ordos Basin, NW China

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Keywords: Lamina types,organic-rich shale,shale oil, Chang 7 Member, Triassic Yanchang Formation, Ordos Basin

The Chang 7 member in Ordos Basin is an important shale oil exploration layer, with new shale-oil discoveries in recent years. TheChang 73 sub-member is rich in organic shale, which is the main source rock of shale oil in the Yanchang formation. In order to clarify the lamina structure, composition, types and distribution characteristics in Chang 73 sub-member and its influence on organic matter enrichment, a full coring well in Chang 73 sub-member located in deep-lacustrine facies is selected to obtain intensive systematic core samples. Core observation, thin section identification, X-ray fluorescence element analysis, X-diffraction analysis, scanning electron microscope, electron probe, rock pyrolysis, and other techniques, are performed to systematically analyze the morphology, structure, thickness, mineral compositions, and organic matter content of the shale lamina in the Chang 73 sub-member. Five types of lamina types are identified: Silty felsic lamina (SF), tuffaceous lamina (TF), organic rich clay lamina (ORC), organic-bearing clay lamina (OBC) and Homogeneous clay lamina (HC), which are further subdivided into eight subtypes. The lamina types change greatly vertically in the Chang 73 sub-member, in which the lower part is mainly silty felsic lamina and tuffaceous lamina, the middle part is mainly organic rich and organic clay lamina, and the upper part is mainly clay lamina and a small amount of silty felsic lamina. Differences laminae show various organic matter types, organic matter content (TOC), and organic matter occurrence states, which can be divided into four occurrence types. The organic matter content of organic rich clay lamina and tuffaceous lamina is high, while that of silty felsic lamina is lower. The relationship between shale lamina and organic matter enrichment is established according to the correlation analysis of laminar characteristics, mineral content and organic matter content. Among them, the organic rich lamina is richest of TOC and is a favorable "sweet point" for shale oil exploration.

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Densification of sandstone reservoirs: new evidences from primordial sedimentation and diagenesis in Fuyu tight reservoir, Songliao Basin, China

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Keywords: Fuyu reservoir, Diagenesis,Primary deposition,Reservoir property

The original deposition determines the composition and structure of the original material of the reservoir at the microscopic level, and the diagenetic evolution of the reservoir also affects the difference of reservoir physical properties. In order to study the control effect of original sedimentation and diagenesis on reservoir physical properties, the control effect of microscopic pore-throat characteristics on reservoir physical properties was clarified by core observation, cast thin section, physical property testing, high-pressure mercury injection and scanning electron microscopy. The results show that the porosity of Fuyu reservoir mainly ranges from 11% to 21%, with an average of 15%. The permeability ranges from 0.01 to 5×10-3μm2, with an average of 2×10-3μm2. The pore types of Fuyu reservoir are mainly dissolution pores and intergranular pores, among which the large pores (>20μm) are less, and the small pores (1-10 μm) and micro-nano pores (<1μm) are dominant. The main laryngeal types were pore constricted larynx, lamellar larynx, curved lamellar larynx and bundle larynx. The laryngeal radius mainly ranges from 1 μm to 10μm. The fuyu reservoir is mainly composed of massive bedding, parallel bedding and cross bedding. The frequency mode peaks of cross-bedding sediment are 1.02 ~ 1.18 φ, the mode peaks of parallel bedding are 1.10 ~ 1.23 φ, and the mode peaks of massive bedding are 1.20 ~ 1.32 φ. Cross - bedded samples have larger pore - throat radius. The content of chlorite in cross bedding is high, and the chlorite film in chlorite has a strong limiting force on the development of quartz secondary growth, which plays a crucial role in the preservation of primary pores in tight reservoirs, so that the development degree of intergranular pores is higher, and the physical properties of reservoirs are better. Feldspar and rock debris occupy a high proportion in tight reservoir, and the two kinds of particles have low stability and are easy to dissolve and form inner pores of dissolution grains. Feldspar particles are easily dissolved by acid and indirectly form internal and intergranular pores. The existence of dissolution pores improves the percolation ability of pores in tight reservoirs, thus improving the physical properties of reservoirs.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
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The oldest known stomatocysts with pyrite discovered in the Triassic Chang7 shale, Ordos Basin, China and palaeo-environment reconstruction

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Keywords: Stomatocysts, oldest known, morphology,ecology,Triassic,Ordos Basin

A variety of chrysophyte cyst fossils, discovered in the Triassic hot shales of Ordos Basin, has been provided as the oldest known cyst fossils. Further studies are necessary to understand its great scientific significance. Fifty-eight core samples with abundant cysts were prepared and observed under scanning electron microscope after gold coating. Four categories, including 24 morphotypes of stomatocysts, were found in the shale samples, among which 10 types are new to science. The distribution of chrysophyte cysts was aperiodic and discontinuous, indicating that environmental changes caused by sudden geological events might be dominant factors for cyst distribution. The lacustrine environment during the Ladinian Age, with fresh to brackish water, oxygen-containing bottom water, and abundant nutrients, is favorable for chrysophyceae reproduction. From the available fossil records, chrysophyceae was speculated to be the earliest siliceous algae on earth, or a new species appearing during ecosystem restoration after the end-Permian mass extinction.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Research on fractal characteristics and influencing factors of pore throats in tight sandstone reservoirsA case study of Chang 6 of the Upper Triassic Yanchang Formation in Huaqing area, Ordos Basin, China

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Keywords: Ordos Basin, Huaqing area, Member 6 of Yanchang Formation, fractal dimension, influencing factors

Tight sandstone oil and gas is an important field of oil and gas exploration and development in recent years. It is great significance to clarify the pore throat structure characteristics of tight sandstone reservoirs to guide production practice. This paper takes the tight sandstone of the sixth member of Yanchang Formation in Huaqing area, Ordos Basin as an example. Based on high-pressure mercury intrusion, casting thin sections and scanning electron microscopy, combined with tube bundle and spherical fractal models, the pore-throat structure and influencing factors of tight sandstone reservoirs were studied. According to the curve characteristics of spherical and tube-bundle fractal models, the pore-throat structures of tight sandstone reservoirs are divided into three categories. Type I is the smaller pore throat, Type II is the medium pore throat, and Type III is the larger pore throat. The results show that the fractal dimension of class I pore-throat distribution is 2.1289~2.9477, with an average of 2.4453; the fractal dimension of class II pore-throat is distributed from 3.1433 to 6.222, with an average of 4.3972; the fractal dimension of class III pore-throat is distributed in the range of 2.1376-3.3559, with an average is 2.6688. Type I pore-throat fractal dimension is the smallest, and type II pore-throat fractal dimension is the largest. It shows that the gap between the pore and throat radius of the smaller pore throat is the smallest, and the uniformity of the pore throat is the best. The gap between the pore and throat radius of the medium pore throat is the largest, and the uniformity of the pore throat is the worst; the larger pore throat is between the two. The main influencing factors for the difference of fractal dimension of different pore throats are diagenesis, rock composition and pore-throat combination type. Diagenesis and rock composition mainly affect the type and development degree of pore-throat, as well as the combination of pore-throat. Type I pore throats are mainly composed of intercrystalline pores and tube bundle throats, with small roars for small pores. Type II and type III pore throats are dominated by residual primary intergranular pore-sheet throat, curved sheet throat assemblage and dissolution pore-necked throat assemblage, with small throats for large pores. The structural differences of different pore throats are manifested in fractal dimension and mercury intrusion parameters and their interrelationships. This paper provides a theoretical basis for the exploration and development of tight sandstone reservoirs.

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Session T9-5: Unconventional petroleum sedimentology
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The Ri-Qing-Wei Basin oil-gas accumulation condition——contrast with Jiaolai Basin

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Keywords: The Ri-Qing-Wei Basin, Jiaolai Basin,Tectonic Evolution, Source Rocks,Reservoir Physical Properties.

During the Jurassic-Cretaceous period, the subduction, rollback and the change of subduction direction of the paleo-Pacific plate had an important influence on the development of eastern China and coastal basins. Due to the subduction of the paleo-Pacific plate to the Eurasian plate in the late Mesozoic, the Sulu orogenic belt between the North China plate and the Yangtze plate was subjected to the lithospheric mantle subsidence to produce a passive continental rift. Under the passive tensile action of the Laiyang period , a series of rift basins with Ri-Qing-Wei Basin as the central rift were formed. After the active rifting stage in the Qingshan period and the depression stage in the Wang period, the middle part experienced thermal uplift and two compressional strike-slip processes , and finally formed the structural form of the current basin. The current drilled wells in the Jiaolai Basin have good oil and gas display in the Laiyang Group, among which the source rocks in the Shuinan section of the Laiyang Group in the Laiyang Sag are the best. The Ri-Qing-Wei Basin is adjacent to the Jiaolai Basin, east of the Tanlu Fault Zone, developed on the Sulu orogenic belt, and separated by Jiaonan uplift in the middle. The Jiaolai Basin is located between the Tan-Lu fault zone and the Wulian-Mouji fault zone. In the right-lateral strike-slip stage at the end of Wang period, the Jiaolai Basin was subjected to strong compression and uplift, and the strata were uplifted on a large scale. As a result, the Wang group as a caprock was eroded, and the source rocks in the Laiyang period were oxidized, resulting in the destruction of oil and gas reservoirs. Ri-Qing-Wei Basin is clamped by Rongcheng fault zone and Wulian fault zone.The Ri-Qing-Wei Basin in Laiyang period is a central rift basin. The source rock in Laiyang period is deeper and thicker, and the uplift at the end of Wang ’ s later period has little effect on its destruction. The magmatic activity in the Qingshan period will have a positive impact on the source rock, but it is not a key factor. The key factor affecting the source rock is the burial depth. The sedimentary filling history, tectonic evolution, burial history, geothermal history and organic geochemical characteristics of source rocks in different basins are comprehensively compared and analyzed by using field profile, drilling, core data and seismic profile. The results show that the Laiyang Group of the Late Mesozoic in the Ri-Qing-Wei Basin has great exploration potential in unconventional fields.

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Pore-throat characteristics of shale reservoirs in the Lower Cambrian Niutitang Formation in northern Guizhou

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Keywords: northern Guizhou,Niutitang Formation,FE-SEM, NMR,low temperature nitrogen adsorption

The shale reservoirs of the Lower Cambrian Niutitang Formation in northern Guizhou have strong hydrocarbon-generating capacity and great development potential. The research on the pore throat structure characteristics of the reservoirs is the basis for oil and gas development. Through field emission scanning electron microscopy (FE-SEM), nuclear magnetic resonance (NMR)experiment, and low-temperature N2 adsorption-desorption experiment, the pore-throat characteristics of shale reservoirs in the Lower Cambrian Niutitang Formation in northern Guizhou were researched. The results show that the pore types of the organic-rich shale reservoirs in the Lower Cambrian Niutitang Formation of Yongfeng 1 Well are compound pores, caves and fractures, mainly organic pores and intercrystalline pores (mainly pyrite intercrystalline pores), intracrystalline pores (mainlysiliceous minerals intracrystalline pores) and micro-cracks, the degree of pore development is controlled by minerals, organic matter and later reformation; the sample pore size distribution is complex, the pore structure is poor, and the storage space is mainly concentrated in the micropores , mesopores, macropores, few small pores, the pore size ranges from 0.1-1nm, 2-4nm, 10-100nm; the average specific surface area of the sample is 9.5366m2/g, the average pore volume is 0.01084 cm3/g, the average The pore size is about 3.708 nm; the pore morphology of the sample is complex, with cylindrical, cracked and ink bottle shapes developed

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Session T9-5: Unconventional petroleum sedimentology
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Controlling effect of the microstructure on lacustrine shale fracability based on image recognition and analysisan example from Paleogene Formation, Subei Basin, East China

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Keywords: lacustrine shale, microstructure, fracability, image recognition and analysis

Rock fracability is a key indicator to measure the effect of fracturing, and the microstructure play a crucial role in controlling the mechanical properties. This study aims to reveal the effect mechanism of the microstructure heterogeneity on lacustrine shale fracability. In this study, we took X-ray diffraction, argon ion polishing-field emission scanning electron microscope, energy spectrum, rock slice/light. To carry out systematic research on the microstructure and structure of shale reservoirs and their influence on the fracability of the reservoir using test methods such as flake microscopic observation, organic geochemical testing, triaxial stress experiment, and rock acoustic wave testing. Moreover, images of lacustrine shale samples from the Paleogene Formation in the Eastern China were systematically analyzed using Image-J software. This paper is the first to analyses the unique effect of microstructure on fracability of lacustrine shale. The quantitative characteristics of microstructure in shale samples were extracted from the FE-SEM images. Studies have shown that the microstructure of lacustrine shale have strong longitudinal heterogeneity, the fracturing index of fine-grained sedimentary rocks is controlled by the microstructure. The lower the organic matter and clay content, the higher the carbonate mineral content, the fewer mineral particles and areal density, and the larger the particles, the greater the fracturing ability. The better, and the smaller the number of laminae and the density per unit area in the sedimentary structure, the wider the width, the stronger the fracturing ability.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
Presentation Preference: Oral Preferred

Enrichment conditions and geochemical markers of organic matter in lacustrine fine-grained mixed sedimentary rocks

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Keywords: Fine-grained Sedimentary Rocks, Enrichment of Organic Matter, Sedimentary Environment, Haian sag

Multiple sets of dark fine-grained sedimentary rocks are developed in continental strata, which is a potential favorable target for shale oil exploration and development. The current lack of in-depth understanding of organic matter enrichment mechanisms in continental sedimentary environments has restricted the progress of shale oil exploration and development. Taking the typical fine-grained mixed sedimentary rocks of Paleogene in Subei Basin in eastern China as the research object. XRD, determination of organic carbon content, trace elements and carbon and oxygen isotopes were used to analyze the sedimentary environment of dark shale and its influence on organic matter in the second member of Funing Formation(FM) in Qutang Sub-Sag of Haian Sag in Subei Basin. Fine-grained sedimentary rocks are mainly mixed and clayey shale; the average abundance of organic matter is 1.32%, and the vertical heterogeneity is obvious; trace elements such as Sr and Ba are significantly enriched, while Ni and Co are relatively depleted; the $\delta^{13}C_{Org}$ average is 27.35%, and the $\delta^{13}C_{Car}$ and $\delta^{18}O_{Car}$ averages are 0.88 ‰ and -5.90 ‰ respectively. The main sedimentary environment of the dark fine-grained mixed sedimentary rocks in the second member of Funing FM is a relatively deep, freshwater to brackish water, semi-arid to semi-humid, semi-reduced to semi-oxidized environment. there is a strong correlation between carbon and oxygen isotopes in the carbonate components of the second member of Funing FM, indicating a relatively closed lake system. Paleo-water depth and paleo-redox conditions in sedimentary environment are important conditions to control the enrichment of organic matter, it's meaning that, with the increase of water depth, the more reductive the water column is, the more favorable the organic matter enrichment. At TOC<1%, the enrichment of saprophytic kerogen was more conducive as the water body modification effect diminished, and at TOC>1%, sapropelic kerogen content is gradually stabilized.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
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Main-controlling factors of the high-quality reservoir in the deep strata of the Guaizihu Depression, Yin-E Basin

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Keywords: deep-buried clastic rock, differential densification, diagenesis, the Guaizihu Depression

This paper studies the differential densification mechanism of cretaceous tight sandstone reservoirs and the development model of high-quality reservoirs in the Guaizihu Depression of Yin-E Basin. This study fills in the shortcomings of previous research on tight sand reservoir heterogeneity in the Yin-E Basin. The research results are of great significance for predicting high-quality reservoir development areas. The reservoir in the study area is characterized by apparent heterogeneity with porosity ranging from 0.3%-16.7% and permeability ranging from 0.01mD-90.41mD. We studied cement's types, occurrence, and formation sequence in a clastic reservoir based on the regional sedimentary background. We also analyzed the effect of microscopic characteristics of a reservoir on pore evolution by using the data of core observation, cast thin section, mercury injection test, scanning electron microscopy, and X-ray diffraction test. Furthermore, we studied the influence of sedimentary facies, diagenesis, and post-diagenesis on reservoir differences. The results show that:

(1) Tight reservoirs are mainly developed in beach bar microfacies, with poor initial physical properties and high plastic mineral content. The average porosity reduced by compaction and cementation is 22.2% and 11.5%, respectively, and the average porosity increased by dissolution is 1.1%. In addition, clastic rocks rich in tuff debris are developed in the upper part of the tight reservoir, and carbonate cement generated by the diagenesis can densify the lower reservoir.

(2) High-quality reservoirs are mainly developed in underwater distributary channel microfacies, with promising initial physical properties. The high-quality reservoir has low plastic mineral content and high content of rigid particles, so the reservoir has weak cementation and high compressive ability. The average pore reduction amount of compaction and cementation is 21.7% and 9.4%, respectively, and the average porosity increase is 5.9%. The diagenetic evolution of "early alkali and late acid" is conducive to developing chlorite rim cement early and inhibits late carbonate cement deposition, which protects the primary intergranular pores in the reservoir to a certain extent.

(3) The sedimentary facies zone determines the spatial distribution of the high-quality sand body and the initial reservoir's physical properties. Diagenesis promotes the differentiation of reservoir porosity and permeability. Moreover, overpressure increases the compaction ability of the reservoir and facilitates the development of deep secondary pores. In short, all these factors act on forming a high-quality deep reservoir.

(4) Secondary dissolution pores and secondary dissolution fractures are the keys to forming high porosity and permeability reservoirs in clastic reservoirs in the study area. Organic acid acidification is the main reason for the appearance of secondary pores. Combined with the distribution area of the dissolution zone, it is concluded that the south depression step slope zone is the development area of the dissolution reservoir, which is the next favorable exploration area.

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Session T9-5: Unconventional petroleum sedimentology
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Architecture characteristics of sand bodies in the Chang 7 Member and prediction of favorable areas in the Heshui area, Ordos Basin

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Keywords: Heshui area,Chang 7,Sandy clastic flow,Sand structure,Favorable area prediction

Abstract: The Ordos Basin is rich in oil and gas resources. In recent years, the Chang 7 Member of the Mesozoic Yanchang Formation has shown huge resource potential under the guidance of deep-water sedimentary theory, and has achieved good oil exploration results. In this study, the Chang 7 Member in the Heshui area was taken as an example. Through the observation of core data, combined with the comprehensive analysis of logging data, the different types of sand bodies in the deep-water gravity flow system of the Chang 7 oil layer group in the Heshui area of the Ordos Basin were systematically studied. Architecture features and favorable zone predictions were made. The Chang 7 sedimentary period in the Heshui area was located on the slope in the southwest of the basin. Influenced by the Indosinian movement, there were frequent tectonic activities such as volcanoes and earthquakes. The delta front sediments formed a sufficient and continuous provenance supply due to slumping. After the slump, sediments accumulated rapidly, and large-scale sandy debris flows, turbidity currents and other gravity flows were developed deep-water sandstones during the Chang 71 and Chang 72 periods,. The reservoir rock types of the Chang 7 Member in the Heshui area are mainly feldspar lithic fine sandstone and lithic feldspar silt fine sandstone, and sand and mud interbed frequently. with poor physical properties, the average porosity is 9.86%, the permeability is 0.167mD, and the argillaceous content is high. The Chang 7 member sand bodies in the study area were divided into multi-layer superimposed type, thick sand-thin mud type, sand-mud interbed type and thick mud type, among which the multi-layer superimposed type and thick sand-thin mud type are high-quality reservoirs. The high-quality sand bodies in the study area are controlled by the sedimentary microfacies of sandy clastic flow, and are formed by rapid accumulation in multiple stages, and are located in the area of relatively deep lake water, and the sediments are hard to be reformed by lake waves. Therefore, the sedimentary sand body order is more mixed, the sorting is relatively poor, and the heterogeneity is strong. According to the plane distribution characteristics of sand bodies, physical properties and sedimentary microfacies, combined with oil test and production data, the favorable storage sand of the Chang 7 reservoir is mainly thick sand-thin mud type, and the local high-porosity area of thick sand-thin sand-mud interlayer sand can also be high-quality reservoirs, mainly distributed in the middle and south of the research area.

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Session T9-5: Unconventional petroleum sedimentology
Presentation Preference: Oral Preferred

Movable fluid characteristics of tight sandstone reservoirs and their sedimentary and diagenetic control: A case study of the Yanchang formation, Ordos Basin

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Keywords: tight sandstone, movable fluid, pore-throat structure, fluid mobility, Ordos basin

The tight sandstone of the Upper Triassic Yanchang formation constitutes important oil reservoirs in the Ordos Basin, Central China. The movable fluid characteristics of tight sandstone reservoir directly affect the oil production and recovery efficiency. Therefore, it is crucial to quantitatively characterize the fluid mobility and influencing factors of tight sandstone. Here, we presented the results of a detailed investigation on the movable fluid in the Yanchang formation in the Nanliang Oilfield, where fluvial channel sandstones intercalate with distributary interchannel muds in a delta setting. Multiple experiments, including cast thin-section, scanning electron microscope, X-ray diffraction, X-ray computed tomography, high-pressure mercury intrusion, and nuclear magnetic resonance were carried out on 16 samples from 12 wells. The integration of micro pore-throat structure investigation with petrographical observations and core descriptions reveals that the fluid mobility is dominantly driven by mudstone proximity, diagenetic mineral, petrophysical property, and pore-throat structure. According to the distribution and combination of pore-throat size and type, it can be identified that there are three types of pore-throat structure (type I, II, and III) and three pore-throat spaces (nanopore, submicron pore, and micron pore), which correspond to different occurrence characteristics of movable fluid. The differences of three pore-throat structure are pore-throat size, connectivity, and heterogeneity. Movable fluid mainly occurs in submicron and micron pores in type I pore-throat structure, submicron pores in type II, and nano and submicron pores in type III. The type I is characterized by large pore throats, high connectivity and weak heterogeneity, with the highest fluid mobility. The type II is dominated by submicron pores, with poor connectivity and moderate heterogeneity. The type III pore-throat structure is characterized by nanopores, lowest connectivity and strong heterogeneity, with the lowest fluid mobility. The fluid fluidity is a significant positive correlation with quartz and feldspar content, showing the residual intergranular pore and feldspar dissolved pore can significantly improve fluid mobility. On the contrary, it is negatively correlated with clay and carbonate minerals because they can block pore-throat and reduce fluid mobility. Detailed analysis of Spatial distribution of movable fluid shows it is distinctly related to mudstone proximity, thickness of single sandbody, and mudstone/formation (M/F) ratio. Typically, thick sandstones forming thick beds in mudstone-poor sequences are commonly low in carbonate and clay mineral cement and relative high in movable fluid. In contrast, sandstones occurring as thin beds in mudstone-rich depositional sequences (high M/F ratio) typically exhibit high carbonate and clay mineral cement, so its movable fluid content is low. The frequent material exchange between sandstone and adjacent mudstone leads to the enhancement of the cementation of clay carbonate minerals, where it may be a devastating factor for pore-throat structure and fluid mobility. This study provides new insights into predicting the best reservoir sandstones with high fluid mobility.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
Presentation Preference: Oral Preferred

Characteristics and Oil-bearing Analysis of Shale Reservoir in Qingshankou Formation in Sanzhao Sag, Songliao Basin

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Keywords: shale oil, Qingshankou Formation, lamina, oil-bearing

The continental shale of Qingshankou Formation in Songliao Basin has excellent potential for shale oil resources and has made substantial breakthroughs in exploration and development. The characteristics and oil-bearing properties of shale reservoirs are the keys to evaluate shale oil resource and sweet spot interval selection. The Qingshankou Formation shale lithofacies characteristics, laminae types, reservoir space geochemical and oil-bearing properties were studied by thin section identification, element scanning analysis, field emission scanning electron microscopy and confocal laser analysis. The results show that minerals of Qingshankou Formation shale in Sanzhao Sag, Songliao Basin are mainly clay minerals, quartz, carbonate minerals and pyrite; bright feldspar-quartz laminae, dark clay laminae and black organic-rich laminae are developed. Reservoir space includes intergranular pores, dissolution pores, clay mineral interlayer pores (fractures), organic matter pores, and intercrystalline pores of pyrite. The pore morphology of feldspar-quartz laminae is like the ink bottle, and the pore diameter distribution ranges from 0 to 200 nm, mainly between 0 to 50 nm, with an average of 14 nm. The particles are cemented mainly by carbonate minerals or clay minerals, which decrease the pore volume, but it can be increased by the dissolution of mineral particles, such as feldspar, calcite. While the pore shape of the clay laminae is slit-type pores, and the pore diameter distribution ranges from 0 to 600 nm, mainly between 0 to 50 nm, with an average of 17 nm. In terms of oil-bearing characteristics, the volume of light hydrocarbons in feldspar-quartz lamina shale is 13.71%, and that of heavy hydrocarbons is 11.35%; the volume of light hydrocarbons in clay lamina is 11.55%, that of heavy hydrocarbons is 15.44%. Compared with clay laminae, feldspar-quartz lamina has a higher ratio of light hydrocarbons to heavy hydrocarbons. The different distribution of light and heavy hydrocarbons of Qingshankou Formation in Sanzhao Sag is controlled by thermal evolution and burial time. The shale of Qingshankou Formation in Sanzhao Sag of Songliao Basin are buried for a short period of medium-low maturity, resulting in more heavy hydrocarbons in clay lamina and more light hydrocarbons in Feldspar-Quartz lamina.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Application of LPGA-N2 and SAXS in pore fractal evaluation of terrestrial shales in China--Example of the Upper Triassic Yanchang Formation in the Ordos Basin, China

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Keywords: Low pressure gas adsorption, small angle X-ray scattering, Fractal dimension, Pore structure

Fractal dimension is a key parameter of evaluate shale reservoir, which can be calculated based on the various experimental results. Low pressure gas adsorption (LPGA) and small angle X-rayscattering (SAXS) experiments were used to evaluate the pore fractal characteristics of bulk, washed and kerogen of shale samples of the Chang 7 member shale of the Upper Triassic Yanchang Formation in the Ordos Basin. The fractal dimensions of the two sets of experimental data were compared, and the application of the fractal dimensions in characterizing the pore structure and liquid hydrocarbon content of the shale was discussed in combination with the parameters of pyrolysis experiment. The following conclusions can be drawn from this study: (1) The fractal dimension of the bulk shale sample is slightly lower than that of the washed sample, and the fractal dimension of the kerogen sample is significantly lower than that of the other two groups of samples, which indicates that the presence of residual hydrocarbons increases the complexity of the pore structure and kerogen has a simpler pore structure. (2) Whether it is bulk shale, washed shale, or kerogen samples, the fractal dimension of most samples measured by SAXS data is higher than the fractal dimension measured by LPGA-N_2 data, which proves that a certain amount of uncracked liquid hydrocarbons exist within the pores of the lacustrine shale, forming many isolated disconnected pores. (3) The fractal dimension decreases with increasing TOC content, indicating that the fractal dimension of organic matter in shale is lower than that of other components. In addition, the fractal dimension decreases with increasing S_1 content, which makes the fractal dimension can be used to approximately reflect the residual hydrocarbon content in lacustrine shale.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
Presentation Preference: Oral Preferred

Multi-factor control on the formation of tight sandstone reservoirA case study from the Carboniferous Yanghugou Formation in the western Ordos Basin

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Keywords: Tight sandstone,Reservoir quality,Diagenesis,Depositional facies,Ordos basin

The study of the formation mechanism of tight sandstone reservoirs has been a hot issue in the field of sedimentological research. The Upper Paleozoic Carboniferous in Ordos Basin is one of the main producers of tight sandstone gas in China. However, the previous researches on the formation mechanism of Carboniferous reservoirs mainly focus on the central-eastern and northern parts of the basin, while the western part of the basin is rarely reported due to the complex geological environment. Based on the observation and sampling of drilling cores, thin section identification under microscope, mercury intrusion and CT scanning analysis, combined with the latest research results of sedimentation, structure and provenance, this study explored the formation mechanism of tight sandstone reservoirs in the Carboniferous in the western Ordos Basin. The study shows that the Carboniferous sandstone reservoir is dominated by quartz arenite and litharenite, with an average porosity of 8.43% and average permeability of 0.405 mD, which is a typical low porosity and low permeability reservoir. The pore types are mainly secondary pores such as intergranular pores and intragranular pores, and the primary pores are almost invisible. Diagenesis, sedimentary environment and provenance are the key factors for the formation of reservoir in the study area: the dissolution of feldspar, rock fragments and cements by organic acids released by mature hydrocarbon materials effectively improves the reservoir quality.The compaction caused by long-term deep burial results in the disappearance of a large number of primary pores, and the cementation mainly composed of tuff, kaolinite, carbonate and silica reduces the reservoir quality significantly. The tidally influenced deltaic front subfacies in the study area has relatively good reservoir properties, followed by barrier sand dam facies. tidally influenced deltaic front has low mud content but high sand content due to continuous sieving and washing by tidal action, and the parent rocks have good physical properties. Compared with the barrier sand dam, the content of rock fragments and interstitial materials in the reservoir is relatively high, which provides material conditions for later dissolution. The supply of Carboniferous sediments in The Ordos Basin mainly came from the Alxa paleocontinent, which is dominated by sedimentary rocks and calcareous mudstones in the northwest, and the Yinshan paleocontinent, which is dominated by alkaline basalt in the northeast. Sedimentary rock fragments and calcareous rock fragments tend to lead to strong cementation and poor reservoir properties. However, the volcanic rock fragments easy to dissolve .and the cementation is weak, so the reservoir physical properties are relatively good. The above research results can provide reference for further exploration and development of the study area and similar basins.

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Session T9-5: Unconventional petroleum sedimentology
Presentation Preference: Oral Preferred

Control of sedimentary characteristics of fluvial tight sandstone reservoir on diagenesis and differential densification process A case study of No.7 and No.8 sand formations of J2s21 Sub-Member in the North of Central Sichuan Basin

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Keywords: tight sandstone, sedimentary characteristics, diagenesis, differential densification

In order to explore the differential densification mechanism of fluvial sandstone reservoir and clarify the relationship between sedimentation and diagenesis, integrated analysis of sedimentary components and structure characteristics, reservoir quality, pore structure, and types and degree of diagenetic alterations of No.7 and No.8 sand formation of $J2s^2_1$ Sub-Member in the North of Central Sichuan Basin was done in this study by employing core and cast thin section observation, scanning electron microscopy combined with EDS, X-ray diffraction, high-pressure mercury intrusion and nuclear magnetic resonance, and obtained the following understanding:

1. The No.7 and No.8 sand formations of $J2s^2_1$ Sub-Member belong to low curvature meandering river sedimentary system, with the characteristics of multi-stage channel sandbody superposition, single sandbody scouring contact and obvious positive grain sequence. Compared with No.8 sand formation, the No.7 sand formation has larger particle size and higher content of magmatic rock debris.

2. The difference of rock debris composition has an obvious influence on the properties of pore fluid in shallow burial period. Due to the intense hydrolysis and alteration of dark iron magnesium minerals in magmatic rock cuttings, The pore fluid of No.7 sand formation is more alkaline and rich in metal ions, which promotes the transformation of smectite film on the grain surface to chlorite. On the contrary, the chlorite content of No. 8 sand formation is low, and the grain surface mainly dominated by I/S mixed layers and illite.

3. The cement developed in syngenesis and early diagenesis stage has obvious sedimentary structure selectivity in alkaline fluid environment. With the decrease of sandstone particle size, the original hydrodynamic conditions, initial porosity and rigid component content gradually decrease, the sorting, pore structure and fluid exchange intensity in shallow burial period gradually deteriorate, and the content of chlorite also gradually decreases. On the contrary, the content of I/S mixed layers, illite and crystal stock calcite gradually increases.

4. The symbiotic association of cements and the degree of dissolution in the middle diagenesis stage is controlled by the pore fluid environment in the early diagenesis stage. Due to the alkaline pore fluid in the early diagenetic stage of No.7 sand formation, the development degree of dissolution in the middle diagenetic stage is limited, the reservoir space is dominated by residual primary pores, and the combination of grain-coating chlorite, authigenic albite and quartz cement is developed. In contrast, the dissolution in No.8 sand formation is relatively strong, the proportion of dissolution pores is relatively high, and the types of cements are diverse, the I/S mixed layers, filamentous illite, crystalline calcite, vermicular chlorite and authigenic quartz crystals have complex symbiotic relationship.

5. Compaction is the main cause of porosity loss of coarse-fine sandstone, but for some siltstone and fine sandstone, the damage of calcite cementation to pores is greater than that of compaction.

6. Weak sedimentary hydrodynamic conditions and high content of filamentous illite are the main reasons for the obvious deterioration of pore structure and permeability of No.8 sand formation compared with No.7 sand formation.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Sedimentary Characteristics and Seismic Response of Tight Sandstone Reservoirs: A Case Study of the Upper Triassic Xujiahe Formation in Central Sichuan

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Keywords: Sichuan Basin,Upper Triassic,Braided river delta,Tight sandstone gas,Fracture system

The Triassic Xujiahe Formation in the Sichuan Basin is one of the most typical tight gas exploration formations in China. According to seismic, core, logging and logging data, the sedimentary characteristics of tight sandstone reservoirs and the "sweet spots" of tight gas reservoirs have been clarified. The second member of Xu is a typical braided river delta deposition, with high-energy underwater distributary channels, low-energy underwater distributary channels, between underwater distributary channels, and beach-bar sedimentary microfacies; based on seismic facies and forward modeling analysis, the amplitude-type envelope is selected The attributes characterize the distribution of sedimentary facies. It is believed that there are NW and NEE provenances in the Xu 2nd Member, and a small amount of provenance can be provided in the east. Under the background of the overall lake level decline, the underwater distributary channels are widely distributed; the Xu 2 Member has typical development In tight sandstone reservoirs, high-energy underwater distributary channels are the most favorable sedimentary facies belts for reservoir development, and the configuration of high-quality reservoirs and fault zones determines the “sweet spot” for oil and gas exploration in tight sandstones. Combined with the results of multi-scale fracture prediction, the spatial distribution of the “fractured body” reservoirs deposited in the braided river delta is finally described. "Desserts" section. The study proposes a prediction method for the sweet spot of tight sandstone "fractured body" reservoirs, which enriches the sedimentary research of tight oil and gas reservoirs and provides a reference for the exploration of the same type of unconventional tight oil and gas reservoirs.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
Presentation Preference: Oral Preferred

Low resistivity reservoir genetic analysis based on sedimentological environment

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Keywords: low resistivity reservoir, genetic analysis, paleoclimate, hydrodynamic action

Low resistivity reservoir is widely distributed in N_1gIII formation, Bohai Sea area, and the genetic analysis has important research significance to clarify reservoir characteristics. Therefore, taking C oilfield, Bohai Sea area as an example, X-ray diffraction (XRD), cation exchange capacity (CEC) analysis, bound water mineralization degree measurement, scanning electron microscopy (SEM), grain size analysis, log interpretation, and productivity test were used to study the influence of sedimentological environment on reservoir resistivity. Through the above analyses, this study discussed the characteristics of paleoclimate and hydrodynamic action, and then the genesis of low resistivity reservoir were established. The results showed that the content of smectite is more than 60% while the climate is dry and cold, which leads to the high content of CEC (15-50 mmol/100g) and bound water mineralization degree (4-7 mg/L). Moreover, honeycomb-shaped smectite has a large surface area, and water molecules preferentially adsorb on it, so the resistivity is relative low. Humid and warm climate leads to the high kaolinite content (more than 70%) and low CEC (1-10 mmol/100g) and bound water mineralization degree (1-3 mg/L) content, while page-shaped kaolinite is not conducive to the enrichment of water molecules, which results in the normal resistivity. The low resistivity reservoir has a poor hydrodynamic action, which leads to a small grain median diameter (less than 50um), while the logging curve is campaniform and the average single well cumulative productivity is less than $1*10^5m^3$. The normal resistivity reservoir has a strong hydrodynamic action, while the grain median diameter is between 70 and 200um, and the logging curve is box like and the average single well cumulative productivity is more than $2*10^5m^3$. Taking resistivity of 4 Ω·m as the threshold value, and ensuring the resistivity greater than 4 Ω·m during drilling could improve single well productivity.

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Session T9-5: Unconventional petroleum sedimentology
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Lignite macrolithotypes sequence in the Erlian Basin and its control on nature fracture distribution

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Keywords: lignite macrolithotypes, Erlian Basin, coal facies, natural fractures, CBM sweet spot

Lignite profiles in the Erlian Basin show a well-developed macrolithotype sequence, starting from the detritic coal, then to xylitic coal, and fusitic coal at last upwards in order. The petrography and palynology analysis shows that the macrolithotypes variation corresponds to the gradual drying of the swamps and shrinking influence of clastic-input. The detritic coal as the base of the cycle is related to low-position swamps with abundant water and clastic supplies. In contrast, xylitic coal in the upper part of the cycle is formed in the relatively dry swamp, less affected by the invasion of flooding and the clastics. And the fusitic coal is closely related to a further oxidizing environment.

Natural fractures which can provide good seepage channels for coalbed methane (CBM) and are conducive to the production of CBM in coal reservoirs, are controlled by macrolithotypes as observed in the profiles. Due to the weak mechanical strength identified by the mechanical tests, the xylitic coals have better natural fractures, being the favorable reservoir intervals. In profiles, xylitic coal is usually found in coal seams with a thickness larger than 2 m, indicating the complete coal facies cycle is thicker than 2 m. For ultra-thick coal seams, xylitic coal is likely to be divided into individual intervals by detritic coal, which could be identified through the cores or logging curves. This developed geological model of fracture based on the macrolithotype sequence can accurately predict the sweet spot to improve the efficiency of CBM exploration.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
Presentation Preference: Oral Preferred

Pore evolution mechanism of shale in the first member of the Qingshankou Formation in the Songliao Basin

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Keywords: Shale, Pore evolution, Qingshankou Formation, Songliao Basin

Shale pore evolution is a complex physicochemical synergistic evolutionary process, and most current studies stagnate at the stage of revealing pore evolution characteristics and laws based on reservoir characterization techniques. Thus, the pore genesis and evolution mechanisms are not understood sufficiently well. Therefore, to reveal the mechanism of shale pore evolution, mineral component analysis, geochemical analysis, microscopic observation, and quantitative characterization of pores were conducted in the first member of the Qingshankou Formation in the northern Songliao Basin. With increasing maturity, the porosity, pore volume, and specific surface area all first decreased and then increased. Moreover, when 0.8% < Ro < 1.4%, porosity continues to be at the maximum and is dominated by small-scale pore development. The evolution process is mainly because of compaction, hydrocarbon generation, acid discharge of organic matter dissolution, cementation, and clay transformation, among which dissolution results in the reduction of mineral volume and the increasing pore size is mainly attributed to the dissolution of calcite, feldspar, and pyrite. The transformation of clay minerals is mainly influenced by temperature and pressure, and the pores are increased by reducing the mineral volume. Compaction and cementation are mainly caused by the pores being squeezed by the formation and filled by quartz, pyrite, and other cements, resulting in pore reduction, thus establishing the shale pore evolution model.

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Session T9-5: Unconventional petroleum sedimentology
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Reservoir characteristics and influencing factors of Yan-9 Formation in Huanxian area, Ordos Basin, China

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Keywords: Ordos Basin ,Huanxian area, Yan-9 oil Member, diagenesis, reservoir characteristics

The Ordos Basin is rich in oil and gas resources, and the Jurassic oil reservoir is one of the main oil layers of the Mesozoic in the basin. Based on analysis of casting thin sections, SEM, porosity and permeability, and pressure mercury testing, the reservoir characteristics of Jurassic Yan'an Formation Yan-9 oil Member are studied and the factors affecting the reservoirs are discussed. It shows that the Yan-9 oil Member is composed of feldspathic lithic sandstone and lithic quartz sandstone, with moderate to good compositional maturity, medium structural maturity. Intergranular pores and feldspar dissolved pores are the major reservoir space. The throats in the sandstone occur as elongated, middle to thin punctiform and flake. Physical properties of the reservoir sandstones are characterized by low porosity and low permeability with good correlation of porosity and permeability. It reveals that the development of the reservoir is affected by following factors: firstly, sedimentary microfacies determined the location of the reservoir; secondly, early chlorite cementation and dissolution enhanced the accumulation property of the reservoir.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
Presentation Preference: Oral Preferred

Carbonate cements in Eocene turbidite sandstones, Dongying Depression, Bohai Bay Basin: origin, distribution, and effect on reservoir properties

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Keywords: Turbidite sandstone, Carbonate cements, Diagenesis, Geochemistry.

Diagenetic carbonate cements occur throughout Eocene turbidite lithic arkose in Niuzhuang Sag, Eastern China, displaying as sporadical siderite, dolomite, calcite 1 (C1), and massive ankerite (Ak) and calcite 2 (C2). Petrographic and geochemical investigations suggest that the non-ferroan C1 (δ13Ccar +3.1 to +4.7‰VPDB; δ18Ocar −12.5 to −10.5‰VPDB) was the earliest carbonate cement that was followed by Ak (δ13Ccar +0.2 to +5.1‰VPDB; δ18Ocar −12.8 to −10‰VPDB) and ferroan C2 (δ13Ccar +2 to +3.1‰VPDB; δ18Ocar −12.6‰ to −15.8‰ VPDB). The homogenization temperatures (Th, 74.3 to 105.8oC, 105.6 to 130.4oC, and 119.7 to 144.6oC, respectively) reflect the pattern of increasing temperature with progressive burial. The δ13Ccar values suggest that C1 and C2 were mainly derived from dissolution of carbonates in calcareous shales (δ13Ccar +3.5‰ to +6.3‰VPDB), with minor contributions from organic matter. The δ13Ccar values of Ak documented some contributions from magmatic carbon.

Ankerite and C2 were restricted under the top seal (geochemical barrier) of overpressure compartment and the of highly cemented zones occur mainly along faults. Carbonate cementation seems to negatively impact the reservoir quality when it exceeds 10%.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
Presentation Preference: Oral Preferred

Coupling variation model of hydrocarbon generation, nanoscale pore structure and diagenesis of the Mesoproterozoic Xiamaling shale in Zhangjiakou, Hebei, China

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Keywords: coupling evolution model, thermal hydrocarbon generation, clay mineral transformation, diagenetic evolution process

Shale formation is an unconventional and complex oil-bearing system with the trinity of source, reservoir and cap. The coupling variation of thermal maturation hydrocarbon generation, nanoscale porosity and diagenesis is the key scientific issues affecting the shale gas accumulation. The main research methods of the coupling evolution of mature hydrocarbon generation, nanoscale porosity and diagenesis of shale are direct observation and physical simulation, both of which have their own advantages and limitations. In this research, a comprehensive study on hydrocarbon generation, nanoscale pore structure and diagenesis of natural marine shale samples from the low-mature Mesoproterozoic Xiamaling shale in Zhangjiakou of Hebei Province was carried out, and diagenetic physical simulation was carried out on the selected samples. Basic geochemical analysis, mineral composition and content testing, characterization of nanoscale pore structure and other qualitative and quantitative experiments were carried out on natural and thermal samples. Nanoscale pore structure evolution and diagenesis of the shale during thermal maturation were discussed. Thus, the coupling variation relationship among thermal maturity hydrocarbon generation, nanoscale pore structure and diagenesis of the Xiamaling shale is clearly and intuitively revealed.

The nanoscale pore system of the researched natural shale is composed of organic pores and matrix pores, the organic hydrocarbon generation and diagenesis are the two main issues influencing their generation and variation. During the variation process, hydrocarbon generation and diagenesis have different influences on the generation and variation of the nanoscale pore system, and then resulting in different variation trends. The simulation experiment show that, the nanoscale pore diameter did not change significantly, while the pore volume decreased first and then increased, reaching the minimum and maximum values at 350°C and 650°C, respectively. The surface area of micropores and mesoporous pores firstly decreased and then increased, reaching the minimum value at 350°C, while the surface area of macropores firstly increased and then decreased, reaching the minimum value and maximum value at 350°C and 650°C, respectively. The diagenetic evolution of the simulation experiment can be roughly divided into four stages, and the main diagenetic types are clay mineral transformation, dissolution, thermal maturation hydrocarbon generation, compaction and recrystallization. In this study, the diagenetic evolution process and pore evolution model of the shale were roughly divided, and the coupling evolution model of thermal mature hydrocarbon generation, diagenesis and pore structure of shale was established based on natural shale sample observation and thermal simulation experiment.

The established coupling evolution model in this research provides a qualitative and quantitative evaluation method for the organic matter hydrocarbon generation, diagenesis and nanoscale pore structure variation of the organic-rich shale. The model has important guiding significance for the reservoir evaluation, the shale gas accumulation mechanism, as well as shale gas exploration and development of the Mesoproterozoic Xiamaling shale in Zhangjiakou, Hebei, but also very important for the other low mature shale of the world.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
Presentation Preference: Oral Preferred

Effects of lacustrine depositional sequences on organic matter enrichment –Case studies from Chang 7 Shale, Ordos Basin, and Qingshankou Shale, Songliao Basin, China

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Keywords: Shale oil, Sequence stratigraphy, Parasequence, Organic matter, Well log, Sweet-spot area prediction

Chang 7 Shale and Qingshankou Shale characterized by lacustrine black organic-rich shales, have become the target for shale oil exploration and development in the Upper Triassic Ordos Basin, and the Upper Cretaceous Songliao Basin, China, respectively. However, the heterogeneous enrichment of organic matter (OM) has led to controversy regarding source rock evaluation and difficulty in accurate prediction of favorable zones in the both basins. Sequence stratigraphy, as a tool for prediction of sedimentary deposits has encountered challenges in lacustrine deep-water environments because of rapid facies changes and limited lateral continuity of key beds. Based on the high order sequences division (parasequences and the T-R cycles within them), this study aims to illustrate the spatiotemporal coupling interaction among tectonic activity, volcanic eruption, climate and lake-level change, water anoxia, and gravity flow activity (e.g. hyperpycnal flow deposition) during high order sequences periods. Depositional sequences have a significant effect on the enrichment of OM, given 1) promising OM types controlled by late TST and early RST, 2) the OM enrichment determined by shale facies with different laminae combination types, and 3) the distribution of shale facies controlled by T-R cycles within parasequences. In particular, the most favorable locations are the longer transgression parts in parasequences in the late TST and early RST. A novel method is proposed to predict OM enrichment based on calibration of well logging and core lithology through analyses of thin sections and geochemical data from 238 core samples in Ordos Basin, and 220 core samples in Songliao Basin, as well as the available well-logging data from the selected wells. By linking meter-level depositional sequences with centimeter-level OM enrichment, this study provides an alternative approach to determine the sweet-spot intervals in a single well profile and realize isochronous inter-well sweet-spot area prediction for shale oil exploration.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
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Sedimentary environment and organic matter enrichment for the Upper Permian Longtan Formation transitional shale in Southern Anhui Province, South China

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Keywords: transitional shale, organic matter, sedimentary environment, controlling factors, Longtan Formation

The marine-continental transitional organic-rich shale in the Longtan Formation in Southern Anhui Province, South China is not only considered as an excellent source rock in the Lower Yangtze region, but also one of the important layers of shale gas exploration in China. In order to clarify the relationship between sedimentary environment and organic matter accumulation in such a setting, a case study was carried out from one core (Gangdi-1 well) and two outcrops (Changqiao outcrop and Daoshanchong outcrop) by conducting organic geochemical test, organic petrologic study, argon ion polishing-scanning electron microscopy (SEM) observation, elemental geochemical analysis. Results show that shales developed in a tidal flat-lagoon environment display high TOC contents ranging from 6.16% to 10.10% (average 8.50%), whereas these formed in a deltaic environment exhibit medium-high TOC contents varying from 0.93% to 6.70% (average 3.26%). These data also elucidate that the target shales in the Longtan Formation were deposited in a complex paleoenvironment with strong water-mass restriction that was mainly characterized by warm and humid paleoclimate, high primary productivity, oxic-to-dysoxic conditions, and a high sedimentary rate. Besides, the transitional shale formation is not determined by a single factor but is the result of the mutual configuration and coupling of multiple factors such as paleoclimate, paleoredox conditions, paleoproductivity, and sedimentary rate. All these factors will directly or indirectly affect the supply or preservation of organic matter. Furthermore, the “integrated model” for transitional organic matter accumulation is proposed. The model stresses two aspects: on one hand, the warm and humid paleoclimate not only facilitates the growth of higher plants, but also accelerates the chemical weathering rate of the parent rocks and increases the input of nutrients to the water column, which is conducive to the blooms of lower aquatic organisms. Both higher plant debris and lower aquatic organisms together provide abundant organic matter sources. On the other hand, although the oxidized water environment is usually unfavorable for organic matter preservation, a higher sedimentary rate can greatly shorten organic matter exposure time in the decomposition region of aerobic bacteria, and a number of organic matters cannot be oxidized or degraded through the rapid burial. These findings also add to our knowledge that despite the oxygenated water environment during transitional shale deposition, TOC contents are not necessarily lower.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Natural gas hydrate enrichment and occurrence under the control of different migration pathways in the Qiongdongnan Basin, South China Sea

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Keywords: Qiongdongnan Basin, natural gas hydrate, enrichment, occurrence, migration pathways

The deep-water area of the Qiongdongnan Basin (QDNB) has considerable gas hydrate resources and these gas hydrates were recovered with multiple geomorphology occurrences, including massive, layers, nodules, fracture filling and disseminated. However, there are few studies on the migration efficiency of migration pathways and the occurrence of hydrate. In this study, 2D and 3D seismic and logging while drilling data, gas hydrate samples, and basin simulation have been used to explore the geological occurrence and enrichment mechanism of gas hydrates controlled by different migration pathways in the QDNB. Based on the seismic reflection characteristics, we identified that diapirs, fault structures and fractures constitute the three main types of natural gas migration pathways in the QDNB. In addition, according to the basin modeling results, drilling results, resistivity spectrum, hydrate core and relative saturation analysis, hydrate enrichment and occurrence controlled by different migration pathways had been explored. The results show that the gas chimney migration pathway is characterized by continuous vertical gas distribution, sufficient gas supply, and high migration efficiency, it makes a significant contribution to hydrate enrichment. The gas hydrate was characterized by massive, layers, veins and nodules at different depths. In addition, the characteristics of deep faults are high efficiency, long-distance and it also has a significant influence on hydrate enrichment. Thermogenic gas migrates vertically through faults and eventually enrichment in the gas hydrate stability zone (GHSZ), leading to the formation of the layers, plaque and near-fault gas hydrates. Compared with the other two migration pathways, the fracture system have low migration efficiency, it is not conducive to the formation of widely distributed, and high-saturation gas hydrate. natural gas migrates through fractures and microcracks, resulting in the formation of thin-bedded, fracture filling and disseminated gas hydrate. These conclusions indicate that the migration pathways are regionally distributed, and closely related to hydrate enrichment and occurrence.

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Scientific Themes: Theme 9. Resource Sedimentology
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Can Eocene lacustrine organic-rich shales formation in the South China Sea linked to astronomically forced climate change and the Middle Eocene Climatic Optimum (MECO)?

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Keywords: Organic-rich shales, Astronomical forcing, Middle Eocene Climatic Optimum, Eocene, South China Sea

The formation of organic-rich shales is believed to be caused by short-term geological events. However, the existing lacustrine sedimentary record in the South China Sea has an inadequate temporal resolution, limiting the study of geological events' temporal constraints and the coupling relationship with organic-rich shales. In this study, we performed a cyclostratigraphy analysis on the Eocene sedimentary records of two basins on the northern margin of the South China Sea. The astronomical time scale (ATS) was constructed by astronomical tuning with absolute ages. The time of the Eocene organic-rich shales in both basins, according to the ATS, is around 40 to 41 Ma, which corresponds to the Middle Eocene Climatic Optimum (MECO). This result suggests a potential link between organic-rich shale and MECO. To further explore the possible response mechanism for the formation of organic-rich shales, we reconstructed lake level variations of both basins using DYNOT and ρ1 noise modeling techniques. We then conducted a comprehensive comparative analysis of astronomical forcing, lake level changes, and geochemical changes of organic matter enrichment element ratios. Our results reveal that the development periods of organic-rich shales correspond to eccentricity maxima, relative lake level rise, and the MECO. Inversely, organic-lean shales correspond to eccentricity minima and relative lake level decline. These results could suggest that astronomically-induced climate change has positive feedback on forming organic-rich shales. High eccentricity intensifies monsoon rainfall and weathering intensity. Thus, nutrients from intensified monsoon rainfall and weathering promote algae blooms in the surface water, resulting in high primary productivity. The lake water becomes deep during the MECO than it was before. Therefore, the lake water stratifies, and organic matter deposits and is preserved under the bottom water of a fresh-brackish and weak oxidation-weak reducing environment, resulting in the so-called excellent-quality source rock.

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The Accumulation Model of Quaternary Mudstone Gas Reservoir in Sanhu Depression, Qaidam Basin

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Keywords: Biogenetic Mudstone Gas Reservoir, Quaternary, Reservoir Forming Conditions, Accumulation Model, The Sanhu Depression

The study of formation conditions and accumulation model of biogenetic mudstone gas reservoir in Sanhu Depression is beneficial to improve the accumulation mechanism and enrichment rule of biogenetic gas reservoirs, and has important theoretical and practical significance for guiding the exploration and development of Quaternary mudstone gas reservoirs. Taking quaternary mudstone in Sanhu Depression as the research object, the reservoir forming conditions of quaternary mudstone in Sanhu Depression were determined and the accumulation model was established through soluble organic carbon analysis, porosity determination, chromatography-mass spectrometry analysis and other experiments. The results show that the high content of soluble organic carbon, herbaceous humic organic matter, as well as the cold and dry, are conducive to the generation of biogenetic mudstone gas. The Quaternary formation in Sanhu Depression has the characteristics of high porosity and low permeability. And a large number of micro-nano pores are developed, which provide a large amount of pore space for the occurrence of biogenetic gas. Besides, gas flow is given priority to fick diffusion and slip flow. Due to the self-sealing effect of mudstone, the biogenetic gas accumulates in situ. In the late Himalayan tectonic movement, the gas containment of mudstone was destroyed. By the buoyancy, gas migrated upward and gathered in mudstone of high part which was adjacent area of gas generating center, superimposed longitudinally with sandstone biogenetic gas reservoirs

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Tight oil reservoir characteristics and controlling factors of Fengcheng Formation in Manan slope area of Junggar Basin

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Keywords: Tight oil, Fengcheng Formation, Unconventional reservoir, Mahu depression, Junggar Basin

As unconventional oil and gas resources, tight oil and shale oil have become an important replacement of conventional oil and gas and an important type of increasing oil and gas reserves and production all over the world. Fengcheng Formation in Junggar basin is an important succeeding formation for continental tight oil and shale oil exploration in Western China. In recent years, Fengcheng Formation in Manan slope area in the northwest margin of Junggar basin has made a breakthrough in oil and gas exploration for the first time in the outer front of delta silty-muddy tight reservoir, but the characteristics and control factors of this type of reservoir are unclear, and there are no relevant research reports. Based on the data of cast thin section, physical properties, whole rock X-ray diffraction, field emission electron microscope, high-pressure mercury injection and physical properties, the petrological characteristics, pore characteristics and pore structure of Fengcheng Formation tight oil reservoir in Manan slope area of Junggar basin are analyzed. On this basis, the reservoir control factors are discussed. The results show that: on the plane, the content of terrigenous clasts in reservoir rocks decreases from the basin edge to the depression, The content of pyroclastic and authigenic minerals increases, which shows the orderly distribution law of sandy conglomerate → sandstone → tuffaceous sandstone → sedimentary tuff; Vertically, the bottom of Feng2 member is relatively fresh water sedimentary (tuffaceous) siltstone, the middle is salt water sedimentary cloud sandstone, and the top is sedimentary tuff affected by volcanic eruption. The tight oil reservoir lithology of Fengcheng Formation in slope area is mainly the combination of (tuffaceous) sandstone, dolomitic sandstone and sedimentary tuff. Among them, the physical property of (tuffaceous) sandstone is the best, the TOC content is the lowest. The physical property and TOC content of dolomitic sandstone are medium. The physical property of sedimentary tuff is the worst, but has the highest TOC content. The pore types of the reservoir are mainly residual intergranular pores and microfractures. The pore size is ten microns (1 ~ 20 μm) to hundreds of nanometers; The strong compaction caused by high tuffaceous matter is the main reason for the tight and low permeability of the reservoir. The devitrification of medium basic tuffaceous matter forms feldspar, which further destroys the pore structure of the reservoir; Reservoirs with higher content of terrigenous sand have higher porosity and wider pore throat; Micro fractures can effectively improve reservoir permeability. Reservoirs developed more fractures have better seepage capacity and higher oil production.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
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Chlorite characterization and diagenetic evolution as primary controls on Zhuhai Formation tight sandstone reservoir quality in Zhu-III sag, Pearl River Mouth Basin, South China Sea

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Keywords: Tight sandstone, Reservoir, Diagenetic evolution, Chlorite

Zhu-III sag is a rich-hydrocarbon sag in the Pearl River Mouth Basin. The Oligocene Zhuhai Formation is a key exploration horizon in Zhu-III sag. However, the exploration results show that the reservoir is deeply buried and belongs to tight sandstone reservoir, the diagenesis is complex and the reservoir heterogeneity is strong. Therefore, looking for high-quality reservoirs, which are zones with relatively high porosity and permeability, is a key point of resource exploration. Based on the previous research results, this study analyzed the reservoir characteristics and diagenesis characteristics, established the pore evolution model of the study area, and defined the main controlling factors of reservoir development and used core observation, thin section, scanning electron microscope, X-ray diffraction and so on. The research shows that compaction is the main reason for the reservoir densification of Zhuhai Formation. There are two kinds of chlorites in Zhu-III sag. Chlorite coating can effectively improve the reservoir quality. Another is chlorite cement which can destroy the pore structure. Different stages of fluid filling have various effects on the reservoir in study area. Fluid in the early stage leads to the carbonate cement and that in late stage leads to the dissolution of carbonate cement. In general, we clarify the diagenesis and pore evolution in key zones in Zhu-III sag and its reservoir is mainly affected by compaction, dissolution, chlorite and fluid filling. This study of reservoir diagenetic evolution process and pore characteristics is crucial and helpful in the exploration and development of reservoir in Pearl River Mouth Basin and other basin.

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Scientific Themes: Theme 9. Resource Sedimentology
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Micro-zone visualization analysis technology for crude oil emulsion

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Keywords: Crude oil emulsion,Microvisualization,Confocal laser technology

1. Introduction

The field produced fluid of shale oil has not been studied effectively. At present, shale oil has entered the stage of combining exploration and development. Shale oil is lighter and less dense than conventional oil, and its field produced fluid is significantly different from conventional oil produced fluid. At present, emulsification phenomenon appears in shale oil field produced liquid, and it is necessary to study the characteristics and laws of emulsion [1].

The original technology is not suitable for the study of shale oil emulsion.

(1)Shale oil is light in weight, low in density, and volatile. The droplet size is generally small (mostly less than 10μm). Under conventional fluorescence or laser beam, it will rapidly volatilize or fuse together, making it difficult to analyze and study it [2].

(2) The original enterprise technical standard "Emulsified Oil Analysis - Laser Confocal Analysis Method" (Q/SY1236-2008) is not applicable to the analysis of shale oil [3].

Therefore, it is of great significance to establish the visualization analysis technology of shale oil emulsion microzone.

2. Main research contents and conclusions

For the first time, a laser confocal automatic cooling and heating platform was used for digital characterization of microzone distribution of shale oil emulsion.

(1)The specific process is as follows:

A pipette was used to remove 1 drop (50μ L) of mid-layer emulsion and place it on a 75mm×25mm×1.5mm flat slide with a 20mm×20mm cover slide.After the emulsion is evenly diffused, it is placed on the microscope platform [4].

Liquid nitrogen is extracted by automatic cooling and heating platform, and the air outlet pipe is placed on the loading platform. The temperature of the air outlet is controlled at 5℃ to ensure that the sample is in a lower temperature environment.

(2)Analysis of type and distribution frequency of shale oil emulsion

Experimental principle: using fixed wavelength laser excitation of dispersed oil, emulsified oil samples, components of crude oil have specific wavelengths of fluorescence signals, and the principle of water not emit fluorescence signal, to identify types of dispersed oil, emulsified oil, by confocal laser 2 D data acquisition technology, quantitative analysis technology, implementation of dispersed oil and emulsified oil particle size distribution of quantitative statistics and analysis [5].

dispersed oilThe oil with the droplet diameter of 10μm ~ 100μm in the emulsion is called dispersed oil.

emulsified oilThe oil with the droplet diameter of 10-3μm ~ 10μm in the emulsion is called emulsified oil.

Choose a representative field of view, but do not duplicate it.

Distribution frequency statistics of droplets with different equivalent diameters:

The equivalent pore diameters were 0μm < D≤5μm, 5μm < D≤10μm, 10μm < D≤15μm, 15μm < D≤20μm, 20μm < D≤25μm, 25μm < D≤30μm, 30μm < D≤35μm, 35μm < D≤40μm, 40μm < D≤45μm, 45μm, respectivelyThe number of droplets in the range of < D≤50μm and D > 50μm was determined to determine the distribution law of droplets with different equivalent diameters

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Exploration potential of Second White Specks Formation in Alberta, Canada

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Keywords: Second White Specks, shale, logging facies, exploration potential

Alberta basin possesses the largest deposits of oil and natural gas in Canada. The Second White Specks (2WS) is a major oil and gas source rock as well as a proven hydrocarbon reservoir of Late Cretaceous in Alberta basin, which becomes a hot spot in academic study.

The 2WS Formation was deposited during the Laramide orogeny. Relative sea-level rise connected cold, nutrient-rich waters from the Boreal Sea with the warm waters of the Tethys Sea during the Turonian, which forms laminated calcareous/siliceous mixed shale. Due to the basin has a high geothermal gradient, the 2WS Formation can enter the maturity threshold at the burial depth of 6500 ft. The overpressure was mainly formed with the transformation of organic matter to oil and gas, which is advantageous to the formation of shale microfractures and improves the seepage capacity of shale reservoir. High quality source rocks and the effective lithological combination are the main controlling factors for the formation of shale oil enrichment.

Based on logging facies analysis for typical wells with high / low production, the logging response characteristics and logging identification standard of high capacity reservoir are determined. High capacity reservoir generally has the logging response characteristics of low GR, medium AC and medium-high ILD. The lower limit of logging response of high capacity reservoir can provide basis for resource potential evaluation of 2WS Formation.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-5: Unconventional petroleum sedimentology
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Dominant controls on oil shale deposition in the Upper Cretaceous Nenjiang Formation, NE China: Evidence from petrographic and geochemical analyses

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Keywords: Marine transgression, Organic-rich shale, Upper Cretaceous, Nenjiang Formation, Stable isotopes

The Songliao Basin located in northeast China is one of the most petroliferous basins in the world. The Upper Cretaceous Nenjiang Formation is an important source rock in the basin owing to its rich development of oil shale successions. From outcrop observation, we found that the oil shale successions can be divided into two types. The type I oil shale (TY1) is composed of multiple thin oil shale layers (~1m) interbedded with organic-poor shale layers and is typically developed in the first member of Nenjiang Formation (k_2n_1), whereas the type II oil shale (TY2) developed one thick succession of oil shale (~ 10 -15m) and was mainly found in the second member of the Nenjiang Formation (k_2n_2). To compare the difference in forming mechanisms with two types of oil shale successions, petrographic characteristics, stable isotopic compositions, and geochemical elements were analyzed from two outcrops (i.e., Yaojia Station and Houjingou Outcrops). Based on the results, a notable higher $\delta^{13}C_{org}$ values are recorded in the TY1, suggesting accelerated primary productivity. The observation of tuff layers and the relatively high P and Fe contents reveal that the frequent volcanic activities would have brought nutrient supply to the Songliao paleolake, thereby stimulating primary productivity and contributing to the deposition of multiple thin-layered oil shales. In contrast, the TY2 show decreased bulk sediment $\delta^{15}N$ suggests intensified denitrification under anoxic conditions. Combined with elevated trace elemental ratios and increasing trend of CIA, we attributed these changes to marine transgression that occurred at the beginning of k_2n_2 deposition. Such conditions increased the accommodation space and favored the formation of stratified, anoxic bottom waters, which might have promoted organic matter preservation and further responsible for the deposition of thick oil shale succession in k_2n_2.

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Division and discrimination of hydrocarbon dynamic field in Huizhou Sag, Pearl River Mouth Basin

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Keywords: The lower boundary of buoyancy-controlled hydrocarbon accumulation,the bottom boundary of hydrocarbon accumulation,hydrocarbon dynamic fields,Huizhou sag

With the in-depth exploration of the middle and shallow layers, the exploration difficulty and risk of conventional structural traps in the middle and shallow layers of the Huizhou Sag, Zhuyi Depression, Pearl River Mouth Basin have become increasingly difficult. The exploration of deep paleogene oil and gas has become the main research direction of oil and gas exploration in recent years. However, in addition to the partial reserves obtained in the Zhuhai Formation, the reserves found in the depressions of Enping and Wenchang Formations are not evenly distributed, and the dynamic boundary distribution of deep unconventional oil and gas resources is unknown, which seriously restricts the exploration process of deep oil and gas in Huizhou depression. In view of this, based on geological, logging interpretation, oil test and high-pressure mercury injection data, the statistical analysis of reservoir physical properties and reservoir examples method are used to analyze the distribution characteristics of reservoir porosity and permeability as well as the distribution law of oil, gas and water. It is concluded that the lower boundary of buoyancy-controlled hydrocarbon accumulation in Huizhou depression corresponds to porosity of 8.5%, permeability of 1mD and depth of 3500-4000m. The calculation methods of the minimum flow pore throat radius and the potential difference between the inside and outside of the reservoir were used to analyze the seepage capacity of reservoir pore-throat and the ratio of potential energy at the reservoir interface with the depth, which were verified by the actual drilling results. It was concluded that the porosity corresponding to the bottom limit of hydrocarbon accumulation in Huizhou Depression was 1.72%-2% , the pore-throat radius was about 0.0325um and the depth ranges from 6000-6500m. The research results have important practical significance for the prediction of the boundary range of favorable exploration areas, the evaluation of oil and gas resource potential and the deployment of oil and gas exploration plans in Huizhou depression.

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Session T9-5: Unconventional petroleum sedimentology
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Biogenic microcrystalline quartz and its influence on pore development of marine shale reservoirs: Lower Paleozoic Wufeng and Gaojiabian Formations, Lower Yangtze Platform, China

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Keywords: marine shale, biogenic microcrystalline quartz, silica sources, geomechanical properties, pore evolution, Wufeng-Gaojiabian Formations

Quartz is one of the most important minerals in marine shales, displays several forms and has multiple origins. In addition, different types of quartz may contribute differently to the geomechanical properties and pore evolution, but their relationships have been less extensively investigated. In this study, a suite of the Upper Ordovician Wufeng and the Lower Silurian Gaojiabian marine shale samples were collected from well GD-1 of the Lower Yangtze Platform in order to better understand quartz types, silica sources, as well as the influence of biogenic microcrystalline quartz on geomechanical properties and pore evolution, with the applications of X-ray diffraction analysis, geochemical analysis, optical microscopy, field emission scanning electron microscope combined with cathodoluminescence (SEM-CL) technique. The results show that quartz types of Well GD-1 are mainly detrital quartz, microcrystalline quartz and organism skeletal quartz. Detrital quartz is characterized by bright luminescence. Microcrystalline quartz is non or low luminnescene, indicative of authigenic origin. Siliceous organism fragments such as radiolarians and sponge spicules, biogenic silica content, Al-Fe-Mn ternary diagram and negative correlation of SiO_2 with Zr, indicate that siliceous organisms provide an important silica source for microcrystalline quartz. Biogenic microcrystalline quartz in the studied shale can be interconnected to form a rigid siliceous matrix framework, which will most likely enhance the rock strength. Moreover, it can effectively protect the organic matter pores and intergranular pores in microcrystalline quartz from compaction, which is conducive to pore preservation.

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Influence of developmental characteristics of clastic grains on physical properties of deep glutenite reservoirs in Chezhen Sag

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Keywords: reservoir, Shahejie Formation,detrital grains,pore evolution

The Chezhen Sag is an east-west extending fault basin in the north of the Jiyang Depression. The reservoirs in the lower sub-member of the third member of the Shahejie Formation are mainly of nearshore subaqueous fan origin and developed in a semi-deep lake-deep lake environment. Previous scholars have conducted detailed research on the provenance of the reservoir in this area. Lin Hongmei and other scholars divided the Chezhen area into three areas: felsic parent rock, carbonate parent rock and mixed parent rock according to the type of parent rock. In this study, a detailed comparative study of the reservoir physical properties of the two wells was carried out based on the data of logging, core scanning, and microscope observation data of the two wells Che 660 and Daxie 722 in the mixed parent rock area of the Chezhen Sag. The study found that although the types of debris in the two wells are generally similar, there are obvious differences in the type of pores and the degree of development. Therefore, in this study, the debris particles of the two wells are classified and counted in detail to analyze their differences and study their impact on the reservoir. physical influence.

Detrital sandstone is developed in Well Che 660, and the detrital particles are mainly detritus, among which the sedimentary rock detritus has the highest content, mainly dolomite detritus and limestone detritus; the second is metamorphic detritus, mainly metamorphic volcanic detritus and Metamorphic quartzite cuttings; the lowest content of magmatic rocks. In addition, the content of quartz particles is high, while the feldspar particles are few and almost invisible. In addition, the content of quartz particles is high, while the feldspar particles are few and almost invisible. The cements are mainly calcite and dolomite, and a small amount of iron calcite, iron dolomite and pyrite are also developed. Its pores are mainly developed by intergranular dissolution, sedimentary rock debris dissolution and a small amount of structural fractures, mainly secondary pores, and few primary pores, and the overall physical properties of the reservoir are poor.

Detrital sandstone is also developed in Well Daxie 722, and the debris particles are mainly debris, among which sedimentary rock debris and metamorphic rock debris have the highest content, sedimentary rock debris is slightly higher than metamorphic rock debris, magmatic rock content is the lowest, and the type of debris Similar to Che 660 well. However, both feldspar grains and quartz grains are developed in a certain amount, and the content of feldspar grains is relatively high. The cements are mainly calcite and dolomite, and basically no other minerals are cemented. The pore development type is mainly intergranular dissolution, feldspar dissolution pores, sedimentary rock debris dissolution and structural fractures are also developed, and the overall physical properties of the reservoir are relatively good.

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Impact of detrital composition, pore throat size, and fractal characteristics on physical properties of low and ultra-low permeability reservoirs

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Keywords: Ordos Basin, Chang 6 low-permeability reservoir, Detrital components, Pore-throat structure,Fractal characteristics

Low and ultra-low permeability sandstone reservoirs are widely developed in the Upper Triassic Yanchang Formation in the Ordos Basin, and the microscopic pore structure characteristics are closely related to the reservoir quality and oil and gas distribution. The Chang 6 oil layer formation in the Xiaojiahe area has the problems of poor reservoir physical properties, strong heterogeneity, and high water content. Research on the microscopic pore structure of the reservoir is of great significance to the exploration and development of low-permeability-ultra-low permeability reservoirs. Utilizing core observation, thin section identification, scanning electron microscope observation, physical property test, and mercury injection analysis, combined with fractal theory, this paper studies the petrological characteristics, pore structure characteristics, fractal characteristics, and influencing factors of reservoir quality of Chang 6 reservoir in this area. The results show that : (1) The Chang 6 reservoir in the Xiaojiahe area is dominated by fine-grained feldspathic sandstone, which has the characteristics of low composition maturity, high structural maturity, and good sorting. The pore type is mainly intergranular pores, and feldspar dissolved pores and intergranular micropores are also developed. The reservoir is characterized by low porosity (average porosity is 8.95 %) and low and ultra-low permeability (average permeability is 1.14 mD). (2) There is a certain positive correlation between the content of quartz and feldspar in clastic components and reservoir physical properties. Among them, potassium feldspar is conducive to improving the magnitude of permeability, while plagioclase accounts for a small proportion, which has a weak impact on reservoir physical properties. The content of plastic components such as biotite and interstitial material is negatively correlated with physical properties. (3) Chang 6 sandstones can be divided into four types according to the characteristics of mercury intrusion curves, and the reservoir quality gradually deteriorates from type I to type IV. Parameters such as displacement pressure and pore throat radius in the pore structure parameters have a good correlation with reservoir physical properties. (4) Based on the pore fractal model of the capillary pressure curve, all sandstones can divide the $Lg(S_{Hg})$-$Lg(P_c)$ curve into two segments by the r_{apex} value (Pittman's plot apex radius) for fractal analysis. The first segment ($r>r_{apex}$) represents a relatively large pore-throat fractal characteristic, the calculated fractal dimension D_1 is greater than 3 and does not have a fractal characteristic. The rear segment ($r<r_{apex}$) represents a relatively small pore-throat fractal characteristic, and the fractal dimension D_2 is between 2.19 and 2.73. The weighted average algorithm was used to calculate the comprehensive fractal dimension D_{ave} and D_P. The correlation analysis between fractal dimension and physical parameters, pore throat structure parameters, and reservoir quality index (RQI) shows that D_2 and D_P are more suitable for characterizing the complexity and heterogeneity of microscopic pore structure. In conclusion, the quality of low and extra-low permeability sandstone reservoirs is controlled by the combination of clastic fraction, pore structure, fractal characteristics, and other factors.

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Characteristics of new marine shale and new sedimentary model: Exploration of shale characteristics from Ordovician Wulalik Formation in Ordos Basin

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Keywords: the Wulalik Formation, sedimentary model, the deep-sea shelf facies

For a long time, marine shale gas in China has only been discovered in the Sichuan Basin on the Yangtze Plate. Until last year, a breakthrough was made in shale exploration in the Ordovician Wulalik Formation in the western Ordos Basin. This shale interval is all different from the well-known Wufeng Formation-Longmaxi Formation shale in the Upper Yangtze Platform in southern China and the Barnett shale in North America. Low-porosity, low gas content, low-pressure coefficient, and high brittleness index (higher carbonate content) are known as "new" marine shale.

The sedimentary environment is dominated by platform margin slope facies and deep-sea shelf facies. However, in the actual exploration and research, it is found that there are various lithologic combinations in the organic-rich interval of the Wulalik Formation, and there may be mixed deposits of different facies at the same time. This deposition also shows that the tectonic setting of the edge of the Ordos Basin was unstable in the Ordovician, and different types of miscible deposits will have an impact on the distribution and enrichment of shale oil and gas.

The study area has high clay mineral content (47.8% on average) and low carbonate content (7.1% on average), with quartz and feldspar content (44.9% on average) in the middle. There are siliceous mudstones and limestones at the bottom of the Wulalik Formation; from the middle to the upper part, the siliceous content gradually decreases, and the content of clay minerals gradually increases. The siliceous mudstone at the bottom of the Wulalik Formation has the highest organic carbon content (average: 0.82%) and hydrocarbon generation potential (average: 1.53 mg/g), and the upper Wulalik Formation has the organic carbon content (average: 0.29%) and hydrocarbon generation potential (average 0.24 mg/g) poor.

The mineral composition of the rock indicates typically mixed deposits. There is a positive correlation between TOC and Fe/Mn, indicating that the change of sea level may be an important factor controlling the enrichment of organic matter. There is a good correlation between TOC and the contents of redox indicator elements V and U, and there is a positive correlation between TOC and V/(V+Ni), V/Cr, U/Th. The relationship among redox conditions, the sea level and TOC content suggests that the hypoxic bottom water environment plays an important role in the sedimentation process of organic matter-rich black shale, or that water conditions are controlled by elevated organic matter fluxes, and therefore oxygen declines. There is a positive correlation between K2O, TiO2, Fe2O3 and Al2O3, indicating that clay minerals are mainly from terrigenous input.

The deep-sea shelf facies deposits of the Wulalik Formation are mainly siliceous and clay minerals and contain a small number of carbonate minerals, which are different from deep-water slope facies deposits with high carbonate minerals. This paper analyzes the sedimentary characteristics and organic matter occurrence conditions of the deep sea shelf facies of the Wulalik Formation and proposes an organic matter occurrence model, which complements the previous research on slope facies and broadens the space for shale gas exploration in northern China.

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Session T9-5: Unconventional petroleum sedimentology
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Spatial-temporal Distribution of Upper Ordovician-Lower Silurian Hydrocarbon Source Rocks around the Proto-Tethys Ocean

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Keywords: Upper Ordovician-Lower Silurian, Proto-Tethys Ocean, graptolite zones, spatial constraint, Spatial-temporal Distribution

Upper Ordovician-Lower Silurian strata are the research focus of biostratigraphy, mass extinction, paleoclimate and shale gas exploration. In this study, we review previous studies featuring the geographic and paleogeography locations, time-stratigraphic units, graptolite zones, palynological assemblages, and lithological characters of these hydrocarbon source rocks developed around the Proto-Tethys Ocean. A synthesis of the spatial-temporal characteristics of these organic-rich shales is presented. Although the results may be more or less modulated by a possible sampling bias, data were collected as completely as possible regarding the Wufeng-Longmaxi sediments in South China, Lower Silurian graptolite shales in Sibumasu and Indochina terrane (Western Yunnan in China, Shan State in Myanmar, Southern Thailand and Malaysia), Lower Silurian hot shale in North Africa, southern Iran, Arabian Peninsula and Turkey, Lower Paleozoic petroleum system in Baltic Basin (central and northern Europe), oil and gas deposits in Siberian platform, organic-rich deposit in Norwegian-Danish Basin, Anadarko basin in the US and Barrandian Basin in Czech Republic. Our compilation reveals the stratigraphic and chronological ranges of these strata based on graptolite zones. Spatial constraint of the organic-rich stratums concerning the eustatic sea level changes was also analyzed according to the graptolite zoning at the vertical direction and relevant characteristics.

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Geochemical characteristics of gas source rocks and origin of shallow gas in the Hetao Basin, Inner Mongolia, China

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Keywords: Shallow gas,Gas origin,Stable isotope geochemistry,Biogenic,Hetao Basin

A large number of gas producing water wells were discovered in the Hetao Basin, Inner Mongolia, China. Understanding gas origin is vital for designing exploration and production strategies, in order to either shallow economic accumulation of biogenic gas. In this study, the Holocene, Pleistocene and Pliocene in Hetao Basin were divided into five sequences(SQ5-SQ1) and geochemical characteristics of gas source rocks and stable isotope composition of co-produced waters and gas were investigated. The results reveal that the gas source rocks are rich in organic matter, with kerogen type II2 and III as the main type. Methanogens have been detected in source rocks.The parent material is mainly from higher plants and mixed with lower aquatic organisms. The evolution of organic matter is in the stage of biochemical methane, which is very conducive to the formation of biogenic gas. Paleontological (palynological) data show that the characteristics of climate evolution lay the foundation for the formation of biogenic gas reservoirs. The sedimentary facies types of shallow lake facies, semi-deep lake facies and shore lake facies also have an intimate relation to biogenic gas. Methane, nitrogen, carbon dioxide and hydrogen are the main components of the gas, and the sum of the four is more than 97%, while the sum of ethane, propane, butane and pentane is less than 3%. The carbon isotope content of methane is -74.2~-78.‰, which has typical biogenic characteristics. Genetic diagrams of δ^{13}C-CH4 versus δ^{2}H-CH4 and additional parameters corroborated biogenesis as the main gas origin. Carbon isotopic differences between carbon dioxide and methane ($\Delta^{13}C_{H2O–CH4}$), as well as those of hydrogen isotopes in water and methane ($\Delta^{2}H_{H2O–CH4}$), also indicated a typical microbial CO2 reduction pathway. The gas produced by culture of methanogens has the same geochemical characteristics as the collected gas. The gas source rocks in Hetao Basin have strong potential for gas generation. SQ3 and SQ1 are the main gas generation horizon. The analysis of source rock and shallow gas shows that the gas is biogenic. This study is important for exploring the geological conditions and exploration potential of biogenic gas reservoirs in the Hetao Basin.

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Relationship between reservoir densification and hydrocarbon charging in Yanchang Formation, South of Ordos Basin

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Keywords: tight oil reservoirs, fluid inclusion, diagenesis, hydrocarbon charge event, ultra-low concentration U-Pb dating, Ordos Basin

As the second largest sedimentary basin in China, Ordos Basin is rich in oil and gas resources. Conventional and unconventional tight oil reservoirs have been developed together, among which Yanchang Formation of Mesozoic is rich in tight oil resources and has great exploration potential. However, the genesis of tight reservoirs in Yanchang Formation in Ordos Basin and its relationship with oil and gas charging remain controversial. Taking Chang 6, Chang 7 and Chang 8 Members of Yanchang Formation in the south of Ordos Basin as the main research object, combined with the study of sedimentary microfacies and strike-slip faults, this study investigated the reservoir diagenesis and hydrocarbon generation, migration and accumulation in the study area, so as to clarify the cause of reservoir densification and its relationship with the sequence of hydrocarbon charge events in this area. The reservoir diagenetic sequences were established by observing the thin sections with transmitted light, fluorescence and cathodoluminescence and stable oxygen and carbon isotopic ratios analysis. It is considered that compaction and carbonate cementation are the main reasons for the densification and porosity and permeability decline of the reservoir, and fracture and acidic-alkaline alternating dissolution are the fundamental reasons for the enhancement of reservoir quality. In the context of diagenetic sequences, fluid inclusions microthermometric measurement, and microscopic fluorescence spectrum analysis of single oil inclusion, combined with the one-dimensional basin modeling, the hydrocarbon charge history in the south of Ordos Basin were reconstructed. The results show that the study area has experienced three hydrocarbon charge events. The first charge event occurred in the early of Early Cretaceous (127.9-120.0 Ma); the second charge event occurred in the middle of Early Cretaceous (119.5-108.0 Ma), and the third charge event occurred in the late of Early Cretaceous (101.0-95.9 Ma). The hydrocarbon charging events are different, in which Chang 6 Member is only experienced with the third hydrocarbon charging event, Chang 7 Member is mainly experienced with the second and third hydrocarbon charging events, and Chang 8 Member have experienced all the three hydrocarbon charging events. In addition, combined with ultra-low concentration U-Pb dating technology, it provides a direct constraint on reservoir densification time. The results show that the two generations of calcite cementation happened from 185 ± 27 Ma to 159 ± 52 Ma in Yanchang Formation of the study area. This result clearly exhibits the reservoir densification time is earlier than that of the oil charging events. It reveals, therefore, the coupling relationship between reservoir densification and hydrocarbon charging events, which has important implication for tight reservoir evaluation in Ordos Basin.

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Genetic mechanism of low resistivity shale and their implications on reservoir quality: A case study in the Southern Sichuan Basin, China

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Genetic mechanism of low-resistivity shale and its impact on reservoir quality are currently hot topic on a world- wide scale. Shale with resistivity lower than 20 Ω· m is widely developed in the Wufeng-Longmaxi formation of the Southern Sichuan Basin and these low-resistivity shales really created barriers for making reservoir prediction using the electromagnetic method. This paper discussed the genetic mechanisms and reservoir qualities of three types of low-resistivity shale reservoirs in the Southern Sichuan Basin (Changning block and Luzhou block). With results derived from mineral composition, organic geochemistry and petrophysical properties, three main reasons controlling the distribution of low-resistivity shales in the Southern Sichuan Basin have been deduced: extensive development of gravity flow deposits, poor structural preservation conditions and the graphitization of shale caused by the Emeishan basalt(1) The distribution of shale reservoir with resistivity < 12 Ω•m is uniform with that of gravity flow deposits in the southern Sichuan Basin. High clay mineral contents (especially illite) in gravity flow deposits increase cation exchange capacity and irreducible water saturation of shale reservoir, resulting in the decrease of electrical resistivity. (2) Resistivity of shale close to complex fault-fracture zone is generally lower than 20 Ω•m, indicating that poor structural preservation conditions led to the wide distribution of low- resistivity shale. The resistivity of shale near the NE trending fault in the Changning block is significantly lower than that in other areas. (3) The Emeishan basalt caused extensive graphitization of shale in the west of the Changning block, while the graphitization degree of shale in the Luzhou block was limited. The resistivity of shale in the Luzhou block was not affected by graphitization. Among three types of low-resistivity shale, type III low-resistivity shale is characterized by high quartz content, high TOC, high porosity, high gas content and low degree of graphitization. Although the resistivity of type III is often lower that 20Ω•m, it is still a favorable exploration target of Wufeng- Longmaxi Formation in the southern Sichuan Basin.

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Reservoir characteristics and formation mechanism of high-quality reservoirs in Ledong Area, Yinggehai Basin

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Reservoir characteristics and formation mechanism of high-quality reservoirs in Ledong Area, Yinggehai Basin

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Abstract

Yinggehai basin is located in the northwest of the South China Sea. It is an extension conversion Cenozoic petroliferous basin controlled by the dual mechanism of lithospheric extension and Honghe fault strike slip. The basin includes three first-order structural units: Yingdong slope, Yingxi slope and central depression. Yinggehai basin is the main battlefield of natural gas exploration in the western South China Sea. The field of medium and deep temperature and overpressure has gradually become the main direction of natural gas exploration.The content of quartz in the sandstone of Ledong area is 8%-92.5% (average 63.84%), followed by feldspar (content 1%-19%, average 11.41%) and rock debris (content 0.5% - 74%, average 7.89%). The sorting of clastic particles in Ledong area is mainly medium to poor. The reservoir porosity in Ledong area is 0.89% ~ 20.4% (average 10.33%), and the permeability is (0.05 ~ 26.38)×10-3 μm2 (average 0.82×10-3 μm2). The reservoir is low porosity and ultra-low permeability, ultra-low porosity and ultra-low permeability. Ledong area has high compaction intensity, less primary intergranular pores, and the contact relationship between clastic particles is mainly linear contact. The reservoir cement in Ledong area is mainly carbonate cement and less siliceous cement. Carbonate cements are mainly calcite and iron calcite, with less dolomite, iron dolomite and siderite.Higher carbonate cement is an important reason for the poor connectivity between pores and throats and poor overall physical properties in Ledong area. The reservoir pores in Ledong area are mainly dissolution pores, and feldspar and other minerals are corroded.The formation mechanism of high-quality reservoir: (1) sedimentation controls the structural characteristics of the original components of sediments and is the internal factor controlling the development of primary and secondary pores. For example, the clastic rock reservoir formed in the traction flow sedimentary environment with strong hydrodynamicforce after long-distance transportation has the characteristics of high content of rigid particles, high composition maturity, good sorting and rounding, strong anti compaction ability, low content of matrix and high content of primary pores. It can still preserve well connected primary pores and good original physical properties before undergoing dissolution modification. (2) The formation of secondary pores by dissolution is an important factor to improve reservoir physical properties. Dissolution can be divided into different mechanisms, typically including thermal evolution dissolution mechanism of organic matter, biodegradation dissolution mechanism of hydrocarbons, TSR dissolution mechanism, transformation dissolution mechanism of clay minerals, deep hydrothermal dissolution mechanism, alkaline dissolution mechanism, etc. (3) Hydrocarbon filling occupies pore space, which can hinder the flow of formation water, inhibit diagenesis such as cementation and compaction, and protect reservoir pores; (4) The abnormal high pressure reduces the effective stress of the formation, slows down the compaction and effectively preserves the primary and secondary pores.

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Session T9-6: Fine-grained sedimentology and shale reservoir

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Oral Preferred

Pore-System Evolution and Dynamic Digital Rocks of Shale Samples during Pyrolysis: Considering Various Diagenesis Events

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Keywords: Shale, Pore system, Organic matter, Thermal maturation, Dynamic modeling

Accurate characterization of shale samples is of great importance for predicting and evaluating their intrinsic properties as they undergo various geological processes and diagenesis events. As such, constructing shale models not only entails accounting for the numerous components and pores, but also requires considering the effects of thermal maturation and diagenesis on the evolutions of the pore systems and components. In this study, a dynamic and diagenesis-based modeling method that integrates the discrete element modeling, quartet structure generation set, and morphological operation algorithms was developed to simulate the diagenesis events and pore-system evolutions which occurred during pyrolysis of shale samples. In the new method, the compaction, cementing, dissolution, and variation of organic matter are simulated. In addition, three types of pores, including organic matter (OM), interparticle (interP), and intraparticle (intraP) pores, and other components including kerogen, pyrite, clay minerals, globigerinids, calcite, feldspar, quartz, and petroleum products, are all considered in our process-based modeling. Also, In order to demonstrate the performance of our diagenesis-based modeling method, dynamic shale models of multiple cases with different geological processes are constructed. Then, to characterize the constructed samples, the occurrences and distributions of all components are studied using a two-point correlation function. Aside from statistical comparisons, the gas flow in these shale models is also simulated to exhibit the permeability variations produced in the process-based models. Moreover, the degree of cementation, the fractions of interP, intraP, and OM pores are varied to mimic new geological scenarios, which aims to further evaluate the performance of the proposed technique. The results indicate that our diagenesis-based modeling method presents an excellent performance. Furthermore, the presented modeling technique can be extended to investigate the effects of various components and pores on the intrinsic properties of shales in the future.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Oral Preferred

A large-scale mudstone fan in an Eocene rift lake basin in China

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Keywords: mudstone,lake,shale oil

Mudstone accounts for about 70% of sedimentary rocks. It widely spreads from fluvial, lacustrine, coastal, shelf, slope to deep sea depositional environments. It occurs in a form of drape or sheet in most cases. Muddy fans have been found in modern semi- to deep sea, e.g., the Quaternary Mississipi fan(Galloway and Hobbday,1996). But their ancient analogues have rarely been identified. In this study, we report a discovery of a large-scale mudstone fan, the Minfeng fan with abundant hydrocarbon that distribute in an Eocene rift lake basin in China. This is achieved by investigating 3-D seismics, well loggings and tests, drilling cores, as well as organic and inorganic laboratory analyses.

The Minfeng fan is about 25km wide, 15km long, and 1.5km thick. Several seismic facies can be identified, i.e., besom-like, mounded, wedged and sheeted. As a whole besom-like seismic facies is distributed on the fault slope, and therefore makes up a slope fan of a fan-delta origin. While the mounded and wedged seismic facies occurs in the deep-lake floor in the front of the besom-like facies. The mudstone fan is thick and mounded in the center, wedged in the margin, and thins out and becomes sheeted southward, eastward and westward. It is interfingered with the fan-delta in the north. There are two channels feeding muddy sediments across the fan delta to the basin floor, resulting in the muddy sublacustrine fan. The muddy sediments were transported in density flow, and deposited with wanning dynamics in a succession: besom-divergent thin bedded conglomerates, sandstone and mudstone(inner fan)—mounded and concave mudstone(middle fan)—wedged mudstone(outer fan)—sheeted mudstone(suspended muds with autochthonous sediments in deep lake plane) .

The mudstone fan is abundant in organic matter. TOC ranges from 1.71%-5.47% with average 2.95%. The organic matter types are II1 and II2 in inner fan, and type I in mid and outer fan.

In addition to the Minfeng mudstone fan, other three mudstone fans have been found to have great potential for shale oil in Lijin, Boxing and Guangli. The size and thickness of a mudstone fan is controlled by topographic gradients and lake-margin canyons. The larger the gradient and lake-margin canyon, the fan’s size and thickness get larger. A steep slope is liable to generate and help sediment gravity flows moving farther to the basin. And a fixed and incised canyon focused the density flow to transport sediments basinward.

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Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Reservoir Development Characteristics of Yudong 1 Gas Field in Tabei Uplift, Tarim Basin

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Keywords: Tabei uplift,Meso-Cenozoic,lithologic gas reservoirs,reservoir characteristics

Yudong 1 gas field is located in the Kalayuergun structural belt of the Tabei uplift of the Tarim Basin, and it belongs to a large area of lithologic gas reservoirs. Two sets of reservoirs are mainly developed in the Yudong 1 gas field, which are distributed in the lower Paleogene sandstone member and the Cretaceous Bashijiqike Formation. By analyzing the core data, logging data, casting thin section data and scanning electron microscope data of the two sets of Meso-Cenozoic reservoirs in the Yudong 1 gas field, the author studies the characteristics of the Meso-Cenozoic reservoirs in the Yudong 1 gas field. The following understandings have been obtained: the lithology of the Paleogene reservoirs in the Yudong 1 gas field is mainly fine-grained feldspar lithic sandstone, with a small amount of dolomite and anhydrite cements, and the pore types are mainly intergranular pores, with a small amount of intergranular pores. Dissolved pores, intragranular dissolved pores and argillaceous micropores, the total surface porosity is 0.1%~21.6%. Through three-dimensional quantitative fluorescence and nuclear magnetic resonance analysis, the porosity is 6.78~26.27%, the average is 14.47%, and the permeability is 0.11~402.38× 10^{-3}μm^2, with an average of 402.38×10^{-3}μm^2, according to the evaluation standard, its physical properties are medium to good; the lithology of the Cretaceous Bashijiqike Formation is dominated by fine sandstone, with a small amount of siltstone and argillaceous cementation. The porosity is 17.4~22.6%, and the average porosity is 21.4%. According to the evaluation standard, its physical properties are the best. The sandstone is extremely developed, the size of the cuttings is moderate, the reservoir is concentrated vertically, and the horizontal distribution is relatively stable.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Oral Preferred

Lithofacies types and characteristics of shale reservoir: A case study from Jurassic Shale of the Da'anzhai Member in Yuanba area, northern Sichuan Basin

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Keywords: Reservoir, Lithofacies, Shale, Da’anzhai, Jurassic, Yuanba

The continental shale strata in the Jurassic Da'anzhai Member have complex lithology and strong heterogeneity, which restrict the selection of optimal intervals and exploratory deployment. To find out the reservoir characteristics and gas-bearing capacity of different lithofacies types of Da'anzhai Member in Yuanba area, experimental methods including TOC measurement, whole-rock mineral composition, thin section analysis, FIB-SEM, mercury injection, N2 adsorption experiment, CH4 isothermal adsorption and physical property test were carried out. Then the lithofacies types of shale and interlayers were identified and divided, and optimal lithofacies were selected based on the comparison of physical properties, pore types and structure, gas content and occurrence status for different lithofacies types. Results show that the shale reservoir of the second sub-member of Da'anzhai can be identified and divided into three types and six categories of shale lithofacies, two types and six categories of interlayer lithofacies, which further combined into three macro-lithofacies assemblage types. Shale pore types of Da'anzhai Member are mainly inorganic pores dominated by clay mineral pores, while fewer organic pores mainly developed in clay shale facies, providing storage space for shale gas. The total shale gas content is calculated to be 2.59~4.38 m3/t, in which the free gas content accounts for about 67%, showing a good gas potential. However, the brittle mineral content of the shale reservoir is only 50%, indicating a poor fracturing performance. It is concluded that, lithofacies assemblages type AB-I has developed good stratification and lamination, pretty hydrocarbon generation potential, high gas content and free gas ratio, as well as widespread limestone interlayers with better fracturability, which is thought the most favorable exploration intervals of the Da’anzhai Member.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Study on the organic matter evolution and nano-scale pore occurrence characteristics of organic- rich shale

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Keywords: Nano-pore, Pore evolution, Frenkel-Halsey-Hill Model, Shale

Abstract

In order to explore the characteristics of nanopores in different maturity shale, the shape and characteristics of shale pores under different maturity were studied by scanning electron microscopy (SEM) and low temperature nitrogen experiment (LP-N2-GA) based on FHH fractal model. The results show that the intergranular pores and organic pores in the shale of the Upper Yangtze area are most developed, and the pore size is distributed from a few nanometers to several tens of micrometers, providing the main reservoir space for shale gas occurrence; SEM gray scale by pseudo color enhancement technology After image processing, the pore development characteristics of shale can be observed more intuitively; the average organic matter face rate in shale is between 16.7% and 23.8%, and with the increase of maturity, the organic matter face rate in shale is gradually increased; The results of low temperature nitrogen adsorption test, using FHH fractal model to calculate the fractal dimension D of nanopores between 2.499 and 2.860, with an average of 2.713, the fractal dimension of shale is positively correlated with TOC and quartz, clay minerals and feldspar and fractal dimension. The number is negatively correlated, but the correlation is not obvious. Combined with the fractal dimension of nanopores in low-mature shale, it indicates that with the increase of maturity, the fractal dimension of nano-pore shows a trend of decreasing first and then increasing gradually. When Ro is less than 0.7%, the mechanical compaction caused by the increase of buried depth causes the pore volume and specific surface area of the mesopores to decrease rapidly; when Ro is between 0.7% and 1.3%, the secondary pores formed by the evolution of kerogen hydrocarbons It supplements the reduction of pore volume and pore specific surface area caused by mechanical compaction. The total pore volume and specific surface area of shale remain basically unchanged at this stage; when Ro is between 1.3% and 2.6%, hydrocarbons cannot be transported effectively. Removal or elimination of reservoir overpressure and the transformation of organic pores between organic nanopores and organic acid groups with hydrocarbon formation leads to a transient increase in shale pore volume and specific surface area; when Ro is greater than 2.6%, the hydrocarbon generation process At the end and the release of pressure, the pore evolution gradually returns to the normal compaction trend, and the pore volume and specific surface area of the shale decrease, but the degree of reduction is limited.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

The mechanism of organic pores formation in lacustrine shales of China and its effect on reflectance measurement

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Keywords: Lacustrine shales, Organic pores, Macerals, Differential developmental characteristics, Reflectance

Shale oil and gas are unconventional resources with great development potential and are gradually being produced commercially by various countries. Shale pores as the main storing space for shale gas and oil have been studied extensively, which can be divided into organic matter (OM) pores, interparticle pores and intraparticle pores (Loucks et al., 2012). And, OM pores are generally considered to be primary storing space for hydrocarbons in shales (Ma et al., 2015).

Previous studies have found that the pore developments of various macerals were very different with each other (Curtis et al., 2012; Sanei et al., 2015). The pore characteristics of dominant macerals in marine shales have been relatively well investigated. It is well known that macerals in lacustrine shales are much more complex than marine shales. However, the pores of various macerals and their influences on reflectance measurement remain poorly understood.

This study explored the mechanism of OM pores formation in lacustrine shales and its effect on reflectance measurement from the perspective of macerals. 80 Typical lacustrine shales with various maturities and TOC contents were selected from the Qingshankou Formation of Songliao Basin, the Shahejie Formation of Bohai Bay Basin, the Yanchang Formation of Ordos Basin, and the Badaowan Formation of Junggar Basin in China. OM pores of different macerals were characterized using integrated correlative light and electron microscopy (iCLEM) and Low-pressure gas adsorption (LPGA) experiments. And the relative contributions of macerals to organic pores were estimated. On the basis of the geochemical parameters, the thermal evolution law of organic pores in macerals was analyzed. Finally, the influence of organic pores on reflectance of vitrinite and solid bitumen was discussed by performing reflectance measurement experiment. Main conclusions of this research are as follows.

(1)The organic pores of lacustrine shale are mostly circular or elliptical in morphology, usually aggregated in a honeycomb shape. The organic pores are mainly distributed in the range of 100—400 nm, and the average plane porosity of macerals is 10.13 %.

(2)Among various macerals, sapropelinite preserved a certain amount of pores, but almost no pores existed in exinite. There was a small amount of microcracks and pores in vitrinite, and a large number of primary pores that retained plant structure can be seen in fusinite. Due to the process of hydrocarbon generation and expulsion, solid bitumen formed amounts of organic pores and microcracks.

(3)The order of organic pore diameter from small to large is solid bitumen, bituminite, alginite, vitrinite, fusinite and exinite, and the order of pore development degree from high to low was alginite, fusinite, bituminite, solid bitumen, vitrinite and exinite. The contribution of organic pores mainly comes from bituminite, solid bitumen and fusinite. As for the controlling factors of organic pore development, thermal maturity is not the only factor, and maceral type also has a significant influence on the formation of organic pores.

(4)The development of organic pores (an increase in pore size and pore number) enhances the surface roughness of vitrinite or solid bitumen, resulting in an underestimate of their reflectances.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Reservoir lithofacies architecture patterns and its controlling effect on sweet spots of terrestrial mixed fine-grained rocks:A case study of Permian Lucaogou Formation shale oil in Jimusaer Sag, NW China

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Keywords: mixed fine-grained rock,lithofacies architecture,shale oi,UAV, mixed shallow lacustrine deposits zone, sweet-spot

In the process of shale oil development, lacustrine mixed fine-grained rocks lithofacies controlling effect of the sweet-spot can be quite complex. Based on the core, outcrop, logging, testing and production data, the classification, 3D prototype model and combination pattern are carried out through lithofacies architecture analysis, UAV and 3D geological modeling technology. The research shows that: (1) Combining traditional fieldwork with UAV photography to characterize the 3D spatial distribution characteristics of the lithofacies architecture of the outcrop section of the Lucaogou Formation. The stratigraphic-structural models and three-dimensional lithofacies prototype models are presented from well setting and lithofacies types quantitatively characterizing. It is believed that its lithofacies architecture has relatively stable but vary locally. (2) The lithofacies architecture combinations of mixed fine-grained rocks are mainly divided into three types: gradient type, mutation type and special type. The graded types characterized by symmetrical lithofacies architecture and a superposition of multiple similar cycles, are widely developed. The reservoir in the graded types is a high-quality reservoir with developed dissolution pores, and is a mixed beach-bar microfacies in a mixed rock belt. The mutant type can be subdivided into two types. The development degree of the sand body is average, characterized by asymmetric lithofacies architecture and a superposition of multiple similar cycles. And the reservoir is a thin reservoir with high-quality hydrocarbon generation. The special type belongs to the thick clastic rock with a high degree of sand body development. It is a relatively reservoir with tight reservoir properties and superimposed by a single cycle of sand bodies. (3) The lithofacies architecture controls the distribution of sweet spots and development strategies. The graded type reservoir shows weak heterogeneity and well-developed sand. This type of reservoir has the best development effect and is suitable for large-scale deployment of horizontal well platform operations. Mutant type reservoirs are well developed, but it shows strong heterogeneity and average development effect. And they are the follow-up succession area. The special type reservoir is distributed with poor continuity, strong heterogeneity, and good development effect. The deployment of horizontal wells requires meticulous research on the lithofacies architecture and NMR oil bearing saturation.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Oral Preferred

Porosity evolution of Minhe oil shale under a rapid heating open system and the carbon storage potentials

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Keywords: Oil shale, Thermal simulation, Reservoir physical property evolution, Open system, Carbon storage

Oil shale has been recognized as an important oil source with great advantages in reserves and development prospects (Han et al., 2014; Pan et al., 2016; Zhao et al., 2017; Liu et al, 2017). When depleted, the pore system can be acting as excellent storage space (Ma et al., 2021). Fracture and pore evolution during in situ pyrolysis of oil shale is crucial to understanding the complex petrophysical changes to enhance the oil extraction (Ma et al., 2021). Meanwhile the increased porosity will provide enough space for carbon sequestration to balance the carbon emission generated by oil consumptions (Oldenburg et al., 2001; Godec et al., 2014; Ma et al., 2019). This paper focuses on porosity evolution and reservoir physical properties changes of oil shale samples at different heating stages from the macro to microscale. The comprehensive analysis was performed based on the results from a wide range of characterizing techniques. During 3 artificial thermal evolution stage, the size, volume, type, geometry, connectivity of pores and fractures were quantitively measured and imaged at mm-scale, μm-scale and nano-scale to understand the evolution comprehensively. These results indicate in the low-temperature heating stage (185~350°C), the volume of fractures and micropores began to increase slowly. The pores are predominately consisting of micropores and transition pores in cylindrical geometry. Organic pores showed a gradual and slow increase, and the change in inorganic pores were increased slightly. In the medium-temperature heating stage (350~440°C), the number and width of fractures increased significantly. Micropores increased rapidly and became largely medium pores in slit geometry. Organic pores show a trend from a rapid increase to a slow increase, whereas the inorganic pores did not change significantly. In the high-temperature heating stage (440~520°C), the micro- and macrofractures of the sample continued to widen and extend slowly, and the adjacent microfractures became connected to form larger fractures. The rate of volume increases in organic pores and fractures and inorganic pores slowed. The pores primarily formed large pores and micropores in cylindrical and slit geometries. The heated oil shale reseroivs of these three stages are classied as Class III, Class II and Class I reservoir respectively with reservoir physical properties poor, good and excellent. The the carbon dioxide storage potential were then accessed based on the above results. These results indicate After in situ conversion, the carbon release of oil shale reservoirs is around 0.014 t, far less than that of carbon dioxide storage (0.2 t), which suggest a possible feasibility of in-situ pyrolysis development and subsequent in-situ carbon storage.

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Session T9-6: Fine-grained sedimentology and shale reservoir
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Dynamic evolution of shale gas occurrence state over geological time

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Keywords: Gas-generated amount, Gas storage capacity, Adsorbed gas, Free gas, Dynamic evolution

The occurrence state of shale gas is significant to shale gas resource evaluation and productivity prediction, and its dynamic evolution needs to be further studied. This paper presents a method to study the dynamic evolution of shale gas occurrence state during burial. This method has two advantages: One is considering the coupling effects of external factors (temperature, pressure) and internal factors (organic matter content and maturity, porosity) on the shale gas occurrence state in geological evolution; The second is determining the actual content and occurrence state of shale gas by matching the gas generation and gas storage capacity in geological evolution. This method is applied to studying the evolution of shale gas occurrence state in the Longmaxi Formation in Sichuan Basin. The results showed that the actual gas content of was 0 in the shallow burial. When the buried depth was 1900-4100 m, the gas-generated amount was less than the gas content capably stored, and the actual gas content depended on the gas-generated amount. With the increase of the gas-generated amount, shale gas first existed in the form of adsorbed gas. After the adsorbed gas was saturated, free gas appeared and gradually increased, exceeding the adsorbed gas content. As the burial depth increased from 4100 m to the maximum burial depth, the gas-generated amount was greater than the gas content capably stored. The actual gas content depended on the gas content capably stored. The adsorbed gas and free gas existed together, the content of adsorbed gas and free gas gradually decreased, but the proportion of free gas was always higher than that of adsorbed gas. To sum up, the dynamic evolution process of the shale gas occurrence state is mainly divided into three stages: the gas-free stage, the stage dominated by adsorbed gas, and the stage dominated by free gas. And there is a depth point corresponding to the highest actual free gas content during the burial, and the shale at this depth point is the “sweet point” for shale gas development.

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Scientific Themes: Theme 9. Resource Sedimentology
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Wettability of different clay mineral surfaces in shale: Implications from molecular dynamics simulations

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Keywords: Shale, Molecular dynamics, Nanoscale, Wettability, Clay minerals

Nanoscale organic and inorganic pores in shale reservoirs are important oil and gas reservoir spaces. Also, the surface wettability of clay minerals significantly affects the oil and gas-bearing capacity of shale reservoirs. Therefore, studying the surface wettability of common clay minerals in shale at the nanoscale is of great significance for shale oil and gas exploration and development. Molecular dynamics (MD) can avoid the limitations of complex mineral composition, strong heterogeneity, difficult sampling, and the high cost of relevant experiments in shale reservoirs. Also, it can analyze the surface wettability from a micro perspective. In this study, the wetting behavior of water in different oil phases (n-hexane and toluene) on different clay mineral surfaces (montmorillonite, kaolinite, chlorite, and illite) at the nanoscale was systematically studied using MD simulation. The results show the following order of inherent water wettability on the surfaces of common clay minerals: montmorillonite > chlorite > kaolinite > illite. The main interactions between water and oil and the mineral surfaces were van der Waals force and electrostatic force. In addition, the temperature, liquid hydrocarbon type, and mineralization of water affected the wettability of clay mineral surface. By comparing the experimental results with the MD simulation results, similar wetting characteristics were obtained, and the reliability of the simulation results was verified. MD simulation was used to explore the water wetting of the surfaces of four clay minerals in a shale reservoir from the micro level. This makes up for the lack of experimental means for clarifying the flow and production mechanisms of shale oil and gas and effectively improves the evaluation technology of shale.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Oral Preferred

Characterization on differences in pore systems heterogeneity for organic-rich laminated shales and organic-poor layered shales of Chang 7 Formation in the southwestern Ordos Basin, China

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Keywords: organic-rich laminated shale, organic-poor layered shale, pore system heterogeneity, fractal dimension, multifractal spectrum

Organic-rich laminated shale and organic-poor layered shale are two vital types in shale stratigraphic systems of Chang 7 Formation in the southwestern Ordos Basin, China, and it is of great meaning to clarify the heterogeneity and difference of their pore structures for the exploration and development of shale oil and gas. By integrating the digital image processing, fractal and multifractal theory, and various experimental methods, the geometric, topological and fractal heterogeneity of pore systems of organic-rich laminated shales (ORLS) and organic-poor layered shales (OPLS) were quantitatively characterized.

Intergranular pores, organic pores and intercrystalline pores of pyrite minerals with higher plane porosity form the main storage space of ORLS. Microfractures and intercrystalline pores in clay minerals play an important role in the pore system of OPLS. Multifractal spectrums show that the wider size range of intercrystalline pores and the discontinuous size distribution of microfractures with stronger holistic distribution heterogeneity, which contribute to the more heterogeneous pore system of ORLS. The wider range and discontinuity of the pore size distribution for intergranular pores and organic pores, and the instability of the morphological structure for microfractures, which all lead to the heterogeneity of the pore system in OPLS. The petrophysical and pore structure parameters indicate that ORLS has better storage and permeability than OPLS. The pore composition of ORLS is dominated by micropores and macropores. Mesopores account for the highest proportion in OPLS. The micropore structure of ORLS is more complex, while pore structure complexity of mesopores is weaker than that of OPLS. The porosity positively correlates with the macropore volume controlled by quartz and pyrite content, and the average pore-throat size affects the fractal characteristics of mesopores and macropores in ORLS. The porosity of OPLS displays a positive correlation with the macropore surface area; the mesopore and macropore volume impact the mesopore and macropore structural complexity, respectively, which are related with feldspar and clay mineral content. This study shows prominent theoretical significance for enriching the research of fine-grained sedimentology, and provides theoretical support for the fine exploration and efficient development of shale oil and gas.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Oral Preferred

Sedimentary model of lacustrine fine-grained sediments: a case study from the Holocene Qinghai Lake, China

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Keywords: Fine-Grained Sediments, Qinghai Lake, Flocculation, Sedimentar Model

The increasing interests in unconventional petroleum resources has led to an advanced research of lacustrine fine-grained sediments. The Qinghai Lake, situated on the Northeast Qinghai-Tibet Plateau, is the largest saline lake in China with fine-grained Holocene sediments. A sedimentary model is proposed for the Holocene Qinghai Lake by integrating short cores, petrographic and geochemical data, satellite images, and physical modeling results. The littoral zone of Qinghai lake basin is dominated by reworked sandstone, oolite sand, and siltstone, with a typically low total organic carbon (TOC). Littoral sediment (siliciclastics) is mainly from delta, with little from wind and coastal erosion. The sublittoral zone, is dominated by organic-poor muddy siltstone and silty mudstone. In contrast, the profundal zone is dominated by organic-rich mudstone associated with fallout biological debris both of autochthonous and allochthonous origins. Satellite images show Buha River discharges flow into the lake like splashiag with sediment plume, which can capture algae by flocculation processes. The algae-containing flocculated particles usually are not deposited in situ but reworked and transported following lake current to sublittoral and profundle zones. Mudstone rich in allochthonous organic matters is commonly deposited by hyperpycnal flow, and typically accumulates in proximity to river mouth. They tend to interbed with thick hyperpycnal sandstone that forms favorable petroleum reservoir. Mudstone rich in autochthonous organic matters is commonly deposited by flocculation of algae and clay particle induced by hypopycnal, meopycnal and homopycnal flows and typically accumulate far away from river mouth. In Qinghai Lake, when moderate salinity meets flood that generates homopycnal and/or hypopycnal flows, mud grains flocculate and capture algae available in the lake, depositing more organic matter in the proximal area. As long as flocculation continues to sediment to aggregate with each other, deeper part of the lake should have higher TOC concentration. The accumulation of such deposits are mainly controlled by concentration of sediment plume, lake current, characteristic of clay mineral, and biological productivity. The proposed sedimentary model is supposed to provide a better understanding on evaluation of hydrocarbon potential of source rocks and identification of target zones for unconventional resources.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
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Study on hydrocarbon enrichment mechanism of deep thin sandstone reservoirs—A case study of Carboniferous Karashayi Formation in Tahe Oilfield, Tarim Basin

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Keywords: Thin sandstone reservoirs,Deep strata, Hydrocarbon enrichment mechanism,Tarim Basin,Karashayi Formation.

Thin sandstone oil and gas reservoirs are an important oil and gas resource and are widely distributed in China. Its reservoir has the characteristics of thin thickness, deep burial depth, vertical sand and mud interbedding, and rapid lateral change (Zhang et al., 2014; He et al., 2014). So, it is difficult to accurately identify and predict the reservoir during the process of oil and gas exploration and development. However, in recent years, with the development of exploration technology and the application of new methods (Chen et al., 2002; Ning et al., 2006; Huang et al., 2009; Wang et al., 2018), this problem is gradually overcome. At present, the unclear oil and gas enrichment mechanism of thin sandstone reservoirs are one of the main problems restricting the exploration and development of thin sandstone oil and gas. Therefore, the research on the oil and gas enrichment mechanism of deep thin sandstone reservoirs have important practical significance. In this paper, the Carboniferous Karashayi Formation thin sandstone hydrocarbon accumulation in Tahe Oilfield, Tarim Basin is taken as an example to analyze and study. Through comprehensively use the data of core, well logging, mud logging, oil testing and analytical testing in the study area to carry out research on the hydrocarbon enrichment conditions and main controlling factors in the thin sandstone reservoirs of the Carboniferous Karashayi Formationand establish the hydrocarbon enrichment mechanism of deep thin sandstone reservoirs. The research results show that the hydrocarbon enrichment of the Carboniferous Karashayi Formation is mainly controlled by three geological elements: sedimentary facies, fluid potential difference and oil source faults. Oil and gas are mainly enriched in medium-fine sandstone reservoirs in the delta front. The surrounding rock capillary force is 8 times greater than the reservoir capillary force, and the distance between the reservoir and the oil source fault is less than 1 km. The formation and distribution of thin sandstone oil and gas reservoirs are controlled by the combination of sedimentary facies, fluid potential difference and oil-source fault. Based on this, a ternary coupled reservoir control model of "premium facies-low potential-near source" was established for deep thin sandstone reservoirs, in order to provide guidance for the exploration and development of thin sandstone reservoirs.

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Session T9-6: Fine-grained sedimentology and shale reservoir
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Geochemistry characteristics and paleoenvironmental significance of trace elements and rare earth elements in late Paleozoic mudstone in the Qinyuan area

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Keywords: Trace elements,rare earth elements, occurrence state, sedimentary environment,provenance,Qinyuan area

Trace elements and rare earth elements in mudstone, as sensitive indicators of sedimentary background changes, are of great significance for reconstructing the paleoenvironment, paleoclimate and provenance attributes of sediments [1,2]. In this study, the contents and distribution of trace elements and rare earth elements, paleosalinity, paleoclimate and provenance characteristics of Upper Paleozoic mudstone in the Qinyuan area were discussed, using X-ray diffraction whole-rock analysis technology and inductively coupled plasma–mass spectrometry. The study showed that the contents of trace elements are relatively enriched in B, Mn, Sr and Zn compared with the average value of the crust. Compared with clay rock, Mn and Zn contents are relatively high. The average content of REY is 306.38 ug/g, higher than the average ∑REY in North American shale and the upper crust. The average values of δEu and δCe are 0.56 and 1.06, respectively. Except for WY001-6 and WY001-15, which are Medium-type of REY enrichments, the REY distribution patterns of the remaining samples are similar, showing the characteristics of light rare earth elements (LREY) enrichment and heavy rare earth elements (HREY) depletion. According to the content of element B and the ratios of B/Ga and Sr/Ba, it is considered that during the late Paleozoic sedimentary period in the Qinyuan area, it was mainly fresh brackish water, and occasionally, there was a direct injection of salt water. The V/(V+Ni), V/Cr, Ce_{anom}, δEu/δCe, Ce/La and Sr/Cu ratios show that the sedimentary medium is in a reduced state, mainly in a dry and hot climate. The mudstone source rocks of the late Paleozoic in the Qinyuan area come from granite and sedimentary rocks and a small amount of alkaline basalt, which has the sedimentary characteristics of the passive continental margin and a continental island arc. Yinshan Upland is the sediment-source region for the Late Paleozoic strata of the Qinyuan area, according to the distribution pattern of rare earth elements normalized by chondrite. HREY has a high positive correlation with B(r=0.95) and Ga (r=0.98), indicating that the occurrence of HERY, Ga and B are the same. Warm and humid environment was conducive to the preservation of light rare earth elements. An acid reduction and relatively high salinity environment can promote the enrichment of heavy rare earth elements in late Paleozoic mudstone in the Qinyuan area.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
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Control of sedimentation on the distribution of terrigenous organic matter in deep water

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Keywords: Delta-shallow sea sedimentary system, Deep Water Area, Terrestrial organic matter, Hydrodynamic conditions

The delta-shallow sea sedimentary system is a special sedimentary system with both terrestrial and marine organic matter. It is generally believed that the distribution of terrigenous organic matter in deep water is limited. However, more and more oil and gas exploration practices in deep water have discovered the contribution of terrigenous organic matter, which proves that terrigenous organic matter exists in deep water areas and is of great significance to oil and gas generation. Therefore, on the basis of a large number of investigations on the control factors of terrigenous organic matter distribution, the flume experiment technology was used to explore the control of different factors on terrigenous organic matter, and the key factors for the enrichment of terrigenous organic matter in deep water areas were clarified. Through a large number of investigations and flume experiments, it is clear that the distribution of organic matter mainly has the following characteristics: (1) Organic matter is more easily adsorbed by fine-grained sediments, and the pre-delta area where argillaceous sediments are enriched is also the enrichment area of terrigenous organic matter; (2) Terrigenous organic matter is distributed near the estuary, and the abundance of organic matter increases first and then decreases towards deep water; (3) In the coastal-shallow sea areas with active biological action, the transformation of terrestrial organic matter by biological action may become the main controlling factor affecting its distribution; (4) The stronger the river action, the farther the terrestrial organic matter can be transported, and the peak area of the organic matter abundance tends to migrate to deep water; (5) The retransportation of terrigenous organic matter by large hydrodynamic forces such as waves, tides, and coastal currents may be the key factor for its occurrence in deep water. This has important guiding significance for the prediction of dominant source rocks in deep-water areas with less drilling.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Provenance analysis of Badaowan Formation of Lower Jurassic in dachanggou basin, Xinjiang

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Keywords: Dachanggou Basin ,lower Jurassic,Badaowan formation,geochemistry,detrital zircon U-Pb dating,source analysis

Dachanggou basin is a Mesozoic coal-bearing and oil shale basin in northwest China, located in the northern Junggar basin(Wang J X et al.,2021).In this paper, the Lower Jurassic Badaowan Formation of Dachanggou Basin in northern Xinjiang was selected as the research object. The main provenance types of sediments in the Badaowan Formation of Dachanggou Basin were analyzed by thin section identification, geochemical characteristics analysis and detrital zircon LA-ICP-MS U-Pb age test.It is found that the roundness and sorting of rock particles reflect the low compositional maturity and structural maturity, which are characterized by near-source deposition.The content of SiO_2 (average 47.48 %) in the sample is low, and the variation range is large, indicating that the quartz content is low(Sircombe,1999). Al^2O_3 (average 15.18) content is higher, indicating that clay minerals and feldspar content is higher ; the chemical alteration index (CIA) ranged from 32. 60 to 86. 95, with an average of 72. 99. Combined with the comprehensive analysis of ICV value and Th / U ratio, it shows that the material source area has experienced strong weathering and weak weathering, revealing that there are certain fluctuations in the paleoclimate.The characteristics of clastic components show that the sandstone of the Badaowan Formation is mainly from the source area of the recycled orogenic belt and a small amount of magmatic arc tectonic background. The lithic types are mainly felsic exhalative rocks, andesite, granite and a small amount of metamorphic lithic fragments. Further combined with geochemical characteristics, it is shown that the source rocks of the clastic rocks in the source area are mainly felsic volcanic rock assemblages, and a small amount of neutral rocks and felsic sedimentary rocks are mixed.Further combined with zircon age test, the U-Pb age of detrital zircon generally presents an obvious main peak age of 282~376 Ma, a secondary peak age of 478~542 Ma and two weak peak ages of 858~922 Ma and 1122~1270 Ma.The zircons of the strongest peak age (282~376 Ma, Devonian-Permian) are mainly magmatic zircons, accounting for 88 % of the peak age of zircons, which are consistent with the Carboniferous, Permian andesite and volcanic lava in the study area(Liu G et al.,2017).Detrital zircons in the peak period of 478~542 Ma (Cambrian) accounted for 10 % of all zircons, indicating that there was still a supply of continental crust materials formed during the deposition of Badaowan Formation.The zircons of 6 grains at 880 Ma and 2 grains at 1300 Ma show that there is still a supply of material sources for the Palaeozoic metamorphic rocks in the study area. At the same time, a series of geochemical parameters and diagrams show that the tectonic background of the provenance area is mainly continental island arc and has the characteristics of oceanic island arc.

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Session T9-6: Fine-grained sedimentology and shale reservoir
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Source rock characteristics of Cretaceous organic rich black shales in the Mid-Atlantic passive continental margin basins

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Keywords: Source rock, black shale, paleotropical Mid-Atlantics, Cretaceous, the ITCZ, paleoclimate

The Cretaceous marine source rocks are mainly mudstones and carbonate rocks, accounting for 30% of the source rocks in geological history. Cretaceous Neocomian, Albian, and Cenomanian-Turonian source rocks have been well developed in the Mid-Atlantic passive continental margin basins. However, the understanding of the quality, quantity, and spatial distribution of these source rocks and their controlling factors are limited. This study reveals the source rock characteristics of Neocomian, Albian, and Cenomanian-Turonian in the Mid-Atlantic passive continental margin basins, on the basis of the IHS, DSDP, ODP, and IODP data, as well as other published data.

In total, 22 deep sea drilling wells have been used to reveal Neocomian, Albian, and Cenomanian-Turonian deposits. The Neocomian source rocks are predominantly deep water mudstone and shale, with limestone and marl on the shelf, whereas the Albian and Cenomanian-Turonian source rocks are principally thick deep water black shale and mudstone, with interbedded black shale, mudstone, and marl. The Neocomian source rocks have a average TOC value of 1.5%, in the range of 0.5%-60%, and a average HI value of 126 mg/g, in the range of 22-768 mg/g. The TOC value of the Albian source rocks ranges from 0.5%-36.5%, with an average value of 2.2%, and the HI value ranges from 30-720 mg/g, with an average value of 207 mg/g. The Cenomanian-Turonian source rocks have a average TOC value of 4.4%, in the range of 0.5%-56%, and a average HI value of 322 mg/g, ranging between 66-687 mg/g.

The results show that the Cenomanian-Turonian mudstones are excellent source rocks, the Albian mudstones are good-excellent source rocks, and the Neocomian mudstones are fair-good source rocks. In terms of the location, each of the Neocomian, Albian, and Cenomanian-Turonian source rocks are well developed in the northwest Africa, the northeast South America, and the Mexico Gulf Basin, whereas they are poorly developed in the southwest Europe and eastern North America. From the perspective of paleolatitude, the maximum average TOC and HI values of Albian and Cenomanian-Turonian source rocks are generally observed in the paleotropical regions, with the minimum standard deviation of TOC and HI values. Significantly, the average TOC and HI values and their standard deviation values of Albian and Cenomanian-Turonian source rocks decrease as the increase of paleolatitude, within the paleosubtropical Mid-Atlantics. This suggests that the deposition of organic-rich black shale and its internal heterogeneity, and ultimately the distribution and hydrocarbon generation potential of source rocks, may have been controlled by large-scale ocean circulation, which was primarily driven by the subtropical trade winds, and hence directly linked to the position of the ITCZ and the dynamics of the Hadley Cell.

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Discovery and significance of storm rocks and storm deposits in shale oil reservoirs of Qingshankou Formation, Gulong Sag

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Keywords: Storm deposition, tempestite, shale oil, Qingshankou Formation, Gulong Sag

Qingshankou Formation in Gulong Sag has attracted much attention because of its rich shale oil. But up to now, some basic geological problems of Qingshankou Formation shale are not clear. Therefore, it is necessary to make clear these basic geological problems. It is generally believed that Gulong Qingshankou Formation is a set of deep-lake and semi-deep-lake fine-grained deposits mainly composed of mud shale. Recent studies have found that storm rocks and storm deposits are commonly developed in Qingshankou Formation. The mud shales in the formation mostly have a sandy structure and the grain size is mainly fine sand, indicating that the environment is affected by undercurrent and the flow velocity is 0.25-0.65 cm/s. Small liquefaction veins are often developed at the bottom of tempestite, which indicates that storm shaking liquefaction is common in Gulong sag. It is also found that the water depth in Gulong sag may be 20-30 meters. These phenomena have a certain significance for understanding the formation environment of qingshankou Formation mud shale, and thus have a certain reference for oil and gas exploration and development.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
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Dikes in shale oil reservoir of Qingshankou Formation in Gulong Sag Geometry characteristics and their causes

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Keywords: sand veins, liquefaction, formation dynamics, gravity subsidence, shale oil, Gulong sag

Gulong shale oil is an important replacement resource in Songliao Basin, with estimated geological reserves of up to 15 billion tons. In terms of sedimentary and petrological characteristics, the Gulong Qingshankou Formation shale is characterized by extensive sand veins, which are not found in other basins. The sandstone veins in the shale oil reservoirs of the Gulong Qingshankou Formation can be divided into five types according to lithology: (1) siltstone veins, (2) mud veins, (3) ostracoda and ostracoda debris veins, (4) pyrite veins and (5) Tuff veins. According to the form can be divided into three kinds: (1) linear; (2) the intestines; (3) mass; (4) lamellar or lamellar and (5) irregular; According to the output mode, it can be divided into (1) bedding or horizontal and (2) bedding or oblique bedding and vertical. According to the nature of the surrounding rock can be divided into three kinds: (1) mud shale; (2) siltstone and (3) dolomite. The overall size is small, with a width of 1-2 mm and a length (or height) of 1-2 cm, but large ones can be seen as wide as 10 cm and can even run through the entire core. Visible length up to 12 cm; Most curved as intestine, few slightly curved. Multi tilt output, tilt direction has a certain rule, 180 degrees of symmetry. Generally developed in gray black shale, a small amount of siltstone and dolomite (nodules). According to the preliminary study, the dikes in the shale oil reservoir of Gulong Qingshankou Formation are formed by gravity subsidence caused by density inversion: the storm rapidly transported sand-grade particles to the newly deposited clay, and the silty sand was deposited into the clay due to the low density of clay and the high density of silty sand, which resulted in the formation of sand-veins. The study of sand veins in Gulong shale oil reservoir has three significations. First, we can know the sedimentary environment, sedimentary process and sediment state when the sand veins were formed. Second, we can know the diagenetic compaction rate of mud shale. Third, it can assist reservoir evaluation.

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Petrology and microscopic pore structure characteristics of shale oil reservoir in the Palaeogene Shahejie Formation of Dongpu Sag

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Keywords: shale oil, fine-grained rock, petrological characteristics, microscopic reservoir, Dongpu sag

The petrology and microscopic pore structure of shale are the key indexes to evaluate the shale oil and gas reservoir performance. The petrological characteristics, lithofacies types, pore-fracture types, pore-throat distribution and oil content characteristics of the Shahejie Formation shale oil reservoir in the Dongpu Sag were studied using core observation, thin section analysis, scanning electron microscopy, mercury injection-liquid nitrogen adsorption and 3D reconstruction of micro-CT. The result shows that the main mineral components of shale oil of Dongpu Sag are clay minerals and carbonate minerals, with less felsic minerals. The main lithofacies includes laminated limestone, laminated clay stone, laminated calcareous fine-grained mixed rocks, laminated argillaceous fine-grained mixed rocks, massive clay stone, massive dolomite. The main reservoir porosity includes intergranular pores, intragranular dissolution pores, clay mineral intergranular pores and organic pores, the microfractures can be divides into diagenetic fractures and tectonic fractures, laminated limestones and laminated calcareous fine-grained mixed rocks possess more types of reservoir space, and the reservoir spaces are relatively large. Lithofacies and bedding structure are important factors that influences pore development and quality. Laminated calcareous fine-grained mixed rocks, laminated limestone and laminated argillaceous fine-grained mixed rocks possess large pore size, well pore connectivity and relatively developed microfractures as well as good shale oil content and mobility, among them, laminated limestone is the most favorable lithofacies, they are the key shale oil exploration targets in Dongpu sag.

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Pore structure characterization of lacustrine shale in the Jurassic Da'anzhai member in Yuanba area, Sichuan Basin

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Keywords: Lacustrine shale, Pore structure characteristics, Da'anzhai member; Yuanba area, Sichuan Basin

The lacustrine shale in Da'anzhai member of Yuanba area is the key research target in the exploration of continental shale oil and gas. We focused our research on well YY2 to research organic geochemistry, petrology, porosity and pore structure characterization. A combination of field emission scanning electron microscopy (FE-SEM), low pressure N2/CO2 adsorption and mercury intrusion porosimetry (MIP) measurements were conducted to characterize the pore structure and the effects of organic matter and inorganic minerals on porosity and the pore structure were discussed. Organic geochemical and petrography analysis shows that the study shale samples contain total organic carbon (TOC) that ranges from 0.70% to 1.68% with an average of 0.98%, and average vitrinite reflectance value (Ro) being 1.42%, that three organic macerals of vitrinite, inertinite and solid bitumen were identified and computed with vitrinite being the uppermost macerals. The dominant minerals in Yuanba area are clay minerals, quartz and calcite. The porosity of shale samples ranges from 2.7% to 5.0% with an average of 3.8%. FE-SEM images have provided relevant information on shale pore morphology, including OM-hosted pores, clay-mineral pores and pores of framework minerals. The Combination of CO2, N2 adsorption and MIP can effectively reveal information pertaining to micro-meso-macro pores up to a limit of 10μm. Mesopore volumes are dominant in the continental shale in the study area, followed by micropores and macropores, and the pore size distribution ranges mainly from 0.3nm to 20nm. The pore specific surface areas range from 12.76 m2/g to 21.24 m2/g with an average of 17.43 m2/g, with the CO2 micropore specific surface area by DFT model and the N2 meso-macro pore specific surface area by BET model accounting for 48.7% and 51.3%, respectively. The micro-nano pore structures in shale matrix are related to clay minerals and organic matter. Micropores, mesopores and macropores all occur in clay minerals, and the mesopores are dominant. Clay-mineral pores contribute most of the specific surface area in shale. OM-hosted pores are mainly micropores and macropores, with relatively smaller specific surface areas. OM-hosted pores are mainly associated with vitrinite, followed by inertinite. Although pores occur within the solid bitumen, the solid-bitumen pores are not mainly contributed to OM-hosted pores. The fractures parallel to bedding are common in Da'anzhai shales, some of which are Calcite-filled and solid-bitumen-filled in, indicating that they belong to natural fractures, once have been opened underground. The unfilled fractures are not necessarily artificial induced fractures. Microfractures observed on FE-SEM images are also considered as macropores to store shale gas. This study has important significance in gaining a comprehensive understanding of continental shale pore structure and the shale gas storage-seepage mechanism.

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Analysis of Difference of Pore Structure between Lacustrine and Marine Shales

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Keywords: lacustrine facies,marine facies,shale reservoirs,pore structure

The key factor influencing oil and gas enrichment is the pore structure of shale reservoirs. Influenced by different depositional environments, the pore structure of lacustrine shale and marine shale is significantly different. Applying the method of gas adsorption, scanning electron microscope and high-pressure mercury injection, as well as taking the lacustrine shale of Shahejie Formation in Jiyang Depression and the marine shale of Longmaxi formation in Sichuan Basin as examples, the thesis deeply analyzes the difference of pore structure between lacustrine and marine shale reservoirs. The results show that there are two kinds of organic matter pores in lacustrine shale reservoirs. The one is complex formed by organic matter and inorganic minerals through adsorption, wrapping or filling. Numerous organic matter pores developed in the interior or edge of the complex in irregular multilateral shape or slit shape. The other one is massive organic matter, which is distributed in inorganic minerals in an isolated form, and developed inside the organic matter in circular or oval shape. The marine shale reservoirs develop densely distributed and interconnected honeycomb-shaped organic pores. The pore volume of marine shale is mainly provided by micropores and mesopores, and the specific surface area is provided by micropores and mesopores. The degree of pore development of marine shale is sorted from large to small, which are micropores, mesopores and macropores respectively. The pore volume of lacustrine shale is mainly provided by mesopores and macropores, and the specific surface area is provided by micropores and mesopores. The pore development degree of lacustrine shale is sorted from large to small, which are macropores, mesopores and micropores respectively. Micropores control the adsorbed gas volume of marine shale reservoirs through large specific surface area, and is of great importance in the contribution of movable gas, which can provide a large adsorption surface and reservoir space for shale gas, beneficial to the occurrence of shale gas. Macropores of lacustrine shale determine the enrichment of movable hydrocarbons through large pore volume, which can provide a large reservoir space and seepage channels for shale oil, beneficial to the occurrence and flow of shale oil.

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Spatiotemporal distribution of major source rocks in the transition from depressed to rifted basin: A case study of the Guyang to Linhe Formations in the Linhe Depression, Hetao Basin, China

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Keywords: Depressed-rifted transition, Organic facies, Velocity-lithology model, Source rock,Differential superposition, Linhe Depression

Source rock prediction in the Linhe Depression is exceptionally difficult owing to inadequate data, while the process by which depressed-rifted conversion influences source rock distribution remains unclear. Thus, this study aimed to predict source rock distribution and demonstrate its influencing factors. Based on outcrop, geochemical, well log, and seismic information, a seismic methodology involving the prediction of organic facies distribution using seismic facies analysis and mudstone thickness via a seismic velocity-lithology model was applied to predict source rocks. Our study showed the suitability of this method for early exploration in basins with inadequate data. The correlation coefficient between the predicted and borehole values of mudstone was 0.94, and the relative error was < 14.6%. The optimal source rocks in the second member of the Guyang Formation were encountered in new wells JHZK9, LHC1, and JH14 and accurately predicted, thereby validating our methodology. Furthermore, optimal source rocks transitioned from broad to limited distributions, moved closer to the boundary fault, and transferred from gentle slopes to deep sags during the depression to rift period. This transition dominated the distribution of source rocks. The basin type restricted the location of source rocks, and the transfer of lacustrine centers played a leading role in the distribution and differential superimposition of source rocks. Additionally, differential compression influenced source rock thickness in the second member of the Guyang Formation, while segmented variations in the boundary fault style and activity rate influenced the thickness in the second member of the Linhe Formation. This study effectively predicted the distribution and thickness of the main source rocks in the Linhe Depression, which was confirmed by new drilling wells, further analyzed the controlling effect of depressed-rifted transition on the distribution of source rocks, which has great reference significance for the study of source rocks in similar superimposed basins.

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Main controlling factors and genetic mechanism of effective reservoir development of deep clastic rocks --- A case study of the Xujiahe Formation in the Northwest Sichuan Basin

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Keywords: Northwestern Sichuan, deep layer, high-quality reservoir, sedimentary microfacies, diagenesis, fracture

The deep clastic rock of Xujiahe Formation in the northwest of Sichuan Basin is an important field of natural gas exploration, and the reservoir is one of the key factors controlling the development of gas reservoir. The main controlling factors and genetic mechanism of reservoir development are studied by using core, outcrop, seismic and logging data, and four new understandings are obtained. First, the deep effective reservoir of Xujiahe formation is a low porosity and permeability reservoir, which is mainly developed in delta underwater distributary channel, estuarine bar and other microfacies. The lithology is mainly coarse sandstone and pebbly fine sandstone. The reservoir space mainly includes primary pores, intragranular and intergranular dissolution pores and fractures. The average porosity is 5.90%, which belongs to ultra-low porosity, and the average reservoir permeability is 12.9 × 10-3 μm2, belonging to extra low-ultra low permeability. Second, the development degree of effective reservoir is mainly controlled by sedimentary microfacies, diagenesis and fracturing. The medium coarse sandstone in underwater distributary channel is a favorable sand body; The dissolution pores formed by dissolution and the transformation of primary pores effectively improve the porosity and permeability of sand body; The structural fractures produced by fracturing play an important role in the reservoir. Third, The genetic mechanism of deep effective reservoir in Xujiahe formation is as follows: underwater distributary channel sand body in delta front was buried rapidly in the early stage and retained a large number of primary pores; Under high temperature and high pressure, feldspar dissolves rapidly, which is conducive to the formation of a large number of secondary pores; The widely developed chlorite cementation can effectively protects the primary poresThe abnormal high pressure in the foreland depression is conducive to the preservation of reservoir space; The tectonic stress during the formation of foreland basin forms a large number of fractures, which is conducive to the formation of large-area effective reservoirs. Fourth, combined with sedimentary microfacies, lithology, reservoir thickness, porosity, pressure coefficient and other factors, comprehensively evaluate four effective scale reservoir development areas in Northwest Sichuan, including Zitong-Laoguanmiao-Wenxingchang, Zhongtaishan, Weicheng, Zhebachang-Bailongchang- Jianmenhe. The results have important reference significance for enriching the genetic theory of deep clastic rocks and guiding natural gas exploration.

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Diagenetic alteration in Carboniferous mudstones, UK: insights from integration of 2D and 3D imaging

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Keywords: Bowland Shale, Mudstone, Diagenesis, XCT

The characterisation of mudstones is challenging owing to their fine-grained and heterogeneous nature, and complex microstructure. Mineral composition, and the diagenetic evolution of this, is an important control on mudstone properties, porosity and permeability. As well as traditional 2D microscopic imaging techniques, mineral distribution and microstructures can be visualised in 3D at the micro- to nano- scale with the use of synchrotron-derived x-ray tomography. This study integrates 2D and 3D imaging to provide a unique perspective on the spatial distribution and texture of minerals in the Carboniferous Bowland Shale Formation, UK, looking at mudstones with both early and burial diagenetic histories.

Early to intermediate diagenetic processes observed include shell dissolution, pyrite precipitation, the precipitation of barite, calcite, kaolinite, dolomite, ankerite and quartz and the replacement of kaolinite by illite. 3D images show that the orientation of kaolinite, barite and anhedral pyrite is preferentially parallel to the bedding, which is related to the presence of laminations and the distribution of shell material. The Bowland Shale samples having undergone deeper burial diagenesis contain kaolinite, illite, chlorite, pyrite, silica nanospheres, micron-sized quartz, quartz overgrowths, non-ferroan and ferroan dolomite, ankerite and calcite (including oscillatory zoned ankerite, non-ferroan and ferroan dolomite). 3D images show that ankerite was precipitated in space created by the dissolution of ferroan dolomite. Ankerite dissolution was also observed in the studied samples, and occurred prior to the formation of calcite-filled veins. Pores are present within and around pyrite and silica nanospheres and the presence of these minerals limited compactional loss of porosity during diagenesis. Three types of carbonate-related pores were observed, namely (i) intra-, (ii) inter-, and (ii) intra- and inter- mineral jointed pores, which are partially within the mineral and partially bounded to the mineral. These jointed pores are interpreted to have formed through the dissolution of carbonate grains during burial diagenesis.

The integration of 2D and 3D imaging data obtained within this project has provided uniquely comprehensive evidence on the mineral-pore and mineral-mineral relationships, allowing the diagenetic histories much better understood from both planar and spatial perspectives.

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Shale lithofacies characteristics and reservoir differences of Wufeng Formation-Longmaxi Formation in southeastern Sichuan-northwestern Guizhou

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Keywords: lithofacies,shale reservoir characteristics,Wufeng Formation-Longmaxi Formation,Southeast Sichuan-Northwest Guizhou

As the basis of shale gas geological research, shale lithofacies control the hydrocarbon generation capacity, reservoir performance and fracturing performance of shale, and affect the distribution of "sweet spots" in shale reservoirs. Based on the test data of thin section identification, X-ray diffraction analysis, total gas content and TOC content, this paper finely divides and analyzes the shale lithofacies of Wufeng Formation-Longmaxi Formation in the southeast Sichuan-northwest Guizhou. It is demonstrated that: (1) the study area develops twelve lithofacies, namely, calcareous shale lithofacies (C-1), mixed calcareous shale lithofacies (C-2), clay-rich calcareous shale lithofacies (C-4), mixed clayey shale lithofacies (CM-2), silicon-rich clayey shale lithofacies (CM-4), mixed siliceous shale lithofacies (S-2), calcium-rich siliceous shale lithofacies (S-3), clay-rich siliceous shale lithofacies (S-4), calcareous/siliceous mixed shale lithofacies (M-1), mixed shale lithofacies (M-2), clayey/calcareous mixed shale lithofacies (M-3) and clayey/siliceous mixed shale lithofacies (M-4). (2) There are differences in reservoirs among various lithofacies. Among them, the TOC content of mixed siliceous shale lithofacies (S-2), calcium-rich siliceous shale lithofacies (S-3) and calcareous/siliceous mixed shale lithofacies (M-1) is more than 3%, the gas content is more than 2m3/t, and the content of brittle minerals is more than 70%; The TOC content of mixed shale lithofacies (M-2) is 2~3%, the gas content is about 2m3/t, and the content of brittle minerals is 64%; The TOC content of mixed calcareous shale lithofacies (C-2), clay-rich calcareous shale lithofacies (C-4), clay-rich siliceous shale lithofacies (S-4), clayey/calcareous mixed shale lithofacies (M-3) and clayey/siliceous mixed shale lithofacies (M-4) is less than 2%, the gas content is less than 2m3/t, and the content of brittle minerals is 60%~70%; The TOC content of mixed clayey shale lithofacies (CM-2) and silicon-rich clayey shale lithofacies (CM-4) is 2%~3%, the gas content is more than 2m3/t, but the content of brittle minerals is less than 30%. (3) Based on the entropy method and the actual geological conditions of the study area, the division standard of advantageous lithofacies is established, and three advantageous lithofacies are divided into class I, class II and class III. Among them, calcareous/siliceous mixed shale lithofacies (M-1), mixed siliceous shale lithofacies (S-2) and calcium-rich siliceous shale lithofacies (S-3) are class I lithofacies (the most advantageous lithofacies); mixed shale lithofacies (M-2), clayey/siliceous mixed shale lithofacies (M-4) and clay-rich siliceous shale lithofacies (S-4) are class II lithofacies; calcareous shale lithofacies (C-1), mixed calcareous shale lithofacies (C-2), clay-rich calcareous shale lithofacies (C-4), clayey/calcareous mixed shale lithofacies (M-3), mixed clayey shale lithofacies (CM-2) and silicon-rich clayey shale lithofacies (CM-4) are class III lithofacies.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Oral Preferred

Mechanism of super-organic matter rich in Triassic Chang 7 shale of Ordos Basin, China

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Keywords: super organic-rich shale, fresh and brackish water,high rates of production,volcanic events,hydrothermal activity,Ordos Basin

Bulk geochemical data indicate that Triassic Chang 7 shale is super rich in organic matters while it was formed in a fresh and brackish water, which is not usually the case for high TOC sediments. So there must be some special conditions favorable for organic matter (OM) enrichment in Chang 7 shales, and systematic petrographic and geochemical analyses were performed. It was shown that the Chang 7 super organic-rich shales are abundant in organic laminae, framboidal pyrites, collophanes, and some elements including iron (Fe), diphosphorus pentoxide (P2O5), copper (Cu), vanadium (V), molybdenum(Mo), and uranium(U). In addition, the organic carbon contents increase as the Fe, P2O5, Cu, V, Mo, and U element contents increase and the ratios of U/Th and V/(V+Ni) are growing. Therefore, high productivity (algae blooming) and anoxic depositional environments are critical for OM enrichment. Many geochemistry data demonstrate that the water is oxic, while the environment under the sediment-water interface is anoxic as a result of a high organic supply that sufficiently consumes oxygen. Combined with the geological settings and our previous studies, we propose that the frequent volcanic events and hydrothermal activity, which were caused by the collision of the North China landmass with the Yangtze landmass and the formation of the Qingling Mountains, are significant in the OM enrichment in the fresh and brackish lacustrine shales. Deposition of volcanic ash into aqueous environments may lead to the increase of some key nutrients, such as Fe and P2O5, which may enhance primary productivity. New evidence for hydrothermal activity, the reddingite, was demonstrated in this study. Not only can the hydrothermal activity provide elements necessary for life, but also it is favorable for anoxic settings. The deposition of the Chang 7 lacustrine organic-rich shales can be explained using the High-Productivity-Driven Model, which is related to volcanic events and hydrothermal activity as a consequence of regional tectonic movement. An anoxic depositional setting is beneficial for OM preservation and slow sedimentation rates in the deep lacustrine are favorable for OM enrichment.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Reservoir characteristics and oil bearing properties of fine-grained sedimentary rocks in Fengcheng Formation of Lower Permian in Mahu Depression, NW China

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Keywords: Mahu Depression, Fengcheng Formation, fine-grained sedimentary rock, reservoir characteristics, oil bearing analysis

Reservoir characteristics and oil bearing properties of fine-grained sedimentary rocks in Fengcheng Formation of Lower Permian in Mahu Depression, NW China

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Great breakthroughs have been made in shale oil exploration of Fengcheng Formation in Mahu depression, Junggar Basin, but the reservoir characteristics and internal shale oil occurrence characteristics of fine-grained sedimentary rocks of Fengcheng Formation need to be further studied. Based on the core observation of MY1 well and combined with macro-micro scale analysis, this study comprehensively reveals the characteristics of various types of fine-grained rock reservoirs and oil-bearing properties.

The fine-grained sedimentary rocks of Fengcheng Formation in well MY1 are mainly deposited in semi-deep lake to deep lake, with thin-layer event deposits such as gravity flow and hydrothermal solution. Based on the classification scheme of felsic carbonate clay minerals and X-ray diffraction data, the main fine-grained rock types and research units are determined as siliceous rock, mixed siliceous mudstone, siliceous carbonate mudstone and carbonate siliceous mudstone. Combined with microscopic identification argon ion polishing scanning electron microscope observation, except that siliceous carbonate mudstone develops a large number of dissolution pores and more intergranular pores, other fine-grained rocks generally develop intergranular pores, intergranular pores and dissolution pores, and each fine-grained rock contains a small amount of organic pores and fractures.Based on the combined analysis of low-temperature nitrogen adsorption high-pressure mercury injection ct-fib-sem and other means, each fine-grained rock type contains nano-sized pores and micron sized pores. According to the fractal theory of nitrogen adsorption and high-pressure mercury injection, the pore structure of siliceous rock is the simplest, which is followed by siliceous carbonate mudstone, carbonate siliceous mudstone and mixed siliceous mudstone.S_1, TOC and OSI parameters of fine-grained rocks show that Fengcheng Formation has good oil bearing property. The oil bearing property of siliceous rock is the best, the oil bearing property of siliceous carbonate mudstone is poor, and the oil bearing property of mixed siliceous mudstone and carbonate siliceous mudstone is medium.

Generally speaking, the shale oil reservoirs are siliceous rock, carbonate siliceous mudstone, siliceous carbonate mudstone and mixed siliceous mudstone from excellent to poor. This achievement will provide a target for further exploration and evaluation of shale oil in Fengcheng Formation.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Oral Preferred

Microfacies analysis and mapping of the late Ordovician-early Silurian Wufeng–Longmaxi shelf shale in southern Sichuan Basin, China

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Keywords: microfacies analysis, microfacies mapping, shelf shale, southern Sichuan Basin, Wufeng–Longmaxi shale

Microfacies analysis and mapping of shelf shale are a hot spot in shale sedimentology. Based on shale thickness and X-ray diffraction whole rock data, microfacies and their distribution are analyzed and mapped systematically. The results show that: (1) Shale thickness and contents of carbonate, quartz, and clay minerals are closely related to topography, water depth, and transportation pathways and can be used to indicate microfacies. Commonly, the lower the topography, the thicker the shale; the deeper the water depth, the higher the quartz content; the shallower the water depth, the lower the carbonate content; the closer to transportation pathways, the higher the clay mineral content. (2) Shelf shale can be subdivided into five microfacies based on shale thickness and contents of carbonate, quartz, and clay minerals, namely, shallow shelf, subaqueous slope, subaqueous plain, subaqueous sag, and turbidite. Shallow shelf has the highest carbonate content above 20%, subaqueous sag has the highest quartz content above 55%, and turbidite has the highest clay mineral content above 35%. (3) Distributions of shale thickness and contents of carbonate, quartz, and clay minerals can be used comprehensively to identify microfacies distribution for the Wufeng–L11 shelf shale. As a result, two highs, one slope, one plain, four sags, and eight turbidite are shown in the southern Sichuan Basin, China.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Oral Preferred

Geological controls on the pore structure of the lacustrine Triassic Chang 7 Shale in the Ordos Basin, China

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Keywords: Pore structure,fractal dimensions,thermal maturity,mineral composition, lacustrine Chang7 Shale.

The complex pore system of lacustrine organic-rich shales poses challenges to the evaluation of shale oil and gas resources. To improve our understanding of the pore structure and its controls of the lacustrine Chang 7 Shale in the Ordos Basin, 12 samples at the oil window stage with varying organic matter contents were analyzed using total organic carbon (TOC), vitrinite reflectance (Ro), X-ray diffraction (XRD), field emission-scanning electron microscopy (FE-SEM), low-temperature N2 and CO2 adsorption experiments and fractal method. The results showed that macro- and meso-pores contribute to the main pore volume in the lacustrine Chang 7 Shale. Pore diameter peaks are dominantly distributed around 0.7 and 37 nm. The intragranular pores in clays and intergranular pores between minerals and OM are well developed, while the pores in OM are rarely observed. The fractal dimensions of the Chang 7 Shale's pore structure suggest that D2 is better than D1 in reflecting the pore heterogeneity. OM shows negative effects on the total pore volume, while quartz promotes the development of macro- and meso-pores. The relationship between clay minerals and total pore volume shows a reversed U-shape curve (pore volume increases first up to 45% clay content and decreases thereafter). Both quartz and clays show negative effects on the heterogeneity of meso- and macro-pores, and positive effects on the micro-pore heterogeneity. A new abrupt change of the pore system in lacustrine shales happens at the critical maturity value of 0.8% Ro. Both the pore structure parameters and fractal dimensions show the inverse trends before and after this critical value. This observation is closely related to the compaction processes coupled with hydrocarbon generation and expulsion, which helps better understand the pore system evolution in the lacustrine shales.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
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Characteristics and diagenetic evolution of fine-grained sedimentary rocks in the first member of Qingshankou Formation in central depression of northern Songliao Basin

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Keywords: Songliao Basin, section 1 of Qingshankou Formation, fine sedimentary rock characteristics, diagenesis, hydrocarbon evolution

The fine-grained sedimentary rock of the upper Cretaceous Qingyi Member in the central depression area of northern Songliao Basin is an important source rock series in this area. In order to determine the characteristics and diagenetic evolution of different types of fine-grained sedimentary rocks, the rock types and fine characteristics of fine-grained sedimentary rocks in the first member of Qingyi Formation in the study area were studied by means of rock thin section, scanning electron microscope, X-ray diffraction and organic geochemical analysis. The diagenetic evolution stages of different burial depths were divided. The burial history, thermal history recovery and hydrocarbon generation evolution characteristics were analyzed, and the relationship between diagenetic evolution and potential unconventional oil and gas types was revealed.

According to core observation and X-ray diffraction analysis, with TOC, felsic minerals, clay minerals and carbonate minerals as parameters, the rock types of the first member of Qingyi Formation are finely divided into eight rock types : high organic clay shale, high organic felsic shale, high organic mixed shale, medium organic felsic shale, medium organic mixed shale, low organic felsic shale, low organic siltstone and low organic carbonate rock.

Through the analysis of TOC, rock pyrolysis analysis, biomarkers and other data, the average TOC of Qingyi Member is 2.59 %, indicating that the overall abundance of organic matter is high. Ro,Tmax, CPI and OEP data show that the Qingyi Member is distributed in the immature-high mature stage. Based on the intersection diagram of S2 and TOC, it is shown that among the eight rock types in the first member of Qingyi Formation, clay shale, feldspar shale and mixed shale with high organic matter have good hydrocarbon generation potential, followed by feldspar shale and clay shale with medium organic matter, and feldspar shale, siltstone and carbonate rock with low organic matter have poor hydrocarbon generation potential.

Through the observation of thin section and light section, scanning electron microscope and energy spectrum analysis, it is found that the diagenesis of Qingyi Member mainly includes compaction and pressure dissolution, cementation, dissolution and clay mineral evolution. The felsic minerals increased with the increase of depth, while the clay minerals decreased gradually. In clay minerals, as a whole, kaolinite gradually disappears, chlorite gradually decreases, and illite-montmorillonite mixed layer gradually transforms to illite with the decrease of depth. Overall, the study area is in the early diagenetic B-middle diagenetic B diagenetic stage.

Through fluid inclusion temperature measurement, combined with previous tectonic uplift data and paleogeotemperature curve in this area, the burial history and thermal history of wells in different regions and different depths are restored. It shows that in the shallow buried area (2150 m), the organic matter has carried out large-scale hydrocarbon expulsion stage in the early stage, and then entered the thermal cracking stage. Based on the organic geochemical characteristics, a thermal evolution hydrocarbon generation model was established. In the immature-low maturity stage , most organic matter hydrocarbon generation basically ended, and the crude oil formed earlier showed light optimization and humidification.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Oral Preferred

Orbital and sub-orbital pacing of mudstones in Dongying Depression, eastern China: Implications for Middle Eocene East Asian climate evolution

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Keywords: Obliquity, semi-precession, Middle Eocene Climate Optimum, East Asian monsoon, Dongying mudstones

The Middle Eocene was a key stage in East Asian and global climatic evolution. A 390 m thick mudstone succession in the Dongying Depression (eastern China) contains a continuous continental sedimentary record that can be used to investigate key climate variations during the Middle Eocene in East Asia. The deposition of the Dongying mudstones extended from ~43.48 Ma to ~39.24 Ma and can be divided into five climate stages based on pollen and mineral compositions. The Middle Eocene Climatic Optimum, which was characterized by a hot humid climate unlike other stages recorded by the Dongying mudstones, was recorded in a stage that contains organic-rich claystones. This study is the first characterization of the Middle Eocene warming event in eastern China. We also found that the orbital and sub-orbital cycles recorded by the Dongying mudstones drove the climatic changes and influenced carbonate enrichment. Based on the relationship between astronomical signals and climate parameters, the obliquity signal may represent variations in cold and dry airflow from high latitudes, while the semi-precession signal may represent changes in warm and wet airflow from low latitudes. These two orbital cycles may have played roles similar to the winter and summer monsoons in the present East Asian monsoon system, respectively. Therefore, the Dongying mudstones not only recorded global temperature fluctuations during the Middle Eocene, but also recorded the early evolution of the East Asian monsoon. This study further indicates that astronomical cycles played a critical role in the onset and strengthening of the East Asian monsoon.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
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Sedimentary and Reservoir Characteristics of lacustrine shale in Jurassic Lianggaoshan Formation, Fuling Area, Sichuan Basin, China

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Keywords: Fuling area,Lianggaoshan Formation,Sedimentary environment,Reservoir space

In order to explore the oil and gas potential of Jurassic lake shale in Sichuan Basin, the lacustrine shale of Lianggaoshan Formation in the Fuling Area is taken as the research object, and the lacustrine shale sedimentary and reservoir characteristics of Lianggaoshan Formation are systematically analyzed based on core observation, thin section analysis, Ar-ion polishing scanning electron microscope and gas content measurement. The Lianggaoshan Formation in the Fuling Area is dominated by delta-lake sedimentary system, in which the semi-deep Lake is a favorable environment for the development of organic shale. The reservoir space of shale in Lianggaoshan Formation is dominated by micro-fractures with high gas content, and the lacustrine shale in the Fuling area is widely distributed, with large continuous thickness and well developed reservoir space, which provides a good preservation condition for shale gas. The study on lacustrine shale sedimentary environment and reservoir characteristics of Lianggaoshan Formation can guide the exploration of lacustrine shale gas in the Fuling Area.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Study on sedimentary environment of fine-grained sedimentary rocks of the Lower Cambrian Qiongzhusi Formation in Sichuan Basin and its periphery

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Keywords: Sichuan Basin, Qiongzhusi Formation, Fine-grained sedimentary rocks, Sedimentary environment, Sedimentary microfacies

The exploration and development practice shows that the shale of the Lower Cambrian Qiongzhusi Formation in Sichuan Basin and its periphery shows a good shale gas exploration prospect. However, due to many factors such as deep burial, complex tectonic sedimentary background and limited research data, the understanding of the rock characteristics and sedimentary environment of this set of shale is relatively weak, which limits the exploration and development of shale gas to a certain extent. Based on the habit that the division of shale sedimentary environment generally depends only on water depth and lithofacies in the previous research, this paper systematically studies the sedimentary environment of Qiongzhusi Formation based on the field outcrop, core and logging data of Qiongzhusi Formation in Sichuan Basin and its periphery, combined with geochemical parameters, paleontological species and other identification marks. In the shelf environment with combined influence of ocean and ancient land, medium water depth and strong reduction, four sedimentary microenvironments are further identified: oxygen-rich wave tide disturbing, oxygen-rich weak evaporation mixing, oxygen-poor limited still water and anoxic upwelling current disturbing. The study of sedimentary microenvironment of Qiongzhusi Formation can effectively help to understand the sedimentary evolution of this set of marine shale and provide reference for the next oil and gas exploration direction.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Oral Preferred

Sedimentology and Organic Geochemical Characteristics of Permian Lacustrine Mixed Source Rocks in the Lucaogou Formation: Indicative of Lake Basin Evolution

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Keywords: Mixed sedimentation, Source rocks, Shale oil, Organic geochemistry, Lucaogou Formation, Junggar Basin

The Permian Lucaogou Formation (P_2l) in the Jimusaer Sag, Junggar Basin in China is considered as a promising target for shale oil exploration and exploitation. It is an essential source rock as well as a shale oil producing layer, characterized by mixed sedimentation of three end-member components of siliciclastics, carbonates, and tuffaceous materials, which is significantly different from the conventional source rocks (e.g., mudstones or carbonates). Methods including core and thin section analysis, X-ray diffraction, Soxhlet extraction, TOC measurements, Rock-Eval pyrolysis, organic maceral analysis, organic carbon isotope analysis and Gas chromatography−mass spectrometry were used to investigate the mixed sedimentation process, hydrocarbon potential and depositional environment characteristics of the fine-grained mixed rocks in the Lucaogou Formation. The P_2l mixed rocks were divided into terrigenous-, carbonate-, and tuffaceous-dominated mixed rocks, formed through the mixing processes of facies mixing, source mixing, punctuated mixing and in-situ mixing. They were highly abundant of organic matter (OM) at the thermally low mature to mature stage, which mainly originated from the mixture of planktonic organisms, bacteria, and terrigenous higher plants. The lithofacies association, OM material source and hydrocarbon generation potential of mixed rocks in the early (lower section) and late (upper section) depositional stages of P_2l showed some differences. Compared with the lower section, there were less terrigenous supply influx during the upper section deposition, which was demonstrated by less terrigenous- and tuffaceous-dominated mixed rocks, as well as terrestrial OM input, but more carbonate-dominated mixed rocks, and sapropelic kerogen of bacterial, algal and planktonic source. Besides, the hydrocarbon potential of the upper section was higher than that of the lower section, proved by higher values of TOC, $S_1 + S_2$, and hydrogen index (HI) parameters in the upper section samples. The mixed source rocks in the lower and upper sections of P_2l were deposited in different environment as well, which was mainly controlled by climatic change, and thus indicative of lake basin evolution. During the lower section deposition, the climate was warm and humid, and the depositional environment was deeper, dysoxic−anoxic and brackish, with a more balanced-filled scenario dominating. Whereas during the upper section deposition, the climate became semiarid and hot with greater evaporation. The lake basin indicated an under-filled setting, with shallow, saline, and evaporative environment. Overall, the fine-grained mixed rocks in the Lucaogou Formation were source rocks of high quality, offering favorable resource potential for shale oil exploration.

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Scientific Themes: Theme 9. Resource Sedimentology
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Paleoenvironmental reconstruction of Bonan Sag, Bohai Bay Basin: Evidence from aragonite laminae

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Keywords: lacustrine organic-rich laminated shales, aragonite, paleoenvironmental

Lacustrine organic-rich laminated shales are often varves representing annual rhythmic deposition, potentially preserving information about the tectonic setting, paleoaltimetry, paleoenvironments, variations in lake water conditions (evaporative concentration, source waters, temperature) and biological activity. Aragonite lamina, which was found from the first member of Shahejie formation, Eocene strata in Bonan Sag, Bohai Bay Basin, provide significant paleolake signatures. Mineralogical and geochemical analyses were conducted on alternating yellowish and greyish aragonite lamina. The yellowish layers are mainly composed of aragonite crystals and algae skeleton, while the greyish layers contain less aragonite and fewer organic remnants that accumulate among debris with sporadic framboidal pyrite. The δ13C values of yellowish layers are remarkably positive, while the δ18O values are slightly negative. Consequently, in the warm season, due to the high salinity and evaporation effects, Mg/Ca ratios are elevated. And the algae bloom causes a decrease in the CO2 content, leading to high pH values, which are favourable for the precipitation of aragonite instead of other carbonate minerals. Moreover, slightly negative δ18O values in yellowish layers are interpreted as the result of intense inflow during warm seasons, which leads to less precipitation of organic matter and debris. The greyish layers in cold seasons are the opposite. The results from this study show that understanding the lacustrine lamina origin of Bonan Sag is essential for paleoenvironmental and paleoclimate interpretations.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
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Sedimentary and geochemical characteristics of marine-continental transitional shale gas in the eastern margin of Ordos Basin

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Keywords: shale gas, marine-continental transitional, lagoon deposits, geochemical characteristics

A systematic study was conducted using intensive sampling, core analysis, rock thin sections and drill logging data to identify sweet spot in the Daning-Jixian region of the Shanxi Formation. The first Marine and continental transitional shale gas iron pillar well in China has been established, and the Shan32 sub-member is proposed as the sweet spot of development target.

The vertical variations of sedimentological and geochemical characteristics suggest that the Benxi, Taiyuan, and Shanxi formations were deposited under different environment conditions. The Upper Carboniferous Benxi Formation was dominated by marine environment, and then changing to transitional facies. The Lower Permian Taiyuan Formation is a sedimentary system with alternating marine and transitional facies. Marine limestones are characterized by abundant marine fauna and flora, along with the lowest detrital influx input among the three formations. In contrast, transitional shales are characterized by higher detrital influx input and oxic sedimentary environment. The Shanxi Formation is a typical marine-continental transitional depositional system. Ten types of lithofacies were identified. In additionten lithofacies were classified into four associations that reflect four depositional environments: tidal flat depositssupratidal to intertidal zones, lagoon deposits, tidal channel to tidal flat deposits and lagoon-tidal flat deposits. The lithofacies association in the deep lagoon are favorable for the development of a high-TOC shale gas reservoir.

The Lower Shanxi Formation is characterized by complex interbed-ding of shales, sandstones and coals. Sandy intervals are resulted from mouth bar and tidal channel deposition, which are characterized by no organic matter enrichment, high Ti and Al content, showing influence, but limited, of seawater. Shale intervals with high TOC, Sr/Ba, U/Th, and trace elemental proxies values (U/Th, MoEF, and UEF) were deposited in a lagoonal environment. Shale intervals were deposited in a lagoonal environment with high TOC (0.94–40.64%, avg. 5.43%), Sr/Ba and trace elemental proxies values (U/Th, 0.18–3.27%, avg. 0.44%; MoEF, 0.95–32.3, avg. 8.56; UEF, 0.67–15.17, avg. 2.53).

This study shows that high-resolution geochemical characteristics of elements could be reliable indicators for sedimentary microfacies analysis, and hence could provide implications for marine - continental transitional shale gas favorable sedimentary facies belt in which sedimentary environment changes frequently and organic-rich sediment accumulated under varied conditions. Marine and continental transitional shale gas opens a new field for shale gas development in China in the future. Large shale gas field is expected to be built i in the eastern margin of Ordos Basin. It is estimated that the production of Marine and terrestrial transitional shale gas will reach more than 10 billion cubic meters in 2035.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Oral Preferred

Laminae characteristics and influence on shale gas reservoir quality of lower Silurian Longmaxi Formation, Sichuan Basin, China

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Keywords: Shale gas, Laminae, Reservoir quality, Longmaxi formation, Sichuan Basin

Widely developed in shale strata, laminae are the most typical shale sedimentary structure. To investigate their influence on shale gas reservoir quality, this study of the marine Silurian Longmaxi Formation in the Sichuan Basin used microscopic observations on standard-size thin sections and larger polished thin sections (7.6 cm × 4.8 cm), X-ray diffraction whole rock mineral analysis, field-emission scanning electron microscopy (FE-SEM) imaging, nitrogen adsorption testing, and mercury intrusion capillary pressure (MICP) techniques. The microscopic observation of thin sections enabled us to detect the laminae characteristics, including the density and maximum thickness of individual lamina, and four types of lamina development were identified: silica-rich lamina, carbonate-rich lamina, clay-rich lamina, and organic-rich lamina. The total organic carbon (TOC) content, mineral composition, natural fracture, pore type, pore size distribution, porosity, permeability, and tortuosity were investigated in these different laminae types using FE-SEM, MICP and geochemical analysis. Within their relatively small lateral extent, laminae mainly present as planar, discontinuous and parallel(Shi et al., 2018). The thickness of laminae ranges from 0.08 mm to 2.2 mm. The silica-rich laminae develop natural fractures(Guan et al., 2019 & 2021). And there are three types of laminasets: silica-organic laminaset, silica-clay laminaset, and carbonate-organic laminaset, the reservoir property and fracability of silica-organic laminaset are better than other laminasets. The silica-organic laminaset is the priority exploration target in the Longmaxi Formation. Combining the laminae and laminaset characteristics, and their pore structure, we concluded that the organic pores and total pore area are mainly affected by the TOC content, whereas the development of the laminae controls the inorganic macropore scale and affects the pore size distribution. Future research should focus on the hydrodynamic background of laminae formation and its influence on organic matter enrichment and reservoir stimulation. Relevant knowledge can provide an important reference and technical support for increasing the optimization and evaluation of favorable reservoirs in the Longmaxi Formation, Sichuan Basin.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Oral Preferred

Jurassic coal accumulation environment and sequence stratigraphic characteristics in Kuqa depression, Tarim BasinChina

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Keywords: coal,lakeside swamp,highstand system tract,Kuqa depression

Three sets of coal seam assemblages are mainly developed in Jurassic in Tarim Basin, which are located in the lower and upper members of Yangxia formation and the lower member of Kezilenuer formation. Due to the different accommodation space required for coal seam accumulation in different system tracts of different sequences and different periods of the same system tract, the development degree of coal seam (peat) and sedimentary environment, the coal accumulation is also quite different, which may be developed in each system tract of the sequence. By analyzing, it is found that Jurassic coal seams are mainly developed in transgressive system tract and highstand system tract of the sequence. The highstand system tract after rapid transgression occurs in shallow and is easy to form thick coal seams with continuous distribution. In addition, the effect of coal formation in the early stage of transgression is general during rapid transgression; When the transgression speed is slow, coal is easy to form in the early stage, and the coal seam is thick. The Jurassic coal sedimentary environment is the plain swamp of Yangxia formation and the lakeside swamp of Kezileinuer formation. The single sedimentary coal seams of flood plain swamp and lakeside swamp are limited in scope and thickness. However, in the early stage of kezileinuer formation, due to silting up of lake, the plain swamp and lakeside swamp were connected together, forming a huge thick coal seam with continuous distribution.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Integrated studies of neutron scattering and nitrogen physisorption for nano-scale pore structure changes during artificial maturation of a shale sample from Shanxi Formation from Ordos Basin in China

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Keywords: Shale,Pyrolysis,Small-angle neutron scattering,Nanopore,Mesopore connectivity

The pore structures of shales, including pore volume, specific surface area (SSA), pore size distribution (PSD), and pore connectivity, are important factors that control petroleum storage and migration. However, due to the lack of comprehensive research on the pore structure of accessible and inaccessible pores during the thermal maturation of shale samples, it is difficult to objectively evaluate the pore structure changes during the hydrocarbon generation process of an immature shale. In order to study the nano-scale pore system of shale during thermal maturation, a series of water-containing pyrolysis experiments (pyrolysis temperatures at 250°C-550°C) were carried out on an organic-rich shale from the Shanxi Formation in the northern Ordos Basin of China. By using (ultra) small-angle neutron scattering [(U)SANS] and low-pressure N2/CO2 adsorption (LNA/LCA) methods to test the residual solids after pyrolysis, we quantitatively assessed the evolution of accessible and inaccessible pores. The pore properties obtained by integrating results from these two methods fully cover the entire nano-sized pore range (0.35-1000 nm), with mesopores (2-50 nm) and macropores (>50 nm) as major contributors to pore volume. Both pore volume and specific surface area decreased firstly, then increased and decreased with increasing maturity, reaching their peaks at 340℃ and 500℃, respectively. The inaccessible pore percentage of mesopores, defined as (SANS mesopores – LNA mesopores / SANS-mesopores), is shown to increase first, then decrease and again increase. According to the oil generation contents and calculated EasyRo, the results from eight pyrolysis temperatures are divided into four evolutionary stages: 250℃-340℃ (“bitumen generation”), 340℃-380℃ (“oil generation”), 380℃-460℃ (“oil cracking”), and 460℃-550℃ (“wet gas cracking”). In the 1st stage, the inaccessible pores of 2-18 nm increase due to a possible bitumen filling. For the 2nd stage, the inaccessible pores of 2-50 nm increase due to the likely filling of generated oil. In the 3rd stage, the inaccessible pores at 9-50 nm are reduced maybe due to the discharge and cracking of residual organic matter. These findings help to characterize the dynamic pore structure changes during petroleum generation process of organic-rich shale, and provide theoretical support for shale petroleum exploration and development.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Oral Preferred

Typical Characteristics and Indicative Significance of Continental Shale Reservoir in Luanping Basin, Yanshan Tectonic Belt, China

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Keywords: Shale oil and gas, Reservoir characteristics, Volcano lake, Sedimentary environmentXiguayuan Formation, Luanping Basin; Yanshan Tectonic Belt

Luanping Basin is a typical faulted basin in Yanshan tectonic belt and there has been no breakthrough in oil and gas exploration for a long time. Our team discovered shale oil and gas in Luanping Basin through a lot of research work, and made the first exploration breakthrough on this basis. Compared with the typical shale reservoirs at home and abroad, the shale reservoirs in Luanping Basin have three typical differences, namely, the source of shale material, the brittleness characteristics of reservoir and the composition of oil and gas. According to the particularity of the material source of shale, core, thin section, main and trace elements, reservoir test, geochemical index and other data were used for analysis. According to the particularity of the brittleness characteristics of the reservoir, X-ray diffraction method is used to analyze it. Gas chromatography-mass spectrometry (GC-MS) was used to analyze the particularity of oil and gas components.

Results: Based on core and thin section observation, it is concluded that there are terrigenous, volcanic and hydrothermal sources in the mud shale of Xiguayuan Formation. By X-ray diffraction analysis, the brittleness index is up to 81.5%. In terms of oil and gas composition, the average saturated hydrocarbon content of crude oil is 87.46%, showing the characteristics of high maturity and medium light oil; the average methane content of natural gas is 75.44%, and the average value of hydrocarbon gas is up to 96.21%, showing the characteristics of low maturity dry gas.

On the one hand, the multiple sources of volcanic and terrigenous materials not only affect the type and development degree of reservoir space, but also affect the hydrocarbon generation potential and other conditions of the source rock, so that the corresponding intervals have better reservoir physical properties and hydrocarbon generation potential. On the other hand, the participation of volcanic and hydrothermal activities provides more brittle minerals such as quartz, feldspar and carbonate for the lacustrine deposits, which not only forms rich reservoir rock types, but also makes its brittleness index better than that of most continental lacustrine reservoirs and has better fracturing performance. In addition, the kerogen macerals in the semi-arid sedimentary environment with volcanic activity are characterized by high vitrinite content. Combined with the catalytic action of trace elements, the source rocks at low to medium maturity stage can form shale reservoirs with oil and gas production and high gas production, and the oil and gas composition is also characterized by high saturated hydrocarbon content and dry gas.

Based on the analysis of the typical characteristics of shale material source, brittleness and oil and gas composition of shale reservoir in Luanping Basin, it is shown that high quality source rock, high quality reservoir and high saturated hydrocarbon reservoir can be formed in the complex semi-arid lake affected by volcanic activities. It provides important theory and support for the follow-up exploration of other similar basins at home and abroad.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Oral Preferred

Development Characteristics and Control Factors of Shale Lithofacies Assemblages in Es4cs formation of Dongying Sag

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Keywords: Dongying sag,Shale, Lithofacies assemblage,Development characteristic, Control factor

Es_4^{cs} formation in Dongying sag is the key member of shale oil exploration in Shengli Oilfield. At present, the lack of systematic and regular understanding of shale lithofacies assemblages in this member restricts the search for shale oil sweet spots. Based on the geological data such as core scanning image, thin section and geochemistry, the shale lithofacies and their assemblages were systematically analyzed, and the typical lithofacies assemblages, vertical variation and their controlling factors were identified. Studies suggest that controlled by ancient lake level and climate change, lithofacies assemblage development with regularity, from bottom to top: during the deposition of $Es_4^{cs}{}_4$ layer, lake level high amplitude and high frequency shifted, the ancient climate was relatively dry, water salinity was higher, the typical lithofacies assemblage was grain layer dolomitic argillaceous aphanitic limestone/grain layer argillaceous dolomite clamping block chip grain dolostone; during the deposition of $Es_4^{cs}{}_3$, the lake level maintained high amplitude and high frequency change, the paleoclimate alternated between dry and wet, the lake salinity decreased, and the lake stratified obviously, mainly developed the lithofacies assemblage of laminated argillaceous limestone interbedded with laminated silty limestone; during the deposition of $Es_4^{cs}{}_2$, the lake level changed with low amplitude and low frequency, the paleoclimate changed from dry and wet frequently to wet gradually, and the lake water was relatively unstable, the lithofacies assemblage of lenticular laminated argillaceous limestone interbedded with calay-bearing mudstone was mainly developed, and the lithofacies assemblage of mesoclastic argillaceous cryptocrystalline limestone and silty mudstone was locally developed. during the deposition of $Es_4^{cs}{}_1$, the paleoclimate was mainly humid, the lake level was relatively stable, the lake salinity increased slightly, and the lithofacies assemblage of massive argillaceous cryptocrystalline limestone mixed with lenticular laminated argillaceous limestone were mainly developed. The results have important guiding significance for paleogene shale oil exploration in Jiyang Depression of Shengli Oilfield.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Comparative study on reservoir characteristics of organic rich shale in different sedimentary microfacies of Late Permian Longtan Formation in western Guizhou, China

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Keywords: Late Permian Longtan Formation, sedimentary microfacies, shale reservoir characterization

Marine-continental transitional shales are widely distributed in coal measure strata in western Guizhou with large cumulative thickness, high organic matter content and high maturity, leading to a certain exploration potential. Though organic petrological analysis, X-ray diffraction experiment, high-pressure mercury injection, N_2 and CO_2 adsorption, argon ion polishing scanning electron microscope observation and other analysis techniques, the geological development characteristics and pore structure characteristics of Longtan shales in different sedimentary microfacies are studied, and the influence of sedimentary microfacies on shale gas generation and reservoir is revealed. Results show that shales have the characteristics of high TOC (generally greater than 2%), low porosity and complex reservoir pore structure.

The sedimentary facies in the west of the study area are mainly delta plain, and the lithology is the interbedding of dark shale, silty shale and coal seam. Due to the turbulent sedimentary environment, the vertical lithology changes of well Y and H are relatively complex. The average TOC of shales reaches 5.87%, while the maturity ranges from 0.99% to 1.16%, which suggested a low maturity stage. The clay mineral occupies a dominant position in the mineral composition (with an average of 69.5%). The sedimentary facies in the middle of the study area where well J and X located is mainly lagoon. The lithology is sandstone, silty mudstone, dark shale and coal seam, which show a typical coal bearing structure of transitional facies. The TOC (2.49-3.25%) is lower than that of shale deposited from delta , while the kerogen has evolved to the high maturity (R_o, 2.64-2.93%). The average content of clay is 26.52%, which is far lower than that of well Y and H. The east of the study area is a carbonate platform, mainly composed of dolomite, basalt and gray mudstone. Compared with other areas, the TOC, maturity and clay content of L are in the middle stage (TOC is 3.07%, R_o is 1.93%, clay is 48.50%).

In the shale deposited in the delta and carbonate platform, the average pore volume is 0.029cm^3/g and 0.026cm^3/g, respectively, and the average specific surface area is 21.63m^2/g and 19.12m^2, respectively. Mesopores are the main contributor to the pore structure, macropores are the second, while micropores contribute less. The pores are mainly wedge-shaped mineral intergranular pores and intragranular pores. A small amount of organic matter pores are developed in kerogen. The pore volume and surface area of shales deposited in lagoon facies are 0.025cm^3/g and 19.89m^2/g. The pore structure is dominated by the ink bottle-shaped micropores. In the samples with high maturity, organic matter pores are developed and can be observed in kerogen or asphaltene in the form of bubbles or sponges. The comparison shows that sedimentary microfacies mainly affect the hydrocarbon generation and storage capacity of source rocks by affecting the abundance of organic matter and mineral composition. The shale deposited in lagoon facies has good hydrocarbon generation potential and reservoir performance, suggesting a greater development potential.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Oral Preferred

Sedimentology and geochemistry of the Lower Permian Shanxi Formation Shan 23 Submember transitional shale, Eastern Ordos Basin, North China

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Keywords: Permian, transitional facies, geochemistry, organic-rich shale, Shan 23 Submember, Ordos Basin

Shanxi Formation Shan 23 Submember transitional shale in Eastern Ordos Basin is characterized by high TOC value, wide distribution, and large single-layer/cumulative thickness. In this study, based on section division of Shan 23 Submember, petrographic, mineralogical, high-resolution geochemical analyses were intergrated to reveal sedimentary environment, detrital influx, paleoclimate, paleosalinity, and paleoredox conditions. Results indicate that Shan 23 Submember is divided into four sections (Shan 23-1, -2, -3 and -4). The upper part of Shan 23-1 section is dominated by bay facies, which is characterized by high TOC value (2.75%-10.96%, avg. 6.98%), low detrital influx proxies (Zr, 97ppm-527ppm, avg. 310ppm; Ti, 1985ppm-7591ppm, avg. 3938ppm), relatively dry paleoclimate condition (CIA*, 41.96-92.58, avg. 75.55; Sr/Cu, 6.23-14.49, avg. 8.87), high paleosalinity proxies (Sr/Ba, 0.39-1.29, avg. 0.62), and relatively anoxic reduction condition (UEF, 0.83-3.00, avg. 1.67; MoEF, 3.95-27.00, avg. 15.56). By comparison, the other three sections are dominated by combination of transitional facies, including barrier island, lagoon, tidal flat and swamp. In this interval, shale is deposited in lagoon facies. The paleoclimate gradually tends to be warm and humid, which result in increasement of chemical weathering intensity. Meanwhile, the detrital influx increases, and the paleoredox condition tends to be oxic. The above conditions are not conducive to the preservation of organic matter in lagoon facies shale.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Depositional controls on lithoface and mineral assemblage of lower Cambrian shale in the upper Yangtze region, China

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Keywords: depositional environment, lithoface, mineral assemblage, lower Cambrian shale, upper Yangtze

Paleozoic marine organic-rich shale is widely developed in southern China, of which the lower Cambrian Niutitang Formation is one of the most potential shale formations. The multiscale sedimentary structure, diagenetic pathway and geochemical characteristics of organic-rich shale in two continuous cores in western Hubei and southern Shanxi were studied by X-ray diffraction, major and trace elements, optical microscopy and FE-SEM imaging. The controlling effect of depositional environment on the lithofacies changes and mineral assemblages of the lower Cambrian Niutitang shale in the upper Yangtze region of South China is discussed. The Niutitang shales are mostly siliceous mudstones deposited under anoxic conditions. Six lithofacies types and three laminar associations (banded silt, sand-mud gradient and sand-mud thin interbedding) have been identified. The mineral grain assemblages are mainly extra-basin grains, including detrital quartz, potassium-rich clay minerals, albite, potassium-feldspar, mica and debris. Organic mineral aggregates, clay complexes, etc. The diagenetic characteristics of authigenic components mainly include grain metasomatism, cementation and hydrothermal action. Quartz in shale includes clay and silt grades, with extra-basin and intra-basin sources, and authigenic clay-sized microcrystalline quartz exists.

Layered argillaceous siliceous mudstone facies, layered siliceous mudstone facies, and layered carbonaceous mudstone facies mainly occur in the lower part of the Niutitang Formation, with high TOC content (2.78wt%) and abundant bio-quartz. Organic-clay minerals are enriched in the form of aggregates or fecal pellets, and the interface of organic-rich laminae is not clear. The content of silty laminae is low, pyrite layers appear, and bioturbation is absent. This is attributable to anoxic conditions and high primary productivity due to rapid sea level rise and increased aeolian fluxes. The TOC content of massive silty mudstone facies and layered dolomitic mudstone facies decreases, and silty laminae and clay laminae are interbedded, indicating that the deposition rate increases and the paleohydrodynamic conditions changed periodically. Higher eolian input during this process resulted in increased primary productivity of surface water, while intermittent anoxic conditions favored organic matter preservation. The upper layered mixed siliceous mudstone facies has low TOC content (1.34wt%) and high calcite content. The carbonate minerals are generally angular, and silt-grade grains and silty laminae increase, indicating the enhanced paleohydrodynamics. It is not conducive to the accumulation of organic matter, because of the reduced primary productivity, strong oxidized water body, and the high dilution of terrigenous debris. Regional tectonics, sea level, sedimentation and climate changes lead to the evolution of the depositional environment, resulting in changes in shale lithofacies and mineral assemblages. A comprehensive study of the lithoface and mineral assemblage under the control of the depositional environment of the lower Cambrian Niutitang shale in the upper Yangtze region of South China reveals the driving mechanism of the shale diagenetic pathway and provides a theoretical basis for shale gas exploration.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Oral Preferred

Characteristics and types of fine-grained sedimentary rocks microfacies in Triassic Chang 9: A case study of centimeter-level core description of two wells in the Ordos Basin, China

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Keywords: Fine-grained Sedimentary Rocks, Interdistributary, Semi-deep Lacustrine, Yanchang Formation, Ordos Basin

With the exploration and development of shale oil and gas, fine-grained sedimentary rocks has become an important research object in sedimentology. Previous studies show that the lacustrine fine-grained sedimetary rocks are developed both in Chang 7 and Chang 9 members. Chang 7 was deposited in the maximum lake flooding period of Yanchang Formation with large thickness and wide distribution; Chang 9 was deposited in the first lacustrine flooding period with relatively thin thickness. Many scholars have carried out researches on Chang 7 Member and obtained a large number of relatively mature understandingsLu et al., 2006Yang et al., 2010WU et al., 2015Li et al., 2017Zhang et al., 2017Hou et al., 2017, while few researches have been carried out on Chang 9.The whole interval coring wells (Well C22 and Well Y84) with fine-grained sedimentary rocks of Chang 9 were selected to carry out centimeter-level core description, and analyze the lithology, microfacies characteristics and vertical sedimentary evolution. The analysis shows that the lithology of Chang 9 is mainly black and gray-black mudstone with thin layer of siltstone and local sandstone. The thickness of single layer of mudstone is 0.1-1.1m, with a maximum thickness of 2.6m, accounting for up to 40% of the thickness of the Chang 9 Memberthe single siltstone layer is 0.1-1.2m, with a maximum thickness of 3.0m, accounting for about 29% of the thickness. The main types of sedimentary facies include interdistributary and underwater distributary channel in braided deltaic front and semi-deep lacustrine. The lithology of the interdistributary microfacies is mainly gray-black silty mudstone,containing a small amount of siltstone, with horizontal bedding, slow wave bedding and common plant debris; the lithology of the underwater distributary channel microfacies is mainly medium and fine sand characterized by fine upper and coarse normal grain sequence, with massive bedding, parallel bedding and cross bedding; the lithology of the semi-deep lacustrine is mainly black and gray-black mudstone, with tens of centimeters thick upward thickening reverse grain order in which the proportion of siltstone increased significantly upwards, mixed with multiple thin-layer sandstones. It should be noted that there are many small scour structures and cross-beddings in the argillaceous siltstone deposited in semi-deep lacustrine of some layers, indicating that the sedimentary conditions is not settling in hydrostatic suspension, likely to be transported and deposited in the form of high-density flow. Although the above sedimentary facies types are distributed throughout the whole Chang 9 Member, overall the proportion of dark mudstone increases from bottom to top, which is consistent with the geological background of lake transgression. In conclusion, the fine-grained sedimentary rocks of Chang 9 are mainly mudstone and siltstone with frequently interbedded deposited in deltaic front and semi-deep lacustrine, which is different from Chang 7 with relatively thick layer. The analysis of Chang 9 is a supplement to the study of fine-grained sedimentary rocks, and provides a sedimentological basis for the exploration of shale oil in the whole Yanchang Formation.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Pore characteristics of shale oil reservoir of Jurassic Da 'anzhai member in central Sichuan Basin ,China

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Keywords: Pore characteristics,Shale oil,thermal simulation experiment,Da'anzhai member,Sichuan Basin

Lacustrine shale in Da 'anzhai member of Jurassic system in central Sichuan Basin is the key exploration target of shale oil and gas resources in China in the future. In this paperthe characteristics of shale rock types and components, pore types and structures, and pore evolution under thermal simulation were studied in detail by field emission scanning electron microscope(FESEM), petrophysical test, X-ray diffraction(XRD), organic carbon testing(TOC), low-pressure N2 adsorption experiments and thermal simulation experiment. The results indicate that: (1) The mineralogy of shale in Da 'anzhai member are mainly clay minerals, quartz and calcite, with a small amount of feldspar, dolomite and pyrite. And the shales can be divided into two types: calcite rich mixed shale and clay mineral-rich mixed shale. (2) The storage spaces of shale oil reservoirs in Da 'anzhai Member are mainly intergranular pores of inorganic minerals, and the proportion of organic pores is relatively low. The specific surface area of the reservoir ranges from 1.064 m2/g to 9.227m2/g, with an average of 4.949m2/g. The pore volume ranges from 0.003 to 0.016cm3/g, with an average of 0.010cm3/g. The mesopores contribute mostly to the total pore volume and total specific surface area.(3) There is a positive correlation between clay minerals and specific surface area and total pore volume in the mixed shale of Da 'anzhai member, and the content of clay minerals has an obvious control on porosity development. (4) With rising thermal simulation temperature, the degree of thermal evolution and porosity of shales increase, and the organic porosity is the main contributor to the added porosity. In the light of the above results, inorganic pores, especially intergranular pores of clays, are the main types of pores in Da 'anzhai Shale oil reservoir, and organic matter evolution degree, burial duration and depth obviously enhance quality of the organic pores.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
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Effects of petroleum chemical fraction on petroleum retention of saline lacustrine organic-rich shale

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Keywords: Oil fractionation, Residual oil, Retention mechanism, Saline lacustrine shale, The Dongpu Depression

Halite and gypsum minerals in saline shale makes the retention mechanism and chemical fractionation of residual oil unique. Shale samples with different gypsum mineral contents were used in organic geochemical experiments, showing that the high total organic matter (TOC) content and type II kerogen leads to a high residual oil content, as shown by high values of volatile hydrocarbon and extractable organic matter. XRD and FE-SEM date indicate that the existence of gypsum in saline shale contributes to an enhanced pore space and a higher residual oil content in comparison to non-gypsum shale. Additionally, the increase in the gypsum mineral content leads to an increase in the saturated hydrocarbon contents and a decrease in polar components contents (resins and asphaltene). Furthermore, thermal simulation experiments on low-mature saline shale show that the content of saturated hydrocarbons in the residual oil is high and remains stable and that the storage space is mainly mesoporous (>20nm) in the oil expulsion stage. However, in the gas expulsion stage, the content of saturated hydrocarbons decreases rapidly, and oil exists in mesopores (>20nm and <5nm). In general, gypsum is conducive to the development of pore space, the adsorption of hydrocarbons and the occurrence of saturated hydrocarbon, leading to large quantities of residual oil. The data in this paper should prove to be reliable for shale oil exploration in saline lacustrine basins.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Microscopic morphological characteristics and controlling factors of shale oil reservoirs in Da 'anzhai member, central Sichuan basin

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Keywords: Sichuan Basin,Da 'anzhai Member,shale oil,pore morphology,controlling factor

Lacustrine facies shale in Da 'anzhai Member is the key strata for shale oil exploration in Sichuan Basin.Pore characteristics are crucial to occurrence and flow of shale oil.In order to understand the microscopic pore characteristics, argon ion dissection, scanning electron microscopy and image processing software were used to extract the pores from high-resolution electron microscopy images, obtain the size and morphology parameters of different types of pore, such as pore diameter, circularity and aspect ratio,clear the microscopic pore morphology characteristics, in-depth analysis of the influencing factors of pore morphology change.The results show that :the pore types of black shale in Da 'anzhai are divided into two types (organic pores and inorganic pores) and seven kinds (organic pores, clay pores, grain edge pores, calcite intracrystalline pores, pyrite intercrystalline pores, feldspar intragranular pores and quartz intracrystalline pores), among which clay pores, quartz / calcite intracrystalline pores, grain edge pores and organic pores are the most common.The morphological characteristics of different types of pores are different,The pore diameter of organic matter is small, the circularity and the solidity values approaches 1. The aspect ratio is small. The the characteristics of interparticle of clay and particle margin pores are low circularity/solidity and high aspect ratio.Quartz/calcite intraparticle pore size is largecircularity/solidity is big . The aspect ratio is small. Shale components have a controlling effect on pore size and shape : pore size sorting shows inorganic pores (brittle minerals) > inorganic pores (plastic minerals) > organic pores ; the morphology of organic pores is close to that of brittle mineral-related pores (pores in calcite crystals), but it tends to be round ; clay pores show strip shape; statistics show that clay pores, grain boundary pores and organic pores have a trend of smaller pore size and better pore circularity.The difference of pore size and shape between undercompaction and compaction of brittle mineral-related pores is small,the pore size of clay pores and organic pores in undercompacted section is larger,and the directionality of clay pores in undercompacted section is poor, which tends to be disorderly arranged.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Oral Preferred

Pore structure and wettability of Bossier Shale, East Texas, United States: Insights from integrated porosimetry, scattering, and imbibition approaches

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Keywords: Pore geometry, wettability, (U)SAXS, spontaneous imbibition, Bossier Shale

Ascertaining the pore geometry and its wettability characteristics of tight shales is of great significance to reveal the mechanisms of occurrence, migration, and production of oil and gas in shale resources. Taking the core samples of Bossier Shales collected from Well A, East Texas, USA, as examples, the pore geometry and its wettability behavior in a broad nm-μm-scale pore spectrum were characterized based on the integrated techniques, including water immersion porosimetry (WIP), mercury intrusion porosimetry (MIP), (ultra)small-angle X-ray scatting [(U)SAXS], contact angle measurement, and liquid spontaneous imbibition (SI). Due to differences in sample size used, data interpretation, the detectable pore type (e.g., connected or not) and pore diameter ranges among different methods, sample porosities derived from WIP, MIP, and (U)SAXS are different, which range from 7.70-13.34%, 5.12-9.52%, and 2.48-6.44%, respectively. Therefore, a comparison of porosity derived from different methods needs to be handled with utmost care. Additionally, although (U)SAXS is an effective technique to detect both connected and non-connected pores, the fraction of non-connected pores could be underestimated by directly comparing the pore size distribution derived from (U)SAXS and MIP tests. Since sample sizes used for and pore information reflected by these two methods are different. Furthermore, the studied Bossier Shales exhibit various contact angle values and imbibition behaviors when using differently polarized liquids, revealing their mixed-wet characteristic. Comprehensively considering the differences in contact angle, imbibition slope, and imbibed liquid volume, three sub-categories of wettability behavior, with respect to more oil-wet (Samples B-12321, B-12360, B-12370, and B-12393), more water-wet (Sample B-12341), and intermediate mixed-wet (Samples B-12403 and B-12422), were qualitatively identified.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
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Classification of fine-grained sedimentary rocks in lacustrine basins and its petroleum geological significance

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Keywords: classification of fine-grained sedimentary rock, lacustrine basin, continental basin, rock classification, rock nomenclature, petroleum geology

Fine-grained sedimentary rock, as the most common type of rock in the surface of the earth's crust, is rich in oil and gas resources, which recently has become a research hotspot in the field of oil and gas industry. Because fine-grained sedimentary rocks are mainly composed of grains or crystals with a grain size less than 0.0625 mm, their composition is diverse and complex, leading to confusion in the use of rock type terms. This problem is particularly prominent in the fine-grained sedimentary rocks of the terrigenous lacustrine basins. In order to build a clear and consistent communication platform between researchers, this paper proposes a set of three-level naming and classification schemes, which are sedimentary structure, texture and composition, and salt component, respectively. First, it can be divided into laminated fine-grained sedimentary rock and massive fine-grained sedimentary rock based on the sedimentary structure. Secondly, it can be divided into seven main rock types based the sedimentary texture and composition. Finally, according to the salt composition, it can be divided into different rock types in different evolution stages of the continental lake basin. Based on the descriptive attribute as the standard of classification, the scheme is progressively described, which has the genetic significance of reflecting the provenance, hydrodynamic conditions and the evolution of saline lacustrine basin. The petrological classification of fine-grained sedimentary rocks in continental lacustrine basin is not only helpful to understand the stratigraphic attribution and evolution of source rock types and abundance in fine-grained sedimentary rock systems, but also helpful to predict the spatial distribution of geological "sweet spots". It is significant in theory and practice of petroleum geology such as oil and gas resource evaluation, scientific targets optimization, and improving the overall efficiency of petroleum exploration and development.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

The pore structure of shale oil reservoir of Jurassic Daanzhai member analyzed by low-pressure N2 adsorption experimentsnortheast Sichuan Basian:A case study of Well-LA1

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Keywords: Pore structure,Shale oil,Da'anzhai member,Sichuan Basin

To gain pore structure characteristics and controlling factors of lower Jurassic Da'anzhai shale oils reservoirs in Northeast Sichuan Basinthe samples from LA1 well were systematically analyzed by organic carbon (TOC) testing, field emission scanning electron microscope, X-ray diffraction (XRD) analysis and low-pressure N2 adsorption experiments. The results show that the shale mainly consists of clay minerals, quartz and calcite, with a small amount of dolomite, feldspar and pyrite. The pore types are dominated by clay intergranular poresfollowed by calcite intragranular pores, quartz intergranular pores, and minor organic pores. Low-pressure N2 adsorption experiments shows that the specific surface area of studied samples are 1.064 to 9.227 m2/g with an average of 4.949 m2/g. The pore volume is 0.003 to 0.016 cm3/g, and average 0.010 cm3/g. The contribution of mesoporous to the pore volume and specific surface area was slightly higher than macroporous. The pore volume and specific surface of shale are mainly contributed by clay intergranular pores, and positive correlation with clay minerals and quartz content. Organic matter has limited influence on pore volume and specific surface area of shale. Fractal characteristics of pore were mainly determined by clay minerals and the fractal dimension (D)ranges from 2.521 to 2.667, the average value is 2.586. The increase of quartz makes the pore structure complicated and resulting the increase of the fractal dimension. The selective filling of intergranular pores or intragranular pores by organic matter makes the pore structure simplified and the fractal dimension decreases with the increase of organic matter.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Oral Preferred

Diagenesis Types of Fine-grained Sedimentary Rocks in the Ek2 of Cangdong sag and Their Influence on Reservoirs

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Keywords: Fine grained sedimentary rocks, Diagenesis, Reservoir, Second section of Kongdian Group, Cangdong sag

Cangdong sag is an important oil-rich sag in Bohai Bay Basin, eastern China. Organic-rich fine-grained sedimentary rocks with a thickness of 400m are developed in the second member of Paleogene Kongdian Formation, which have good shale oil resource potential. However, there are few studies on diagenesis of fine-grained sedimentary rocks in Kong-2 member of Cangdong sag, especially the study on pore-increasing and pore-reducing mechanism based on diagenesis is insufficient, which restricts the fine evaluation of shale oil reservoir performance in different lithofacies and stratigraphic units.

Based on the qualitative analysis of core observation description, rock thin section analysis and scanning electron microscopy of Well G108-8 , Well GD12, and Well GX12X1 in Cangdong sag, combined with quantitative characterization techniques such as XRD whole rock analysis, XRD clay mineral analysis and energy spectrum analysis, it is clear that the diagenesis of fine-grained sedimentary rocks in the second member of Kong in Cangdong sag includes compaction, cementation, dissolution, metasomatism, clay mineral transformation and thermal evolution of organic matter. Because of the widespread development of cristobalite in Cangdong sag, a large number of cristobalite cements are filled in cracks or intergranular pores. The thermal evolution of organic matter is mainly characterized by internal hydrocarbon generation pores and marginal contraction joints. Under the scanning electron microscope, it is observed that the organic matter in the second member of Kong Formation in Cangdong sag is easy to combine with clay minerals to form 'organic matter-clay aggregate'. The conversion process of clay minerals can catalyze the hydrocarbon generation of organic matter, thus promoting the development of organic pores in the aggregate. Corrosion is common in the second member of Kong in Cangdong sag, mainly developed feldspar and carbonate rock corrosion. Under the influence of organic acids released from hydrocarbon generation of organic matter, corrosion pores formed by dissolution are more likely to be seen in unstable minerals in carbonate or clastic lamina adjacent to organic matter.

According to the data of porosity and permeability, pressure porosity and permeability, gas adsorption, high pressure mercury injection and nuclear magnetic resonance, the reservoir characteristics of Kong 2 member in Cangdong sag are analyzed. The results show that the porosity of the fine-grained sedimentary rock reservoir in Kong-2 member of Cangdong sag is between 0.24% and 9.35%, with an average of 2.95%. The permeability is between (0.01-25.3) × 10^{-3}μm^2, with an average of 0.613 × 10-^{3}μm^2, and the overall reservoir is ‘ultra-low porosity and ultra-low permeability’. Pores include inorganic pores, organic pores and micro cracks. The pore size is small, mainly micro-nano pores.

The influence of diagenesis on the reservoir of the second member of Kong Formation in Cangdong sag is complex, including the mechanism of increasing porosity and reducing porosity. The pore-increasing mechanism includes thermal evolution of organic matter, dissolution and clay mineral transformation;compaction and cementation are the main factors affecting the porosity and permeability of the reservoir, which belong to porosity reduction for the reservoir of Kong 2 member in Cangdong sag.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

An integration of 3D pore characterization and fluid-flow visualization of tight-gas sandstones: Lower Cretaceous Denglouku Formation, Songliao Basin, NE China

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Keywords: micro-CT, 3D pore characterization, fluid-flow simulation, tight-gas sandstones, Lower Cretaceous Denglouku Formation, reservoir quality

The development of High-resolution X-ray computed tomography (micro-CT) as a complementary tool to laboratory core tests has been widely applied to the study of petroleum geology. Micro-CT has been widely used as a non-destructive technique, allowing 3D imaging and analysis of internal features of various object such as tight-gas sandstone reservoirs. Reservoir quality controls the storage, distribution, and flow of fluids within tight-gas sandstone reservoirs, however, it remains difficult to predict. Micro-CT is performed on representative tight sandstone samples from the Lower Cretaceous Denglouku sandstones in the southern Songliao Basin to quantify the internal architecture in 3D and to carry out fluid-flow modelling. These sandstones are mainly fine- to medium-grained, braided fluvial and braid-delta feldspathic litharenites with the dominant diagenetic regime corresponding to mesodiagenesis. The quantitative 3D imaging and modelling by means of micro-CT provides a better insight of pore network connectivity and pore preservation characteristics at the pore scale. The pore-scale imaging and modeling provide information on volume of pore space and effectiveness of pore connectivity and, consequently, are likely to investigate the control of pore-lining clay minerals on pore preservation effectiveness and the role of pore network on reservoir quality of the studied sandstones. A combined integration of 3D pore characterization and fluid-flow visualization is compared with pore characteristics predicted by textural, depositional and diagenetic variations, and it can be found that these results are in good agreement, and may be useful for pore-to-core prediction of reservoir quality in tight-gas sandstones.

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Oral Preferred

Lithology and its influence on physical properties of silurian L1 member shale reservoirs in Zhaotong area, China

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Keywords: shale reservoir, fine-grained sedimentary rock, clay mineral,Silurian Longmaxi formation, Zhaotong demonstration area

A set of black shale sequence formed by marine shelf environment is developed in L1 member of Silurian Longmaxi formation in Zhaotong area, which is the key exploration and development section of shale gas in this area. In order to deeply and systematically understand the characteristics of organic shale reservoir in L1 member of Longmaxi formation in this area, the lithology and physical properties of shale reservoir were characterized by core and field specimen observation, thin section identification, scanning electron microscope analysis, x-ray diffraction element analysis (XRD), nuclear magnetic resonance experiment and nitrogen adsorption experiment. The study shows that the main mineral composition of L1 member fine-grained rock consists of quartz and feldspar, clay minerals, carbonate minerals and pyrite, the content of clay minerals is higher with an average value of 33.8% and the content of quartz is up to 30.5%.Fine-grained rock has developed texture, thick color depth, stable lithology and continuous thickness of 30 meters or more;The high quality shale reservoirs are mainly black thick layered organic-rich mixed shale, followed by organic-rich ash mixed shale and organic-rich siliceous shale.The shale develops nano scale organic pores, the average porosity of the shale reservoir is 2.437%, the average permeability is 0.00314mD, and the heterogeneity is strong. The low-porosity and low-permeability reservoirs are mainly composed of micropores and mesopores whose pore sizes are less than 10nm, in which micropores are the most developed.The organic-rich mixed shale in the L1 member is characterized by relatively high content of clay minerals, and the increase of clay mineral content makes the physical properties of fine-grained reservoir deteriorate.Quartz enrichment enhances the compaction resistance of fine-grained rocks and is beneficial to the preservation of micro nano pores.Authigenic chlorite and illite produce a certain amount of intercrystalline micro nano pores in clay minerals, which makes the pore throat curved and changeable and the pore structure complex.The large flake kaolinite and nano scale honeycomb imemonite mixed layer gradually transformed into curved flake illite. The edge of the flake became filamentous, which made the micro and nano scale pores more complicated and the overall physical properties deteriorated.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
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Analysis of pore characteristics and lithofacies characteristics of Qingshankou Formation Unit 1

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Keywords: Qingshankou Formation, shale oil, lithofacies

As a new energy source, shale oil has attracted great attention in China. The study of pore characteristics and controlling factors of shale can help to understand the pore system and its evolution of lacustrine organic-rich shale, which has guiding significance for the exploration and development of continental shale oil and gas in China.

In this study collect predecessors about late cretaceous the Qingshankou Formation Unit 1 of Songliao Basin on the basis of research results, the integrated use of geochemical data, core observation and micro of the microscopic observations of the Qingshankou Formation Unit 1 of Songliao Basin shale pore characteristics and its control factors were studied, and the pore evolution are discussed.

According to the average pore size, the lithofacies of the Qingshankou Formation Unit 1 of Songliao Basin is classified into massive medium-grained mudstone(MMM), discontinuous laminated medium-grained mudstone(DLM), discontinuous laminated fine-grained mudstone(DLF), continuous laminated fine-grained mudstone(CLF), continuous laminated medium-grained mudstone(CLM) and massive fine-grained mudstone(MFM). From the perspective of sedimentary structure and grain size structure, the average pore size of continuous lamellar and fine-grained mudstone is larger, which is the most favorable for oil and gas storage and migration. However, there is only one block fine-grained mudstone sample, so the conclusion may not be representative and this lithofacies is ignored. The lithofacies with the largest average pore size is CLM, followed by CLF.

The content of clay minerals in the Qingshankou Formation Unit 1 does not change obviously with depth. According to the clay mineral content, the lithofacies of the Qingshankou Formation Unit 1 is classified into MMM, CLM, CLF, DLF, MFM and DLM. From the perspective of sedimentary structure and grain size structure, the massive structure and fine grain structure are more favorable to the development of clay minerals. The influence of sedimentary structure on clay mineral content is less than that of grain size structure.

According to the quartz content, the lithofacies of the Qingshankou Formation Unit 1 is divided into DLF, DLM, MFM, CLF, CLM and MMM. From the perspective of sedimentary structure and grain size structure, the massive structure and medium-grain structure are favorable to the development of quartz.

Therefore, it can be preliminarily concluded that the average pore size of the CLM is the largest, and the corresponding quartz content is second only to that of the MMM. It can be concluded that the CLM is a lithofacies conducive to oil and gas storage and migration.

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Session T9-6: Fine-grained sedimentology and shale reservoir
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Temporal distribution of black shale in the geological past: sourcing from a global Deepdive knowledge base

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Keywords: Information Extraction, Deepdive, Knowledge base construction, Black Shale

The black shale, comprised of dark-colored, organic-rich sediment, is one of the most common sediments in the depositional systems of Earth through the geological time. Black shales usually deposited in relatively low-energy settings and represent important carbon burials that link with global climate changes. They are also important source rocks for conventional petroleum and gas as well as unconventional shale gas. Spatiotemporal distributions of black shales therefore have attracted increasing interests for sedimentologists and petroleum geologists. Here, we construct a high-resolution knowledge base of global black shales using a novel deepdive approach from published literatures worldwide. All PDF documents recording black shales are first collected and converted into text using an OCR method. Then, an NLP (Natural Language Processing) software-labeled glossary of terminology and tags is employed to recognize all possible candidate pairs from each sentence in these 7237 papers collected. Each pair and its features represent a factor graph model, and a series of heuristic procedures is operated to score the weights of each pair's features in order to test each candidate's likehood. The deepdive datasets achieve 92%/1004, 97%/1688, and 84%/1420 of accuracy/distinct pairs on location, age, and strata, respectively, with probability >90%. The global dataset deciphers that black shale units are commonly present from the Archean to Cenozoic. Of these, the Cretaceous records the highest occurrence frequency of black shale, followed by the Devonian and Cambrian. Geologically, most of the deep-time black shales deposited in the North America, Europe, and China.

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
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Sequence Stratigraphy and Reservoir between the Organic-rich Fine-grained Siliciclastic and Carbonate System

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Keywords: Fine-grained deposits, shale, reservoir, sequence stratigraphy

Fine-grained deposits are characterized by a particle size of less than 1/16 mm (62.5 μm), including mudstone, shale, marl, siltstone, and other deposits with fine-grained composition. Mineral components mainly include clay minerals, feldspar, quartz, carbonate minerals, and organic matter. According to the carbonate presence, the organic-rich fine-grained system can be divided into siliciclastic-rich and carbonate-rich deposits. In order to better predict the reservoirs associated with the depositional processes in time and space. We identified the 5th to 3rd order sequence boundaries in the typical lacustrine to marine fine-grained rocks in China, North America, and South America based on the detailed core description, geochemical, mineral, and petrophysics analysis, logging curve motif, and seismic data. The rock properties in the sequence stratigraphic framework show that the transgressive systems tract (TST) and the early highstand systemS tract (EHST) of the lacustrine to marine siliciclastic fine-grained deposits are characterized by high uranium gamma value, high organic matter content, and high biogenic quartz content, with the highest value corresponding to the maximum flooding surface (MFS). For the carbonate-rich fine-grained deposits, the TST and EHST intervals are characterized by low gamma, low organic matter content, low detrital quartz content, and high carbonate content. The common feature of both types of fine-grained deposits is the condensed section corresponding to the maximum flooding surface is characterized by the lowest content of clay minerals. Both the TST and EHST for the siliciclastic and carbonate-rich fine-grained systems have the best reservoir quality with highest fractability index. Common high-quality reservoirs include heterogeneous organic-rich and siliceous shale and organic-poor fine-grained carbonate rocks.

Reference

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Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
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Development Characteristics and Formation Mechanism of Tectonic Fractures in Continental Shale Reservoirs of the Permian Fengcheng Formation in Mahu Sag, Junggar Basin, Northwestern China

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Keywords: shale oil, reservoirs, tectonic fractonics

The maximum burial depth of the alkaline lacustrine shale of the Lower Permian Fengcheng Formation in Mahu Sag of Junggar Basin is more than 5000m, which has great potential for shale oil exploration and development. Tectonic fractures are widely developed in continental shale, which can provide important storage space and main seepage channels for shale oil reservoirs. In order to guide the exploration and development of this area, the genetic types and development characteristics of tectonic fractures were analyzed by comprehensively utilizing various data of outcrops, drilling cores, thin sections and imaging logging. On this basis, combined with the evolution of tectonic stress field in the Mahu Sag and formation sequence of fractures, using fluid-inclusion analysis of fracture filling, calcite U/Pb dating, and burial history analysis, the formation mechanism of tectonic fractures is clarified. The result shows that tectonic fractures in the study area can be divided into transformational shear fractures, bed-parallel shear fractures and intraformational open fractures according to their origin. High dip-angle tectonic fractures with dip-angles of nearly 90° are the most abundant in shale oil reservoirs. Due to the small thickness of rock mechanical stratigraphy of shale, the scale of tectonic fractures is generally small with the height of mostly less than 25cm. The density of tectonic fractures is mostly distributed below 2/m. Tectonic fractures with high density appear around faults because of stress concentration disturbed by fault movements. Tectonic fractures were determined to be formed at the end of the Permian and the end of the Triassic. In the late Hercynian movement, the fractures with the strike of NW-SE and NNW-SSE were formed due to NW-SE compression, with fluid-inclusion homogenization temperatures approximately 70 to 100°C. During the Indo-China movement, the fractures with the strike of NNW-SSE and NNE-SSW were formed by the near south-north compression, with fluid-inclusion homogenization temperatures approximately 110 to 130°C. It is observed in cores and thin sections that the unfilled tectonic fractures have good oil-bearing property, and the filled tectonic fractures are reopened due to late dissolution or tectonic activity, which has good effectiveness. The formation time of the two-stage structural fractures coincides with the charging time of shale oil, which is the key factor for the enrichment of shale oil.

Reference

Tectonic Fractures, Formation Mechanism, shale oil, Mahu Sag, Fengcheng Formation

Scientific Themes: Theme 9. Resource Sedimentology
Session T9-6: Fine-grained sedimentology and shale reservoir
Presentation Preference: Oral Preferred

Evolution of pore structures during the entire hydrocarbon generation process of Marine Carbonate-rich shale: the inspiration from thermal simulation experiments

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Keywords: Carbonate-rich shale,pore evolution,thermal simulation experiment

The immature marine Carbonate-rich shale(TOC=6.13%,VRo=0.59%) is selected for s series of thermal simulation experiments in a Semi-enclosed pyrolysis system from immature to overmature stages.CO2 adsorption and N2 adsorption tests were carried out on rock samples at different evolution stages, quantitatively characterized their pore structure characteristics, and studied the coupling relationship between the evolution process of organic matter hydrocarbons and the evolution of pores.The results show that with the increase of the simulated experimental temperature and pressure, the yields of total oil, expelled oil, retained oil and hydrocarbon gas showed different evolutionary characteristics, and the total oil yield reached a peak at Ro=0.97%, which was also the maximum storage period of retained oil.The organic matter hydrocarbon generation-rentention-expilsion and diagenesis interacted with the pore evolution of the organic shale from beginning to end and the mechanism of action at different stages of thermal evolution was different. Mesopore and macropore have a greater influence on the total pore volume, more than 70% of the total specific surface area is contributed by micropores and mesoporous.And there is a certain degree of transformation between different scale pores in the organic matter diagenesis-hydrocarbon formation process. The research results are helpful to understand the formation and evolution characteristics of carbonate-rich shale oil and gas, and can provide simulation experimental theoretical support and guidance for the exploration and development of deep shale oil and gas.

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Characteristics and enrichment mechanism of Platinum group elements in black shale of Early Silurian Longmaxi Formation in southwestern Sichuan Basin

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Keywords: Longmaxi formation,PEG,Enrichment mechanism

In order to explore the content characteristics and enrichment mechanism of platinum group elements in the black shale of Longmaxi formation of Early Silurian in the southwest margin of Sichuan Basin, the content of platinum group elements in the black shale of Longmaxi formation of Silurian in YNP section and MCP section was measured by HR-ICP-MS, and its enrichment mechanism was discussed in combination with the characteristics of major elements, trace elements and petrology. The study shows that the black shale PGE of Longmaxi formation in the southwest margin of Sichuan Basin shows a Pt Pd distribution model with relatively strong enrichment of Pd and Pt and relatively strong loss of Ir. According to the analysis of Ir content, Pd/PtPd+Pt/Os+Ru+Ir and It/Pt-Pd/Pt parameters, it is considered that the black shale PGE in the study area does not have extraterrestrial material sources. According to the content characteristics of rare earth elements, the enrichment coefficient of trace elements, Pd/IrAl_2O_3-SiO_2Pt-PdIr/Pd-Pt/Pd and other parameters, combined with the comparison of PGE distribution patterns of black shale platinum group elements and typical hydrothermal geological bodies in the study area, it shows that PGE in the study area is closely related to submarine hydrothermal activities. According to the correlation between PGE and environmental parameters in the study area, it indicates that redox state is the main controlling factor of PGE enrichment. The difference of sedimentary facies and sea level fluctuation are the main reasons for the difference of PGE main controlling factors between YNP section and MCP section. In addition, TOC in the study area has a good positive correlation with redox parameters, and PEG can be used as a discriminant parameter for redox state of water and enrichment of organic matter.

Theme10

Sedimentary Geochemistry

Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment

Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Source rock characteristics and sedimentary environment of Qingshankou Formation outcrop in the southeast of Songliao Basin

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Keywords: Songliao Basin, Qingshankou formation, Source rock

The research results of source rocks of Qingshankou Formation based on core analysis in Songliao basin are rich, but few people pay attention to the characteristics of field outcrop source rocks and sedimentary environment. The characteristics and sedimentary environment of field outcrop source rocks of Qingshankou Formation in the southeast of Songliao basin are analyzed using geochemical research methods based on field outcrop, such as lithology fine description, whole rock microscopic examination, rock pyrolysis analysis, constant and micro analysis, etc . The results show that the thickness of Qingshankou Formation exposed in Songliao basin is 10-35m. It is a set of lacustrine stratigraphic unit rich in biological fossils, with gray black mud shale as the main framework and thin argillaceous dolomite, ostracod and stromatolite dolomite as the secondary framework. The lithology is mainly grayish green and grayish black mud shale, with relatively developed foliation, rich in biological fossils such as ostracods, leaflimb media and plant debris; The source rocks are dominated by planktonic algae, followed by sapropel amorphous body, type I kerogen, followed by type II 1, with medium poor hydrocarbon generation potential. The pyrolysis parameter w (TOC) of Qingshankou Formation source rock is 6.8-7.6%, Tmax is 430-441 ℃, S1 is 0.95-1.26mg/g, S2 is 32.68-69.17 mg / g, RO is 0.49% - 0.55%, which is located near the oil generation window and has good hydrocarbon generation potential. The paleoclimate index parameter w (SR) / w (Cu) of the common trace element combination parameter is between 3.5-11, the paleosalinity index parameter w (SR) / w (BA) is between 0.25-0.61, and the redox environment index parameter w (V / (V + Ni)) is between 0.76-0.79, indicating that the set of source rocks was formed in the freshwater brackish water reduction environment under the warm tidal and humid climate. The research results can effectively guide the exploration deployment of Gulong shale oil in Songliao basin.

Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Salinization origin and paleoenvironment conditions of the Permian Lucaogou Formation in the southern Junggar Basin, NW China

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Keywords: Early Permian, paleoclimate, arid, salinization, Central Asian Orogenic Belt

The Early Permian is regarded as a critical period for marine to continental transition of the Junggar Basin. Lacustrine organic-rich shale successions were deposited in the Lucaogou Formation in the southern Junggar Basin (SJB) at that time. Although the paleoenvironmental reconstruction of the Lucaogou Formation has been discussed from diverse perspectives, the genesis of lacustrine salinization remains controversial. Revealing its depositional environment and salinization origin are vital for shale oil exploration in this succession. This study investigated the Lucaogou Formation in three sags from the SJB, namely the Chaiwopu Sag, the Fukang Sag, and the Jimsar Sag. Paleoclimatic indicators (i.e., CIA values and Sr/Cu ratios) show that the Lucaogou Formation was generally deposited under semiarid to arid conditions, among which the Jimsar Sag was more arid than the other two sags. Meanwhile, V/Cr and V/(V+Ni) ratios illustrate dysoxic-anoxic conditions prevailing during its deposition. Sr/Ba and B/Ga ratios suggest brackish-marine salinity levels in the three sags, among them the Jimsar Sag exhibited saltier conditions than the other two sags. Provenance indicators suggest that samples from the Fukang and Chaiwopu sags were mainly derived from felsic to intermediate igneous rocks, while samples from the Jimsar Sag were mainly derived from felsic rocks with a certain sedimentary recycling process. We propose that the lacustrine salinization of the Lucaogou Formation is attributed to marine transgression, which both explain the increasing of paleosalinity and deepening of lake basin during its deposition. The SJB was composed of a cluster of lakes which were relatively independent and rarely connected with each other. However, seawater inpouring and lake levels rising rapidly may have coalesced to form a giant paleo-lake when marine transgressions took place.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
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The influence of Cretaceous climate change on organic matter enrichment in the Cote d'Ivoire Basin

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Keywords: Palynology, elemental and organic geochemistry, organic sources, paleoenvironment, marine source rocks

The Cote d'Ivoire Basin is a typical transform margin basin in the northern Gulf of Guinea in West Africa. After the marine incursion caused by the separation between South America and Africa, marine source rocks of the Cote d'Ivoire Basin began to develop from the Late Albian. Based on the evaluation of source rock quality and thermal maturity of organic matter, the Upper Albian-Turonian organic-rich marine shales were suggested as important marine source rocks in the studied area. Data of palynology, elemental geochemistry, and organic geochemistry were used to figure out the main controlling factor on the organic matter enrichment and the development of high-quality marine source rocks during the Late Albian-Turonian. The variations of the chemical index of alteration (CIA) and the relative abundances of *Ephedripites* pollen and *Classopollis* pollen demonstrate that the climate was relatively arid during the Late Albian, and predominantly warm and humid but intermittently arid during the Cenomanian-Turonian. The element ratio (Calcium /(Calcium+Iron) and biomarker parameters (Pristane/Phytane and Gammacerane / C_{30} αβ hopane) suggest that the Upper Albian-Turonian high-quality source rocks were deposited under anoxic environments with salinity stratification. The high values of Phosphorus / Aluminum and (2-methylhopane + C_{25} highly branched isoprenoids) / C_{30} αβ hopane indicate high primary productivity due to the flourishing of cyanobacteria and diatoms in the marine environment. In addition, marine dinoflagellate input is indicated by a detailed investigation on calcareous phytoplankton. The low values of Titanium / Aluminum and (C_{19}+C_{20})/C_{23} tricyclic terpanes reflect decreased terrigenous detrital matter (TDM) input during the deposition of high-quality source rocks. Therefore, low TDM input, reducing environment, and high productivity were controlling factors on the organic matter enrichment. According to the synchronous variations of climate, TDM input, salinity and reducing condition of the water column, and bio-productivity, it is proposed that climate change played an important role in organic matter enrichment by influencing the freshwater supply and TDM input. Under the relatively arid climate, less rainfall could lead to less freshwater influx and decreased TDM input. Therefore, inorganic nutrients and organic matters were less diluted, thus boosting the flourishing of aquatic organisms. The small amount of freshwater inflow and TDM input in combination with the stronger evaporation could facilitate the salinity stratification of the water column. This was beneficial for organic matter preservation.

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Effective parameters for the redox condition of high thermal maturity black shale: A case study of Sinian–Cambrian fine–grained sediments in the Sichuan Basin, SW China

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Keywords: High thermal maturity, fine–grained sediments, redox conditions, Sinian–Cambrian system

The redox conditions during the formation of the fine–grained sediments comprise one of the factors affecting the content of organic matter. The Sinian–Cambrian system in the central Sichuan Basin has experienced unusually high thermal maturity, with equivalent vitrinite reflectance exceeding 3.0% (Wei *et al*., 2017; Qiu *et al*., 2021). For fine–grained sediments (such as the QZS and DY–3 Fm.), it is an important research topic to evaluate which parameters remain effective for the redox condition. Many studies have shown that the redox backgrounds of the QZS and DY–3 Fm. are significantly different (Gao *et al*., 2017). Based on organic geochemistry and inorganic geochemical analyses (trace elements, TEs), the parameters of Pristane (Pr) and Phytane (Ph), Ph/nC18, Pr/nC17, carbon isotopes ($\delta^{13}C$), V/(V+Ni), Th/U, and TEs enrichment factors (TEs–EF) in the QZS and DY–3 Fm. were compared. The results showed that high thermal maturity resulted in similar ratios of certain organic geochemical biomarkers (such as the Pr/Ph), which could not be well distinguish redox conditions exactly. However, the correlation shown among the ratios between $\delta^{13}C$ values and some TEs ratios can still help distinguish between the QZS Fm. (anoxic) and DY–3 Fm. (dysoxic–suboxic).

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Scientific Themes: Theme 10. Sedimentary Geochemistry
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Influence of paleo-sedimentary environment on shale oil enrichment in lacustrine basins: A case study of Shahejie Formation in Raoyang Sag, Bohai Bay Basin

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Keywords: Paleo-sedimentary environment, Shale oil enrichment, Elemental geochemistry, Shahejie Formation, Raoyang sag
Paleo-sedimentary environment, Shale oil enrichment; Elemental geochemistry; Shahejie Form

A set of high-quality hydrogen-rich shale was found in the upper third sub-member of Shahejie Formation (Es_3^U) in Raoyang sag, which has the geological conditions for shale oil enrichment. However, the formation paleosedimentary environment of the shale oil sweet spot reservoir is not systematically studied. Based on petrology, organic geochemistry, and elemental geochemistry analysis, the control effect of the characteristics of paleosedimentary environment on lacustrine shale oil enrichment is revealed and the shale oil enrichment model is established in this paper through the comprehensive study of the occurrence and migration of elements in different sedimentary facies areas. The results show that: 1) Carbonate-rich, calcareous and clay-rich shales are well developed in the study area, and the total organic matter content is high enough to meet the shale oil enrichment standards; 2) The parameters of V/(V+Ni), δU, Sr/Cu, Rb/Sr, Zr/Rb, Zn/Al, and Sr/Ba indicate that deep and semi-deep lacustrine deposits are developed in the target strata, which were characterized by strong reduction, semi-drought, high paleoproductivity, and brackish water. 3) Lake water evaporates in a hot and dry climate. And brief transgression events led to the increase of water salinity, the outburst of salt-eating organisms such as algae and nutrients from the provenance provided the material basis for the enrichment of organic matter. The quiet and strong reduction paleowater far away from the provenance provides good preservation conditions for the enrichment of organic matter. 4) The Mg^{2+} provided by transgression moved towards the center of the lake basin under the action of gravity, and the low magnesium and calcium-rich saline environment were conducive to the occurrence of penecontemporaneous dolomitization. Calcite and aragonite laminae were generated in the center of the sedimentation of the lake basin and interbedded vertically with the organic matter carried by fine-grained materials. 5) The areas where carbonate-rich, calcareous, and clay shales with rich organic matter developed are relatively developed are sweet spot reservoir areas of shale oil, which are mainly located in the center of the lake basin. Through the above studies, the shale oil enrichment model based on lithofacies and paleosedimentary environment is established, which can guide the shale oil exploration and development in the Raoyang depression successfully.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Source rock deposition of the Upper Permian Longtan Formation in response to co-evolution of environments and organisms controlled by tectonic subsidence and transgression, Sichuan Basin, SW ChinaEvidences from organic and inorganic geochemistry

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Keywords: source rock, organic matter input, redox conditions, sedimentary environment, organic facies

The upper Permian Longtan Formation from the Sichuan Basin, one of the most petroliferous basins in China, were analyzed with sedimentological and geochemical techniques to characterize the lateral source rock heterogeneities, to reveal the environmental and ecological changes and to construct depositional models for marine source rocks under the influence of geological events including the tectonic movement induced by the Emeishan mantle plume activities and the marine transgression during the late Permian. The Longtan Formation displays widely variable lithology, stable carbon isotope composition of kerogen biomarker composition across the basin, suggesting changes in organic facies from marine to marine-continental transitional sediments. The Longtan Formation has distinctly different organic and inorganic geochemical indices, which indicate alkaline-saline marine environment with anoxic bottom water conditions and type I-II kerogens dominated in the northeast (higher ETR, lower 4-/1-MDBT, lighter $\delta^{13}C_{kerogen}$, lower 1,7-/1,9-DMP, lower 2,6-/2,10-DMP), acidic freshwater environments with dysoxic bottom water conditions and type II-III kerogens dominated in the southeast (lower ETR, higher 4-/1-MDBT, heavier $\delta^{13}C_{kerogen}$, higher 1,7-/1,9-DMP, higher 2,6-/2,10-DMP). Such environmental changes corresponded to changes in tectonic subsidence and transgression process, from the rapid subsidence and early marine transgression in the northeast to slow subsidence and late transgression in the southeast and resulted in synchronous changes in terrigenous materials input, phytoplankton contribution and primary productivity. The co-evolution of environment and organisms controlled by tectonic movement and transgression process accounted for the deposition and distribution of source rocks with distinctly different geological characteristics. Most basins experienced the change from marine to continental deposit. The geochemistry indices used and the model constructed in this paper may have important implications for organic facies classification and source rock prediction in other basin with similar geological setting, especially for the source rocks with high-over maturity.

Scientific Themes: Theme 10. Sedimentary Geochemistry
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Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Characteristics of Paleogene Source Rocks and Fine Oil-source Correlation in Liaohe Western Depression

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Keywords: geochemical characteristics, sedimentary environment, oil-source correlation, biomarker

In order to clarify the differences in source rock characteristics and investigate the source of crude oil in different areas in the Liaohe Western Depression, the TOC, rock pyrolysis, Ro, and saturated hydrocarbon gas chromatography-mass spectrometry (GC-MS) are adopted to analyze the characteristics of source rock and crude oil, and the fine oil-source correlation is carried out. Results indicate that the Es4 source rock of Liaohe Western Depression is developed in the north (about 700 m), with high organic matter abundance but low maturity (<0.5%). The organic matter of Es4 source rock was dominated by terrestrial higher plants, mixed with a small amount of lower aquatic organisms, and the sedimentary environment was a partially reduced saline-brackish water environment; The Es3 and Es1 source rocks of Liaohe Western Depression are developed in the south with high abundance and maturity. The organic matter was mainly derived from aquatic organisms and deposited in the oxidized freshwater environment. Results show that the crude oil in the northern part comes from the Es4 source rock. The crude oil in the central part mainly comes from the Es3 source rock (the crude oil in the Lengjia area comes from the Es4 and Es3 source rock). The crude oil in the southern part comes from the Es3 and Es1 source rock.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Organic matter accumulation of the Lower Cretaceous shale in the southern Songliao Basin (NE China): Implications from geochemical analyses

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Keywords: Shale, redox, paleoclimate, organic matter enrichment

The Cretaceous period was a time of long-term variable climates with relatively warm temperatures resulting from high atmospheric greenhouse gas contents (Skelton et al., 2003). During this time, terrestrial sediments were continuously deposited within the Songliao Basin which record the paleoenvironmental and paleoclimatic information. The Songliao Basin is well-known as one of most prolific petroleum basins in China, and contains several organic-rich shale successions in the lower Cretaceous strata (Xu et al., 2019). Reconstruction of the paleoclimate and paleoenvironment is of great significance to understand lacustrine organic matter accumulation under the Cretaceous greenhouse climate conditions. Paleoenvironments and mechanisms of organic matter enrichment were investigated by lithology, mineralogy, major element and trace element geochemistry in the Lower Cretaceous Shahezi Formation which is divided into the first member (Ks1) and second member (Ks2). Redox proxies such as U/Th, V/(V+Ni) and V/Cr demonstrate that the Lower Cretaceous Shahezi shale was mainly deposited under dysoxic to anoxic condition. And paleoclimatic indicators (CIA values, Rb/Sr and Sr/Cu ratios) show that the Shahezi Formation was generally deposited under semiarid to arid condition. An obviously increasing of CIA and Rb/Sr ratios can be identified from bottom to top, suggesting a warmer paleoclimate. Ks1 is characterized by low terrigenous input, high salinity level, arid climate and anoxic water column condition which are stratified. During deposition of Ks2, the climate became somewhat warmer and more humid, which was marked by higher intensity of chemical weathering, higher terrigenous input, lower salinity and dysoxic bottom water condition. Relationship between geochemical proxies and TOC suggests that salinity and redox condition are critical factors controlling the enrichment of organic matter. While high terrigenous input may result in a dilution of organic matter. Anoxic water column, high salinity level and low terrigenous input are conductive to preservation of organic matter.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment
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Coupled weathering-hydrothermal process and its geological significance during the Early Cambrian

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Keywords: Paleo-weathering, Hydrothermal Activity, Early Cambrian, Paleo-productivity, Photic Zone Euxinia, Tarim Basin

To discuss paleo-weathering, hydrothermal activity, and their influence on organic matter (OM) enrichment, samples from the Lower Cambrian Yuertusi Formation black rock series in the Northwest Tarim Basin were analyzed for total organic carbon (TOC), rock-eval, biomarkers, carbon isotope of kerogen ($\delta^{13}C_{ker}$), sulfur isotopes of pyrite, major & trace elements, and rare elements. The combined weathering and hydrothermal processes enhanced the deposition of ^{13}C-depleted organic-rich shale with $\delta^{13}C_{ker}$ lower to -36‰ in the Lower Cambrian, according to the findings. Plankton blooms were driven by abundant teleorganic nutrients (e.g., Fe) and terrigenous clastics brought into the sea by paleo-weathering, which enhanced the adsorption and sink of OM in water, laying a material basis for the formation of organic-rich source rocks (TOC, up to 29.8%). Hydrothermal activity brought abundant reducing gases (H_2S) and hydrothermal silicon into the sea. The former induced a sulfur-anoxic sedimentary environment and photic zone euxinia, which improved sedimentary OM preservation. However, the latter may dilute the amount of sedimentary OM to some extent, resulting in the relatively organic-poor siliceous shale rocks. Paleo-productivity was high during the time of significant paleo-weathering and weak hydrothermal activity, whereas hydrothermal silicon dilution was minimal, promoting the production of black organic-rich shales. Paleo-productivity was low during a period of intensive hydrothermal activity and mild paleo-weathering, but hydrothermal silicon dilution was significant, resulting in the formation of organic-poor siliceous shales. The combined weathering-hydrothermal process thus regulated the formation of the Lower Cambrian source rocks in the Northwest Tarim Basin. Furthermore, the aryl isoprenoids-based oil-source correlation revealed that the source rocks formed during this linked process made significant contributions to the Tarim Basin's vast hydrocarbon resources. It will serve as a useful guide for future deep petroleum exploitation in the Tarim Basin and other similar basins throughout the world.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Geochemical Characteristics of the Middle Devonian Dacaozi-Tanshanping Shale Strata in the Yanyuan Basin, Southwest China

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Keywords: Organic matter accumulation, Preservation, Devonian, Yanyuan basin, China

How the geochemical characteristics of organic matter shale for the carbonate platform facies remain uncertain, which restricts an integrated reconstruction of the model of organic matter accumulation and preservation. Here, we present new results from element geochemical fingerprinting and integrated analyses of paleoclimate, paleoproductivity, paleoredox environment, and terrigenous input of the targeted Middle Devonian Tanshanping and Dacaozi Formations in the Ninglang-Yanyuan Basin, Southwest China. It is worth noting that although the carbonate platform connects with the open sea partially, the redox environment will not be completely controlled by relative sea level variations. Specially, the paleoclimate, paleoproductivity, and paleoredox conditions are the main controlling factors of the accumulation and preservation of organic matter. In view of the paleoclimate indexes, we suggest that both a relatively warm- humid climate characterized by intensifified chemical weathering conditions and a higher terrigenous input are identifified as two major drivers forcing the reductive environment in the sedimentary waterbody. Finally, a comprehensive model is established for providing new insights into the mechanism of organic matter accumulation and preservation for the carbonate platform facies. The paleoredox environment, paleoproductivity, paleoclimate, and terrigenous input are believed to have exerted a very considerable force on reconstructing the model of organic matter accumulation and preservation for the carbonate platform facies. Specially, the coupling interactions between the paleoproductivity and redox condition are thus also stressed. We found that the preservation condition is much more important than the paleoproductivity, resulting in the degree of organic matter enrichment. Even if the paleoproductivity of a sedimentary waterbody of a depositional period of the Dacaozi Formation was higher, the TOC concentrations were relatively low due to the poor preservation condition by fall of the sea level and increase of the terrigenous input. In another aspect, the better preservation condition of the Tanshanping Formation makes the TOC concentrations higher in the case of lower paleoproductivity in the sedimentary waterbody.

Scientific Themes: Theme 10. Sedimentary Geochemistry
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Presentation Preference: Oral Preferred

Coal facies and hydrocarbon generation potentials of the Paleogene coal-bearing series in Xihu Depression, East China Sea Shelf Basin

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Keywords: Coaly source rock, coal maceral, hydrocarbon generation potential, Paleogene, Eocene

Xihu Depression is situated in eastern Zhedong tectonic belt of the East China Sea Shelf Basin, and has great exploration potential for oil and gas resources. The Pinghu and Huagang Formations of the Paleogene are the coal-bearing series containing major source rocks in this Depression. The lithological types of the Pinghu and Huagang Formations include sandstone, siltstone, mudstone and coal. The Pinghu Formations was deposited in the tidal-influenced delta and tidal flat environment, while the overlying Huagang Formation was deposited in the fluvial, meandering river delta and lacustrine environment. The maceral contents of the coals were statistically counted by coal petrology, and based on the maceral compositions, the coal facies in different environments were analyzed. The results showed that although vitrinite is the dominant contributor to macerals with an average content of
90.1%, the exinite accounts for an obviously high level compared to the other common coal samples, attaining to 8.4% on average. In contrast the average content of inertinite is only 1.4%. The exinite macerals make a great contribution to both total hydrocarbon and liquid hydrocarbon though the content is low. The contribution of vitrinite, exinite and inertinite for total hydrocarbon are 63.21%, 36.46% and 0.33%, respectively. The contribution of vitrinite and exinite for liquid hydrocarbon are 40.95% and 59.05%, respectively. Four coal facies were recognized, including intermittent dry swamp facies, shallow water swamp facies, flowing water swamp facies and open water swamp facies. The hydrocarbon generation potential of the coal deposited in different depositional environments was determined by means of parameters including the organic matter abundance, organic matter type, and
organic matter maturity. The results showed that the TOC varied from 30% to 74.99% with an average of 44.16%, indicating a medium to high organic matter abundance. The “S1+S2” ranged from 42.76mg/g to 165.76mg/g with an average of 97.86 mg/g, demonstrating a high hydrocarbon generation potential. The organic matter types of the coals were dominated by type III and type III2 evidenced by relatively low HI and H/C value. The Ro values ranging from 0.31% to 1.41%, revealing that most of the coals were in the mature stage. The tidal flat and tide-influenced delta environments were developed in association with the favorable coal facies including intermittent dry swamp facies, shallow water swamp facies and thus have the best hydrocarbon generation potential.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
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Presentation Preference: Oral Preferred

Paleoenvironment controls on the enrichment of organic matter in the Middle Devonian Givetian shale, Youjiang Basin, South China

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Keywords: Shale, Sedimentary environment, Organic matter enrichment, Middle Devonian Givetian stage, Youjiang basin, South China

To reveal the shale processes of the organic matter enrichment in the Dian-Qian-Gui area during the middle Devonian Givetian Stage, the core samples from the slope regions and the basin regions were selected for the study. The sedimentary environment of shale was analyzed by means of petrology, multi-scale mineralogy, organic geochemistry and elemental geochemistry, using total organic carbon (TOC), X-ray diffraction (XRD), major elements, trace elements, optical microscope and field emission scanning electron microscope. The indicators of V/Cr, V/(V+Ni), V/Sc, V_{EF}, and the degree of pyritization (DOP) showed that the slope water columns were in the rich oxygen conditions and the basin water columns were in the poor oxygen environments. The values of Sr/Ba, Si_{bio} and Ba_{bio} indicated that the low salinity of the northern water columns and the productivity levels were increased by the blooming algae. The low TiO_2 and Al_2O_3 contents in the basin shale, indicating a low terrestrial detrital influx. The deposition environment was divided into four stages based on the analysis results. During Stage 1, oxic water columns were wide-spread, and dysoxic water columns were locally distributed; dysoxic water columns were reduced, and oxic water columns were expanded during Stage 2; the transgression had led to a large distribution of dysoxic-anoxic water columns during Stage 3; the depositional environment was changed to an oxygen-rich condition with the marine retreat during Stage 4. Laterally, the TOC contents are higher in northern basin water columns than in southern basins. The correlations between the indicators and the TOC contents indicate that anoxic environments, high palaeoproductivity, and low terrestrial debris flux are conducive to organic matter enrichment. The anoxic environment is the main controlling factor of shale organic matter enrichment. Accordingly, a model is proposed for the organic matter enrichment on the paleogeographic pattern of the platform-basin interval during the Givetian Stage.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment
Presentation Preference: Oral Preferred

Sedimentary environment characteristics of transitional shales in the lower member of Longtan Formation, Western Guizhou: Insights into the influence of Emeishan large igneous province and organic matter accumulation

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Keywords: Longtan Formation, transitional shale, sedimentary environment, lagoonal shale, Emeishan large igneous province

The marine-continental transitional shale in the upper Permian Longtan Formation is not only an important target of shale gas exploration and development, but also an important research object of extreme paleoenvironmental events in Middle-Late Permian. Based on X-ray diffraction (XRD), polished sections, scanning electron microscopy (SEM), total organic carbon content (TOC) and elemental geochemistry, the paleoenvironment characteristics of the transitional shale in the lower member of Longtan Formation in Western Guizhou were studied, including primary productivity, paleo-redox conditions, paleoclimate, provenance. The influence of Emeishan large igneous province on sedimentary environment and the organic matter enrichment mechanism of transitional shale are analyzed. The results show that in the Middle-Late Permian transition, with the Dongwu movement and the eruption of Emeishan basalt, the paleogeographic pattern of high in the west and low in the east was formed in the Upper Yangtze region. The Western Guizhou was in a marine and continental transitional environment, and the lower member of Longtan Formation was deposited in a marginal tidal flat-lagoon environment. Influenced by seawater and rivers, sand and mud were interbedded frequently, and the organic matter content in shale were generally more than 5%. Longtan shales were deposited in a complex environment with warm and humid paleoclimate, anoxic-reducing, brackish to saline bottom water, high terrigenous detrital input and high deposition rate. The weathering products of Emeishan basalt were the main source of longtan Formation. The mineral and element composition characteristics of shale are closely related to Emeishan basalt. In addition, transitional shale was accompanied by a small amount of volcanic ash and hydrothermal input, and the elements carried by the hydrothermal increased the salinity of water, and was conducive to the anoxic-reducing environment. In general, the organic matter enrichment in transitional shale of the lower member of Longtan Formation is closely related to sedimentary facies. The shale deposited in mire has the highest organic matter content (>20%), followed by the shale deposited in tidal flat (10%). The organic matter content in lagoonal shale is the lowest (5%). Lagoonal shales are dominant in the lower member of Longtan Formation, and their organic matter enrichment mechanism is mainly “preservation model”. The lagoonal shales were deposited in a warm and humid, brackish-saline water, anoxic-reducing environment, with good preservation conditions for organic matter. The primary productivity was low and organic matter mainly came from higher plants. However, hot and humid climate strengthened terrestrial weathering and increased terrigenous detritus, diluting the organic matter content in shale. Higher deposition rate reduced the decomposition time of organic matter and was beneficial to the preservation of organic matter.

Scientific Themes: Theme 10. Sedimentary Geochemistry
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Presentation Preference: Oral Preferred

Lacustrine organic carbon burial in response to the rift sequence evolution and palaeoclimate changes across the Early Cretaceous Oceanic Anoxic Events

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Keywords: black shale, organic matter, rift sequence, palaeoclimate, Cretaceous, oceanic anoxic events

The Cretaceous rift lacustrine basins comprise extensive deposits of organic-rich black shales and archived high-resolution information from terrestrial climate changes. An integrated sequence stratigraphical and geochemical study was conducted on the Lower Cretaceous (Middle Aptian–Lower Albian) Shahezi Formation (K_1sh_{2-1}) rocks in Songliao Basin, northeastern Asia, to reveal the variation of lacustrine organic carbon sequestration in relation to rift stratigraphic evolution and palaeoclimate changes. The targeted layer was divided into two sedimentary cycles and four systems tracts (TST-1, HST-1, TST-2, and HST-2) through a combination of petrological, geophysical, and continuous 1-D wavelet transform methods. The intensive chemical weathering and warm-humid climates reflected by high CIAcorr and $Ln(Al_2O_3/Na_2O)$ values prevailed in the K_1sh_{2-1} period with intermittent cold-dry climate fluctuations. The terrestrial-sourced organic matter (OM, type III gas-prone kerogen) preserved during the long HST period largely contributed to the organic-rich shale deposition. And the proportion of aquatic-sourced OM (type I oil-prone kerogen) increased upward from TST-1 to HST-2, which was ascribed to decreased base level and cooling drought events. The high TOC concentrations of Shahezi Formation shales dominated by terrestrial OM resulted from a combination of volcanism, warm-humid climate, abundant vegetation, intensified chemical weathering, and anoxic bottom-water. Two time-equivalent sedimentary records from high- (Shahezi Formation, Songliao Basin, 118-111 Ma) and low- palaeolatitudes (Sialivakou-Argilles Vertes Formation, Congo Basin, 125-113 Ma) suggest that the shift from active-rift phase to post-rift phase is accompanied by an increase in TOC concentration and a change toward type I kerogen. And the correlation between lacustrine sediment with its marine counterpart (Albian-Santonian shale sequences in the south American Margin) may also reflect the variation of organic matter sources and abundance in relation to global terrestrial ecosystems across the Early Cretaceous oceanic anoxic events.

Scientific Themes: Theme 10. Sedimentary Geochemistry
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Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Organic matter accumulation of the Wufeng-Longmaxi shales in southern Sichuan Basin: Evidence and insight from volcanism

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Keywords: Volcanic activities, Bentonite,Redox condition, Paleoproductivity, Sedimentary environment,Trace elements

The Wufeng-Longmaxi Formations (WF-LM Fms) in the Sichuan Basin are sets of graptolite-bearing shale strata containing high-frequency bentonite layers. In order to investigate the influence of volcanism on the organic matter (OM) accumulation in shales, detailed observations of several typical profiles and wells were performed. Also, analyses including total organic carbon (TOC) contents and mineral compositions were conducted on 126 shale and 5 bentonite core samples. Major and trace element analyses were conducted on the selected 25 shale and 5 bentonite samples in the WF-LM Fms of well Lu-A. Results show that WF and LM1-4 members are the bentonites concentrated sections, while LM5-6 are the bentonites relatively concentrated sections and no bentonite is found in LM7-9 members. The high potassium (K) content of bentonites have the typical characteristics of intermediate-acid calcium-alkaline volcanic rocks such as andesite and dacite, which probably originated from intraplate collision or volcanic arc structural backgrounds related to the collision belt of the Cathaysia Block to the Yangtze Block. Productivity indicators (P content, excess Si, P/Al, Cu/Al, and Ni/Al) in the WF and LM1-3 members are all significantly higher than those in the Lingxiang (LX) and LM4-5+ members. The higher biological productivity during the Ordovician-Silurian (O-S) transition was attributed to the massive and intensive volcanism. The fertilization by volcanic ash brought abundant biologically relevant nutrient elements (N, P, Si, Fe, and Al) into the ocean, thus triggering the phytoplankton bloom and enhancing primary biological productivity. All the redox condition indexes (MoEF, UEF, NiEF, VEF, Mo/TOC, Corg/P, and U/Th) positively correlate with TOC content. During the O-S transition, the intensive and massive volcanic eruptions triggered global cooling, sea-level changes, late Ordovician mass extinction, and primary productivity increases, thus promoting anoxic, and possibly intermittently euxinic bottom conditions. In addition, the deposited bentonite layers had a strong capacity for oxygen isolation. Volcanism should be considered when modeling the OM accumulation of the WF-LM shales.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Development environment and main controlling factors of Permian main source rocks in Junggar Basin

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Keywords: Junggar, source rock, sedimentary environment, main controlling factors, development model

Years of exploration practice has confirmed that P_1f and P_2w are important source rock strata in Junggar basin. Predecessors have carried out a lot of in-depth research on the rock and mineral characteristics (Kuang Lichun et al., 2012; Zhu Shifa, 2013), geochemical characteristics (Zhang Shanwen, 2013; Qiu Zhen et al., 2016) and thermal simulation (Qiu Nansheng et al., 2002; Wang Chengyun et al., 2014) of the two sets of source rock series and obtained rich research results. However, there are few studies on the development environment of the two sets of source rocks and the main controlling factors causing the quality difference, This directly affects the evaluation of Permian oil and gas exploration prospect. Based on previous studies, combined with exploration and field geological survey data in recent years, the author studied the sedimentary environment of the two sets of source rocks, such as paleoproductivity, paleosalinity and redox conditions, through core observation, thin section identification, paleontological community combination and geochemical data analysis. The results show that the two sets of high-quality source rocks were formed in the sedimentary environment of anaerobic, low deposition rate, high productivity and under compensation. Among them, high productivity, low deposition rate, hypoxia and upwelling are important factors affecting the enrichment of organic matter. High productivity can provide a large amount of organic matter, and low deposition rate can enrich the slowly settling organic matter in a long time scale. The development of upwelling and limited sedimentary basin lead to hypoxia in the bottom water body, which is conducive to the supply of nutrients and the preservation of organic matter.

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Petrographic and geochemical characteristics of organic-rich fine-grained rocks of the Upper Triassic Chang 7 member in the southern Ordos Basin, northern China: Implications for shale oil exploration

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Keywords: Organic-rich fine-grained rocks, Lithology, Geochemical characteristics, Biomarkers, Sedimentary model, Shale oil

Organic-rich lacustrine fine-grained rocks in Chang 7 member of the Upper Triassic Yanchang Formation are potential shale oil reservoirs. Petrographic and geochemical data were used to study their lithologic and geochemical characteristics, mineral composition and sedimentary environments. Three different types of deep lacustrine deposits are identified, including unstratified massive mudstone (muddy debrite), normally graded mudstone (muddy turbidite) and laminated shale. Mudstones and shales contain relatively abundant brittle minerals (quartz, feldspar, pyrite and carbonates), which are favorable for the hydraulic fracturing. Terrigenous input and diagenesis conversion process are the main sources of felsic minerals. Laminated shales yield the highest TOC values (average of 7.47%) as well as S1 and S2 values. Most of the mudstones and shales contain Type II organic matter, while contain little Type I organic matter.

The Ro and Tmax values combined with OEP versus CPI and C29ββ/(ββ+αα)sterane versus αααC29sterane20S/(20S+20R) discrimination diagrams and Ts/(Ts+Tm) ratios, indicate that the fine-grained rokcs are mature. Ph/C18 versus Pr/C17 and Pr/Ph versus gammacerane/C30-hopane discrimination diagrams together with U/Th, V/(V+Ni) and Ce/La ratios show that fine-grained rocks reflect a reducing depositional environment. N-alkanes of ΣnC21-/ΣnC22+ values and C27-C29 regular sterane distributions suggest that plankton and terrestrial plants are the parent materials of organic matter. In addition, small amounts of extended homohopanes (>C31) and gammacerane combined with Sr/Ba values support a fresh water depositional environment. These conditions have resulted in high quality and widespread distribution of organic fine-grained rocks, which are favorable for shale oil exploration.

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Presentation Preference: Oral Preferred

Paleoenvironmental conditions and organic matter enrichment of the Late Paleoproterozoic Cuizhuang Formation dark shale in the Yuncheng Basin, North China

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Keywords: Paleoenvironments, Organic matter enrichment, Paleoproterozoic source rocks, Cuizhuang Formation, Yuncheng Basin

The Paleoproterozoic Cuizhuang Formation dark shale is the main potential petroleum source rock in the Yuncheng Basin of northern China. Multiple mineralogy, organic and inorganic geochemical analysis were applied in this study to evaluate the sedimentary paleoenvironments and the factors that control the enrichment of organic matter and to reconstruct the organic matter accumulation model of the Cuizhuang Formation dark shale. Quartz and clay minerals are the most abundant minerals in the Cuizhuang Formation dark shale. The TOC content of the dark shale is relatively fair, ranging from 0.13% to 1.09% and averaging of 0.51%, with the organic matter having a high thermal maturity (mean of 2.24 Ro%) and type I kerogen. The Cuizhuang Formation shale was deposited in a passive continental margin setting, and the climate was under moderate warm and humid conditions with low salinity of seawater as evidenced by the proxies of chemical alteration index (CIA) and Sr/Ba. The paleoproductivity proxies of Ba_{bio}, Ba%, Ba/Al, P_2O_5 and P/Ti indicate low productivity with negative and no correlations with TOC content and thus did not control the organic matter enrichment. The low productivity may have significantly played a role in limiting the organic matter formation resulting in relatively low TOC content. The anoxic redox environment of the dark shale is indicated by the proxies of V/(V + Ni) and V/Sc, with strong positive correlations of V and V/Al with TOC. The anoxic redox environment in deeper waters and along with a higher sedimentation rate of the dark shale than the grey and red shale, played the main role in enriching the organic matter of the dark shale. Therefore, the Cuizhuang Formation dark shale in the Yuncheng Basin is regarded as a potential source rock, holding promise for petroleum exploration.

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Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Palaeoenvironment and organic matter enrichment of Middle Permian source rocks in Taibei Sag of Turpan-Hami Basin, China

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Keywords: Organic matter enrichment, Palaeoenvironment, Primary productivity, Salinity

The organic-rich source rocks in Taibei Sag of Turpan-Hami Basin are mainly developed in the Middle Permian Taerlang Formation (P2t) with great heterogeneity in-plane distribution. The controlling factors of organic matter (OM) enrichment in saline water lacustrine source rocks need to be further investigated to promote the oil exploration process. The organic and inorganic geochemical methods include total organic carbon (TOC), Rock-Eval pyrolysis, gas chromatography-mass spectrometry (GC-MS), X-ray diffraction (XRD), and trace elements are used to evaluate the quality, hydrocarbon generation potential, palaeoenvironmental conditions and OM enrichment of source rocks. The results show that the mudstone of P2t is high in organic content, ranging from 4% – 15% TOC, and has good hydrocarbon generation potential (Type II kerogen) in the mature stage (Tmax values ranging from 435 to 445℃). The analysis of biomarkers and trace elements shows that the P2t source rocks are mainly formed in a brackish lacustrine basin with a dysoxic water body and warm-humid environment. The salinity of water played an important role in the OM enrichment progress. The gammacerane index (indicator for salinity) is positively correlated with the total organic carbon (TOC) and the content of C28 regular sterane, indicating that the salinity of the water column controls the abundance of OM and the growth of salt-loving organisms. The contents of trace elements Cu and Zn are high and positively correlated with TOC, indicating that the primary productivity was sufficient in the P2t period and contributed to the enrichment of OM. The salinity of water columns dominates the enrichment of OM in source rocks of P2t from two aspects. The dysoxic and brackish-saline water columns contribute to the enrichment of OM through enhancing the primary productivity by promoting the growth of salt-loving microorganisms. The dysoxic environment created by saltwater column stratification is conducive to the preservation of OM, and the source rocks developed in these environments have high OM abundance. OM enrichment was greatly affected by the palaeoenvironment during the P2t period. The horizontal difference of paleoclimate and paleo-productivity controlled the distribution of organic-rich source rocks. The statistical results of paleo-salinity of P2t source rocks show an increasing trend from south to north in the study area, which provides evidence for the development of high-quality source rocks in the depression area in the north of the Taibei Sag.

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Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Paleo-environment of the formation of pediastrum and its petroleum geological significance

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Keywords: Pediastrum,Paleoenvironment,Hydrocarbon generation simulation,Source rocks

The E_{2-3a} lacustrine sedimentary source rocks are widely developed in Junggar Basin. The research degree of this set of source rocks is relatively low at present, and their hydrocarbon generation parent materials, sedimentary environment and hydrocarbon generation potential have not been systematically studied. Due to the relatively low abundance of source Rock samples drilled by E_{2-3a} drilling, outcrop samples were systematically collected in the Anjihaihe section of Junggar Basin, and Rock-ever and TOC analyses were performed on the samples. The results show that the samples have a high abundance of organic matter. Through rock thin section, SEM observation by a large number of form a complete pediastrum, rich pediastrum samples for the analysis of trace and rare earth elements reveals its sedimentary paleoenvironment, contrary to previous studies is pediastrum in the salt water and brackish water environment can still be good enrichment, which has important indicating significance for sedimentary paleoenvironment. The high temperature and high pressure thermal simulation experiment was carried out on the samples with the highest abundance in a closed container. The results show that the algophytes have good hydrocarbon generation capacity, indicating that E_{2-3a} has the material basis for a good set of hydrocarbon source rocks.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
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Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Organic geochemistry and depositional environments of the Middle Jurassic shales in the Suotuo Subsag, Yabrai Basin, Northwest China

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Keywords: Geochemistry, Depositional environment, Shale, Biomarker, Yabrai Basin

The Suotuo subsag is located in the eastern part of the Yabrai Basin, northwestern China, where the shales of the Lower Member in the Xinhe Formation (LXH Fm.) and the Qingtujing Formation (QTJ Fm.) of the Middle Jurassic are mainly developed. Based on the analysis of total organic carbon (TOC), Rock-Eval pyrolysis, kerogen carbon isotope and biomarker of source rocks, the origin and depositional environment of organic matter were analyzed. The TOC and S_1+S_2 of shales in the LXH Fm. ranges from 0.27% to 15.46% (ave. 2.76%) and 0.26 mg HC/g rock to 676.14 mg HC/g rock (ave. 15.84 mg HC/g rock). Moreover, TOC and S_1+S_2 of shales in the QTJ Fm. ranges from 0.55% to 60.8% (ave. 5.36%) and 0.37 mg HC/g rock to 110.34 mg HC/g rock (ave. 20.83 mg HC/g rock). Organic matter type of the LXH Fm. is dominated by Type I with oil-prone characteristics. And there are also some Type II and Type III kerogens with oil and gas potential. The shale samples of the QTJ Fm. fall into the Type II kerogen with oil-prone and gas-prone, and some of the samples fall into the range of Type II-III kerogen. Most of the shales in the LXH Fm. and the QTJ Fm. are in the early mature-mature stage.

Applying the Pr/nC_{17} and Ph/nC_{18} cross plots can determine the organic matter sources and depositional environments of source rocks. Most of the source rocks from the LXH Fm. and the QTJ Fm. were formed in a strongly reducing depositional environment, and the type of organic matter is mainly Type I and Type II, mainly from lower aquatic organisms, such as algae. The depositional environment of the LXH Fm. was more reductive than that of the QTJ Fm. The relative compositions of C_{27}, C_{28}, and C_{29} regular steranes were commonly used to classify the origin of the organic matter. The source rocks of the LXH Fm. and the QTJ Fm. mostly fall into the area of plankton and terrigenous higher plants, indicating that the source rocks have mixed inputs of lower aquatic organisms and terrigenous higher plants. Applying the Pr/Ph and gammacerane index cross plots can determine the salinity conditions and water-column stratification of the depositional environment of the source rocks. The relationship between Pr/Ph and gammacerane index of source rocks in the LXH Fm. and the QTJ Fm. in Suotuo Subsag shows that most source rocks were formed in anoxic to strongly reducing environment and heavy reduction salt water with stratification in the water column.

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Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Marine potential shale characteristics and hydrocarbon generation potential in the middle and lower Yangtze region

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Keywords: Middle and lower Yangtze, organic matter, shale, organic carbon, maturity, gas generation conditions.

Three sets of organic rich shale strata are developed in the middle and lower Yangtze region, mainly including Sinian Doushantuo Formation, Cambrian Niutitang Formation, Ordovician Silurian Wufeng Formation and Longmaxi formation.The second and fourth members of Doushantuo Formation deposit relatively stable dark mudstone in the region, and other strata develop dolomite and limestone, mainly developing clastic shore, carbonate platform, shelf and limited marine basin sedimentary environment. Black mud shale and carbonaceous mud shale are developed in the middle and lower part of Niutitang Formation, and the upper horizon is dominated by siltstone deposition. The main sedimentary environments include shore facies, shallow sea shelf facies (groove facies in shelf, shallow water shelf facies and deep-water shelf facies) and shelf margin facies. Carbonaceous and siliceous shales are developed in the lower part of Wufeng Formation, and bioclastic limestone is developed in the upper part, which is mainly deposited in deep-water shelf; The sedimentary water of Longmaxi formation becomes shallow, dominated by mud shale and siltstone, which is a relatively shallow shelf deposit. The middle and lower Yangtze region is rich in organic shale, and the thickness of organic shale in the lower Yangtze region is greater than that in the middle Yangtze region.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
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Presentation Preference: Oral Preferred

The heterogeneity of lithofacies types and sedimentary model of continental shale restricted by high-frequency an example from Paleogene Formation, Subei Basin, East China

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Keywords: continental shale, high frequency sequence, lithofacies, paleoenvironment, sedimentary model

Compared with marine shale, the lithofacies of continental shale change rapidly and the heterogeneity is obvious. The lithofacies characteristics and controlling factors pose some of the greatest challenges in sedimentology. The solutions to these problems will offer accurate predictions of continental shale. This study is established through wavelet transformation of the natural gamma curve the high-frequency sequence framework of the lacustrine shale. Here we also used thin-section observation, total organic carbon analysis, X-ray diffraction experiments, their elements and carbon and oxygen isotopic compositions to analyze the lithofacies characteristics. The results show that 12 types of lithofacies were developed in the continental shale. it is found that the formation is composed of three-level sequence of low-level system tract (LST), transgressive system tract (TST), and early high-level system tract (EHST), corresponding to 6 fourth-level sequences and 10 fifth-level sequences. The lithofacies type is affected by the paleoenvironment. The deeper the water body and the hypoxic conditions are the basis for the production and preservation of organic matter; the deeper the paleowater body reflects the stronger the weathering of the land surface, which is conducive to the accumulation of clay minerals and felsic minerals. Carbonate deposition is mainly controlled by ancient salinity; anoxic conditions and increase in ancient salinity are conducive to the development of laminar structures. The lithofacies of the Paleogene Formation show obvious vertical sequence and cyclicity under the sequence framework of different scales. The third-order sequence system tract controls the organic matter enrichment, and the fourth-order sequence controls the lithofacies subclasses and coupling rhythms. Three lithofacies assemblage models A, B and C developed in different system tracts were established, and sedimentary models of different lithofacies assemblage patterns were established based on the results of paleoenvironmental analysis. This study provides new insights that the lithofacies type is affected by the paleoenvironment. The lithofacies are regularly superimposed in the high-frequency sequence framework, and a lithofacies sedimentary model is established of continental shale.

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Presentation Preference: Oral Preferred

Geochemical characteristics of Linxing area and influencing factors of shale organic matter enrichment

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Keywords: Ordos Basin, Linxing area, REE, Environment, TOC

In recent years, major breakthroughs have been made in the exploration of Sea-land transition phase shale gas, but the evaluation system is still in its infancy. And basic research on the development characteristics, sedimentary characteristics, and organic matter enrichment characteristics of transitional shale needs. further research. Based on the trace elements of 17 shale samples in the Linxing, Ordos Basin, results have been achieved in terms of material sources and sedimentary environment. The results show that from the Benxi Formation to Shihezi 8 section is a marine to the terrestrial environment, furthermore, the oxidation gradually increases. It is concluded that the sediments of the Upper Paleozoic strata in the study area are from the northeast margin of Ordos Basin in the Yinshan area. The organic matter enrichment is mainly controlled by redox conditions, moreover, Taiyuan formation is a reduction environment and with the highest total organic carbon content. The analysis of the sedimentary environment and sedimentary sources in the study area provides a strong basis for shale gas exploration, and the evolution characteristics of the Ordos Basin during the Permian period are inferred from the seawater variation in the Linxing area.

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Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

New insight on crude oil types genesis and evolution of Fengcheng Formation in Mahu sag, Junggar Basin, China

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Keywords: Crude oil type, Thermal maturity evolution,Fengcheng formation, Mahu Sag, Junggar Basin

The Mahu Sag in the Junggar basin is one of the hot spots of oil-gas exploration, with rich oil-gas resources and great exploration potential. The Fengcheng Formation of Mahu Sag is not only an important source rock but also an important oil-gas accumulation play. Previous studies have focused on the hydrocarbon source rocks, reservoirs and crude oil characteristics of the Fengcheng Formation. Some scholars believe that different types of crude oil of Fengcheng Formation come from different horizons, while others believe that those come from Fengcheng Formation. Based on the geochemical parameters of source rocks and combined with the hydrocarbon generation thermal simulation experiment of source rocks, this study comprehensively analyze the genesis and evolution characteristics of different crude oil types. The research shows that the crude oil of Fengcheng Formation can be divided into three types according to the relative content of C_{20}, C_{21} and C_{23} tricyclic terpane: ascending, mountain-shaped and descending types. The three types of crude oil are orderly distributed in space. The hydrocarbon generation thermal simulation experiment of source rocks shows that the experiment products gradually transition from ascending type to descending type with increased maturity, indicating that different types of crude oils come from the different maturity stages of Fengcheng Formation source rocks. The natural evolution profile of crude oil shows that the biomarkers parameters of crude change regularly with the increased maturity, including the relative content of tricyclic terpane gradually increases, the relative content of C_{20} and C_{21} tricyclic terpane decreases first and then increases, the content of C_{28} sterane gradually decreases, and the crude oil types gradually transit from ascending to descending type. This research reveals that different types of crude oils of Fengcheng Formation come from different thermal evolution stages of Fengcheng Formation source rocks, and the biomarkers thermal evolution of crude oil has a complete sequence. According to the biomarkers characteristics of crude oil, the thermal maturity stage of crude oil can be judged, and then judge its accumulation period, which has important enlightenment significance in the further exploration and development of Fengcheng Formation.

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Relationship Between Extended Tricyclic Terpene Index ETR and Several Geochemical Indices in Lacustrine Source Rocks:By Taking Lishu Fault Depression in Songliao Basin for Example

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Keywords: Extended tricyclic terpene, Lishu Fault Depression, ETR, Maturity, Source rocks

Extended tricyclic terpene index ETR[ETR=(C_{28}TT+C_{29}TT)/(C_{28}TT+C_{29}TT+Ts)] was first developed by Holba et al.[1] proposed for dividing the parameters of the Triassic and Jurassic, due to the thermal stability of Ts is better than hopane, compared with tricyclic terpene(TT)/C_{30}H, ETR can weaken the effect of thermal maturation of parent material source, its relevant parameters are usually used to water chemical conditions in lacustrine environments[2], indicates the effect of transgression[3] and judgment of biodegradation[4], and thus more and more cause the attention of geologists to extended tricyclic terpene. Songliao Basin is one of the largest continental petroliferous basins in China, Lishu fault depression is a secondary tectonic unit of songliao Basin. In this paper, gas chromatography and gas chromatography-mass spectrometry (GC-MS) data for saturated hydrocarbons of 48 lacustrine source rocks samples in Lishu fault were analyzed, and the relationship between ETR and several geochemical indexes in source rocks was discussed in detail. Results show that: (1) ETR is negatively correlated with Pr/Ph, but not with G/C_{30}H (degree of salinization), indicating that the relative abundance of extended tricyclic terpanes is related to the degree of oxidation-reduction of water during organic matter deposition, but not with water salinity. (2) ETR is correlated with the diahopanes (C_{30}*, C_{29}*, C_{29}Ts) and C_{24}TeT/C_{26}TT, indicating that the extended tricyclic terpanes and diahopanes have similar parent material sources, and the more continental the organic matter sources in higher ETR. (3) Difference in maturity of source rocks in Lishu depression is the main factor influencing the relative abundance of extended tricyclic terpanes. ETR is negatively correlated with maturity parameters Ts/(Ts+Tm), C_{29}-(ββ/ββ+αα) and disterane sterane/regular sterane, and high degree of thermal evolution of source rocks is not conducive to the enrichment of extended tricyclic terpanes. (4) In addition, the ETR values of lishu fault depression are also correlated with the internal parameters of tricyclic terpanes, specifically, ETR is negatively correlated with (C_{19}TT+C_{20}TT)/C_{23}TT, C_{19}TT/C_{20}TT, and positively correlated with C_{23}TT/C_{21}TT. The correlation between these different tricyclic terpanes may reflect the changes of parent materials of hydrocarbon generation during deposition and record the evolution of lacustrine geochemistry.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment
Presentation Preference: Oral Preferred

Sedimentary environment and biological source evolution of shales in Lucaogou Formation in Jimusaer Sag, Junggar Basin, ChinaImplication for source rock hydrocarbon generation and expulsion

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Keywords: Sweet spot, Shale oil, Biological source, Lucaogou Formation, Junggar Basin

The Lucaogou Formation in the Jimusaer Sag is a hot spot for the exploration and development of lacustrine shale oil in China. In this paper, the shale oil potential is evaluated from the perspective of source rock hydrocarbon generation and expulsion. Based on a detailed organic petrological and geochemical characterization of the target interval within the key well JHBE, kinetic experiments were conducted on representative shale samples from well JHBE, and the lower limit index of hydrocarbon expulsion of the source rock is established. According to the findings of this study, the Lucaogou Formation shale is generally good to excellent source rock and mainly contains type I-type II1 of organic matter (OM) in the mature thermal evolution stage. Biomarker shows that the Lucaogou Formation shales were deposited in the dysoxic to anoxic and clay-poor lacustrine environment with normal to higher water salinity, and their OM was contributed from both lamalginite and telalginite with minor vitrinite and intertinite. The development of different primary organic matter is related to the salinity of the water column. The lamalginite was prone to flourish in water with lower salinity, while the telalginite was developed in water with relatively high salinity. Both lamalginite and telalginite have good-excellent hydrocarbon generation potential, although the former has a higher OM content than the latter, the current generated hydrocarbon amount is lower than the latter, for the telalginite has a higher hydrocarbon conversion rate than lamalginite in the current thermal maturity, which is indicated by higher HCI, EOM/TOC, C29ββ/ (αα+ββ) and C29ααα20S/(20S+20R) ratio values from telalginite than lamalginite, as also evident by the difference of activation energy distribution between lamalginite and telalginite source rock. Determined by relationships of sterane maturity parameters C29ββ/ (αα+ββ) and C29ααα20S/(20S+20R) vs. EOM/TOC ratio and HCI values, the lower C29ββ/ (αα+ββ) and C29ααα20S/(20S+20R) limit for active rocks is around 0.28 and 0.44 respectively. So, the reservoirs adjacent to the effective source rocks determined by the above-mentioned have good shale oil exploration potential in the Lucaogou Formation.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment
Presentation Preference: Oral Preferred

Sedimentary environment and model for lacustrine organic matter enrichment: lacustrine shale of the Early Jurassic Da'anzhai Formation, Central Sichuan Basin, China

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Keywords: Lacustrine shal, Sedimentary environment, organic matter enrichment

Based on the analysis of element geochemistry and total organic carbon (TOC), this study investigates the main factors controlling organic matter (OM) enrichment, reconstructs the evolution process of the sedimentary environment, and proposes a dynamic OM enrichment model of the Jurassic Da'anzhai (D) Formation, Sichuan Basin. The results indicate that the Sichuan Basin was generally dominated by a warm and oxidizing sedimentary environment, but with some peculiarities, such as a hotter climate in the D1 member and more anoxic lake water in the D2a member. The sedimentary evolution of the Da'anzhai Formation can be divided into a fluctuating sedimentary stage, a stable sedimentary stage and a reef-building stage. The D2a member showed the strongest hypoxia, the weakest weathering, the largest amount of terrestrial inputs, and the highest TOC content. The TOC is positively correlated with reducing conditions and terrestrial inputs, negatively correlated with weathering. Based on these findings, it is suggested that the global climate in the Early Jurassic period had a complex regional effect and the global oceanic anoxic events of the Toarcian did not spread to the Sichuan Basin. Thus, the anoxic deep water, high terrestrial inputs, and weak weathering were conducive to rapid deposition and preservation of lacustrine OM.

Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Distribution pattern change of tricyclic terpane in humic coal under the transgression

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Keywords: Tricyclic terpane, transgression,kuqa depression,sichuan basin

Tricyclic terpenes (TT) are an important component of saturated hydrocarbons, which are widely present in source rocks and crude oil. The variation of tricyclic terpenes' distribution can well reflect the changes of sedimentary paleoenvironment, paleoclimate and tectonic movements. This paper uses geochemical analysis to research on the humic coal in the Kuqa Depression of the Tarim Basin and the Sichuan Basin, and found that there are three different distribution patterns of tricyclic terpenes in the Kuqa Depression and the Sichuan Basin: "C_{19}TT>C_{20}TT>C_{21}TT >C_{23}TT" descending type, "C_{19}TT<C_{20}TT<C_{21}TT>C_{23}TT" and "C_{19}TT<C_{20}TT<C_{21}TT<C_{23}TT" single peak type. In addition, the Kapushaliang River profile and the Sichuan Basin humic coal posses a high maturity (1.1%<Ro<1.485%), but the distribution pattern of tricyclic terpenes does not change within a certain maturity range (Ro<1.5%)[1]. Therefore, maturity exert a rare impact on the distribution pattern of tricyclic terpenes. The tricyclic terpane of humic coal in the Kuqa River profile basically controlled by C_{19}TT descending distribution, while the Sichuan Basin and Kapushaliang River profiles are still being a single peak distribution of C_{21}TT and C_{23}TT. over and above that,compare with the Kuqa River profile,some geochemical parameter are especially different ,such as the higher gammacerane index around 0.21, the lower Pr/Ph value around 0.62, and the higher SF/OF value around 5.42, which is different from the geochemical parameters of conventional humic coal,too. Previous studies have shown that the Kapushaliang River profile, the Sichuan Basin and the Kuqa River profile were all affected by transgression[2-4], but the distribution of tricyclic terpenes between the Kuqa River profile, the Kapushaliang River profile and the Sichuan Basin was significantly different. The study shows that the tricyclic terpenes of humic coal in the original swamp facies environment that affected by the transgression perform the same distribution characteristics as fluvial/delta facies, while the tricyclic terpenes distribution of the original lacustrine facies obtain more C_{23}TT after the effect of the transgression. But without massive alien resources imput and long term transgression,in general the distribution of the "C_{19}-C_{20}TTC_{21}TTC_{23}TT" still bias to lacustrine sedimentary environment.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment
Presentation Preference: Oral Preferred

Element geochemical characteristics and organic matter enrichment mechanism of mud shale: A case study of the first member of Qingshankou Formation in the northern Songliao Basin

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Keywords: elemental geochemistry, depositional environment, organic matter, enrichment mechanism

Elemental geochemical tests were conducted on shale samples in the first member of Qingshankou Formation in the northern Songliao Basin, and a series of element indicators were used to identify paleo-climate, paleo-salinity, paleo-productivity and paleo-redox conditions. By restoring the depositional environment of black shale, the enrichment mechanism of organic matter in mud shale is further explored. According to the characteristics of organic matter content and geochemical element indicators, the first member of Qingshankou Formation can be divided into three units: bottom unit, middle unit and upper unit. Due to the differences in organic matter content and sedimentary environment of the three units, the organic matter enrichment mechanism is also different.

The bottom unit develops oil shale, with the highest organic matter content. At this stage, affected by the massive death of organisms caused by transgressive events, high paleo-productivity develops. Meanwhile, the salinity stratification and reduction environment of lake water caused by transgression provide good conditions for the preservation of organic matter, which leads to the enrichment of organic matter; Mud shale with large depth range is developed in **the middle unit**, and the content of organic matter is high. The abundant nutrients brought by transgressive events resulted in biological bloom and high paleo-productivity, but at the same time, it also brought a certain degree of bioturbation to affect the organic matter enrichment. The strong reduction environment sedimentary environment at this stage is conducive to the preservation of organic matter. Therefore, even if there is a certain degree of bioturbation, the organic matter enrichment is well completed; **The upper unit** is mainly black shale, and the thin-layered siltstone is distributed at intervals, and the organic matter content is lower than the previous two units. The warm and humid climate brings a lot of rain, and the thin-layered siltstones are mostly related to the input of terrigenous materials along with rainwater, which also destroys the preservation conditions of organic matter, resulting in low organic matter content at the top.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment
Presentation Preference: Oral Preferred

Weathered Residual Petroleum in the Deep Water Sediment of the South China Sea; how much is there and where did it come from?

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Keywords: Sediment Cycles, Organic Geochemistry, Thermal history, Biomarker, Sediment Sources

Organic carbon that has been geologically processed in sediment cycles becomes recalcitrant, and one of the most resistant types of organic matter is asphaltic weathered petroleum. Detecting this type of organic carbon is difficult because it is chemically unreactive and poorly solvent-soluble and consequently analysing small quantities is difficult. While some information on carbon cycling can be obtained from stable isotope measurements, this data lacks molecular specificity. Thus when different types of organic carbon are mixed together trace quantities of small amounts of weathered petroleum will be missed. This means that for asphaltic weathered petroleum, there is not currently a clear picture of how it is recycled over deep geological time or a direct quantification in major sediments reservoirs.

The quantities of resistant biomarker, and for the first time asphaltene, have been measured at trace concentrations in deep water sediments from the South China Sea by using Surface Enhanced Raman Scattering. By making comparisons to sediments found on continental shelves and in petroleum-bearing formations exposed on land, it can be shown that weathered asphaltic petroleum found in the distal parts of the South China Sea has survived transportation to its current location despite likely moving through sediment reservoirs on shelves to the north and north east. Furthermore, based on the relative proportions of resistant biomarker, asphaltic petroleum may have been degraded only very lightly during this process and therefore the main process that lowers concentrations is dilution by mixing with other sediments.

Previously trace quantities of petroleum biomarker within sediment have mostly been considered only in the context of carbonate rocks, however the reworked petroleum-bearing formations within the deepwater sediments of the South China Sea show that siliclastic sediment can still possess organic geochemical finger-prints and this has consequences and applications for determining thermal history and for carbon cycling, as well as applications for determining sediment provenance and mass balancing petroleum systems on geological timescales.

Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Organic-Rich Strata of the East Beni Suef Basin, Egypt: Implications on Source Rock Potentiality

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Keywords: East Beni Suef Basin, Source Rock Evaluation, Kerogen Types, Organic Matter Richness, Thermal Maturity

The Mesozoic deposits of the Tethyan realm represent the most prolific source rocks, which contribute approximately 70% of the total world hydrocarbon reserves (Huc, 1995). The East Beni Suef Basin is an extensional rift basin in north-central Egypt that has initiated under tensional tectonics in the wake of the post-Hercynian break-up of Gondwana. The basin stratigraphy consists of a mixed siliciclastic carbonate succession ranging from the Albian to the Eocene (Zahran et al., 2011), where the Upper Cretaceous Abu Roash Formation comprises the essential petroleum system elements of the basin. The main goal of this study is to evaluate the source rock potentiality of the sedimentary succession in terms of organic matter richness, thermal maturity, and kerogen types. To achieve this goal, we used an extensive data set of geochemical and kerogen analyses including total organic carbon (TOC), Rock-Eval pyrolysis, and visual kerogen composition that were performed on 190 cutting samples from three wells in the East Beni Suef Basin and made accessible through the Egyptian General Petroleum Corporation. Based on the organic richness, the sediments show a wide range of fair to excellent source potential, where The Abu Roash “F” Member shows the highest hydrocarbon-generating potential (1.04–4.02 wt% TOC and S2 from 3.55 to 27.91 mg HC/g rock), while the Bahariya Formation exhibits the lowest source potential (0.5–2.25 wt% TOC and S2 from 0.54 to 4.43 mg HC/g rock). Three kerogen types can be distinguished: oil-prone type II kerogen in the Apollonia Formation and Abu Roash “F” Member, mixed type II/III kerogen in the Abu Roash “A” and “G” members, and gas-prone type III kerogen in the Abu Roash “E” Member and Bahariya Formation. In general, the sediments are distributed along most of the kerogen evolutionary pathways due to variations in organic matter and lithologic composition, which in turn reflect the different depositional environments of the sedimentary succession from lagoonal to open marine setting. Visual kerogen composition reveals variation in the maceral composition of the sedimentary succession from liptinite to vitrinite with minor traces of inertinite, which reflects variations in the depositional conditions as confirmed by the Rock-Eval pyrolysis results. The vitrinite reflectance profiles show that most of the analyzed sediments are immature to marginally mature (0.39–0.71% Ro), which is confirmed by the Tmax and the thermal alteration index measurements. Based on the source rock evaluation, it could be concluded that the Abu Roash “F” Member is the main source rock with good to excellent source potential, oil-prone mainly type II kerogen, and immature to marginal maturity levels.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment
Presentation Preference: Oral Preferred

Paleoenvironments and enrichment of organic matter of the Yuertusi Formation shaleTarim basinA study of the Luntan 1

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Keywords: Early Cambrian, Tarim block, Hydrothermal activity, organic matter enrichment

The organic-rich sediments were widely deposited over the Tarim Block during the Early Cambrian. But the depositional mechanism and organic matter enrichment processes are poorly understood. In this study, we investigated the systematic changes in total organic carbon, X-ray diffraction, major elements and trace elements for samples from the Luntan 1 borehole, located in the Lunnan depression, to reconstruct the climatic conditions, redox changes, primary productivity. Yuersiti Formation mainly includes mudstone in the lower part and limestone in the upper part. Paleoclimatic proxies (Sr/Cu ratios and C-values) suggest that the Yuertusi formations experienced significant changes from warm-humid to cold-dry. Paleoredox indices (U/Th, Ni/Co, V/(V+Ni), Mo_{EF} and U_{EF}) also demonstrate fluctuating redox variations from anoxic to oxygenated. Paleoproductivity parameters (TOC, Ba_{bio} contents and Cu/Al ratio) suggest that the low sections of the Yuertusi formation were deposited with high biological productivity while the upper sections were deposited with low biological productivity. Moreover, the evidence for the existence of hydrothermal activities consisted of high contents of quartz and pyrite, large positive Eu anomalies related to hydrothermal fluids. These data demonstrate large climatic and oceanic fluctuations during the Early Cambrian, providing essential controlling factors on the oceanic anoxia, productivity, and organic-rich black shale depositions in the Tarim block during the Early Cambrian.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment
Presentation Preference: Oral Preferred

Geochemical tools points to organic richness and possible unconventional hydrocarbon potential in previously underestimated organic rich Triassic and Jurassic strata, Precaspian Basin, Kazakhstan

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Keywords: source rock, biomarker analysis, pyrolysis, shale oil, petroleum geochemistry

Precaspian basin (Kazakhstan) is a globally important petroleum province. The basin is divided into two main sequences separated by thick Kungurian (Permian) salt deposits. The source rock for super-giant sub-salt oil fields (i.e. Tengiz, Kashagan, and Karachaganak) are believed to be deep marine carbonate facies (Type IIS) formed syndepositionally with Devonian and Carboniferous reef build-ups (Ulmishek, 2001). This interpretation is supported by a very high (4-20%) sulfur content in all sub-salt oil fields.

The origin of oil in post-salt Triassic and Jurassic reservoirs is debatable. Their physical properties and composition are affected by a variable degree of biodegradation that followed oil emplacement. In contrast to pre-salt oils, the reported bulk oil composition from post-salt reservoirs shows dramatically lower concentrations of sulfur (0,1-1,5%).

Detailed study of biomarkers including sterane homologues ratios, hopanes, and tricyclic terpanes from more than 100 reservoirs of Emba region (Seitkhaziyev et al., 2019; 2020) suggests that post-salt reservoirs are charged from two distinct sources: carbonate and shale facies. Our quantitative analysis of published Dibenziothiophenes (DBT) to Phenanthrene ratios and Pristane – Phytane ratios (both depositional paleoenvironment indicators) confirms that conclusion and suggests mixed-sourced oils in some reservoirs. The question is where the clastic shale source rocks are?

Integration of data from oil-shale potential (surficial mining) studies of shallow shale subcrops (Sapargaliev, 2017) with paleo-geographic maps, pyrolysis results, and subsurface logs, allowed us to suggest that Late Permian, Triassic and Jurassic clastic shales have matured in deeper parts of the basin. This interpretation supports Pairazian et al., (1999) assumption based on interpreted tectono-stratigraphic framework. The presence of post-salt source rocks explain the origin of compositionally different oils in post-salt oil accumulations. Furthermore, it points to a likely presence of overseen unconventional reservoirs. Characterization of post-salt organic rich strata, their burial history, and hydrocarbon generation potential is a subject of ongoing research. Results are expected to provide new information for revising the petroleum system and assessing the unconventional potential in post-salt sedimentary successions of Precaspian Basin.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment
Presentation Preference: Oral Preferred

Enrichment mechanisms of Organic matter in late Triassic Xujiahe Formation mud shale, southeastern Sichuan Basin

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Keywords: Late Triassic, Sedimentary environment, Climate, Organic-rich sediments, Sichuan Basin

The upper Triassic Xujiahe Formation in Sichuan Basin is characterized by self-generation and self-preserving reservoir. As a source rock, the mud shale of Xujiahe Formation has high abundance and wide distribution of organic matter(OM), which is of great research value. There are few studies on the mechanism of OM enrichment in the Xujiahe Formation in southeastern Sichuan Basin. Based on the investigation of the Xujiahe section in southeastern Sichuan Basin and the analysis of element geochemistry, the evolution process of the sedimentary environment is reconstructed. Combined with previous studies, the factors that control OM enrichment during the Rhaetian are discussed. The sedimentary system in the study area of the Late Triassic Xujiahe Formation was lacustrine-delta. The ratios of U/Th and Ni/Co indicate that the organic-rich sediments were mainly deposited in a weakly oxidized environment, which is not conducive to the preservation of OM. The chemical index of alteration (CIA) indicates the palaeoclimate. A warm and humid paleoclimate favored the growth of organisms, which could enhance the surfcial biotic productivity. The sedimentation rate in southeast area is much lower than that in western Sichuan depression. Slower deposition rates are also detrimental to the preservation of OM. According to the data analysis, OM enrichment in southeastern Sichuan Basin is mainly affected by redox environment and climate, and is almost not affected by sedimentation rate. The upper part of the third member of Xujiahe Formation has the lowest oxygen content, the warmest and wettest climate, and the highest TOC content. These studies reveal that sedimentary environment and paleoclimate might be responsible for the enrichment of OM in the Xujiahe Formation in southeastern Sichuan Basin.

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Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Biological sources and sedimentary environment of organic enriched Member 2 of Kongdian Formation (Paleogene) in Cangdong Sag, Bohai Bay Basin, China

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Keywords: Source rock,Biomarker,Organic input,Depositional environment,Ecological evolution,Cangdong Sag

The Member 2 of Kongdian Formation(Ek2, Paleogene) in the Cangdong sag is an oil-rich interval in the Bohai Bay Basin, China. In this research, we are committed to studying the organic matter composition, ecological community structure, and sedimentary environment of Ek2 through rock pyrolysis and molecular geochemistry. The studied samples have vitrinite reflectance (Ro%) values of 0.66–0.82 % and maximum pyrolysis temperature (Tmax) values of 443–457 °C, suggesting that organic matter is mainly located in the low mature to mature stage. Biomarkers are mainly distributed as low-to-high-molecular-weight n-alkanes (n-C14 to n-C35), The decrease in the value of L/H throughout the period represents a gradual increase in the input of higher plants. the trend in the ratio of C24 TeT to C26 TT is consistent with the trend in the relative content of C29 steroids, implying that at 3170 m the relative amount of higher plant input begins to increase. The relative bloom of zooplankton species represented by C27 steroids occurs at 3170 m. The change in vegetation appearance can be reflected by the ratio of (C27 +C29) to (C31+C33). The ratio changes more frequently throughout the deposition period, but generally decreases, implying a gradual evolution of vegetation appearance from woody to herbaceous plants. The relative changes in the Paq and Pwax ratios can be used to reflect the relative inputs of higher plant input species submerged versus phytoplankton and emerging plant plants, showing an opposite trend, with phytoplankton and submerged plants gradually decreasing relative to emerging plant plants at 3065 m. while Pr/Ph and Gammacerane/C30 hopane values are both low reflecting a reduced and freshwater depositional environment, and at 3070 m, Gammacerane/C30 hopane values gradually increase and Pr/Ph was decreased, shown the salinity of the water column increases. Pr/n-C17 vs Ph/n-C18 also confirms that the water body is a reduced environment. Based on different indicators of biomarker compounds and other types of data, we have derived the pattern of lake evolution, evolution of biotopes and biological composition of hydrocarbon source rocks in three stages (Ek 4 2-Ek 3 2, Ek 2 2, Ek 1 2)) in different periods during the deposition of the Member 2 of Kongdian Formation. which is very favorable for the preservation of organic matter and favorable to the formation of high-quality hydrocarbon source rocks

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Microscopic pore throat structure of the Permian Wutonggou formation reservoir in the eastern Junggar Basin

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Keywords: Reservoir,Microscopic pore throat structure,Junggar Basin

Due to the influence of sedimentation and diagenesis, the reservoirs of the Permian Wutonggou formation in the Dongdaohaizi sag in the eastern Junggar basin and the Di'nan-8 wellblock in the Baijiahai uplift generally show rapid lithologic changes, compact lithology, poor physical properties, and significant differences in reservoir microscopic characteristics. At present, the distribution of the reservoir facies belt is unknown, and the detailed research on reservoir characteristics is consequently insufficient, resulting in a bottleneck restricting the prediction of high-quality reservoir distribution and oilfield development in the study area. Based on observation and description of the rock core, as well as microscopic observation and identification of conventional sheets and casting sheets, the characteristics of the Permian Wutonggou formation reservoir in the Di'nan-8 wellblock are studied by analyzing heavy minerals, porosity, and permeability, high-pressure mercury injection, clay mineral X-ray diffraction, graphic granularity, graphic pore-throat, microbeam fluorescence, homogenization temperatures of fluid inclusions, laser Raman component, and scanning electron microscopy. Under the development mechanism of the fan-delta reservoir, the reservoir characteristics such as micro petrological characteristics, physical properties, pore-throat structure distribution, and clay mineral composition are clarified. Furthermore, the types and characteristics of diagenesis, the classification of diagenesis stages, the diagenesis-pore evolution and pore development, and the prediction of secondary pore zones are determined. The following results can be obtained: The physical properties of the reservoir are jointly affected by the water power in deposition and diagenesis, and the rock particle size affected by the water power determines the quality of the original reservoir. Cementation is the main diagenesis (average pore reduction of 25.1%) for the loss of primary pores in the reservoir; and secondly, compaction (average pore reduction of 10.2%) and dissolution (average pore increase of 6.5%) enhance the reservoir performance to a certain extent. The reservoir in the uplift zone experiences weak compaction but strong cementation and dissolution; in contrast, the reservoir in the sag experiences strong compaction, whereas cementation and dissolution are relatively weak. The Wutonggou reservoir is a matrix and fractured dual porous media reservoir with very low porosity and permeability. The pores are mainly secondary dissolved pores, but the pore-throat structures are complex and variable. The seepage capacity and oil saturation of a reservoir are controlled by both matrix pores and fractures. The research findings will be useful in the future for oil reservoir evaluation, wellblock location deployment, reservoir evaluation, and effective production, accelerating exploration and development, and increasing reserves and production of Permian oil and gas reservoirs in the Di'nan 8 wellblock.

Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment
Presentation Preference: Oral Preferred

Multiple controls on the organic matter accumulation in early Cambrian marine black shales, middle Yangtze Block, South China

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Keywords: primary productivity, redox condition, hydrothermal activity, upwelling

The Lower Cambrian black shales are considered important source rocks possessing huge potential in shale gas exploration. To unravel the differential organic matter accumulation, we present a detailed analysis of mineralogy and major and trace elements for the lower Cambrian Shuijingtuo Formation in the outer-shelf Three Gorges area. Based on the investigation of primary productivity (EF(Cu), EF(Ni)), redox condition (Mo-U covariations, Corg/P), and terrigenous input (Ti/Al), the Shuijingtuo Formation is divided into three units. The organic-poor lower unit (TOC=0.69% on average) records suboxic-oxic conditions, low primary productivity, and high terrigenous input. The organic-rich middle unit (TOC=5.40% on average) was featured by anoxic-euxinic conditions, high primary productivity, and low terrigenous input. The organic-moderate upper unit (TOC=1.12% on average) is characterized by shifting anoxic-suboxic conditions, decreasing primary productivity, and low terrigenous input. At first, the transgression from southeast to northwest brought about the anoxic bottom water condition in the basinal area. The organic matter accumulation in the shelf (Unit 1) was controlled by both suboxic bottom water and low primary productivity. Later, this situation was intensified by the release of reduced gas by hydrothermal activity, and increased oxygen consumption due to the phytoplankton blooms promoted by upwelling and hydrothermal activity. The anoxic even euxinic bottom water manipulated the organic matter accumulation of Unit 2. Last, as the hydrothermal and upwelling weakened, the organic matter accumulation of Unit 3 was dominated by the low primary productivity. The vertical variations in primary productivity and bottom water conditions reflect the different intensities of upwelling and hydrothermal activities in a semi-restricted environment linked with sea-level changes. In summary, the organic matter accumulation of the lower Cambrian Shuijingtuo Formation is ultimately controlled by the bottom water redox condition, where the primary productivity exerts indispensable influence.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment
Presentation Preference: Oral Preferred

Paleoenvironment and origin of heavy oil of the lower Cretaceous-Oligocene: a case study

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Keywords: Hetao Basin, geochemical characteristics, Biomarkers, thermal simulation of gold tube

Many heavy oil wells have been found in the Jilantai shallow depression in the Hetao Basin. The origin of heavy oil in the study area was analyzed comprehensively according to the physical properties and geochemical characteristics of heavy oil. Two sets of source rocks were detected in the Guyang and Linhe groups, in the Hetao Basin. During the Guyang Formation, the differences of sedimentary environments resulted in brackish water sedimentary environment in the south of the study area and freshwater reducing environment in the north of the study area. The high content of boron in the source rocks of Linhe Formation indicates its saltwater environment. By the method of oil source comparison, it is found that the Pr/Ph of the crude oil in Jilantai area and Linhe Formation is lower than 0.50, and the Pr/nC_{17} is between 0.7 and 3.5, which should come from the source rock of the first segment of the southern moderate lacustrine Guyang Formation. The C_{29} sterane 20S/(20S+20R) and C_{29} sterane ββ/(αα+ββ) parameters indicate that the low maturity of crude oil is the main cause of heavy oil formation. The research on the genesis and geochemical characteristics of Jilantai crude oil indicates that the northern and central depression of the Hetao Basin is a rich area of favorable resources.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

The Origin and Genesis of the Permain Hydrocarbon in the Northeast of Dongdaohaizi Depression, Junggar Basin, China

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Keywords: Thermal evolution of source rocks, Biomarkers, Pingdiquan formation, Petroleum geochemistry, hydrocarbon evolution, oil-source correlation

Studying the geochemical characteristics of the source rock extract and the surrounding structural crude oil in Dongdaohaizi Depression, the differences in stable carbon isotope, biomarker compound, and molecular relative composition of the three sets of main source rock products in the research fields are summarized. The results reflect that the drying coefficient of natural gas in the study area is generally low, and the fractional distillation value of methane and ethane is 0.32, which is most likely due to the loss of oil and gas migration and the mixing of different types of natural gas. The carbon isotope value is relatively low, Pr/Ph is generally less than 3.0. The content of sterane C_{29} is the highest in the relative composition of steranes, followed by the range of sterane C_{28}, accounting for more than 80% of the total sterane content and the lower content of C_{27} sterane, accounting for only 5%−20% of the total content, which generally conforms to the characteristics of Permian Pingdiquan Formation source rock products. The carbon isotope value of crude oil ranges from −30.94‰ to −28.31‰, which is different from the characteristics of typical Permian source rocks (value is −34.49‰ to −28.21‰) while is related to typical Carboniferous products (value is −29.98‰ to −24.1‰), which indicates that small amounts of Carboniferous source rock products were mixed in different degrees in the Dinan fault area. According to the distribution law of oil and gas, the geochemical characteristics and hydrocarbon sources were considered the oil source in the east of Dongdaohaizi Depression, mainly from the source rocks of the Permian Pingdiquan Formation. The products of the peak period of hydrocarbon generation in the source rocks of the Pingdiquan Formation have not been transported to the high structural positions on a large scale to form reservoirs. It may still exist in the deep part of the Depression and the slope area. The low-amplitude structural and lithologic traps in the slope area of Dongdahaizi Depression are promising targets for finding the products of the peak period of hydrocarbon generation. It is of great significance to reveal the Permain hydrocarbon evolution in Junggar Basin and guide further research on the oil-source correlation of natural gas from paleo-strata.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Low-latitude sedimentary records response toof late Carboniferous glacial cycles

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Keywords: Carboniferous, North China Plate, sea-level fluctuation, zircon dating

The late Paleozoic ice Ages (LPIA) of the Carboniferous and Permian (~360-260 Ma) is the only documented icehouse-to-greenhouse transitions on earth, providing a deep temporal perspective on climate-glacier-environment coevolution and future climate change. In order to reveal the sedimentary response of LPIA in low latitude area. We investigate the sections material of Palougou and Shimenzhai in the middle of the North China Plate (NCP), the Benxi-Taiyuan Formation of Pennsylvanian has been studied in terms of chronostratigraphy and sedimentology. Three new radiometric dates from tuffaceous claystones provide a precision stratigraphic framework and constrain the succession to ~315 to 299 Ma. Results date the Benxi Formation to the late Bashkirian-late Moscovian stages of the Carboniferous, and the lower part of Taiyuan Formation ranging from the late Moscovian stage of the Carboniferous to the early Asselian stage of the Permian. Based on the analysis of the depositional environment of the two sections, the eight facies can be divided into three depositional systems: Delta plain, Delta front and Prodelta, and Offshore Marine., Sea level change during the Pennsylvanian is recovered based on the vertical superposition model, the relatively high sea level during the late Bashkirian-early Moscovian interglacial, the large sea level decline during the middle Moscovian, and the sea level rise during the late Moscovian-Gzhelian interglacial, the Asselian sea level decreasing. The sea level change curve of the NCP is highly coupled with the glacial-interglacial cycle of the high latitude Gondwana. In addition, the extensive development of ferrite nodules, limestone and volcanic deposits in the late Bashkirian, Kasimovian and Gzhelian periods in the North China Plate reflects the warm and hot paleoclimate during the interglacial period in the study area. The enhancement of coal accumulation in the early -middle Moscovian and early Asselian reflects the extensive development of coal forming plants due to shallow or even exposed water caused by sea level decline, and the enhancement of coal accumulation due to peat accumulation caused by the change of sedimentary environment caused by regressive. Our results also confirms that the fluctuation of ice sheets at high latitudes affects the sedimentary records at low latitudes through changes in sea level.

Scientific Themes: Theme 10. Sedimentary Geochemistry
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Presentation Preference: Oral Preferred

Carbon mobility and degassing at the contact between organic-rich rocks and magmatic intrusions

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Keywords: dispersed organic matter, magmatic intrusions, Raman spectroscopy, carbon degassing

There is increasing interest in recent years in the interaction between organic-rich rocks and magmatic intrusions due to a growing focus on unexplored hydrocarbon plays in continental rift or back-arc settings (Alves et al.,2020), and because of the role of carbon degassing in past climate shifts (Svensen and Jamtveit, 2010).
Classical studies based on organic geochemistry and numerical thermal modelling have shown that enhanced maturation and carbon degassing approaching the magma are the main effects of these thermal anomalies in the shallow crust.
New Raman spectroscopy and petrographic data from two sites in the isle of Skye and one from the Midland Valley, all in Scotland, help to shed light on the behaviour of different carbon phases that are formed and migrate as a consequence of magmatic heating.
Starting from the general assumption that carbon content decreases towards an intrusion (Iyer et al., 2017), our data show that this is true only in some cases, while in other cases it remains constant or can also increase. The generation of liquid hydrocarbons and carbonaceous alteration products (i.e., bitumen) has been found to play a pivotal role on carbon mobility. This implies that the original organic matter composition as well as the petrophysical properties of the rocks strongly influence the products derived from carbon degassing.
This conclusion will help to progress towards more refined carbon degassing models to be used in paleoenvironmental studies.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment
Presentation Preference: Oral Preferred

Organic petrography and geochemical characterization of the middle-upper Miocene Onnagawa Formation (Akita Basin, Japan): new insights into the relationship between paleo-environment and preservation of sulfur-rich kerogen

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Keywords: Euxinic, Middle-upper Miocene, Onnagawa Formation, Organic petrography, Rock-Eval 7S, Sulfur-rich kerogen

Middle-upper Miocene siliceous formations from the North Pacific Sea are important source rocks for oil and gas. These formations include large amounts of phytoplankton-derived kerogen, which can be enriched in organic sulfur (type IIS kerogen with atomic Sorg/C > 0.04). Due to the different petroleum generation kinetics of Type IIS and Type IS kerogens, these source rocks can generate oil at lower thermal maturities than sulfur-lean Type I and Type II.

In this study, twenty samples from the middle-upper Miocene Onnagawa Formation`s siliceous shales, Akita Prefecture, were collected from a 42 m-long core. Organic petrography and organic geochemical characterization through the new Rock-Eval 7S analyzer were used to define the organo-facies and determine sulfur species (i.e., organic vs. inorganic sulfur), hydrocarbon potential, and kerogen type (i.e., type II vs. type IIS kerogen, based on the Sulfur Index of Carvajal-Ortiz et al. (2021)). The data were coupled with Iron (Fe) from XRF and petrographic observation of framboidal pyrite to interpret the paleo-oxygenation conditions of the water column in the Akita Basin.

Based on microscopic observations, the organic matter consists mainly of telalginite with golden-yellow fluorescence. Fluorescent pollens, rare phytoclasts (vitrinite-like and inertinite), and solid bitumen were also recognized. Rock-Eval 7S analysis indicated moderate amounts of total organic and pyritic sulfur, and low amounts of sulfate sulfur. The majority of Sorg is associated with the reactive and thermally labile portion of the TOC (S2-Sulfur or S2-S). Additionally, TOC, S2, and HI values suggest a fair to very good potential for the generation of hydrocarbons and the prevalence of kerogen type IIS, Type II, and mixed II/III. SI values greater than 100 mg/g TOC (equivalent to Sorg/C > 0.04) suggest that most of the analyzed samples are enriched in reactive organic sulfur (Type IIS and Type IS).

Additionally, the TOC-TS-Fe relationship indicated that Onnagawa Formation was characterized by a high degree of pyritization. More than 95% of the pyrite is framboidal and small-sized (average diameter = 4.73–5.55 μm). Thus, our results suggest that a euxinic water column was established in the Akita Basin during deposition of the Onnagawa Formation. The euxinic conditions in the bottom waters favored the preservation of hydrogen-rich, oil-prone organic matter and the occurrence of sulfur-rich kerogen.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Constraints on the Organic Matter Accumulation of Lower Cambrian Niutitang Shales in the Middle Yangtze Region, South China

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Keywords: Niutitang Formation, Hydrothermal activity, Redox conditions, Primary productivity, Sea level

The lower Cambrian Niutitang shales, as one of target intervals with the greatest potential for shale gas exploration and development, have attracted much attention. Nevertheless, the organic matter enrichment mechanisms of the lower Cambrian Niutitang shales need further study, especially in the hydrothermal active zone. In this study, samples from ND1 well in western Hubei Province, middle Yangtze region, South China, were investigated for the controlling factors of organic matter accumulation of Lower Cambrian Niutitang shales by detailed petrographic, mineralogic, and geochemical proxies. The results show that hydrothermal activity and sea level fluctuation controlled the redox conditions and paleoproductivity of seawater and ultimately controlled the organic matter accumulation of Niutitang formation. In the Niu-1 member, the intense hydrothermal events lead to a suboxic to anoxic environment, which is conducive to the organic matter preservation. However, low sea level strengthens the restriction of water mass and reduced nutrient upwelling into the shelf, leading to decreased marine primary productivity, which was ultimately responsible for depleted organic matter accumulation in the Niu-1 member. In the Niu-2 member, the anoxic-euxinic environment and high paleoproductivity, driven by continuous hydrothermal activity and rising sea level, were the main factors controlling the enrichment of organic matter. In the Niu-3 member, the dysoxic to oxic condition plus low primary productivity, caused by the disappearance of hydrothermal activities and sea-level fall, resulted in the unfavorable organic matter accumulation. The results of this paper enrich the model of organic matter enrichment in the lower Cambrian black shale in the middle Yangtze region.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment
Presentation Preference: Oral Preferred

Palynomorph Darkness Index: a quantitative and well-constrained optical method for defining the thermal maturity of organic matter

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Keywords: Palynomorph Darkness Index, Reflectance Vitrinite, Thermal Maturity of Organic Matter

The assessment of thermal maturity of organic matter is a fundamental task in many types of geological investigation, including the reconstruction of burial history of stratigraphical successions in sedimentary basins, paleotemperature profiling and the detrmination of hydrocarbon generating potential. Palynomorph Darkness Index (PDI) is a quantitative method for evaluating thermal maturity in sedimentary basins, based on the image-analysis of palynomorphs. The growing use of this method has demonstrated the need for calibration with other maturity indicators such as reflectance vitrinite, Tmax, Raman spectroscopy, SCI (Spore Color Index) and TAI (Thermal Alteration Index). In this study, calibration of miospore PDI against Vitrinite Reflectance (VR) was achieved on a set of 82 borehole samples of known VR, ranging from 0.20 Ro% (immature stage) to 2.06 Ro% (overmature stage). We present a strong correlation of VR with PDI. This demonstrates that PDI is not only an excellent, independent, quick and cheap method for defining the thermal maturity of organic matter but that it also has potential for the elucidation of phenomena such as reworking and recycling that may not be recognizable by the use of VR or Tmax.

Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Sedimentary Environment Identification and Hydrocarbon Source Significance of Black Shale in Ordovician Meitan Formation, Banqiao section, Zunyi,Guizhou, China

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Keywords: black shale, source rocks, shallow water sedimentary environment, trace elements, Meitan Formation

The Middle Ordovician Meitan Formation in the Upper Yangtze area of South China is a set of thick mud shale deposits, in which black shale is well developed. However, the current understanding of its sedimentary environment is controversial. Taking the Banqiao section of Zunyi as an example, this paper focuses on the analysis of the relative water depth, sedimentary hydrodynamics and physical and chemical properties of paleo-seawater during the deposition of black shale and its symbiotic rocks through the comprehensive study of the sedimentary characteristics and geochemical characteristics. The results show that: (1) The black shale of Meitan Formation is characterized by its dark color and well-developed horizontal texture, and does not produce micropaleontology fossils. It is mainly produced in the symbiotic form of frequent interbeds with different thicknesses of bioclastic limestone or calcareous siltstone, indicating that the black shale of Meitan Formation should not be the sedimentary product of deep-water environment, but deposited in the low-energy shallow cement lagoon environment in the mixed platform. (2) Interbedded with black shale, the bioclastic limestone section mostly develops the tapering inverse graining structure, and iron oxides can be seen at the top, while the calcareous siltstone, interbedded with black shale, mostly develops interlaced bedding and biological drilling, showing shallow water deposition characteristics; (2) The bioclastic limestone interbedded with the black shale mainly developed the reverse sequence structure of the lower fine and the upper coarse, with iron oxides at the top, while calcareous siltstone with the black shale is mainly composed of wavy cross bedding and biological boreholes, showing the characteristics of shallow water deposition; (3) The average values of V/ (V+Ni), Th/U, V/Cr and Ni/Co of black shale are 0.71, 5.52, 1.07 and 2.04, respectively, indicating the hypooxidation-oxidation environment; Sr/Ba values range from 0.11 to 2.20, with an average value of 0.55, indicating fresh-brackish water environment; (4) Macroscopically, obvious erosion surface can be seen in some sections of bioclastic limestone, and karst development can be seen through microscopic observation. At the same time, the REE distribution pattern tends to be horizontal, and the ∑ REE value is higher and Y / Ho is lower, showing the characteristics of exposed karst. (5) TOC values of black shale ranged from 0.09% to 1.05%, with an average of 0.39%. TOC values of recovered black shale ranged from 0.28% to 3.16%, with an average of 1.25. The average Ro is 2.095, and the organic matter is mainly sapropelic. Comprehensive analysis of this study shows that: The black shale of Meitan Formation in Banqiao section of Zunyi is a set of effective hydrocarbon source rocks formed in an shallow water and oxygen-lean environment and high paleoproductivity is the main reason for the organic matter enrichment. The research results provides strong evidence for identifying the sedimentary environment and hydrocarbon generation potential of black rock series in Meitan formation in southern Sichuan, and also provides a new example for the identification of sedimentary environment conditions of shallow-water black shale.

Scientific Themes: Theme 10. Sedimentary Geochemistry
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Presentation Preference: Oral Preferred

Response of Paleofire to Paleoclimate since Late Pleistocene in the Dajiuhu

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Keywords: Dajiuhu,monsoon,Paleofire,charcoal

The paleoclimate changes of Dajiuhu from the last glacial period has been reconstructed in previous studies. However, the charcoal and history of wildfires in this area have not been revealed. In this study, charcoal and TOC in the 300cm drilling core of 20ZK-5-2 has been used to reconstruct the paleofire events and clarity the response mechanism of fire to climate. The results of charcoal abundance show that the area concentration was 0.91~195.77mm2/g, with an average value of 17.27±15.32mm2/g, and the average TOC content was 27 %. The maximum value of charcoal concentration appeared at the depth of 25~40 cm (0.5~1kaB.P.), reflecting the obvious drought event in this period. In addition, the peak of charcoal also appeared at 50~65 cm and 104~120 cm (around 4kaB.P.), and the average area concentrations were 24.69 mm2/g and 17.21 mm2/g, respectively.

(1) From Late Pleistocene to Holocene, the charcoal and TOC was low with weak fluctuation, indicating that the climate is humid and cold. It is in good agreement with the cold and wet characteristics of the last glacial period.

(2) In the early Holocene, with the charcoal and TOC increasing gradually, the climate began warming and drying, but the range is small. it generally inherited the characteristics of the late glacial climate, cold and humid; meanwhile, the charcoal reflected the cooling events about 8.2ka B.P., with a peak of 26.31 mm2/g, indicating drought events.

(3) In the Middle Holocene, fires increased and indicated that the current climate warming dry; thereinto, the charcoal appeared high value at 4ka B. P. to point more prominent drought events. Huang et al used BNA15 to reconstruct the paleotemperature of Dajiuhu in 2013 and the paleoclimate reconstructed by Hu et al to δ18O of Heshang Cave in 2008 show that this stage is a process of gradual weakening of monsoon and relatively less precipitation. In addition, the mid-late Holocene monsoon recession around 4ka B.P. is characterized by a rapid shift from warm and humid climate to cool and dry climate.

(4) In the Late Holocene, Fires increased significantly and began to appear larger fluctuations, indicating that the current climate warming dry; the sharp increase in charcoal may derive from the use of fire in this period of human activity. But the frequency of fire decreases since 0.5ka B. P, this record is consistent with the TOC and other indicators of other sedimentary columns in the Dajiuhu, indicating that the climate in the Dajiuhu region has gradually turned to cold and humid and the reduction in slash-and-burn behavior.

The climate and environmental evolution information recorded by the various indicators of the Dajiuhu Lake is consistent with the charcoal record, which is a good response to the climate change since the Holocene in the Dajiuhu. Compared with the similar sedimentary profiles in the East Asian monsoon region, with the monsoon change model of “dry after the weakening monsoon in the early-middle Holocene”, the dry-wet change model maybe can be constructed using charcoal.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-1: Application of organic matter research for palaeoenvironment, palaeoclimatic and palaeogeographic reconstructions and thermal maturity assessment
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Petrology and geochemistry features of the Middle Triassic Anisian shale in Sichuan Basin, South China: Implications for the climatic and environmental condition change.

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Keywords: Middle Triassic, Shale, Chemical weathering, Anoxia

The Middle Triassic was an important stage during which the global environment gradually stabilized following the severe environmental disturbance of the Late Permian to Early Triassic. After entering the Anisian stage, the recovery rate of ocean ecosystems suddenly accelerated and the cracking of the Pangea continent peaked and responded in the Leikoupo Formation, located in the Sichuan Basin in South China. Shallow-water carbonate rocks were deposited in the Leikoupo Formation but there was also the abrupt deposition of a thick shale interval in the Lei^3 member. A comprehensive analysis of the elemental, geochemical, and stable isotope ($\delta^{13}C_{org}$ and $\delta^{15}N_{org}$) characteristics of the black shales was performed.

The chemical weathering intensity was high during the Anisian, as indicated by the weathering proxies (e.g., CIA) of shale. The CO_2 concentration, $\delta^{13}C_{org}$ and $\delta^{15}N_{org}$ excursions indicated the promotion of paleoproductivity by the high degree of weathering. This was consistent with the rapid recovery of the ecosystem in the Anisian period after the P-T mass extinction.

The CO_2 concentration in seawater gradually decreased, the ocean acidification weakened, the $CaCO_3$ production rate increased, and the corresponding lithofacies changed. Furthermore, anoxic bottom water conditions were confirmed by the enrichment of U, V, Mo, and other elements. The sedimentation of the shale intervals and the enhanced weathering intensity were likely linked to the regional tectonic movements induced by the continental cracking of Pangea.

Scientific Themes: Theme 10. Sedimentary Geochemistry
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Presentation Preference: Oral Preferred

Organic material in the geological cycle: Deciphering the Earth's past using an intergrated approach

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Keywords: organic material, palynology, fossil charcoal, palaeomire

Terrestrially derived organic material in the Earth's crust is common, but typically comprises only a small percentage in any sedimentary sequence. Nonetheless, the amount of information that can be gleaned from examination of these particles is huge and often underrated. Whereas most sedimentologists may concentrate on the inorganic sediment facies and their structure and composition, organics are mostly lumped into a general category of 'terrestrial'. This is a mistake, especially in sequences where other data can be hard to come by or interpret. Fundamentally, organics from plants use the sun's energy to drive photosynthesis, which in turn creates large molecular structures made up of C, H, O, and N. When these organics become buried they preserve clues to the past in many ways. For example, we can understand what types of vegetation grew in palaeomires and adjacent ecological niches by studying the palynology, biogeochemistry or identifying the preserved tissues. Palaeoclimate, fire frequency and even atmospheric oxygen level can be estimated through the study of fossil charcoal. Examination of trends in stable carbon isotopes can also help to unlock both regional and global events that were impacting on the organics during deep time. The organics we find in sediment, either in dispersed or concentrated (i.e. coal) forms are vital puzzle pieces that help to give high resolution reconstruction of the Earth's past. So, remember, the truth is out there, and it's probably in the organics!

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Presentation Preference: Oral Preferred

A Novel Method for Maturity Evaluation of Sedimentary Organic Matter by High Resolution Mass Spectrometry

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Keywords: High resolution mass spectrometry, Polar molecular compounds, Molecular structure evolution, Organic matter maturity, Source rock evaluation

The maturity of sedimentary organic matter is one of the key parameters in oil and gas evaluation. The accuracy of its evaluation results is particularly important for high-quality exploration and development of oil and gas resources. However, the existing maturity evaluation indexes are mostly limited by the measurement principle and can not fully meet the needs of current oil and gas geochemical evaluation. Fourier transform ion cyclotron resonance mass spectrometry (FT-ICR MS), as an ultra-high resolution mass spectrometry analysis technology, has gradually been paid attention to and widely used in the field of energy geology. The composition and content of polar molecular compounds of sedimentary organic matter can be analyzed with high accuracy by FT-ICR MS. The components and contents of polar molecular compounds of organic matter deposited in different basins and strata show similar changes in the process of thermal evolution of organic matter. The carbon number and DBE of each target compound generally decrease with the increase of maturity, and the types of compounds also decrease in varying degrees with the increase of maturity. Count the signal abundances SA1 and SA2 (signal abundances) corresponding to the defined interval, and finally calculate MIFT (Maturity index of FT-ICR MS) according to the formula MIFT = (SA1) / (SA2), so as to realize continuous quantitative maturity evaluation. In order to fully verify the feasibility and universality of MIFT, representative typical source rock samples are selected from different strata in different basins around the world. The MIFT of the above typical samples is fitted and compared with the commonly used maturity indexes vitrinite reflectance (Ro) and pyrolysis peak temperature (Tmax). In general, the MIFT analysis method is based on the general law of the structural evolution characteristics of organic matter, follows the logic of "element-molecule-compound" analogy, quantifies the structural characteristics of polar molecular compounds in the thermal evolution process of organic matter, and the evaluation principle returns to the essence of the molecular structure evolution of organic matter compounds in the thermal evolution process, which is expected to become a new and practical maturity evaluation index.

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Session T10-2: Authigenic minerals and global changes: micro-archives of the big picture

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-2: Authigenic minerals and global changes: micro-archives of the big picture
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Genetic mechanism of calcite cementation in continental sandstone and its petroleum geological significance

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Keywords: Calcite cementation, genetic mechanism, calcareous interlayer, distribution prediction, Tahe Oilfield

Calcareous interlayer is widely developed in deep sandstone reservoir and is the key factor affecting the distribution of remaining oil. At present, the research on the genetic mechanism of calcite cementation is relatively weak, which restricts the prediction of the distribution of calcareous interlayer and increases the uncertainty of efficient oil and gas exploration and development. Taking the deep clastic rock reservoir of Lower Triassic oil formation in Tahe oilfield as the research object, combined with thin section analysis, XRD whole rock and clay test, cathodoluminescence, electron microprobe, element analysis and carbon and oxygen stable isotope analysis and testing, this project carries out macro and micro fine characterization of authigenic calcite cementation, and explores the distribution law of calcareous interlayer. The study shows that the calcareous interlayer rock type is mainly fine sandstone, and the cement is mainly calcite cement, with a content of 0 ~ 16.2%There is mainly two stages of calcite, and the pore water forming calcite is mainly fresh water, and a small part is a slight mixture of salt water and fresh water. The cementation content of early calcite is low (< 2%), mainly adherent particles are developed, bright yellow under cathodoluminescence, the values of iron and manganese are significantly higher than those of late calcite, the formation temperature distribution range is 60 ~ 75^{O}C, and the formation mechanism is microbial fermentation. The cementation content of late calcite is high, which is mainly filled with intergranular pores and cemented in the form of large particle continuous crystal. A few are located in the intergranular pores of feldspar or rock debris dissolution. The cathode luminescence is orange red, and the formation temperature distribution range is 90-122.2 ℃. The late calcite mainly comes from the decarboxylation of organic matter. The carbonate cementation zone occurs frequently and is easy to identify. The thickness of calcareous interlayer on the core can reach 4.6m. Calcareous septum is mainly distributed in the middle and lower part of positive rhythm and the top of anti rhythm. Calcareous interlayer is distributed in the delta plain and delta front. On the delta plain subfacies, the distribution range of calcareous interlayer is small and locally distributed in river sand bars. The calcareous interlayer of delta front subfacies is mainly distributed in distributary channels and river mouth bars for many periods.

Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-2: Authigenic minerals and global changes: micro-archives of the big picture
Presentation Preference: Oral Preferred

Revealing the effect of barite-bound Sr on the use of detrital Sr isotope systematics in marine sediments - with pertinent Mediterranean examples

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Keywords: Sr isotopes, Barite, Sapropel, Mediterranean Sea, Provenance, Marine sediments

In marine sediments, the Sr abundance and isotope composition (87Sr/86Sr) of the terrigenous detrital component are widely used to track changes in provenance and related transport and weathering processes. Accurately separating detrital- from other sedimentary Sr-phases is a prerequisite for such studies. Conventionally, it is assumed that Sr in the carbonate-free residue corresponds to detrital Sr alone. However, the decarbonated residue may contain barite with a significant amount of Sr, which could substantially affect the derived detrital Sr signal. The Mediterranean Sea is an ideal area to examine this hitherto unreported phenomenon, because 1) detailed provenance studies have been done using Sr and 87Sr/86Sr of the residual fraction, and 2) enhanced levels of barite repeatedly occurred in association with distinct, organic-rich sapropel sediments.

Here, we use the most-recent sapropel S1 interval to evaluate the effect of barite-bound Sr in the residual fraction after decarbonation. A total of 130 samples were taken from 10 cores in the eastern Mediterranean Sea (EMS) and from 1 representative core in the western Mediterranean Sea (WMS). This selection represents a geographic and bathymetric coverage of the EMS and permits a basin-wide comparison between the EMS and WMS. After decarbonation using 1 M HCl solution, the residual sediments were subject to NH4Cl extraction (2 M, pH 7), known to selectively dissolve barite.

Our results demonstrate the presence of Sr-bearing barite after traditional carbonate removal and its effect on the derived “detrital” Sr signature. This barite-Sr effect is significant for samples with barite-Ba >400 μg/g in bulk sediment. The impact of barite is prominent if accompanied by a detrital provenance background of high 87Sr/86Sr (>0.713) or low Sr/Al (<1.0 mg/g). In such cases, removal of remaining barite is required to obtain an adequate signal of detrital Sr. We recommend an improved procedure for detrital Sr separation in marine sediments, with an additional NH4Cl leaching step to eliminate any remaining barite after decarbonation. This approach is particularly important for areas/eras of high biological productivity, where sediments are often characterized by abundant barite content.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-2: Authigenic minerals and global changes: micro-archives of the big picture
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The origin, genesis and distribution of carbonate cements in Paleogene Shahejie Formation of Bohai Oilfield

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Keywords: carbonate cements, carbon and oxygen isotopes analysis, paleogeographic environment, Bohai Oilfield

Bohai Oilfield is the largest crude oil producer in China, and the Paleogene Shahejie Formation is one of the important exploration and development targets. The tight layers generated by carbonate cementation are widely developed in Shahejie Formation, which strongly influences reservoir performance by controlling fluid flow and recovery factors. The elucidation of the origin and distribution of carbonate cements is of great importance for the effective development of Bohai Oilfield.

Based on the comprehensive utilization of core scanning under white light and fluorescence, thin section analysis, cathodoluminescence, carbon and oxygen isotopes analysis, the carbonate cements are divided into three types, namely, pore-filling sparry calcite cements, basal calcite cements, bio-rich micrite calcite and dolomite cements.

Pore-filling sparry calcite cements account for the highest proportion in tight layers. The cathodoluminescence showed bright red, indicating low iron and magnesium content. The $\delta_{13}C_{PDB}$(‰) is between -6~0, which reflects that it is formed by precipitation from carbonate supersaturated alkaline fresh water, and its material source is related to the dissolution of feldspar and carbonate bioclasts. The pore-filling sparry calcite was cemented later than the oil and gas charging at Late Paleogene, so its distribution is significantly controlled by the fluid properties. The content of cements in the water layers where the pore fluid is alkaline is significantly higher than that in the oil layers where the pore fluid is acidic.

The basal calcite cements clearly show an eogenetic origin, formed before compaction. The cements in deltaic sandstones occurs as scattered and strata bound concretions at the flooding surfaces at the top of delta-front deposits. The cements are often associated with carbonate intraclasts, and their cathodoluminescence show dark red, indicating the characteristics of high iron and magnesium content. The $\delta_{13}C_{PDB}$(‰) is between 0 and 2, and the paleosalinity is basically greater than 122, reflecting that the eogenetic carbonate cementation is closely related to marine fluids. The carbon and calcium ions can be transferred directly from the sea water by diffusion subsequent to the establishment of chemical potential gradients with low ionic concentrations in pore waters due to calcite precipitation.

The bio-rich micrite calcite and dolomite cements constitutes fluid-flow barriers along layers rich in intraclasts or carbonate bioclasts. The original distribution of the carbonate bioclasts, which they consider to be the main cement source, and the number of nucleation sites are the primary controls on the spatial distribution and geometry of calcite and dolomite cement.

During the Middle-Late Paleogene, the lake basin in the Bohai Sea largely shrank, forming micro-geomorphic units such as limited shallow basins and underwater highlands. The shallow water, warm climate, and the strong evaporation had provided favorable paleogeographic conditions for the formation of carbonate cements.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-2: Authigenic minerals and global changes: micro-archives of the big picture
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Morphological characteristics of organic-rich shale pyrite and its significance to the restoration of sedimentary environment: an example from the first member of Qingshankou Formation, Gulong Sag, Songliao Basin

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Keywords: Organic-rich shale, Pyrite, Morphological characteristics, Sedimentary environment, the first member of Qingshankou Formation

Pyrite, as an important constituent mineral in organic-rich shale, can be used to recover the depositional environment in the light of its morphology, the size distribution of pyrite framboids and sulfur isotope indicatively. In this study, we used the organic-rich shale in the first member of Qingshankou Formation, Gulong Sag, Songliao Basin(K_2qn^1) as the object, observed the morphology of pyrite by scanning electron microscopy and determined the sulfur isotope value of pyrite by the method of "chromium reduction", in order to restore the sedimentary environment of the target section. The study shows:

(1) Four types of euhedral pyrites, pyrite framboidals, fine-grained pyrite aggregates and polyframboids are developed in the K_2qn^1, and pyrites are often associated with organic matter (OM) and clay minerals, among which the OM is often filled in the intergranular pores of pyrite framboids, while the morphology of euhedral pyrites associated with clay minerals is often controlled by interlayer pores of clay minerals.

(2) In terms of pyrite morphology, pyrite framboids, some of which has the characteristics of cementation and overgrowth, are less developed while euhedral pyrite is more developed, and the size distribution of pyrite varies widely (ranging from 100nm to 10μm). Therefore, it is suggested that the pyrite in the K_2qn^1 has both bacterial sulfate reduction (BSR) and thermochemical sulfate reduction (TSR) genesis, and due to the increase of temperature at the later burial depth, the pyrite framboids of BSR is most likely to be transformed to euhedral pyrite by TSR.

(3) From the pyrite sulfur isotope, the pyrite sulfur isotope value ($\delta^{34}S_{py}$) in the area ranges from 13.3‰-23.3‰, with a mean value of 18.2‰, which is quite close to the sulfur isotope value of marine sulfate (18.55‰) during the deposition of K_2qn^1. The low isotopic fractionation value indicates that the marine incursion occurred during the deposition of K_2qn^1, the pyrite of BSR was formed in a closed system with limited sulfate supply, and the depositional environment was a reduction environment at that time.

Scientific Themes: Theme 10. Sedimentary Geochemistry
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Presentation Preference: Oral Preferred

Field based relationship between cellular sulfate reduction rate and ∂34S of chromium reducible sulfur in the shallow southern Baltic Sea

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Keywords: Sulfur isotopes, cellular sulfate reduction rates, shallow coastal sea, iron-sulfur authigenesis

The ∂^{34}S of chromium reducible sulfur (CRS; essentially pyrite) reflects the stable isotope composition of reacting dissolved sulfide. The ∂^{34}S of CRS is thereby shaped by factors like: cell-specific sulfate reduction rate, microbial community structure, organic matter content, temperature, availability of reactive iron, availability of sulfate, and sulfide oxidation. The latter may be impacted by sediment mixing due to the activity of organisms and anthropogenic disturbances. Experimental studies suggest an inverse relationship between cell-specific sulfate reduction rate and the ∂^{34}S signature of sulfide, but this specific relationship is only seldom investigated in field studies, and may vary with further site-specific conditions as organic matter quality and sulfate-reducing genera and fitness. Here, we report on results obtained as part of the project MGF-Ostsee, focusing on surface sediments of the shallow coastal brackish Baltic Sea in the Fehmarn Belt region. Sediment cores were collected at six adjacent sites (within a 5 km area), which have similar modern sedimentation histories. We assessed the porewater biogeochemistry, the sediment geochemical composition (TOC, TN, reactive Iron, ∂^{34}S-AVS, and ∂^{34}S-CRS), and depth resolved gross rates of sulfate reduction (SRR) via ^{35}S radiotracer incubations. Per-cell SRR were estimated using bulk sediment gross SRR, total cell counts (by microscopy) as well as estimates of the relative abundances of sulfate reducing microbes (amplicon sequences with taxonomic assignments). The gross rates of microbial sulfate reduction were highest in the top 5-7 cm below sea floor. We find that the ∂^{34}S of CRS was heaviest in the top 5-7 cm (between -34 and -37 ‰-VCDT), followed by a rapid decrease in ∂^{34}S signature with depth (over 1-2 cm) to minima of -39 to -42 ‰. We relate these changes in ∂^{34}S signature of CRS to changes in cellular SRR superimposed by sulfide oxidation in the top sediments. Sediments under impact of ground-net fishing activity were characterized by disturbances of the vertical isotope composition in an additional two sites.

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Session T10-2: Authigenic minerals and global changes: micro-archives of the big picture
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Mineral distribution and biogeochemistry of coastal sediments affected by anthropogenic impact of mobile bottom-contact fishing

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Keywords: Carbon, Sulfur, Biogeochemistry

The research project MGF-Ostsee deals with the consequences of the exclusion of mobile bottom-contact fishing in the southern Baltic Sea, specifically to assess its effects on the biogeochemistry of surface sediments and across the benthic-pelagic food chain. In Summer 2021, an in-situ monitoring experiment was conducted to investigate the short-term impacts of bottom trawling. Herein, we present results on how this anthropogenic intervention affects the base of ecosystems, i.e., biogeochemical processes and associated elemental cycling, as well as the resulting changes in geochemical mineral tracers. We analyzed porewater and sediment, as well as the water column for major, minor and trace elements, and the stable isotope composition (C, S, O) of dissolved and solid carbon and sulfur species. The measurements of porewater gradients are combined with lander-based oxygen-consumption and radiotracer-based microbial sulfate reduction rates to elucidate how the potential disturbances affect element (C, P, Mn, Fe, S) and mineral (re)distribution on a long-term scale.
The controlled trawling experiment generated a re-suspension plume of up to 4 NTU and that reached up to 2 m above the sea floor. In the area affected by trawling, short cores were taken with a MUC prior and one to two hours after the experiment, and on the following day. In addition, sediment cores were recovered by divers from furrows and mounds of recent trawl marks. First results suggest that in the trawled area, the coupled Fe-Mn-P cycle reacts most sensitively, as expressed by altered porewater gradients. In the trawl marks, pore waters are affected differently whether sediments are removed, as in trawl furrows (erosion), or added/topped, as in trawl mounds (burial). In general, the tentative results point towards a loss of dissolved Mn in the trawling area and in the furrows, whereas in the mounds, Mn/(Fe+P) ratios are enhanced in the top few cm, a result similarly portrayed for instance in particle bound chlorophyll pigments.

Scientific Themes: Theme 10. Sedimentary Geochemistry
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Presentation Preference: Oral Preferred

Sulfate-methane transition zone movements in ancient marine sediments recorded by diagenetic barite-calcite-pyrite nodules in the Silurian Longmaxi Formation of the Yangtze Block, South China

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Keywords: Anaerobic oxidation of methane, Diagenesis, Sulfur and carbon isotopes, Early Silurian

The sulfate-methane transition zone (SMTZ), an important biogeochemical boundary, is ubiquitous in marine sediments, ranging in depth from a few centimeters to hundreds of meters. Organoclastic sulfate reduction (OSR), sulfate-driven anaerobic oxidation of methane (SD-AOM), fermentation, and methanogenesis, the dominant diagenetic processes near the SMTZ, play key roles in marine sulfur and carbon cycling (Jørgensen et al., 2019). However, under non-steady-state conditions that common to most sedimentary successions, frequent and large fluctuations in the depth of the SMTZ complicate or erase corresponding sedimentary and geochemical records, thereby making it difficult to uniquely recognize paleo-SMTZs in ancient rocks (Borowski et al., 2013). Moreover, the history of SMTZ movement in the geologic record has been rarely studied because of equivocal evidence (Lash, 2015). Toward an improved understanding of the dynamism of paleo-SMTZs, we report on a newly found interval of an authigenic barite-calcite-pyrite assemblages hosted by the Silurian Longmaxi Formation of west Hubei, South China. The inferred paleo-SMTZ comprises nodules made up of barite ($BaSO_4$), calcium carbonate ($CaCO_3$) and pyrite (FeS_2), and pyritic laminae. Strong ^{34}S enrichment of barite (50 to 62.1‰ VCDT) and modestly ^{13}C-depleted calcite (− 11.4‰ to − 5.3 VPDB) of the nodules associated with positive $\delta^{34}S$ values of pyritic laminae (4 to 6.2‰ VCDT) suggest precipitation of these minerals sourced by mixed carbon and sulfur sources close to and/or within the paleo-SMTZ. Nodules from center to edge display mineral zonation that may reflect the effects of depth fluctuations of the paleo-SMTZ. Initial (stage 1) barite mineralization in nodule centers appears to have occurred within the base of the sulfate reduction zone (SRZ). By the time if stage 2 mineralization, the stratigraphic locus of precipitation had migrated closer to highly alkaline SMTZ resulting in barite dissolution and calcium carbonate precipitation. Higher proportions of calcium carbonate exhibiting some enrichment of ^{12}C associated with cubic pyrite crystals in nodule centers are consistent with the occurrence of SD-AOM within the SMTZ. Stage 3 acicular barite mineralization along nodule edges likely took place near at the base of SRZ immediately above the SMTZ, whereas the replacement of barite by calcite during stage 4 mineralization occurred again within the SMTZ. Combined with published data (Zan et al., 2020), vertical movement of paleo-SMTZs suggested by the occurrences of barite-calcite-pyrite assemblages in the Longmaxi Formation across Yangtze Block, are likely the consequence of the complex interplay of varying sedimentation rate, organic matter quality, methane flux, and perhaps seawater sulfate concentration.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
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Mn(II) carbonate authigenesis marks the benthic SMTZ and is fueled by Mn-driven anaerobic oxidation of methane: A Black Sea perspective

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Keywords: Manganese-driven anaerobic methane oxidation, SMTZ;alkalinity, CaMn-carbonate solid-solution, rhodochrositization front

In the Black Sea, sediment cores covering the last brackish-limnic transition were recovered and investigated for anaerobic biogeochemical processes controlling sulfur, carbon, and metal cycling. The development of a sulfate-methane transition zone (SMTZ) is nowadays found below the brackish zone in the limnic part of the sediments that limits the upward migration of biogenic methane into surface sediments and the water column. The position of the SMTZ may have changed in the past due to dynamic fluxes of dissolved species in the pore water. Besides dissolved sulfate, metal-bearing minerals have been shown to serve as potential reactants, also converting CH4 into dissolved inorganic carbon (DIC). The pore water and sediment stable isotope (C, S, O) and geochemical composition were investigated, as well as in-situ microbial rates of sulfate reduction and total anaerobic oxidation of CH4 (AOM) obtained from sediment incubations for the identification of a potential contribution of manganese-bearing minerals to AOM in the limnic part of the sediments (Mn-AOM). In the limnic Black Sea sediments Mn-AOM is causes an upward flux of dissolved Mn whereas intense SO4-AOM located in shallower sediments leads to an increase in pH and a maximum in DIC concentrations in the SMTZ. The resulting change in saturation states leads to the precipitation of mixed MnCa-carbonate solid-solutions (‘rhodochrozitization front’) and the development of a zone enriched in excess sedimentary Mn(II). We further argue that these authigenic fronts may survive changes in pore water composition and are stable in the anoxic sedimentary record, marking the position of paleo-SMTZs. The persisting formation of this geochemical marker is in contrast to the temporal development of a sulfidization front of metastable mackinawite, that is fromed by the reaction of downard migrating sulfide with upward diffusing Fe(II), originating from SO4-AOM and Fe-AOM, respectively.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-2: Authigenic minerals and global changes: micro-archives of the big picture
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Mineral reaction kinetics: Very likely a prerequisite to correctly read the geochemical fingerprint of sediments

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Keywords: mineral growth, mineral dissolution, kinetics, upscaling

How important are the results generated at the molecular scale and how do we connect these results with meso- and large scale processes? This is certainly a complex problem that may require complex answers. In other words how do we manage the upscaling task and make frontier research results accessible for the multitude of applications that our daily work demands?

Within a relative short time period of just a couple of decades the joined effort of field and experimental research, sophisticated analytical methods and (quantum) computational models has generated vast and important progress in our fundamental understanding of mineral reactions and its kinetics. Importantly, this progress was generated largely by studying so-called low temperature minerals – or better the formation and dissolution/weathering of minerals at low to moderate temperatures. Here, we will briefly review some of the highlights of these sometimes even exciting results. Results that are highly appreciated in the light of the ever increasing number of applications that demand a better quantitative understanding of mineral reactions. Their often critical role in large scale processes such as the prediction of long-term behavior of geo-reservoir rocks, ocean acidification, hazardous (nuclear) waste deposits, and – maybe most importantly – their role in global climate change demand our full attention and creativity.

Beside our challenge of making the cutting-edge achievements of mineralogical and (geo)chemical research accessible to a broad audience in sedimentology, geochemistry, and geobiology the ability to upscale our findings at the microscopic level to macroscopic system sizes should be a central task (e.g., Luttge et al., 2019). Often, the results at different scales are already available but the interfaces to connect them are still missing. To highlight just one example, we recognize that crystal dissolution, weathering and growth rates are not correctly described by a single rate constant but by a multitude of rates, a rate spectrum. However, this insight seems difficult to implement in reactive-transport models and is often met with significant skepticism. Consequently, we may have to focus on new strategies that will provide a pathway of up-scaling our results, i.e., how do we utilize the fast increasing results at the molecular scale with the meso- and large(r) scale problems, both in length scale as well as in time.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-2: Authigenic minerals and global changes: micro-archives of the big picture
Presentation Preference: Oral Preferred

Disentangling the biological role in authigenic pyrite formation

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Keywords: authigenic, pyrite, framboidal, geochemistry

The association of minerals and life has appeared very early in Earth History. Hence, the presence of certain authigenic minerals, even very small ones, can be considered as microarchives of former life. But determining the biological role in the development of these minerals is not always an easy task. This is the case for pyrite that often display a framboidal texture commonly interpreted as indicative of a biogenic influence. But determining factors controlling the development of the framboidal texture may be either external influence, due to biologic activity, or an internal consequence of pyrite crystallization (Sweeney and Kaplan, 1973 and references herein). Recent technical developments are now providing critical information to disentangle the role of the different players in their formation.

Modern lakes and their sediments offer the opportunity to study the relationship between their living and non-living compartments and, thus, the formation of authigenic minerals and their potential significance as environmental proxies. Greigite, a highly magnetic iron sulfide and often considered as a precursor of pyrite, has been clearly identified in Lake St. Moritz, Switzerland. The prevailing environmental conditions during the occurrence of this mineral have been recognized through existing historical data (Ariztegui and Dobson, 1996). Detailed SEM investigations along with XRD and magnetic data have shown a clear sequence from spherical and irregular crystal shapes often related to bacterial activity, further evolving to perfectly framboidal forms. At the time, however, the technical ability to precisely determine this bacterial role was missing.
Recent investigations by Marin-Carbonne et al. (2022) are providing critical data concerning the relationships between microbial metabolic activities and their signatures in pyrite forming in modern microbialites. The used geochemical approach is not only uncovering the biological role but also showing the importance of alternating redox conditions in the formation of these authigenic minerals. Thus, it is anticipated that micropyrite crystals in microbialites can be used as a mineral signature for reconstructing past Earth surface and microbial environments at different geographical and temporal scales

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-2: Authigenic minerals and global changes: micro-archives of the big picture
Presentation Preference: Oral Preferred

Sulfur authigenesis and isotope discrimination in a coastal peatland under impact by flooding with seawater

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Keywords: peatland, flooding, iron sulfides, sulfur isotopes, textures

Land-ocean interactions in the coastal zone are of particular interest regarding the exchange of substances, like carbon, sulfur, nitrogen, phosphorus, metals, and water. Rising sea levels enhance the pressure of salty solutions on previously fresh water ecosystems. We present new results on the isotope biogeochemistry of a modern rewetted wetland, at the southern Baltic Sea coast, the Huetelmoor, that is under impact by event-type flooding by brackish seawater. Sediment cores on transects within the wetland were investigated for the chemical composition of the pore water and the soil. The soil samples were analyzed for elemental composition, mineral micro-textures, and the stable isotope composition of different fractions to understand the water and biogeochemical carbon-sulfur-metal cycles and the geochemical signatures in authigenic mineral phases.

Flooding events with brackish water enhance the availability of sulfate as an electron acceptor for microbial carbon transformations. This additional sulfur in the peatland impacts the remineralization capacity of organic substrates, and creates space for mineral authigenesis with distinct textures. The characterization yields isotope signals that are indicative for ecosystem biogeochemistry and allow for a transfer of proxy information to other modern and past coastal peatlands.

The cored peat sequence was found to reflect the activity of sulfate-reducing bacteria and the associated formation of pyrite with different textures, as well as isotope evidence for a sulfurization of organic matter. Sedimentary sulfur fractions and their stable isotope signatures are controlled by the availability of dissolved organic matter and/or methane, reactive iron, and in particular by the availability of dissolved sulfate. Therefore, their formation varies with the relative position from the coast line further depending on surface topography and peat characteristics. Mechanistic investigations consider the role of dissolved organic sulfur upon changing sulfur substrate availability.

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Session T10-3: Organic - inorganic interactions in sedimentary basins

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-3: Organic - inorganic interactions in sedimentary basins
Presentation Preference: Oral Preferred

Sedimentary geochemical characteristics of deep and shallow lacustrine source rocks: a case study of Zhusan depression, Pearl River Mouth Basin, China

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Keywords: sedimentary geochemistry, source rock, deep lake, shallow lake, Zhusan depression

Zhusan depression is a key exploration area in Pearl River Mouth Basin. Source rocks are distributed in Wenchang-A and Wenchang-B sags. Affected by tectonic movement, shallow lacustrine source rocks are developed in Wenchang-A sag, and a set of middle-deep lacustrine source rocks are developed in Wenchang-B sag. To explore the development environment and sedimentary geochemical characteristics of source rocks in different sedimentary facies in different sags, 355 samples from 6 wells were collected to carry out the main trace element experiment, 120 samples were used to rock pyrolysis, 50 samples were subjected to kerogen maceral and vitrinite reflectance experiment, and 30 samples were subjected to saturated hydrocarbon chromatography-mass spectrometry analysis. The result shows: i) The organic matter types of middle-deep lacustrine source rocks are mainly type I and type II_1, and the maturity is between 0.6 % and 0.9 %. The organic matter abundance is good-excellent. The organic matter types of shallow lacustrine source rocks are mainly II_2 and III, and the maturity is between 0.8 % and 1.2 %. The abundance of organic matter is widely distributed, with poor, good, good-excellent. Therefore, it can be considered that the medium-deep lacustrine source rocks mainly generate crude oil, and the hydrocarbon generation potential is better than that of shallow lacustrine source rocks. The shallow lacustrine source rocks mainly generate natural gas. ii) Sr/Cu reflects the climate change during organic matter deposition: the climate of middle-deep lacustrine source rocks is warm and humid, and the hot and dry climate is found at the bottom. The climate of shallow lacustrine source rocks was more humid than that of middle-deep lacustrine source rocks. Through the redox indicators of Cu/Zn, gammacerane/$C_{30}H$, Pr/Ph, rearranged sterane, etc., it was found that the middle-deep lake phase was dominated by the reduction environment, with high Cu/Zn value at the bottom, which was the oxidation environment, and the shallow lake phase was the transitional environment. The middle-deep and shallow lake facies source rocks are developed fresh water environment, and the water depths in different regions have certain changes. iii) Through the correlation analysis between each index and TOC, it was found that paleoclimate and redox environment were the main factors affecting the enrichment of organic matter. The purpose of this study is to explore the sedimentary geochemical characteristics of different lacustrine source rocks in the same basin by combining organic and inorganic geochemistry, to clarify the difference of source rock characteristics in Zhusan depression, and to enrich the research methods of oil and gas system, to provide theoretical reference for exploration and development.

Reference
No references

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-3: Organic - inorganic interactions in sedimentary basins
Presentation Preference: Oral Preferred

Reactive Transport Modeling of Thermochemical Sulfate Reduction Reactions

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Keywords: TSR, H2S gas, RTM, Carbonate Reservoir

Hydrogen sulfide (H2S) is an undesirable constituent of petroleum, which is likely to be derived from thermochemical sulfate reduction (TSR) at concentrations higher than a few percent. TSR is the most important process to generate high level of H2S in carbonate reservoirs with anhydrite intercalations. The TSR modeling facilitates the investigation of organic-inorganic interactions and their impact on both petroleum and reservoir qualities.

In this study, we developed 1D reactive transport models to simulate the TSR process in Puguang gas reservoir in SW China. The models quantify the mass transfer processes of minerals and gases, including gas consumption/generation and mineral dissolution/precipitation. It integrates thermodynamic equilibrium reactions for gas-water-rock interactions and kinetic reactions for sulfate reduction. Based on burial depth, paleo temperature and pressure, and lithology of the reservoir, the model can simulate hydrocarbon consumption, H2S generation, anhydrite dissolution, and calcite precipitation in TSR process, and quantify the associated modification of reservoir quality.

The modeling results show that the abundance of effective anhydrite (as the oxidizing agent) and hydrocarbon (as the reducing agent) were responsible for the generation of H2S and calcite cements, as well as the porosity increase during TSR. It is noted that anhydrite abundance is an important factor to control the extent of TSR reaction and H2S distribution. However, the porosity generation during the TSR reactions are insignificant around 0.23%, probably because the impacts of anhydrite dissolution and calcite precipitation on porosity offset each other. After calibration, the predicted H2S and CO2 concentrations and gas souring index are comparable with the observed ones in the wells.

Reactive transport modeling (RTM) is a powerful tool to investigate the interaction of acid gas, water, rock and hydrocarbons and predicts subsequent modifications of hydrocarbon and reservoir qualities. It would be useful for evaluating H2S risk and mapping the detrimental gas in exploring and developing of carbonate reservoir.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-3: Organic - inorganic interactions in sedimentary basins
Presentation Preference: Oral Preferred

Microbially mediated hydrothermal Mn redox cycling and Mn carbonate precipitation after the Marinoan glaciation

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Keywords: Manganese, Mn-oxidizing bacteria, Mn-reducing bacteria, Nucleation site

Manganese is an important redox-active transition metal and bioelement in the Earth system, with transformation between dissolved Mn (II) and insoluble Mn (IV) in geological history being a response to environmental redox conditions (Wittkop et al., 2020). The predominant mechanism of Mn cycling involves redox conversion between Mn (II) and Mn (III/IV), controlled mainly by the type and availability of oxidants and reductants (Havig et al., 2015), and external environmental conditions (Barley and Groves, 1992). In addition, the recent research show that microorganisms may play a vital role in mediating Mn redox cycling in laboratory simulation (Myers and Nealson, 1988; Learman et al., 2011; Li et al., 2019; Yu and Leadbetter, 2020) and modern oceanic Mn nodules (Shiraishi et al., 2016; Jiang et al., 2020; Li et al., 2021). However, there is no solid evidence for microbially-mediated redox cycling of Mn under actual geological conditions. The carbonate-type Mn deposit in the Ediacaran Doushantuo Formation along the northern margin of the Yangtze Block, South China, provide an excellent natural laboratory for the research of Mn redox cycling in deep time.

In this study, we applied high-resolution in situ mineralogical and geochemical analyses based on the morphological characteristics of different types of microorganisms and geochemical markers generated by their biological activities processes. The geochemical results indicate that Mn in carbonates at the top of the Doushantuo Formation along the northern margin of Yangtze Block was derived from deep submarine hydrothermal fluids as Mn (II), increasing the concentration of Mn (II) in the seawater reservoir. According to the result of fossil morphology and geochemical markers, we presume the process which microorganisms fix CO_2 in organic matter by oxidizing Mn (II), providing energy for their metabolic activities under obligatory oxidation conditions can occur in natural geological environments. In oxidation condition, Mn-oxidizing bacteria oxidize Mn (II) to generate unstable todorokite symbiotic with organic matter, with accompanying Co and Ce oxidation and enrichment. Under suboxic conditions, heterotrophic Mn-reducing bacteria use organic matter as an electron donor and Mn bio-oxide as a terminal electron acceptor to generate Mn (II) and ^{12}C-rich dissolved inorganic carbon (DIC), which are the necessary materials for the formation of Mn carbonate minerals. Meanwhile, the bio-reduction of Mn (IV) provides the ideal alkaline geochemical environment for Mn carbonate minerals precipitation. On this basis, microorganisms and alga also provide nucleation sites for the precipitation of Mn carbonate minerals with biological morphology.

Our findings provide new evidence of the central role of microorganisms in Mn redox cycling and Mn carbonate mineral precipitation. Microbial activity facilitates Mn redox cycling and promotes precipitation of Mn carbonate minerals by providing nucleation sites. At the same time, microbially mediated Mn redox cycling also stimulates the cycling of Carbon between inorganic and organic environments, with C isotopic fractionation being a by-product of Mn biogeochemical cycling in deep time. Therefore, the process of microorganisms mediate Mn redox cycling and precipitation of Mn carbonate minerals may be universal phenomenon in geological evolution.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-3: Organic - inorganic interactions in sedimentary basins
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Influence of activities of deep thermal fluids on the reservoir diagenesis and quality: A case study of the Zhuhai formation reservoir in the Baiyun Sag, Pearl River Mouth Basin, South China Sea

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Keywords: Deep thermal fluids, Fluid-rock interaction, Diagenesis, Reservoir quality, Baiyun Sag

With the continuous research of the sedimentary basin fluid, the study of deep thermal fluid changes from the process of earlier mineralization to the influence of reservoir diagenesis. The diagenetic fluid components and sources are excellently significant to understand the diagenetic process, fluid-rock interaction and reservoir quality. Recently, the influence of the deep thermal fluid on reservoir diagenesis and pore evolution has come to the frontier in hydrocarbon exploration and development. Baiyun Sag which belongs to the Southern Depression Belt of Pearl River Mouth Basin (PRMB), is one of the largest deep-water sags, with its main body located beneath the present continental slope[1]. The thermal state of the Zhuhai formation was changed by the tectonic thermal event after Baiyun Movement which occurred across the Oligocene-Miocene boundary at 23.8Ma[2], and the thermodynamic conditions become one of the principal factors affecting the diagenetic evolution of the deep reservoir.

Previous studies show that the CO_2 of mantle-sourced magma origin charges the reservoir in the Baiyun Sag[3], but the thermal fluid activity range and its influence on the diagenetic process are still unclear. This study focuses on the fluid activity range and the reformation of the reservoir diagenetic sequences by thermal fluid to determine the beneficial reservoir distribution and the developmental mechanism and assess the influence of the reservoir quality. Based on the thin section, SEM and cathodoluminescence microscopy, the reservoir diagenetic sequences of the Zhuhai formation are divided, then combined with X-ray diffraction, fluid inclusion and geochemistry analysis to determine the fluid activity range and assess the influence of the thermal fluid on the reservoir diagenesis. The results show: (1) sharp decline of smectite content and occurrence of dawsonite indicate that the Zhuhai formation reservoir is affected by the external thermal fluid; (2) with temperature rises, the dissolution of albitite, calcite and iron calcite occurs in the CO_2 charged reservoir. The dissolution intensity is enhanced by rising temperature and forms secondary pores, which improves the pore space of the reservoir; (3) the authigenic kaolinite precipitates and carbonate cements form through the heat-mass transfer process with the continuous increase of CO_2 charge. When the CO_2 partial pressure keeps increasing and the temperature ranges from 25℃ to 100℃, kaolinite dissolution provides the dawsonite cement with additional sources of Al^{3+}. Cements forming is adverse to reservoir space and permeable space preservation, which causes poor physical properties; (4) The overall result shows that the influence of mantle-sourced CO_2 charged in the deep formation on the reservoir is double-edged, however the cementation intensity is lower than dissolution intensity in the study area. These results are of great significance for understanding the diagenetic process, fluid-rock interaction and assessing reservoir quality.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-3: Organic - inorganic interactions in sedimentary basins
Presentation Preference: Oral Preferred

Oil-Gas-Water-Rock Interactions in Mud Volcano Systems in Xinjiang, NW China

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Keywords: mud volcano systems, emitted gases, mud breccia and brine water, host rocks, organic-inorganic interactions, bleaching effect

As one kind of geofluids emission systems on the Earth surface, petroleum-related mud volcanoes are significant to petroleum resources evaluation, environmental impacts, natural hazards, and also the tourism resources. A series of samples including emitted gases, formation water, erupted mud, and also their host rocks were collected from the Dushanzi mud volcano system along with one argillite sample distal from the mud volcanoes for comparison in southern margin of the Junggar Basin, NW China. Their mineral and chemical compositions and also iron species were determined using XRD, XRF, and Mössbauer spectroscopy, respectively. The results indicated a series of marked oil-gas-water-rock interactions in the mud volcano systems with the followwing main variations: 1) chemical and isotopic variations for emitted gases compared with well gas samples from the corresponding reservoir nearby; 2) some conversion of clay minerals from smectite into chlorite and illite, and also the precipitation of newly formed metals carbonate preicipitant inlcuding calcite and siderite; 3) silicon depletion and significant elemental enrichment of Fe, Mg, Mn, Ca and P etc; 4) transformation of Fe from ferric species in hematite and smectite into ferrous species in siderite, chlorite, illite and even pyrite. These geochemical alteration likely induced various colour change of the original reddish Neogene argillite to the mud breccia in grey or black, resulted in elemental reduction and/or mineral alteration along with hydrocarbons oxidation, which is so-called as bleaching effect. Such a complex process might be positively contributed to the reduction of greenhouse effort of erupted gases from mud volcanic systems compared to direct emission of natural gas from the corrrespoding petroleum reservoirs, and also eventually significant to a better understanding of physical properties such as porosity and permeability of reservoir rocks and also the migration pathways, and even implicable to the evolution of long-term stability of geologically sequenced carbon dioxide.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-3: Organic - inorganic interactions in sedimentary basins
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Study on the adsorption pattern of alkanes on inorganic mineral surfaces based on molecular simulation method - An example from the Ordos Basin

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Keywords: Ordos, Geochemistry, Molecular simulation, Organic-inorganic, Hydrocarbon accumulation

The Ordos Basin is a complex basin with gentle slopes and simple tectonics, formed through multiple phases of tectonic movements. The late strata were deposited on top of the Paleo-Late Proterozoic North China Craton Basin. It is also one of China's largest oil and gas producing areas. The main source rock series in the basin is the Triassic Yanchang Formation. The Yanchang Formation develops high-quality lacustrine black shale, and the content of organic matter abundance (TOC) is exceptionally high, generally above 5 %, and the highest is above 30 %. Maturity is moderate. The organic matter type of source rock is mainly II_1, which is in the stage of oil generation. Ordos Basin has high-quality source rocks, but the research on its accumulation mechanism and resource reserves evaluation is not yet mature. It has become a problem restricting exploration and development. Therefore, it is of great significance to study the migration state of oil and gas underground for the accumulation mechanism of oil and gas. The existing experimental methods cannot intuitively show the interaction between alkanes and pore walls, so the molecular dynamics simulation technology is used to intuitively show the adsorption state of oil on the mineral surface. This paper uses Gromacs software to study the interaction between alkanes and pore walls. Based on the geochemical data of Ordos Basin, a mixed proportion model of n-C_8, n-C_{12}, and n-C_{15} n-alkanes was established, and kaolinite slits were used to replace inorganic pores. The interaction between alkanes and inorganic mineral surfaces was simulated, and the adsorption characteristics of alkanes were obtained. The adsorption density curve can then calculate the adsorption capacity per unit area, and the adsorption free ratio of oil and gas in the pores can be calculated. The results show that heavy alkane is easier to adsorb on the wall of kaolinite and exists in an adsorption state. Light alkanes are more accessible to migrate in the form of a free state due to their strong interaction with the kaolinite wall. The adsorption free ratio model is established by unit area adsorption capacity, which can calculate the momentum in the migration process and judge the migration efficiency of oil and gas in the pores, which is beneficial to the evaluation and optimization of resource quantity.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-3: Organic - inorganic interactions in sedimentary basins
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Geochemical characteristics and significance of aromatic hydrocarbons in Suowa Formation carbonate rocks in Shuanghu area, Qiangtang Basin

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Keywords: Qiangtang basin, Suowa formation, Source rocks, Aromatic hydrocarbon geochemical characteristics, Origin of parent material, maturity

Qiangtang basin is a large Mesozoic marine sedimentary basin, and there are several sets of source rocks in the basin. In order to understand whether the carbonate rocks of Suowa formation in Shuanghu area of Qiangtang basin have hydrocarbon generation capacity, the abundance, type, source of organic matter, sedimentary environment and maturity of source rocks will be analyzed. In this study, the geochemical characteristics of aromatic compounds in source rocks were analyzed by total organic carbon, kerogen carbon isotope, extraction and separation and gas chromatography-mass spectrometry. The results show that the source rocks of Suowa formation in the study area have high abundance of 1,2,5-trimethylnaphthalene, 9-Methylphenanthrene, graphene and chrysene series compounds, indicating the source of higher plants. The distribution characteristics of trifluorene series compounds, alkyl dibenzothiophene, alkyl dibenzofuran and triarylesteroid series compounds indicate that the sedimentary environment of source rocks of Suowa formation is a strong reducing environment. The comprehensive study on the maturity parameters of alkyl naphthalene, alkyl phenanthrene, alkyl dibenzothiophene and triarylstane series compounds shows that the source rocks of Suowa formation in Shuanghu area of Qiangtang basin have reached the maturity stage, which is consistent with the results of equivalent vitrinite reflectance Rc1, Rc2, Rc4 and Rc5. Based on the discovery of many ancient oil reservoirs and hydrocarbon displays in Suowa formation in Shuanghu area, and comprehensive analysis of organic matter abundance and types of the Suowa formation carbonate rocks, it is concluded that the Suowa formation carbonate rocks in Qiangtang Basin have certain exploration value of oil and gas resources.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-3: Organic - inorganic interactions in sedimentary basins
Presentation Preference: Oral Preferred

Oxygen contribution from oxides to highly 18O-depleted Mn carbonates

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Keywords: Oxygen isotopes, Fe- and Mn-oxides, Fe- and Mn-carbonates, Anaerobic oxidation of methane, Rare earth elements

Fe- or Mn-rich carbonates with d13C < -10‰ spread widely over the Proterozoic to Archaean sediments, and may have precipitated from HCO3- from sulfate reduction or microaerobic methane oxidation in anoxic water columns or via reactions between Fe-/Mn-oxides and organic matter or methane during diagenesis (Wittkop et al., 2020; Cai et al., 2021). However, it is hard to distinguish these two processes. Here, we demonstrate that strongly 13C- and 18O-depleted Mn-rich carbonate cements from the Triassic conglomerate of Junggar Basin, China, may have both oxygen and carbon derived from Mn oxides via redox reactions with methane. The Mn-rich calcites have bulk (5.9 to 13.6 ‰, n=6) and SIMS (4.1 to 15.5 ‰, n=40) d18OVSMOW values that correlate negatively with MnO concentration and d13C with R2 of 0.81 and 0.74, respectively. They display decrease in SIMS d18OVSMOW values towards those of the coexisting Mn-rich hematite (from -5.8 to 3.3 ‰), and shifts from normal or negative Y, Ce and Eu anomalies to the positive with increasing Mn contents or reducing degrees. These features may have resulted from increasing transfer of 18O-depleted oxygen from Mn oxides and intense alteration of rare earth elements and yttrium due to progressive Mn reduction in a closed diagenetic system. Similarly Fe-/Mn-rich carbonates with 18O-depletion and Eu positive anomaly have been reported from the Proterozoic worldwide (Baur et al., 1985; Heimann et al., 2010), thus, we propose that such carbonates may have a similar origin, and thus may have played an important role in the global carbon cycles especially in low sulfate early Earth.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-3: Organic - inorganic interactions in sedimentary basins
Presentation Preference: Oral Preferred

Evolution of nC16H34-water-mineral systems in thermal capsules and geological implications for deeply-buried hydrocarbon reservoirs

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Keywords: nC16H34-water-mineral systems, organic-inorganic interactions, hydrocarbon degradation, mineral alteration, deeply buried hot reservoirs

Organic-inorganic interactions between hydrocarbons and most minerals in deeply buried reservoirs remain unclear. In this study, gold capsules and fused silica capillary capsules (FSCCs) with different combinations of nC16H34, water (distilled water, CaCl2 water) and minerals (quartz, feldspar, calcite, kaolinite, smectite, and illite) were heated at 340 °C for 3-10 days, to investigate the evolution and reaction pathways of the organic-inorganic interactions in different hot systems.

After heating, minerals exhibited little alteration in the anhydrous systems. Mineral alterations, however, occurred obviously in the hydrous systems. Different inorganic components affected nC16H34 degradation differently. Overall, water promoted the free-radical thermal-cracking reaction and step oxidation reaction but suppressed the free-radical cross-linking reaction. The impact of CaCl2 water on the nC16H34 degradation was weaker than the distilled water as high Ca2+concentration suppressed the formation of free radicals. The presence of different waters also affects the impact of different minerals on nC16H34 degradation, via its impact on mineral alterations. In the anhydrous nC16H34-mineral systems, calcite and clays catalyzed generation of low-molecular-weight (LMW) alkanes, particularly the clays. Quartz, feldspar, and calcite catalyzed generation of high-molecular-weight (HMW) alkanes and PAHs, whereas clays catalyzed the generation of LMW alkanes and mono-bicyclic aromatic hydrocarbons (M-BAHs). In the hydrous nC16H34-distilled water-mineral systems, all minerals but quartz promoted nC16H34 degradation to generate more LMW alkanes, less HMW alkanes and PAHs. In the nC16H34-CaCl2 water-mineral systems, the promotion impact of minerals was weaker than that in the systems with distilled water.

This study demonstrated the generation of different hydrocarbons with different fluorescence colors in the different nC16H34-water-mineral systems after heating for the same time, implying that fluorescence colors need to be interpreted carefully in investigation of hydrocarbon charging histories and oil origins in deeply buried reservoirs. Besides, the organic-inorganic interactions in different nC16H34-water-mineral systems proceeded in different pathways at different rates, which likely led to preservation of liquid hydrocarbons at different depth (temperatures). Thus, quantitative investigations of the reaction kinetics in different hydrocarbon-water-rock systems are required to improve the prediction of hydrocarbon evolution in deeply buried hydrocarbon reservoirs.

Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-3: Organic - inorganic interactions in sedimentary basins
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Origin of authigenic kaolinite with implications for Permian tight gas sandstone reservoirs in the northern Ordos Basin, Central China

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Keywords: Authigenic, kaoliniteTransport mechanism, Permian tight gas sandstone, Ordos basin

Authigenic minerals are commonly developed during progressive diagenesis in the siliciclastic rocks and exert significant impacts on reservoir properties. Therefore, it is important to decipher the origins of these authigenic minerals and accurately determine their temporal and spatial distribution in buried sandstones. Authigenic kaolinite is pervasively developed in alumosilicate-rich sandstone reservoirs, owing to the interaction of acidic groundwater with alumosilicate minerals from early to late diagenetic regimes. However, whether or not authigenic kaolinite is precipitated in a geochemically open or closed system has been debated for decades and the essence of this debate is mainly associated with the scale of mass transfer for fluid-rock interactions during kaolinite precipitation. One group of geologists argues that authigenic kaolinite can be formed in an geochemically open system owing to high influx of meteoric waters extensively flushed into the siliciclastic sediments and the resultant dissolved ions can be transported out of the system for long distances; this process would create net porosities for total reservoir quality. The second group of geologists considers that authigenic kaolinite is precipitated under extremely low velocity of pore-fluids in a geochemically closed system and that the dissolved ions would be precipitated in-situ or be transported for very short distances within the system; this process leads to little or no net porosities within the system and would not enhance total reservoir porosities. Therefore, the origin and distribution pattern of authigenic kaolinite are strongly related to the mass transfer in a geochemically open or closed system, which significantly affects the total reservoir quality of a sandstone.

This study deciphers the origin of authigenic kaolinite in the lower unit of Permian Shihezi Formation (P2x) tight gas sandstones in the Hangjinqi gas field, northern Ordos Basin, China, to determine its implications for reservoir quality. Authigenic kaolinite is the most abundant diagenetic cement and two occurrences of authigenic kaolinite are identified in the P2x sandstones: 1) in-situ replacive kaolinite; and 2) pore-filling kaolinite. Petrographic and geochemical evidence reveals that authigenic kaolinite is mainly derived from dissolution of K-feldspar via flushing with organic fluids from underlying source rocks. This evidence includes: 1) spatial association of partially dissolved K-feldspar and authigenic kaolinite; 2) the amount of K-feldspar dissolution is mostly equal to that of kaolinite precipitation within sandstones; 3) a homogenization temperature of 110-120oC for aqueous inclusions in quartz overgrowths; 4) negative stable carbon isotopic compositions of calcite cements (δ13CPDB from -16.05‰ to -9.35‰). Dissolution of K-feldspar, coupled with precipitation of kaolinite and quartz, is interconnected fluid-rock interactions within sandstones that are inferred to simultaneously occur in a relatively closed system. Intra-formational diffusive transport is inferred to be the dominant transport mechanism during these fluid-rock interactions, which may result in precipitation of in-situ replacive kaolinite or pore-filling kaolinite. This transport pattern may have been localized (several centimeters to meters). The fluid-rock interactions lead to redistributional secondary porosity and would not significantly enhance total reservoir porosity. The occurrence of authigenic kaolinite greatly reduced reservoir permeability by occluding the pore-throats in the P2x sandstones.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-3: Organic - inorganic interactions in sedimentary basins
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The “Three-factors driving”on origin of microbial carbonate rocks reservoir and their distribution

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Keywords: microbial carbonate rock, microbial dolostone, carbonate rock-evaporite sedimentary sequence, microorganic matter degradation and pyrolysis process, early dolomitization

Microbial carbonate rocks are very important hydrocarbon reservoirs.In view of the problems of that stromatolite & thrombolite carbonate rocks have a better reservoir-developing potential than other microbial carbonate rocks and no-microbial carbonate rocks and, this paper made a series of study on modern microbial sediments & salted lake sedimentssimulated experiment on early degradation and buried pyrolysis of microbial organic matter and simulated experiment on early low-temperature microbial-reduced protodolomite precipitation and replacive dolomite, three geological understandings could be achieved.1compaired with other microbial carbonate rocks and no-microbial carbonate rocks, stromatolite & thrombolite carbonate rocks have a higher original porosity and content of microbial organic matter,which results that high-grade microbial carbonate rock reservoir mainly developed in stromatolite & thrombolite carbonate rocks2the production of organic acid by early degradation and buried pyrolysis of microbial organic matter helps the protection and enhancement of original porosity in burial stage, which is the key factor for development of microbial carbonate rocks reservoir3early dolomitization is helpful for the protection of pre-buried porosity, and carbonate rock-evaporite sedimentary sequence easily occurs dolomitization by microbial-reduced and replacive process, which results that stromatolite & thrombolite dolostone reservoirs mainly developed in carbonate rock-evaporite sedimentary sequence.These understandings are of great significance for distribution & prediction of microbial carbonate rocks reservoir. Stromatolite & thrombolite facies belt in carbonate rock-evaporite sedimentary sequence beneficial for the development of stromatolite & thrombolite dolostone reservoirs

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-3: Organic - inorganic interactions in sedimentary basins
Presentation Preference: Oral Preferred

In situ calcite U-Pb geochronology by high-sensitivity single-collector LA-SF-ICP-MS

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Keywords: Calcite U-Pb geochronology, SF-ICP-MS, LA-ICP-MS, Sensitivity enhancement, Jet sample cones

U-Pb geochronology of calcite using laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) is an emerging method, with potential applications to a vast array of geological problems. Due to the low levels of U and Pb in calcite, measurement using higher-sensitivity instruments, such as sector field (SF) ICP-MS, have advantages over more commonly used quadrupole (Q) ICP-MS instruments. Using a Thermo Element XR ICP-MS, we demonstrate that the Jet + X cone combination with the N2 enhancement technique provides the best sensitivity for measuring U and Pb isotopes. This higher sensitivity improves the precision of calcite U-Pb isotope measurements, and permits dating at high spatial resolutions (< 110 μm) and for samples containing low contents of 238U (< 1 μg g-1) and/or 207Pb (i.e. young samples < 10 Ma). Using a spot size of 85 μm with a low fluence (~2.0 J cm-2),the laser-induced elemental fractionation of 206Pb/238U in the NIST SRM 614, ARM-3 and WC-1 reference materials are insignificant (< 2.2%). Adopting the optimized instrument parameters, we analysed four commonly-used calcite U-Pb reference materials (WC-1, Duff Brown Tank, JT, and ASH-15). The results match well with published isotope dilution data, demonstrating the reliability of our technique. ARM-3, an andesitic glass, is shown to be an appropriate reference material for both 207Pb/206Pb calibration and instrument optimization because of its moderate contents of U (~3.75 μg g-1) and Pb (~12.7 μg g-1). We further demonstrate that the image-guided approach using LA-ICP-MS elemental mapping is an efficient tool in obtaining robust ages.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-3: Organic - inorganic interactions in sedimentary basins
Presentation Preference: Oral Preferred

The evolution process of H2S in gas reservoir based on multi-sources sulfur isotope constraints —A case study in Longwangmion Formation, the central Sichuan Basin, China

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Keywords: Sulfur isotope, Microbial sulfate reduction, Thermochemical sulfate reduction, Longwangmiao Formation, Pyrite

As multiple-source reservoirs and polyvalent reaction states of elemental Sulphur, it usually used as tracer evidences to monitor organic-inorganic reaction mechanisms, cyclic processes, and redox degrees. Within the case study of Longwangmiao Formation in Anyue Gas-field, there are large deviations of sulphur isotopes (δ^{34}SV-CDT) between contemporaneous gypsum, pyrite and H_2S, confusing the source and accumulation interpretation of H_2S in gas trap. To solve this question, this study applied in-situ $\delta^{34}S$ analysis (Nano Secondary Ion Mass Spectrometry) of multi-phase pyrites and $\delta^{34}S$ analysis of pyro-bitumen, combining with known $\delta^{34}S$ values of gypsum, water-soluble sulphate (WSS) and H_2S. The organic-inorganic evolution process of $\delta^{34}S$ was established in Longwangmiao Formation, revealing that: i) Early framboidal pyrite aggregates (Py1) and intergranular solitary crystalline pyrite (Py2) are the products of microbial sulfate reduction (MSR), and the $\delta^{34}S$ values gradually increase from -7.1‰ to +44.8‰, which contain a wide initial $\delta^{34}S$ fractionation up to 39.1‰ with contemporaneous gypsum (ca. +32‰). By Rayleigh fractionation model, MSR process could make the $\delta^{34}S$ of residual sulfate increased up to +80‰. ii) The middle to coarse crystalline pyrite (Py3, Py4) associated with later hydrothermal dolomites and hydrocarbon charging, recorded $\delta^{34}S$ variations in the range of +8.6 to +15.5‰, with small fractionation deviations (less than 10‰) from the $\delta^{34}S$ values of WSS (ca. +16.4 ~ +16.9‰), H_2S (ca. +19.7 ~ +21.6‰) and bitumen (ca. +20.7 ~ +26.0‰), which inferring the presence of thermochemical sulfate reduction (TSR) at deep buried realm. Therefore, late TSR process utilized exogenous sulfate in this process, e.g., underlying Ediacaran contemporaneous sulphate ($\delta^{34}S$ range from +15 to +23‰), indicating that deep-supplied sulfate through the fault stimulated TSR process within upper Longwangmiao Formation. Thus, the low H_2S content (<2%) in studied stratum is the result of early MSR depletion sulphate and TSR utilized limited deep source sulphate. This study further clarifies the H_2S formation in Longwangmiao Formation gas reservoirs based on multi-sulphur isotope studies.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-3: Organic - inorganic interactions in sedimentary basins
Presentation Preference: Oral Preferred

Coupled marine iron and carbon cycles 1.4 billion years ago

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Keywords: iron, carbon, Mesoproterozoic ocean, siderite, hydrothermal

Most marine massive Fe deposits formed from 3.0−1.8 Ga, with a billion-year hiatus until a brief return around 0.8 Ga. During this gap period, the iron formation (IF) shortage was thought to be a result of significantly decreased Fe^{2+} concentrations in the ocean, which was either substantially oxidized or sulfurized. Recent studies provide increasing evidence that ferruginous water was still widespread in the deep ocean until 0.58 Ga. Although atmospheric oxygen levels are still controversial in the time window of 1.8−0.8 Ga, it is believed that oxygen was deficient compared to the last 0.7 Ga.

Thus, although IF deposition is limited from 1.8−0.8 Ga, there are recent reports of significant ferrous carbonate deposition generating siderite-dominated IFs, such as the ~1.40 Ga Xiamaling IF in North China and the ~1.33 Ga Jingtieshan IF in Qilian. Siderite deposits are also found in the ~1.45 Ga Sherwin ironstone in Australia. To further explore the mechanisms of siderite-dominated IF deposition and the associated marine Fe and C cycles, we analyzed the contents and isotopic compositions of Fe and C of the Xiamaling IF.

A genetic model is introduced to interpret the dynamic and coupled Fe and C cycles in Mesoproterozoic oceans and sediments. Although the positive Eu anomalies of Xiamaling siderites are relatively low in the Xiamaling deposits, an enhanced input of hydrothermal Fe^{2+} is recognized from the isotopic compositions of Fe and C. Our results show evidence for hydrothermal Fe2+ input during the deposition of Xiamaling IF, where the Fe and C cycles were tightly coupled. Hydrothermal fluid is suggested as a key controlling factor during the Xiamaling siderite deposition.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
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Formation of giant Datangpo Mn-carbonates deposits participated by organic matter with multiple aspects

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Keywords: Mn-carbonates, organic matter, diagenetic reduction, pulsed oxidation, the Cyrogenian Datangpo Formation

Introduction: The Mn-carbonates deposits hosted by black shales of the Cyrogenian Datangpo Formation contribute to a large proportion of Mn sources of China. These Mn-carbonates are also rich in organic matter (~2 wt %), but the accumulation of organic matter and its roles in the formation of Mn-carbonates deposits are not well discussed, yet. Many recent studies have reported the contents and isotopic compositions of organic matter and Mo and Fe speciation of the Datangpo Mn-carbonates, providing a large database to addressing these questions.

Results and implications: (1). The total organic carbon (TOC) contents of Mn-rich samples (Mn>1 wt %) first decrease with increased Mn content (1−10 wt %) and then increase when Mn content further increase from 10% to 40%. Negative relationships between Mn content and the isotopic compositions of both organic and inorganic carbon are evident. These results suggest that consummation of organic matter (possibly oxidized by MnO_2) may be important to the formation of Mn-carbonates, but enhanced Mn-carbonates precipitation were accompanied by additional input of organic matter enriched in light carbon isotopes. (2) Mn enrichment is well correlated with several elements' contents and ratios, including Fe, P, Zn, Ni and Eu/Eu*, indicating a hydrothermal source for Mn and nutrients. Thus accumulation of organic matter along with Mn may be associated with elevated primary productivity and bacteria activities. (3) Fe speciation data suggests that pore water changed from sulfidic condition during the deposition of black shale to ferruginous condition during the deposition of Mn-carbonates. Large input of reduced Fe associated with hydrothermal activity may be responsible for this critical change. In addition, the oxidation of dissolved H_2S species in pore water by MnO_2 would produce hydroxide ions, resulting in alkaline pore water and facilitating the precipitation of Mn-carbonates.

Therefore, a first formation of MnO_2 that was then reduced by both organic matter (producing Mn^{2+} and CO_3^{2-}) and H_2S may be required for the formation of Mn-carbonates, indicating pulsed bottom water oxidation but ferruginous pore water. This is also supported by much lower Mo content but comparable Mo isotopic compositions of Mn-carbonates relative to those of the black shale that was deposited in sulfidic condition. These solid evidences support diagenetic reduction of MnO_2, related to changes in both material sources and redox condition, to be the main cause of giant Datangpo Mn-carbonates deposits.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-3: Organic - inorganic interactions in sedimentary basins
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Controls of diagenesis on the quality of shallowly buried terrestrial coarse-grained clastic reservoirs: A case study of the Eocene Shahejie Formation in the Damintun Sag, Bohai Bay Basin, Eastern China

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Keywords: Diagenesis, Mechanical compaction, Carbonate cementation, Reservoir quality, Shallowly buried clastic reservoir

A typical shallowly buried (800~2000 m burial depth) coarse-clastic, nonmarine, fan-deltaic reservoir is well developed in the Eocene Shahejie Formation, Damintun Sag, Bohai Bay Basin, China. In this study, diagenesis and its control on the reservoir quality of fan-deltaic sandstones and conglomerates in the Shahejie Formation were investigated in detail by petrographic and geochemical analyses, including cathodoluminescence, X-ray diffraction, scanning electron microscopy, electron probe microanalyses and X-ray fluorescence. The reservoir sandstones and conglomerates mainly consist of moderately sorted feldspathic litharenite, which has undergone various diagenetic processes such as mechanical compaction, cementation, and dissolution, and are currently in the eodiagenesis stage with porosity and permeability averaging 21.56% and 435.2 mD, respectively. Mechanical compaction and cementation caused an ~ 45% reduction in the original reservoir porosity, especially the former, which exerted a more significant influence. In regard to cementation, the late calcite that formed at the mudstone-sandstone interface is more destructive and enhances reservoir heterogeneity, and its source material is believed to be primarily derived from the adjacent mudstones in conjunction with oil and gas charging. Feldspar dissolution plays a limited constructive role in reservoir properties by creating ~ 10% secondary porosity and changing reservoir wettability to oil wet through the formation of authigenic kaolinite. As a result, massive primary pores (~ 90% of the total pores) in the shallowly buried sandstones and conglomerates in the Eocene Shahejie Formation are still preserved. This systematic study is expected to be applicable in a general way to other shallowly buried terrestrial clastic reservoir systems.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-3: Organic - inorganic interactions in sedimentary basins
Presentation Preference: Oral Preferred

Calcite-cemented concretions in non-marine sandstones: An integrated study of outcrop sedimentology, petrography and clumped isotopes from Lower Cretaceous Qingshuihe Formation, northwestern margin of Junggar Basin

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Keywords: Calcite-cemented concretions, Clumped isotopes, Non-marine sandstones

Calcite-cemented concretions can reduce reservoir quality and form important low-permeability baffles for fluid flow in sandstone carrier beds/reservoirs. Understanding origin and distribution patterns of concretions have important implications for characterizing reservoir heterogeneity and developing fields. The origin of calcite concretions in non-marine sandstones without detrital carbonate to source the cement is still cryptic. Practical difficulty of obtaining precipitation temperature of concretion prevents the precise determination of the source of cement components, solute flux and porewater microenvironment in which cement precipitated. Carbonate clumper isotope thermometry can give unique constraints to temperature of concretion precipitation. This study focused on outcrops of the Lower Cretaceous non-marine Qingshuihe Formation in the Urho area, northwestern margin of Junggar Basin (West China). Four depositional facies were recognized: channel deposit, mid-channel bar, abandoned channel and overbank floodplain. Calcite concretions occur only in sandstones, including spherical, ellipsoidal and tabular forms. They are isolated and aligned in layers; selective to either the top, middle and bottom of channel and mid-channel sand bodies. The clumped isotope temperatures for the concretionary calcite range from 35°C to 45°C with standard error (SE) of <3°C. The calcite has the highly variable, low δ13C values ranging from –16.91 ± 0.01 to –2.93 ± 0.02‰ (VPDB). The δ13C depleted bicarbonate source was most likely linked to biodegradation of the oils at shallow burial due to uplift. δ18O values of the calcite are very consistent and fall between –12.30 ± 0.04 to –9.79 ± 0.31‰ (VPDB). Introduction of meteoric water was a dominant mechanism for the significant depletion in the oxygen isotope of pore water along with alteration of volcaniclastic materials in sandstones. Flushing of meteoric water down the regional paleo-slope might under arid paleoclimate conditions biodegraded the migrating oil and enable a sufficient flux for precipitation of concretions.

Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-3: Organic - inorganic interactions in sedimentary basins
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Native sulfur deposits along faults and implications for carbonate reservoirs

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Keywords: Native sulfur, sulfur isotope, carbonate corrosion, hydrogen sulfide migration

Large native sulfur deposits can be part of sulfate-bearing (e.g. gypsum and anhydrite) salt diapirs caprock or strata-bound evaporite rocks. Native sulfur is formed by sulfate reduction when hydrocarbons come in contact with sulfate minerals in presence of liquid water. Here we present a study of native sulfur deposits in the Liuhuanggou, Xinjiang, China. Native sulfur deposits associated with gypsum are found in many 3-15m caves of Ordovician carbonate reservoirs, and are distributed along faults like a series of beads. Native sulfur and gypsum show wide range of $\delta^{34}S$ values from -30‰ to -3‰, and majority is less than -10‰. They are obvious less than those of seawater in all geological history (10~35‰). This indicates that native sulfur and gypsum are probably biogenic. The prevailing model is that sulfide produced by sulfate-reducing bacteria is oxidized to zero-valent sulfur and six-valent gypsum. However, bacteria sulfate reduction (BSR) might not occur in the Ordovician native sulfur deposits because: (1) there are no associated authigenic carbonate minerals, such as BSR calcite; (2) coexisting sulfur and gypsum have similar $\delta^{34}S$ values, even that $\delta^{34}S$ values of gypsum is less. Thus, H_2S are probably derived from underlying strata. Sulfuric acid is generated when rising H_2S encounters oxygen-rich water at or near the water table. Gypsum has similar Sr concentration, $^{87}Sr/^{86}Sr$ ratios and REE pattern to surrounding limestones. It suggests that gypsum formed after limestone corrosion by sulfuric acid. This process leaded to karst caves. Gypsum is extremely finely crystalline and porous, indicating rapid oxidation. When lack of enough oxidizing agent, H_2S can be characterized by production of native sulfur, which is proved by filling of sulfur in the pores of gypsum. Actually, the oxidation of H_2S has led to the formation of some of the world's largest caves through a process known as sulfuric acid speleogenesis (SAS). Significance of sulfuric acid-related dissolution for epigenic karstification probably been underestimated for carbonate reservoir. The new model for oxidation of external BSR-derived H_2S has potential implications of native sulfur deposits and carbonate reservoirs.

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Session T10-3: Organic - inorganic interactions in sedimentary basins
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Local marine sulfate is unlikely the sulfur source of the Huize Pb-Zn deposit, South China

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Keywords: Evaporate sulfate, Sulfur source, Huize Pb-Zn deposit

The Mississippi Valley-type (MVT) Pb-Zn deposits became abundant after the second Great Oxidation Event (GOE; i.e., 1.8 Ga) when oxidizing evaporate sulfate minerals began to extensively accumulate in the sea. These new large sulfur reservoirs may act as sulfur sources for MVT deposits, but their role in the formation of MVT deposits is still debatable due to the ability of evaporite to dissolve or be altered. The Huize Pb-Zn deposit in South China is one of the largest MVT deposits in China (7 Mt Pb+Zn @25-35%) and mineralization is mainly hosted in Carboniferous dolostones. However, a new Pb-Zn orebody within the Ediacaran dolostones has been recently discovered and provides a rare opportunity to compare sulfur source(s) in these different ore-bodies. In this study, we present LA-(MC)-ICPMS in situ S isotopic compositions from sphalerite and pyrite hosted in Carboniferous and Ediacaran strata. They have similar $\delta^{34}S$ values ranging from +14.6‰ to +15.8‰, and from +14.5‰ to +18.1‰, respectively. These narrow ranges are different from the large ranges of marine sulfate documented during the Carboniferous ($\delta^{34}S$ = +15‰-+20‰) and Ediacaran ages ($\delta^{34}S$ = +20‰-+39‰). Therefore, the sulfur source of the two types of epigenetic MVT mineralization was likely derived from an external source, probably similar in origin, rather than from a local source related to marine sulfate hosted in the ore-hosting strata. This study encourages performing sulfur isotopic studies in various mineralization types hosted in different host-rocks before interpreting the origin of sulfur in a Pb-Zn deposit.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-3: Organic - inorganic interactions in sedimentary basins
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Effects of storm activity on pyrite sulfur isotope records from Holocene sediments

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Keywords: Sulfur isotope, Storm deposit, “Heavy” sedimentary pyrite

Storm-driven variations in depositional conditions can play key roles in modifying sulfur isotope signatures in sedimentary pyrites. Here we present the sulfur isotopic compositions of pyrites in a complete Holocene muddy storm deposit, which has been identified by a comprehensive study on sediment components, n-alkanes, bulk organic carbon isotope values (δ^{13}Corg), carbon and oxygen isotope values (δ^{13}C and δ^{18}O), and trace element concentrations. We observe that the positive (+5.83‰ to +15.76‰) and negative (–8.95‰ to –19.72‰) $\delta^{34}S_{pyrite}$ values were preserved in two intervals of the muddy storm deposit, which are exactly corresponding to the high-energy storm peak phase (HESPP) and the waning-energy late storm phase (WELSP), respectively. We propose that the ^{34}S enrichments in pyrites in the HESPP are due to the surficial and buried sulfide oxidation and high sedimentation rates promoting by storm activity. In contrast, the ^{34}S depletion in pyrites in the WELSP is attributed to microbial sulfate reduction (MSR) still playing a major role. The rapid shift in $\delta^{34}S_{pyrite}$ values can reflect the dramatic physical and chemical conditions transition in the depositional environment between the HESPP and WELSP. These results suggest that storm activity can both generate isotopically “heavy” and “light” sedimentary pyrites in the HESPP and WELSP, respectively, and thus pyrite sulfur isotope can be applied as a proxy for identifying and deciphering muddy storm deposits.

Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-3: Organic - inorganic interactions in sedimentary basins
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Sulfur isotope variations between pyrite and organic matter reveal influence of the Mesoproterozoic oxygenation event on ocean sulfur cycle

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Keywords: Mesoproterozoic, sulfur isotopes, ocean redox structure, oxygenation event, sulfur cycle

Great debase occurs about the atmospheric O_2 levels <0.1% to 1 % PAL or > 4% PAL in the Mesoproterozoic (Planavsky et al., 2014; Zhang et al., 2016). It has been found that Xiamaling Formation (about 1.4 Ga) in the North China Block is an excellent geological record providing information about atmospheric oxygen level (> 4% PAL) during the deposition of Xiamaling formation Unit 3. Paired organic sulfur and pyrite sulfur isotopes along with trace and rare earth elements were measured from two North China sections in this study and show a significant increase in the oceanic dissolved O_2 level upwards from Unit 3 to Unit 1, as indicated by an increasing trend in the difference ($\Delta\delta^{34}S_{OM\text{-}py}$) between pyrite $\delta^{34}S_{py}$ and OM $\delta^{34}S_{OM}$ from -16.7 to +9.57 ‰ and Ce anomaly. In Unit 3 the lowest strata we investigated, we find that organic sulfur $\delta^{34}S_{OM}$ is depleted in ^{34}S compared to the associated pyrite $\delta^{34}S_{py}$, or $\Delta\delta^{34}S_{OM\text{-}py} < 0$, which is rarely reported in the Phanerozoic sediments, and is attributed to low reactive iron availability and thus ^{34}S-depleted H_2S was preferentially incorporated in organic matter leaving later formed pyrite enriched in ^{34}S in low sulfate environment. In Unit 2, $\delta^{34}S_{py}$ values are roughly parallel with $\delta^{34}S_{OM}$ values, the $\Delta\delta^{34}S_{OM\text{-}py}$ values are increasing to -4.9 ~ +7.4‰ with an average of +1.09‰, suggesting both may have formed from reactions with H_2S. Then in Unit 1, the $\Delta\delta^{34}S_{OM\text{-}py}$ values were increased to -0.47 ~ +9.57‰, and there are positive Ce anomalies accompanied by Mn elements enrichment, which are not observed in the Units 2 and 3. Thus, the gradually elevated $\Delta\delta^{34}S_{OM\text{-}py}$ values in the Unit 1 suggests incorporation of intermediate S species from oxidation of H_2S by the ocean dissolved O_2 and/or oxidants (Amrani et al., 2006). This proposal is supported by Ce positive anomaly which indicates Ce release to the bottom water during reduction of Mn oxides in sediment-water interface and Mn oxides may have deposited from dissolved oxygen levels > 5 μM (Tostevin et al., 2016; Wu et al., 2019), which can be translated to the elevated atmospheric O_2 level.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-3: Organic - inorganic interactions in sedimentary basins
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Effect of illite on heavy oil biodegradation by Pseudomonas stutzeri L1SHX-3X strain isolated from Liaohe Oilfield

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Keywords: Biodegradation, Illite, Pseudomonas stutzeri, Heavy Oil, Inhibition, Promotion

Illite is a widely distributed clay mineral with huge reserves in the earth's crust and its effect on microbial degradation of heavy oil is not clear even though it is very important for understanding biodegradation in heavy oil reservoirs or contaminated sites. This study takes illite, heavy oil and in-situ microorganism *Pseudomonas stutzeri* L1SHX-3X strain from Liaohe Oilfield as an example to explore the effect of illite on biodegradation. The results showed that illite slightly reduces the total degradation rates of heavy oil by *P. stutzeri* (4.5~8.5%), which is all contributed from the part of inhibition of all 64 detectable saturated hydrocarbons. Illite does not affect the biodegradation of all 96 aromatic hydrocarbons in terms of total amount for it has two equally opposite effects: promoting the biodegradation of 48 aromatic hydrocarbons and inhibiting the other 46 aromatic hydrocarbons. Generally, illite does not affect the microbial degradation mechanism. The transformation of crystal characteristics from illite to kaolinite under the action of microorganisms was observed at laboratory temperature and pressure conditions for the first time. These results are of great potentially helpful to the understanding of illite-modulated microbial degradation, the geochemical evolution of heavy oil and selective degradation of hydrocarbons.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-3: Organic - inorganic interactions in sedimentary basins
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The chemical and isotopic compositions of natural gas in the Dongdaohaizi Depression of Central Junggar Basin, China: insights into gas mixing

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Keywords: Thermal evolution of source rocks, Biomarkers, Pingdiquan Formation, Petroleum geochemistry, hydrocarbon evolution, oil-source correlation

The study of mixed natural gas can clarify the specific sources of natural gas accumulation and provide the basis for the exploitation of natural gas resources. Through the analysis of gas compositions and carbon isotope ratios of different components of a mixed natural gas, it is found that the carbon isotope fractionation of methane and ethane from different sources have a small difference after mixing. Ro% of the source rocks (C-J) between 0.48% and 1.7% (average =0.88%). Well DN8 and DN9 produced light oil with density between 0.75-0.82g/cm^3, viscosity between 3.3-1.63MPa·s. Generally, in the high maturity stage of organic matter, the carbon isotope fractionation values of methane and ethane of natural gas from single source should be display a difference of at least 4‰-5‰. The carbon isotope values of methane and ethane in well DN8 only 1.6‰. It is considered that the mixing of natural gas from different sources causes this phenomenon.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-3: Organic - inorganic interactions in sedimentary basins
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Research on Bleaching Genesis of Red Sandstone in Liujiagou Formation of the Middle Triassic in the Luxi Block, North China Craton

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Keywords: sandstone bleaching, carbon and oxygen isotopes, organic-inorganic interactions, oil and gas

The bleaching of red sandstone is an important process related to the organic-inorganic interactions, playing an important role in indicating fluid migration and carbon cycling. Red sandstone bleaching in the Triassic and Jurassic is a universal phenomenon which is widely distributed in the Luxi Block, but its genesis is less studied. In this paper, red sandstone bleaching in Middle Triassic Liujiagou Formation is systematically studied by petrological methods, diffraction of x-rays and carbon and oxygen isotope test to reveal the bleaching genesis. The bleaching occurred along bedding and rock fractures, the former being diffuse and speckled along the layer, while the latter being linear in the plane. Under the microscope, the red sandstone shows the mineral edge covered by iron oxide grain coating, and the coating of the sandstone mineral edge dissolved after being bleached by the reducing fluid. Noticing the content of hematite in the bleached sandstone is 0.69%, indicating the bleaching of red sandstone did not a complete organic-inorganic interaction. By comparing the other mineral contents of unbleached and bleached sandstone, we found that the calcite content of bleached sandstone is higher than that of unbleached sandstone, indicating that there is dissolution of primary calcite and formation of secondary calcite during the reduction fluid migration, and this change in calcite content is a strong evidence of organic-inorganic interaction. Carbon and oxygen isotopes show that $\delta^{13}C$ vales of the Liujiagou Formation bleached sandstone are -3.65‰~-1.75‰ and $\delta^{18}O$ vales of the Liujiagou Formation bleached sandstone are -14.45‰~-12.83‰, which representing a hydrocarbon fluid bleaching. The fluorescence thin sections of black residues in the flint strip of the field outcrop at the bottom of the Liujiagou Formation show the characteristics of yellow and light blue fluorescence under ultraviolet light, indicating that oil and gas migration have occurred in the Liujiagou Formation. All these evidences stated above demonstrating that the red sandstone bleaching of the Liujiagou Formation of the Luxi Block is attributed to the organic-inorganic interaction between oil and gas and hematite in rock. Reducing aqueous fluids such as organic acids or hydrogen sulfide in oil and gas reduce Fe^{3+} in red sandstone to Fe^{2+} through fluid-rock interactions, resulting in bleached sandstone. But the bleaching is incomplete and non-intense due to the long-distance migration of oil and gas from the Dongying Depression or the Dawenkou Depression.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-3: Organic - inorganic interactions in sedimentary basins
Presentation Preference: Oral Preferred

The volcanic impacts on the formation of organic-rich shales from the freshwater to saline lakes

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Keywords: volcanism, the freshwater and saline lake, organic-rich shale, Chang 7 Member, Lucaogou Formation, Fengcheng Formation;

High organic matter abundance is necessary for large-scale hydrocarbon accumulation and enrichment in shale oil. Comparing conventional marine basins with lacustrine ones, the formation of organic matter in the latter usually changes rapidly with strong heterogeneity, which brings great challenges to identify sweet spot prediction and resource evaluation. In addition, water columns with different redox conditions also affect the burial and preservation of organic matter during the deposition of lacustrine shales, especially under the impact of ephemeral critical geological events such as volcanic activities. Therefore, determining the properties and the influencing factors on the water columns is one of the key scientific issues in revealing the differential enrichment of organic matter in such basins. By comparing the petrological and geochemical characteristics of organic-rich shales between a typical freshwater and a saline lacustrine basin, this study analyzes the depositional environment and water column properties during the burial and preservation of organic matter in the Ordos and Junggar basins. The results demonstrate that volcanic activity intensifies the degree of hypoxia during the formation of organic-rich matter, which in turn affects organic matter preservation. The sulfate reduction index (SRI) indicates that the organic-rich shale of the Chang 7 Member (Ch7) of Yanchang Formation in the Ordos Basin and the Lucaogou Formation (P2l) in the Jimsar Sag of Junggar Basin in freshwater-saline environments have a certain intensity of sulfate reduction (BSR) (SRI < 1.375). The organic matter consumed by BSR is lower than the preserved organic matter, resulting a higher TOC content. However, excessive volcanic activity or the input of hydrothermal fluids caused strong BSR (SRI > 1.375) of the Fengcheng Formation (P2f) in saline lake of the Mahu Sag in Junggar Basin. This indicates that a large amount of organic matter was degraded and consumed, causing more iron oxides (and other iron-containing minerals) dissolve gradually to form pyrite, reducing the TOC content. This study enabled us to understand the shale oil enrichment, sweet spot prediction and evaluation, and propose a better theoretical and practical model for hydrocarbon accumulation in shale formations, to guide future exploration efforts.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-3: Organic - inorganic interactions in sedimentary basins
Presentation Preference: Oral Preferred

The geochemical characteristics of the cortical increments of ooids recorded in the Lower-Middle Jurassic sediments of the Indus Basin, Pakistan

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Keywords: Ooids, Cortex, Geochemistry, Jurassic, Indus Basin

The ooids are important contributors to the carbonate production on the globe and occur in sediments of almost all ages. Despite its common occurrence, their genesis is still ambiguous with no emphatic explanation and different factions of their biotic vs abiotic origin exist. Following the conventional mode of origin of ooids, this study uses an integrated petrographic and geochemical approach to explain the genesis of the cortical increments of ooids preserved in the Lower-Middle Jurassic sediments of the Indus Basin of Pakistan. The radial-concentric ooids epitomize dune mode of sedimentation across the region, having skeletal allochems and pellets as nuclei. Other constituents include miliolids, echinoderms, gastropods, pelecypods, pellets, intraclasts, and siliciclasts. Among them occur some exotic ooids having distinct cortical increments, conspicuous in the petrography, and the geochemical signatures of which signify differences across the cortex. The elemental concentration of conspicuous cortical increments is incongruent with the rest of the cortex and the cementing material. The increments reveal relatively low Sr, Fe, Si, Al, K, S, and slightly higher Mg, P and Mn concentrations. These increments are believed to represent the inherited cements, suggesting growth in the eogenetic environment, and subsequently modified by cement exhumation or physio-chemical abrasion during the transportation mode. The ooid development, fluid chemistry, and turbulence infer that the cortices of these ooids represent precipitation in the active dominant phase of ooids genesis, and the conspicuous increments signify eogenetic precipitation in the very shallow subsurface. Incorporation of thick or multiple eogenetic increments into the ooid cortices would reduce the average time duration for ooids to reach mature sizes.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-3: Organic - inorganic interactions in sedimentary basins
Presentation Preference: Oral Preferred

Underestimated thermogenic methane hydrate dissociation in the modern and ancient Earth

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Keywords: Gas hydrate, anaerobic oxidation of methane, methane sources, authigenic carbonate, global carbon cycle, climate change

Methane hydrate dissociation (MHD) and the subsequent anaerobic oxidation of methane (AOM) have direct feedback to climate, oceanic and atmospheric chemistry, and biosphere during the Earth's history. Yet crucially, quantifying methane sources (biogenic vs. thermogenic) for gas hydrate through time is almost impossible due to the absence of these geological records, although they are of great importance to evaluation the abovementioned impacts from MHD. AOM pervasively occurs during MHD and may have preserved gas source information in its authigenic carbonate (AC). By compiling the global $\delta^{13}C$ data of methane and AC in the modern and recent cold seep sediments, and utilizing a numerical simulation approach of AOM and AC precipitation, we show that the varying $\delta^{13}C$ data of methane and AC could be best explained by the different proportions of gas sources (biogenic vs. thermogenic) and AOM rates. Crucially, our result suggests that thermogenic methane consists 5% to 85%, average at 35.7%, of the total methane volume in typical cold seep areas. Hence, the releasing of methane from MHD, which preferentially occurred in warmer climates during the past 350000 years, may have been underestimated by overlooking their contribution from thermogenic methane. The acceptance of vast thermogenic methane in the modern and ancient seep areas forces us to rethink the operation of global carbon cycles, climate change, and mass extinctions throughout geological time.

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Session T10-5: Oxygen isotope in sediments: from Modern ocean to Archean

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-5: Oxygen isotope in sediments: from Modern ocean to Archean
Presentation Preference: Oral Preferred

High resolution carbon and oxygen isotopes of the Early Ordovician-late Silurian of the Baltica: Implications for palaeoenvironmental changes and palaeotemperature trends

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Keywords: Stable carbon and oxygen isotopes, sea-level, brachiopods, palaeotemperature, Ordovician, Silurian

Oxygen isotope paleotemperature studies of the Paleozoic are based mainly on brachiopod shell material which is resistant to diagenesis and generally precipitated in isotopic equilibrium with ambient sea water. Here we present high-resolution brachiopod and bulk rock C and O stable isotopic data from the Ordovician-Silurian, for evaluating the palaeotemperature and palaeoenvironmental variability in the Estonian Shelf of the Baltoscandian Palaeobasin. As the region has not been influenced significantly by tectonic events or deep burial diagenesis, the studied carbonate rocks and fossils are well preserved in most of the locations. $\delta^{18}O$ and $\delta^{13}C$ values for the Ordovician and Silurian range between ca -7‰ to 0‰ and -1.5‰ to +7.6‰ respectively. High $\delta^{18}O$ values, sometimes accompanied also with higher $\delta^{13}C$ values, correspond to cooling if the isotope signal reflects the original oxygen isotopic composition in seawater, and vice versa. Several $\delta_{13}C_{brac}$ excursions identified in the Ordovician-Silurian in the Estonian Shelf reflect global chemostratigraphy and palaeoenvironmental history, being synchronous with the previously documented excursions in the bulk carbonate stable isotopic curves. Combining the published and new $\delta^{13}C_{brac}$ and $\delta^{18}O_{brac}$ data allow us to address chemostratigraphy in the interval from Lower Ordovician (Floian) up to the topmost Silurian (Přidoli). The $\delta^{18}O_{brac}$ data suggest warmer temperatures during early Ordovician (Floian-Dapingian) and a cooling trend into the Mid-Ordovician. The Hirnantian glaciation episode (corresponding to HICE) reveals the minimum temperature in this interval and the post-HICE data suggest a rising temperature trend. Another temperature minimum is evident in the strata reflecting the Ireviken Event (Sheinwoodian). Our study shows that $\delta^{18}O$ values from the brachiopod Ordovician-Silurian carbonates could tentatively be interpreted as reflecting the major temperature trends.

Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-5: Oxygen isotope in sediments: from Modern ocean to Archean
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Triple Oxygen Isotope Relationships during Microbial Sulfate Reduction

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Keywords: triple oxygen isotope, isotope fractionation, porewater sulfate

The atmosphere O_2 and CO_2 levels are evolved with the environment's change in geological history, leaving the atmosphere signal (pO_2/pCO_2) in the minor oxygen isotope composition ($\Delta'^{17}O$) of sulfate mineral. However, the ubiquitous microbial sulfate reduction (MSR) adapts the oxygen isotope composition of sulfate. To extract the atmosphere signal from the MSR-adapted sulfate, the determination of diagnostic triple isotope exponent $^{17}\theta$ ($\equiv \ln^{17}\alpha/\ln^{18}\alpha$) for microbial sulfate reduction is required. The oxygen isotope fractionation during MSR depends on the reversibility of intracellular enzymatic steps, dominated by equilibrium isotope fractionation between intracellular water and intermediate valence state sulfur species under low high reversibility and dominated by the kinetic isotope fractionation during each step under low high reversibility. Here we propose that the porewater sulfate profiles ($\delta^{18}O_{SO4}$ and $\Delta'^{17}O_{SO4}$) in organic-poor sediment and methane-seeps can be used to deduce the apparent $^{17}\theta$ value dominated by equilibrium and kinetic respectively. The constrained triple isotope exponent of MSR in nature new insight into using $\Delta'^{17}O_{SO4}$ as a proxy for pO_2/pCO_2 and marine sulfate budget.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-5: Oxygen isotope in sediments: from Modern ocean to Archean
Presentation Preference: Oral Preferred

Distribution characteristics and genetic mechanism of calcareous sandstone of Shahejie Formation reservoirs in J oilfield, Bohai Bay

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Keywords: Calcareous sandstone,reservoir properties,carbonate cementation,diagenesis,Bohai Bay

The deeper burial of the Paleocene Shahejie Formation reservoir and the abnormal development of carbonate cement in J oilfield of Bohai Bay have led to strong reservoir in-homogeneity, which has seriously affected the development and production of the oilfield. Using sedimentary mineralogy and petrology, combined with thin section identification, logging, core testing, carbon and oxygen isotopes and other analytical methods, the lithological characteristics, logging identification characteristics and distribution characteristics of calcareous sandstone of Shahejie Formation in J oilfield were researched, and the genesis mechanism of calcareous sandstone from the perspective of material origin and diagenesis were analyzed. On the basis, the influence of carbonate cements on reservoir quality was analyzed to provide a geological basis for reservoir description and remaining oil distribution in J oilfield.

The study shows that the calcareous sandstone of Shahejie Formation in J oilfield is mainly distributed in highly porous and highly permeable areas, such as at the bottom of the underwater diversion channel depositions and the top of the estuary dam depositions, and the carbonate cement content shows a distribution pattern that increases with the depth of burial and increases from the high part of the structure to the low part. The rock formation mainly includes compaction, cementation, accounting and dissolution, the diagenetic stage enters the early diagenetic B stage. The type of cementation is mainly early mud-powder crystal calcite, mud crystal dolomite and late iron calcite and iron dolomite cementation, with local development of rhodochrosite and iron dolomite colloid, oolite and iconoclastic development. The formation of carbonate cement is related to the decarboxylation of organic acids, and its material source is mainly from the dissolution of feldspar and hydration of clay minerals, while carbon and oxygen isotope analysis shows that the dissolution of abundant calcareous biogenic fossils is also an important source of calcium. The research shows that carbonate cement has a significant influence on the reservoir physical properties and non-homogeneity of the Shahejie Formation.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-5: Oxygen isotope in sediments: from Modern ocean to Archean
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Carbonate cement distribution and Carbon and oxygen isotope enrichment characteristics of sandstone reservoirs in M Oil Formation in Shiyougou Oilfield

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Keywords: Carbonate cement,Carbon and oxygen isotopes;M-oil group,Shiyougou oil field ,Jiuxi Basin

Carbonate cement is the most important authigenic mineral in M reservoir sandstone reservoir of Jianquanzi Formation in Jiuxi Basin, and its content and distribution form are the main factors affecting reservoir quality.Through mineralogy, petrology and geochemical analysis, it is concluded that the carbonate cements in this area are mainly composed of iron-free dolomite and calcite, and are often developed in the form of ring-side and speckle.The content of carbonate cement ranged from 2.11% to 56.39%, with an average of 12.93%.Microzone observation shows that the iron-free microcrystalline dolomite cements are distributed outside the particles and cover the whole particles, and they are mainly formed from cogenesis to the early stage of premorphic rock. The iron-free dolomite cements formed in the early stage increase the mechanical strength and compact-resistance of the rocks, which is beneficial to the development of the reservoirs in the study area.Speckle like sparry calcite cement mainly grows along the pore space and finally occupies the entire pore space. It is the chemical precipitation product in the late diagenesis, which is unfavorable to the development of reservoir.The value of δ18O (PDB) is -11.14‰~-3.25‰, and the value of δ13C (PDB) is -7.32‰~-0.42‰, indicating that the carbonate cement in this area comes from the brachywater environment and is related to the dissolvation-deposition process and is of chemical origin.The δ13C isotope is generally negative in the speck distribution of carbonate cements, which may be due to the addition of light organic carbon in the M oil layer, and the calcium ion produced by the organic acid produced by decarboxylation of organic matter under high temperature and pressure and the reaction with clay minerals provides the Source of Ca2+ for diagenetic diagenosis of carbonate cements.The study also shows that carbonate cementation may be one of the important factors that make the sandstone reservoir physical property of M oil group worse, and the porosity loss rate of M oil group is up to 16% due to carbonate cementation.The research results on the characteristics and formation mechanism of carbonate cements provide key parameters for quantitative evaluation of reservoirs and experimental support for acidification and stimulation measures.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-5: Oxygen isotope in sediments: from Modern ocean to Archean
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

High-resolution in-situ SIMS conodont apatite δ18O records from South China: Implications for the Frasnian–Famennian biotic crisis

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Keywords: Frasnian–Famennian transition, conodont, oxygen isotope, paleotemperature, biotic-crisis

The Late Devonian Frasnian–Famennian (F–F) transition is a critical interval in geological history during which major marine ecological crisis occurred, featuring the severe losses of low-latitude shallow-water benthic faunas. Climate change has long been proposed as a potential cause for this biotic crisis. The oxygen isotopic compositions ($\delta^{18}O$) of biogenic apatite (e.g., conodont microfossils) are considered as reliable carriers to reconstruct the paleotemperature due to their temperature sensibility and relatively higher resistant to diagenetic alterations. In this study, the in-situ Secondary Ion Mass Spectrometry (SIMS) conodont apatite oxygen isotopes ($\delta^{18}O_{apatite}$) from Luofu section (inter-platform basin facies) were measured to recover the high-resolution sea surface water temperature (SST) variations across the Frasnian–Famennian interval in South China. The new in-situ oxygen isotope datasets reveal a $\delta^{18}O_{apatite}$ decline from 18.55 ± 0.37 ‰ to 17.6 ± 0.23 ‰ (VSMOW) in the late Frasnian and a subsequent increase from 17.6 ± 0.23 ‰ to 18.85 ± 0.24 ‰ in the latest Frasnian-earliest Famennian, which translate into sea surface temperature (SST) warming of ~ 4.3 °C and cooling of ~ 5.6 °C, respectively. These $\delta^{18}O_{apatite}$ shifts temporally agree well with reported results from other paleocontinents using the thermal conversion–elemental analyzer–isotope ratio mass spectrometry (TC-EA-IRMS) method, which, thus, is suggestive of a global signal. Furthermore, the positive $\delta^{18}O_{apatite}$ shift during the latest Frasnian-earliest Famennian is coincident with an apparent positive $\delta^{13}C_{carbonate}$ excursion, indicating that enhanced burial of organic carbon resulted in the drop in atmospheric PCO_2 and concomitant climate cooling. Overall, the SST data from the Luofu section exhibit a warm-to-cool fluctuation pattern, especially the climate cooling during the F–F transition, which may further cause escalating detrimental ecological pressures and lead to the Frasnian–Famennian biotic crisis.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-5: Oxygen isotope in sediments: from Modern ocean to Archean
Presentation Preference: Oral Preferred

Sulfur and oxygen isotopic compositions of sulfate from Lingulida shell: Constraining the late Devonian ooidal ironstone formation in South China

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Keywords: Sulfur cycle, sulfur isotopic, oxygen isotopic, Lingulida

Since the Phanerozoic, the cycle of iron, as an essential life and mineral element, in the earth system has been widely concerned. The study of the iron cycle is inseparable from global iron formation. As a representation of the global iron formation, the genesis of ooidal ironstones has not been entirely explained. It is difficult to explain the genesis of ooidal ironstones if we only study the iron cycle. The sulfur cycle is coupled with the carbon cycle on the global scale and the iron cycle on the local or regional scales, so we can use the sulfur cycle to restrict the iron cycle. In our study, we analyzed sulfur and oxygen isotopes of trace sulfate extracted from late Devonian Lingulida fossils, which were collected between two ooids ironstone layers. The sulfur and oxygen isotopic compositions of sulfate from Lingulida shells to reconstruct the ancient marine environment is a new method, so we also analyzed the same in the living Lingula shells. The results of δ34S and δ18O in the living Lingula shells, 14.42±1.77‰ and 9.81±0.34‰, suggested that the new Lingulida method is reliable. The δ34S and δ18O in the Devonian, 29.42±0.99‰ and 14.22±0.92‰, suggested the oceans here have heavier δ34S and nearly identical δ18O. It probably indicates that ooidal ironstones' formation requires a unique environment, where the seawater is oxic, and the sediments are anoxic.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-5: Oxygen isotope in sediments: from Modern ocean to Archean
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Conservative transport of dissolved sulfate in the Yarlung Tsangpo River constrained by triple oxygen isotopes

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Keywords: Oxidative pyrite weathering, CO2 counteraction, microbial sulfate reduction, conservative sulfate transport, Yarlung Tsangpo River

Global carbon-silica cycles are classically viewed as the primary processes controlling the stability of Earth's climate system. However, oxidative weathering of pyrite (OWP) gives rise to sulfuric acid weathering carbonate coupled with CO2 release globally and particularly in rapidly eroding environments. The OWP induced CO2 counteraction needs the vital prerequisite of conservative transport of dissolved sulfate because microbial sulfate reduction (MSR) transfers organic carbon to HCO3- latterly precipitated as CaCO3 in the ocean. Yet, conservative sulfate transport in the terrestrial environments remain elusive. We conduced field work in the Yarlung Tsangpo River during monsoon season and no-monsoon season, sulfur and triple oxygen stable isotope ratios of sulfate constrained sulfate sources and behaviors along the 1800km main stem. The simultaneously increased δ34SSO4 and δ18OSO4 ratios coupled with decreased SO42- concentrations but relatively stable Δ′17OSO4 ratios were observed along the river flow path through these both seasons. This spatial variation of sulfate concentrations and isotope ratios were resulted from mixing between OWP-derived sulfate and atmospheric deposition, and MSR does not affect the riverine sulfate isotope compositions. Our findings support the hypothesis that the uplift and erosion in the Qinghai-Tibet Plateau release OWP-derived sulfate and counteract CO2 consumption via silicate weathering.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-5: Oxygen isotope in sediments: from Modern ocean to Archean
Presentation Preference: Oral Preferred

Pore fluid and diagenetic evolution in turbidite sandstone reservoirs: A case from the Eocene Shahejie Formation, Niuzhuang Sag, Bohai Bay Basin, China

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Keywords: pore fluid, diagenetic evolution, carbonate cementation, siliceous cementation

Turbidite sandstones is the crucial petroliferous clastic rock reservoirs in the Niuzhuang Sag, Dongying Depression. The evolution of diagenetic fluid during burial environment has always been an urgent and difficult point in the research of diagenesis of clastic reservoir, which contributes to explore the formation of high-quality reservoirs. Thus, the nature and source of diagenetic fluids in turbidite sandstone reservoirs are studied by means of core, thin section, cathodoluminescence and SEM observation, as well as fluid inclusion microthermometry, EPMA, C-O isotope of bulk rock, LA-ICP-MS and SIMS.

Geochemistry analysis indicate that diagenetic fluid of authigenic minerals is controlled by the surrounding mudstones owing to turbidite sandstone reservoirs are adjacent to mudstone in sedimentation. The siliceous fluid in turbidite sandstone reservoirs mainly originates from the transformation of clay minerals and dissolution of feldspars and other mineral particles, which also provide abundant metal ions into pore water in the reservoir. While diagenetic fluid of precipitation of late-stage carbonate cementation is mainly controlled by the dissolution of micritic carbonate within mudstone and early-stage carbonate cementation. However, the origin of acid fluid for the dissolution of minerals is obvious in the different wells. $\delta^{18}O_{VSMOW}$ values of siliceous cements and REE characteristics of late-stage carbonate cements in the well W107 indicate that pore fluid is affected by meteoric water in the strong tectonic activity area; In contrast, the acid fluid within the other wells sources from the thermal evolution of organic matters. Moreover, based on the burial history of wells in different tectonic setting and homogenization temperature of aqueous fluid inclusions within authigenic minerals, the transformation time of diagenetic fluid properties from alkaline-acid-alkaline in the turbidite sandstone reservoirs is determined, and the evolution history of diagenetic fluid is revealed. Ultimately, the differential evolution model of diagenetic fluid in the middle part of third member of Paleogene Shahejie formation are established in the Niuzhuang Sag, Dongying Depression.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-5: Oxygen isotope in sediments: from Modern ocean to Archean
Presentation Preference: Oral Preferred

Calibrating the high-precision measurements of triple oxygen isotopic compositions in sulfate

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Keywords: Triple oxygen isotopes, Sulfate, High-precision measurements, Fluorination methods

By contrast with large mass-independent oxygen isotope fractionation signatures exclusive to a restricted set of mechanisms, small triple oxygen isotope variations are widely distributed in natural samples. Among them, small triple oxygen isotope variation signals in sulfate may bear critical information of the atmospheric pCO_2 and pO_2, bioproductivity, hydrological cycles, and biogeochemical cycling in the ocean through deep Earth history. To enable research into this field, sufficient analytical capacity for triple oxygen isotopic compositions in sulfate is required. However, current measurement approaches are far from satisfactory in both accuracy and precision due to the non-quantitative conversion from sulfate to O_2 (i.e. the only gaseous analyte for accurate triple oxygen isotope analysis) and the difficulty in pinning down the exact oxygen isotope fractionation effects imposed by the conversion. In this study, we will calibrate the oxygen isotope fractionation between O_2 and sulfate during the conversion processes through theoretical calculations, sulfate-water oxygen isotope exchange experiments at relatively high temperatures, as well as CO_2-laser fluorination and Ni-tube fluorination experiments. The obtained fractionation in oxygen isotopes during fluorination will be presented. And the factors which may influence the fractionation will be discussed.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-5: Oxygen isotope in sediments: from Modern ocean to Archean
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Oceanic oxygenation evidenced from barite nodules in the Ediacaran black shales

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Keywords: Ediacaran, barite, sulfur isotope, oxygen isotope

Extensive anoxia and redox stratification, as well as low sulfate concentrations, have been widely suggested to characterize the oceans for most of the Ediacaran period (~635-539 Ma), although multiple episodes of short-term oceanic oxygenation might have occurred. However, abundant centimeter-scale barite nodules were in surprise observed in the Member II black shales of the Ediacaran Doushantuo Formation, which would indicate the marine sulfate were not as scarce as previously thought, if they were formed during the syn-depositional process. To reveal their origin, we did a systematic analysis of their sulfur (δ34S) and oxygen (δ18O) isotope compositions. The δ34S values range from 40.6‰ to 59.4‰, much higher than that in pyrite from the contemporaneous sediments. Together with the high δ18O values (14.8-24.3 ‰), the mechanism involving pyrite oxidized by seawater or meteoric water [O2] during post-deposition or outcrop weathering could be fairly excluded. Instead, their values, as well as a good correlation between, are consistent with a pore water realm during the early diagenesis. Given barite nodules could be destroyed through reductive dissolution within an anoxic setting, we propose they should have been formed under oxic water conditions with high sulfate concentrations, implicating at least local oxidation in the predominantly anoxic ocean.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-5: Oxygen isotope in sediments: from Modern ocean to Archean
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

An improved phosphate extraction method for igneous weathering profiles

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Keywords: oxygen isotope of phosphate, phosphate extraction, igneous weathering profiles, R-Ca-R method, reproducibility

The oxygen isotope of phosphate (δ18OPO4) has been widely employed for reconstructing paleo-environment and tracing biogeochemical phosphate cycling. Several existing protocols of phosphate extraction from soil, sea water, fossils, and sediments as silver phosphate were tested for their use in igneous rocks and igneous weathering profiles. Each has its merit, but none can be successfully applied directly due to low yield, and unknown fluctuation of the δ18OPO4 in extracted phosphate sample. A simple and reliable method is needed. Through trial and error, we have developed an effective phosphate extraction method, which comprises dissolution, purification and crystallization. The purification method is characterized by two cationic exchange resin treatments separated by a step of calcium hydroxide addition (R-Ca-R), and the crystallization method is characterized by evaporating to dried or appearance of white crystals.

To evaluate the phosphate extraction method, KH2PO4 solution, phosphorite rocks and igneous rocks with rare or slight weathering were tested. As to the new R-Ca-R method, phosphate solution and phosphorite rocks had over 96% phosphate covert to calcium phosphate in reaction with calcium hydroxide. From dissolution of fine-grind rocks to final silver phosphate crystallization, all igneous rocks and phosphorites yielded enough well-crystallized silver phosphate. The δ18OPO4 values of igneous rocks are 6.4‰ - 8.0‰, consistent with the characteristics of fresh and slightly weathered igneous rocks. The differences (less than 0.5‰) within 2σ (0.6‰) analytical errors of all repeated samples indicate satisfactory reproducibility of this new phosphate extraction method.

Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-5: Oxygen isotope in sediments: from Modern ocean to Archean
Presentation Preference: Oral Preferred

Triple oxygen isotope systematics of diagenetic recrystallization of diatom opal-A to opal-CT to microquartz in deep sea sediments

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Keywords: triple oxygen isotopes, opal, chert, sediments

The oxygen-18 isotopic composition ($\delta^{18}O$) of silica preserved in oceanic sediments is an important archive of Earth's temperature and/or seawater $\delta^{18}O$ from the Archean to present. Recent advances in high-precision measurements of both $\delta^{18}O$ and $\delta^{17}O$ values have been used to provide additional constraints on what the oxygen isotopic composition of chert reflects about past conditions. Here, we examine the effects on the triple oxygen isotopic composition of chert that occurs during transformation and recrystallization of biogenic opal-A to opal-CT to microquartz in deep sea sediments. We studied late Miocene to present samples from the Sea of Japan at ODP Site 795 and measured biogenic diatom opal-A, opal-CT, microquartz chert, and 'altered' opal-A samples—previously measured for $^{\delta 18}O$ values only—for both $\delta^{18}O$ and $\delta^{17}O$ values. We find that $\delta^{18}O$ decreases and $\Delta'^{17}O$ increases with depth, coincident with the conversions from diatom opal-A to opal-CT to microquartz. Silica samples deviate from the trend expected for triple oxygen isotopic equilibrium with modern seawater. To explain these data, we developed a model that shows that local temperature gradients and pore fluid $\delta^{18}O$ profiles in combination lower the measured opal-CT and microquartz $\delta^{18}O$ values and raise the $\Delta'^{17}O$ values relative to the initial opal-A, but deviate from triple oxygen isotopic equilibrium with seawater. We find that a steeper local temperature gradient and a larger influence of hydrothermal alteration of basalt at the base of the sediment column (which lowers pore fluid $\delta^{18}O$ values) in the past explain both the measured $\delta^{18}O$ and $\Delta'^{17}O$ values of the opal-CT and microquartz. The diagenetic processes taking place in the Japan Sea do not explain a large portion of the existing Archean to present triple oxygen isotope chert data, which likely require either changes in the oxygen isotopic composition of the source water (i.e., ocean water) and/or alteration by meteoric fluids. Further, our data demonstrate that the triple oxygen isotopic composition of preserved chert need not represent surface conditions, but instead may reflect processes that occur in subsurface sediments at elevated temperatures and with modified pore fluid oxygen isotopic compositions.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-5: Oxygen isotope in sediments: from Modern ocean to Archean
Presentation Preference: Oral Preferred

The effect of time averaging and stratigraphic disorder on geochemical proxy records: cautionary examples from the Adriatic Sea

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Keywords: sequence stratigraphy, oxygen isotopes, Corbula gibba, Northern Adriatic Sea

The occurrence and abundance of fossils is known to be steered by changes in the eustatic sea-level. Variations in sediment supply, sediment transport, bioturbation, erosion and accommodation space alter the concentration of fossils and the extend of time averaging systematically. These effects are well studied for the fossil record, though, an evaluation of effects on the geochemical proxy record extracted from these fossils is currently missing. We analysed the $\delta^{13}C$ and $\delta^{18}O$ record from ^{14}C- and amino-acid dated Holocene *Corbula gibba* shells from drill cores from the Northern Adriatic Sea near Piran, the Po river delta and the Panzano river. The samples cover transgression and sea level highstand since the last deglaciation. The hypothesis was that an increase in absolute age span, which is typical for the more time-averaged fossil assemblage in the transgressive succession, results in a higher range of $\delta^{13}C$ and $\delta^{18}O$ values as well, while a narrower age span from the highstand strata were expected to show a smaller range of isotope values. The first results show the expected increase in age range with sediment depth, though, the carbon and oxygen isotopic ranges decrease with a few exceptions. Possible causes are a higher variation or higher pace of environmental change during the highstand, or by diagenetic homogenisation downcore due to the increased time of exposition to diagenetic fluids and cement generation. Either way, the results give cause for concern about the extent of this bias.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-5: Oxygen isotope in sediments: from Modern ocean to Archean
Presentation Preference: Oral Preferred

Triple Oxygen Isotopic Geochemical Behaviors of Basalt Weathering

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Keywords: Triple oxygen, Basalt Weathering, Continental weathering, Regolith

The triple oxygen isotope of seawater (δ18Osw and Δ17Osw) is determined by continental weathering and hydrothermal alteration of the oceanic crust. Exchanging between seawater and mid-ocean ridge basalt is leading to an increase δ18Osw with quickly decreasing Δ17Osw. Recent research of riverine fine-grained sediments suggested that continental weathering makes δ18Osw decline and Δ17Osw slowly increase. Therefore, these two processes might not maintain δ18Osw and Δ17Osw at the same time, indicating positive Δ17Osw and negative δ18Osw in archean, which is contradict the triple oxygen isotope of chert. The contribution of hydrothermal alteration could be well estimated, while the detail of weathering is still ambiguous. Fine-grained sediments come from various weathering profiles and lost the original information of protolith, which is not a direct material to restrict the influence of continental weathering. Because there are too many variants during continental weathering, such as temperature, rainfall, porosity, mineral composition, triple oxygen isotope of protolith and meteoric water. In this regard, we have studied the triple oxygen isotopes of four basalt weathering profiles located in different climatic regions. Our study found that δ18O of regolith (δ18OR) keeps increasing in every section, while Δ17O of regolith (Δ17OR) shows a different pattern. In the tropical zone, Δ17OR decreases slightly with increasing δ18OR, but Δ17OR decreases dramatically in the temperate region. Our result manifests that temperate, rainfall, and the triple oxygen isotope of precipitation could influence the process of basalt weathering.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-5: Oxygen isotope in sediments: from Modern ocean to Archean
Presentation Preference: Oral Preferred

Genesis of Saline Springs and Potassium-prospecting in Zhenyuan area, Yunnan

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Keywords: Recharge source, solute source, circulation and evolution, potassium-prospecting, reservoir temperature

Simao Basin in Yunnan province is an important salt-bearing basin in China. The Mengyejing solid potash deposit is located in the south of Simao Basin, which has a industrial exploitation value. Zhenyuan area is located in the ZhengDong salt belt of Simao Basin, and cretaceous evaporites, clastic sediments and saline spring water are widely developed in this place. Based on the hydrochemistry and isotopes ($\delta^{2}H$, $\delta^{18}O$, $\delta^{37}Cl$), this paper systematically analyzed the recharge source, solute source, reservoir temperatures, circulation evolution model of saline spring water in Zhenyuan area, and it also discussed the potash exploration prospect in study area. The hydrogen and oxygen isotope characteristics indicate that the saline springs in this study are mainly derived from meteoric water and/or ice and snow melt from the surrounding mountains (Ailao Mountain and Wuliang mountain).The element characteristics show that the solute source of saline springs is mainly derived from the leaching of halide minerals (rock salt), and partly from the leaching of sulfate minerals (gypsum, anhydrite) and Ca-carbonate minerals (aragonite, calcite, dolomite). The stable chlorine isotope characteristics show that rock salt leaching is the main Cl source of saline springs, while atmospheric precipitation recharge and water-rock interaction (volcanic rock, mudstone and sandstone) are the secondary Cl sources of saline springs. The estimated reservoir temperatures for the saline springs range from 44.3-72.4℃ and its estimated circulation depths range from 914 m to 1884 m. The hydrochemical characteristic coefficient shows that saline springs in this study are of rock salt solution filtrates genetic water, and the salt bearing strata have good sealing and high metamorphism degree. Both direct and indirect potassium exploration indexes show that Guohe village and Dahebian Village in Zhenyuan area are abnormal concentration areas for potassium exploration, which can be considered to be the most promising areas in search for potash ore.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-5: Oxygen isotope in sediments: from Modern ocean to Archean
Presentation Preference: Oral Preferred

Triple oxygen isotope of chert in South China during the Ediacaran-Cambrian transition

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Keywords: Triple oxygen isotope, Quartz, Ediacaran-Cambrian transition, Ge/Si

As the foundation to explain the oxygen isotope of chemical sediments, the oxygen isotopic composition of the ocean has been discussed for a long time. Without paleo-ocean samples of primary nature, it is necessary to calculate δ18Osw by using minerals in equilibrium with the seawater. Based on chemical sediments and ophiolite sets, two completely different δ18Osw trends have been recovered. δ18O in calcite and silica shows a 10 ‰ increasing trend from archean to present. If the paleo-temperature is not very high, δ18Osw should have a similar curve. But the archean δ18Osw value recovered by ophiolite sets shows no difference from that of today's ocean, and this model suggests ancient chemical deposit has been altered by diagenesis. To deal with this debate, we measured the triple oxygen isotope of chert from six sections in South China deposited during the Ediacaran and Cambrian transition. Excluding contamination from detrital silicate and hydrothermal, pristine quartz precipitated from ocean records converged δ18O (~24.2‰) and 17O (~-0.145‰) following the fractionation slope between water and quartz. After analyzing the influence of diagenetic alteration, we suggest this phenomenon indicates that the Proterozoic ocean has a lower δ18Osw (about -5‰) with a positive 17O (about 0.0325‰).

Session T10-6: Biogeochemical cycling of nutrient elements

Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-6: Biogeochemical cycling of sulfur and nutrient elements in gelogical time
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

The sulfur cycling process influenced by hydrothermal activities in the Cryogenian Nanhua Basin

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Keywords: Neoproterozoic, Nanhua Basin, Hydrothermal activities, Sulfur isotope composition

The Nanhua Basin of South China records a nearly complete Cryogenian stratigraphic succession, including the syn-Sturtian Tiesi'ao Formation, the interglacial Datangpo Formation and the syn-Marinoan Nantuo Formation in ascending order. In the Songtao area, Guizhou Province, the Tiesi'ao and lower Datangpo (Mn-carbonate unit and the overlying black shale unit) formations are characterized by elevated CAS (carbonate-associated sulfate) $\delta^{34}S$ (+38.8-69.8‰, mean +56.0‰) and framboidal pyrite $\delta^{34}S$ values (+29.1-72.4‰, mean +54.8‰). This phenomenon is consistent with the coeval strata globally, such as Australia, Namibia and Canada, which is attributed to the low sulfate concentrations and high sulfate $\delta^{34}S$ values (e.g., Gorjan et al., 2000, 2003; Hurtgen et al., 2005; Li et al., 2012). However, the paired pyrite and CAS $\delta^{34}S$ show frequent negative sulfur isotope fractionations, and the $D^{34}S$ ($\delta^{34}S_{CAS}$-$\delta^{34}S_{pyrite}$) range from -11.6‰ to +13.5‰ with the mean of +0.7‰. Besides, the Tiesi'ao Formation show low TOC (0-2.7%, mean 0.2%) but high TS contents (0-4.6%, mean 2.4%), while the lower Datangpo Formation show high TOC (0.6-3.5%, mean 2.0%) and TS contents (0.5-4.8%, mean 2.2%), indicating that the in situ microbial sulfate reduction (MSR) cannot have been the sole control on pyrite $\delta^{34}S$, and other processes are necessary during the formation of the framboidal pyrites. The Cryogenian Nanhua Basin experienced intense hydrothermal activities, which are proved by Fe/Ti-Al/(Al+Fe+Mn), initial εNd(t)-$^{87}Sr/^{86}Sr$ crossplots and positive Eu anomalies (Yu et al., 2016 and this study). Based on these considerations, we propose that the sulfur cycling process in the Cryogenian Nanhua Basin was influenced by hydrothermal fluids which can release large amounts of ^{34}S-enriched H_2S to the water column. During the Sturtian glacial interval, material exchange between continent and ocean was suppressed, the pyrites were mainly formed through the reaction of the hydrothermal H_2S with the dissolved Fe^{2+}, resulting in the formation of large amounts of ^{34}S-enriched pyrites. After the Sturtian Glaciation, the released H_2S was partly precipitated as syngenetic framboidal pyrite and partly oxidized to sulfate, and the sulfate reservoir in the Nanhua Basin mixed with influx of open ocean seawater with relatively lower sulfate $\delta^{34}S$ (~ +30‰; Gorjan et al., 2000; Hurtgen et al., 2002, 2005), thus accounting for the unusual combination of high TS concentrations, similar strongly ^{34}S-enriched sulfur isotopic compositions for CAS and pyrite, and frequent negative $D^{34}S$ values in the Datangpo Formation. Our model provides new insights into sulfur cycling processes within a semi-restricted marine basin that are likely to have wider applicability to Neoproterozoic marine systems.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-6: Biogeochemical cycling of sulfur and nutrient elements in gelogical time
Presentation Preference: Oral Preferred

Intra-crystal variations of pyrite sulfur and iron isotopes fingerprint anaerobic microbial processes

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Keywords: Dissimilatory iron reduction (DIR), Dissimilatory sulfate reduction (DSR), Nantuo Formation, Doushantuo cap dolostone, Ediacaran

Sedimentary and diagenetic pyrites archive the geochemical signals of microbial dissimilatory iron reduction (DIR) and dissimilatory sulfate reduction (DSR), which represent two of the earliest evolved metabolic pathways and account for the majority of anaerobic organic matter degradation in the modern ocean. DIR and DSR associate with significant fractionation in iron and sulfur isotopes, and accordingly pyrite sulfur (δ34Spy) and iron isotopes (δ56Fepy) have been applied to track the redox evolution in Earth's past. However, recent studies indicate that interpretations of bulk sample δ56Fepy and δ34Spy data are complicated by local environmental factors, obscuring the reconstructions of DIR/DSR processes and the redox landscapes in Earth's history. In order to develop a new geochemical proxy that can better constrain DIR and DSR processes and pyrite formation, in this study we conducted in situ (i.e., intra-crystal) δ56Fepy and δ34Spy analyses of two sets of diagenetic pyrite samples from ~635 million-year old sedimentary rocks in South China. The origins of these pyrite samples have been well characterized in previous studies. Pyrites from the top of Nantuo Formation were precipitated in sediment porewater with H2S diffused from sulfidic (H2S-rich) seawater, while the formation of pyrites in the basal Doushantuo cap dolostone was driven by DSR in sediment porewater with sulfate diffusion from ferruginous (Fe2+-rich) seawater. Both δ56Fepy and δ34Spy show intra-crystal variations with consistent core-to-rim trends. The Nantuo pyrite shows a core-to-rim increase of δ34Spy and a decrease of δ56Fepy, while the Doushantuo pyrite shows the opposite trends. The diffusion-advection-reaction (DAR) and coupled Rayleigh distillation models were developed to simulate core-to-rim variations of δ34Spy and δ56Fepy, respectively. The modeling results indicate that the intra-crystal isotopic variations of diagenetic pyrites are dependent on, (1) the location of DSR, i.e., water column or sediment porewater, and (2) the variation of degree of pyritization (fFe-py), which may be dominated by the relative rate of the supply of H2S and Fe2+. Our study indicates that in situ δ34Spy and δ56Fepy analyses in a single pyrite crystal can be applied to refine marine redox profile in paleoceans. Moreover, this approach could fingerprint the evolutions of DSR and DIR in the early Earth and their occurrences in other planets, such as Mars.

Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-6: Biogeochemical cycling of sulfur and nutrient elements in gelogical time
Presentation Preference: Oral Preferred

Impacts of paleoenvironmental evolution during Early-Middle Cambrian on organic matter accumulationA case of the Keping-Bachu area in the Tarim Basin, China

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Keywords: Paleoenvironment, source rock development model, Keping-Bachu area, Middle-Lower Cambrian, Tarim Basin

In order to understand the organic matter accumulation model of the Middle-Lower Cambrian source rocks in Tarim Basin more comprehensively, we used the experiment of TOC, major elements, trace elements, and carbon isotopes to test the samples from the Keping-Bachu area. Based on the research of sedimentary evolution, the Early-Middle Cambrian paleoenvironmental characteristics were analyzed, and the organic matter accumulation models in each period were established. The results show that the shale of the Yuertus Formation and the argillaceous carbonate rock of the Xiaoerbulak Formation in the Keping area deposited in the middle-outer ramp of the transgressive system. In the Yuertus period, upwelling and hydrothermal activity occurred, and the intensity of hydrothermal activity gradually weakened in the early stage stopped in the middle stage. The TOC, V/(V+Ni), U/Th, excess Ba(Baxs), and other indicators indicate that the organic matter abundance, paleo-productivity, and anoxic degree of sedimentary water first increased and then decreased from the first member of the lower part of Yuertus Formation to the first member and the second member of the lower part of Xiaoerbulak. The highest part was the lower part of Yuertus Formation, with the TOC average of 5.21%, the V/(V+Ni) average of 0.98, the U/Th average of 10.08, and the Baxs average of 95221×10^{-6}. In the Bachu area, the argillaceous carbonate source rocks of Xiaoerbulak and Awatag developed in the intra-platform lagoon in dry and hot paleoclimate. During the sedimentary period of the upper Xiaoerbulak Formation and Wusonger Formation, the deep lagoon made hypoxia possible. Therefore, the initial stage of the evaporation cycle is an anoxic environment, and it provides good preservation conditions for organic matter accumulation. In summary, sedimentary facies, paleogeomorphology, hydrothermal activity, sea level, and upwelling affect the paleo-productivity and redox environment, thus controlling the abundance and accumulation model of organic matter. The organic matter accumulation models in the Keping area from bottom to top are transgression-strong hydrothermal-upwelling model (the first member of the lower part of Yuertus Formation), the transgression-weak hydrothermal-upwelling model (the second member of the lower part of Yuertus Formation), the transgression-upwelling model (the middle part of Yuertus Formation), and transgressive model (The lower part of Xiaoerbulak Formation). In the Keping area, the transgression and upwelling are the basis, and the influence of hydrothermal on organic matter accumulation has two sides: promotion and inhibition. The organic matter accumulation of Xiaoerbulak and Wusonger Formation in the Bachu area is an evaporation-stratification model in intra-platform lagoon. Paleomorphology and sea-level change play a significant controlling role in this model.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-6: Biogeochemical cycling of sulfur and nutrient elements in gelogical time
Presentation Preference: Oral Preferred

Feedback Between Carbon and Nitrogen Cycles During the Ediacaran Shuram Excursion

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Keywords: Ediacaran, South China, Doushantuo Formation, Shuram excursion, nitrogen isotopes

The middle Ediacaran Period records one of the deepest negative carbonate carbon isotope (δ13Ccarb) excursions in Earth history (termed as the Shuram excursion). This excursion is argued by many to represent the large perturbation of the global carbon cycle. If true, this event may also have induced significant changes in the nitrogen cycle, because the carbon and nitrogen are intimately coupled in the global ocean. However, the response of the nitrogen cycle to the Shuram excursion remains ambiguous. Here, we reported high resolution bulk nitrogen isotope (δ15N) and organic carbon isotope (δ13Corg) data from the upper Doushantuo Formation in two well-preserved sections (Jiulongwan and Xiangerwan) in South China. The Shuram-equivalent excursion is well developed in both localities, and our results show a synchronous decrease in δ15N across the event. This observation is further supported by bootstrapping simulations taking into account all published δ15N data from the Doushantuo Formation. Isotopic mass balance calculations suggest that the decrease in δ15N during the Shuram excursion is best explained by the reduction of isotopic fractionation associated with water column denitrification (εwd) in response to feedbacks between carbon and nitrogen cycling, which were modulated by changes in primary productivity and recycled nutrient elements through remineralization of organic matter. The study presented here thus
offers a new perspective for coupled variations in carbon and nitrogen cycles and sheds new light on this critical time in Earth history.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-6: Biogeochemical cycling of sulfur and nutrient elements in gelogical time
Presentation Preference: Oral Preferred

Intensified continental chemical weathering linked to volcanism during the Triassic–Jurassic transition

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Keywords: Mercury, extinction, volcanism, continental sediments

Direct evidence of intense chemical weathering induced by volcanism is rare in sedimentary successions. Here, we undertake a multiproxy analysis (including organic carbon isotopes, mercury (Hg) concentrations and isotopes, chemical index of alteration (CIA), and clay minerals) of two well-dated Triassic–Jurassic (T–J) boundary sections representing high- and low/middle-paleolatitude sites. Both sections show increasing CIA in association with Hg peaks near the T–J boundary. We interpret these results as reflecting volcanism-induced intensification of continental chemical weathering, which is also supported by negative mass-independent fractionation (MIF) of odd Hg isotopes. The interval of enhanced chemical weathering persisted for ~2 million years, which is consistent with carbon-cycle model results of the time needed to drawdown excess atmospheric CO2 following a carbon release event. Lastly, these data also demonstrate that high-latitude continental settings are more sensitive than low/middle-latitude sites to shifts in weathering intensity during climatic warming events.

Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-6: Biogeochemical cycling of sulfur and nutrient elements in gelogical time
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Genetic mechanism of authigenic chlorite in ultra-deep clastic rocks reservoir and its geological significance: inspiration from diagenetic physics simulation experiment

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Keywords: Authigenic chlorite, Genesis mechanism, Ultra-deep, Diagenetic physics simulation experiment, Southern margin of Junggar Basin

Authigenic chlorite exists widely in petroliferous basins, its effect on the quality of clastic rock reservoir in ultra-deep has been one of the hot-spot issues in globole researches. The ultra-deep clastic reservoirs in the southern margin of Junggar Basin have undergone a special burial process of "long-term shallow burial and late rapid deep burial", its diagenetic evolution is strongly influenced by volcanic materialsand authigenic chlorite is commonly found in the reservoirs. At present, the genetic mechanism of authigenic chlorite is not clear in this area, which restricts its application in oil and gas exploration. In this study, the geological burial process of "long-term shallow burial and late rapid deep burial" was taken as the constraint condition to reconstruct the process of loose sediment turning into rock through diagenetic physical simulation experiments, and combined with the actual geological data, comprehensively discusses the genetic mechanism of authigenic chlorite under the constraint condition of geological burial process and its significance to development of reservoir. The experimental results show that the geological burial process has an obvious control on the development of authigenic chlorite. The iron ions and magnesium ions required by authigenic chlorite are very sensitive to temperature and pH value. In the stage of long-term shallow buried, the combination of low temperature and dissolution of atmospheric fresh water results in low concentrations of iron ions and magnesium ions, and the lower temperature inhibits the montmorillonite which produced by volcanic ash alteration transforms into authigenic chlorite too. The above two points lead to a small amount of "thin coat" authigenic chlorite at the edge of grain in the stage of long-term shallow buried, which does not effectively inhibit the formation of siliceous precipitation. Overpressure was developed in the stage of late rapid deep burial, which not only protected the primary pores but also inhibited the transformation of montmorillonite into illite, indirectly laying the foundation for the formation of authigenic chlorite. At the same time, the organic acid charging and the gradual increase of temperature lead to the increase of concentration of iron ions and magnesium ions, and promote the transformation of montmorillonite to authigenic chlorite. Due to the low content of "thin coat" chlorite at the shallow burial stage, the crystals of late authigenic chlorite continue to grow along the early "thin coat" authigenic chlorite, which further increases the thickness of authigenic chlorite at the edge of grain, but does not occupy the intergranular pores. Authigenic chlorite in this stage strengthens the reservoir's ability to resist compaction, and inhibits the occurrence of siliceous precipitation, and effectively improves the reservoir physical properties. The surface of chlorite coat has oil wettability. The oil will be adsorbed on the surface of "thick coat" autogenic chlorite at the edge of grain after oil filling, which makes the reservoir show obvious oil wettability, and is conducive to oil migration and storage in the reservoir. Therefore, this study on the genetic mechanism of ultra-deep authigenic chlorite also reveals the geological significance of organic-inorganic synergy.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-6: Biogeochemical cycling of sulfur and nutrient elements in gelogical time
Presentation Preference: Oral Preferred

Biological matter enhanced iron release from the benthic bioturbated sediment: a case study from the Late Cretaceous sandstone, northern Saudi Arabia

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Keywords: burrows, bioturbation, biological matter, coastal sediments, iron cycling

Benthic bioturbation is a prominent function in marine ecosystem (Lohrer et al., 2004), enhancing pore-water ventilation (Jégou et al., 2001; Shull et al., 2009), oxygen and nutrition cycling (Meysman, 2014), and ecosystem productivity (Cribb and Bottjer, 2020). Here we investigated the cementation and element concentration in the benthic bioturbated sediment. The result shows that the well-preserved biological matter cemented and shaped the benthic burrows, making it highlighted from the surrounding sand grains. Micro-environments in the burrows play an important role in mediating oxidation and reduction of the iron. Reducing micro-environments are predominant in bioturbated sediments in research area where presumably have relatively high level of oxygen according to the shallow water setting and intensive bioirrigation. Reducing environment, various iron species, and enhanced hydrodynamic by bioturbation are likely accelerated the transportation and release of iron from bioturbated sediments into overlying water, which could be a potential source of micro-nutrients for ocean productivity.

Session T10-7: Tracing past climate and environmental change using novel isotopic approaches

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-7: Tracing past climate and environmental change using novel isotopic approaches
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Experimentally precipitated cryocalcites – towards a better understanding of complex cave archives formed at glacial-interglacial transitions.

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Keywords: Cryocalcite, experimental, morphotypes

Cryocalcites represent a specific type of speleothem precipitated from freezing ponds in caves during glacial-interglacial transitions and in the context of Dansgaard-Oeschger events. Over the past decade, considerable progress has been made concerning cryocalcite petrography, crystallography and geochemistry. Uncertainty remains, however, as the cave waters from which the cryocalcites formed are not preserved. Moreover, the number of well-constrained cryocalcites ^{230}Th/U data is still limited. Here we report, for the first time, the outcome of experimental work inducing cryocalcite precipitation in the laboratory. We apply gradually cooled, calcium-rich bicarbonate water with a known isotopic composition. The experiments include cryocalcite precipitation at temperatures of 2, 1, 0,-1 and -2^{o}C with complete freezing occuring at -2 ^{o}C and partial freezing at -1 ^{o}C. The δ_{18} O and δ^{13} C values, pH, conductivity, and alkalinity of the parent fluid were recorded before and after the experiment. The results show the significance of relevant parameters but are not accessible with regard to fossil cryocalcites. Experimental work documents a clear dependency of $\delta^{18}O_{cryocalcite}$ on the initial $\delta^{18}O_{water}$, the temperature at which the crystals precipitated, the freezing rate, the calcite saturation index of the water and kinetic effects during the cryogenic precipitation. A large increase in $\Delta^{13}C_{DIC}$ values is found between experimental fluids at the experiments' beginning and end (31.9 ‰). These maximum values coincide with the experiments running over 90 days. Reasons may include significant CO_2 degassing leading to a markedly ^{13}C enriched solution. In contrast, experiments running over seven days only record a $\Delta^{13}C_{DIC}$ of 7.11 ‰. Based on experimental data, crystal morphotypes can be placed in context with a precipitation sequence. Sharp-edged rhombohedra are precipitated first. These are followed by spherulitic types that form later only from frozen water with the solution's increasing calcite saturation index. The relation of specific morphotypes resulting from experimental parameters emphasizes the system's complexity, which must not be underestimated when exploring fossil counterparts.

Reference

Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-7: Tracing past climate and environmental change using novel isotopic approaches
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Geochemical Characteristics and Environmental Implications of Trace Elements of the Paleocene in the West of Lishui Sag, East China Sea Basin

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Keywords: Lishui Sag, Paleocene, Paleoenvironment, XRF, elemental geochemistry

Analysis of sedimentary environment during clastic formation process is of great significance for reservoir evaluation and dessert prediction. This paper focuses on the Paleocene in the West of Lishui Sag, East China Sea Basin. XRF fluorescence diffraction and carbon and oxygen isotope tests were carried out on core samples from four wells. Based on the geochemical characteristics of the samples and the changes of the ratios of the elements, combined with the lithologic characteristics and sedimentary structure, the paleoclimate, paleosalinity, paleowater depth, redox environment, paleowater temperature and other paleoenvironmental characteristics of the sedimentary period in the research area were analyzed. The results show that the Paleocene in the west of Lishui Sag is mainly in the reducing environment of brackish-salt water with weak water stratification. As a whole, the water depth shows a trend of becoming deeper, then shallower and then deeper. The upper part of E1m2 has the deepest water, the strongest reducibility and the highest salinity. The Sr element and oxygen isotopes were used to quantify the paleowater temperature. The sedimentary period of the Paleocene in the west of Lishui Sag was warm on the whole. However, the cotent of Sr becomes smaller after later deposition, so the calculated paleowater temperature is higher. In addition, oxygen isotopes are affected by diagenesis, resulting in a negative oxygen isotope value. Therefore, the calculated temperature is close to the diagenetic temperature, which needs further study. The values of Baxs, Znxs and the ratio of trace elements show that the paleoproductivity of the study area is low, and the hydrocarbon generation potential is poor. The content of nutrient elements mainly comes from terrigenous input rather than biological origin. Meanwhile, the Si/Al ratio also shows that the overall study area is greatly affected by the terrigenous input, the terrigenous intrusion characteristics gradually increased from the Yueguifeng Formation to the lower part of the Mingyuefeng Formation.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-7: Tracing past climate and environmental change using novel isotopic approaches
Presentation Preference: Oral Preferred

Mercury isotopes show vascular plants had colonized land extensively by the early Silurian

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Keywords: Paleozoic, Hg isotope, vascular plants, Silurian, land colonization

The colonization and expansion of plants on land is considered one of the most profound ecological revolutions in Earth's history. However, the precise timing of the onset and colonization patterns and processes remain controversial due to discrepancies between sparse micro/macro-fossil records and molecular clock results. Because land vegetation can enhance weathering intensity and terrigenous input to the ocean, changes in terrestrial plant biomass with distinct negative odd-MIF (Δ199Hg) and even-MIF (Δ200Hg) signatures have the potential to disturb the positive MIF signatures in marine sediments. By investigating secular variations in the mercury (Hg) isotopic composition of Cambrian to Permian marine sedimentary rocks from South China and peripheral paleocontinents, we highlight distinct negative excursions in both odd- and even- MIF at Stage level starting in the early Silurian. We propose that these geochemical signatures were driven by increased terrestrial contribution to ocean sediments due to the rapid expansion and accelerated diversification of vascular plants. These excursions broadly coincide with rising atmospheric oxygen concentrations and global cooling during the Paleozoic. Based on these geochemical data, we propose that vascular plants were widely distributed on land during the transition from the Ordovician to Silurian (~ 444 Ma ago), long before the earliest reported vascular plant fossil, Cooksonia (~ 430 Ma).

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-7: Tracing past climate and environmental change using novel isotopic approaches
Presentation Preference: Oral Preferred

Revising the Mg isotopic systematics of siliciclastic components of sediments and sedimentary rocks: A new geochemical proxy of continental weathering in Earth's history

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Keywords: Saprolites, Mg isotope fractionation, South China, Carbonate, Soil clays

Continental weathering is the key geochemical process linking the terrestrial and marine systems, and has been playing the key role in the evolution of Earth System. Mg isotope is applied as a potential weathering proxy in deep time, based on increasing trend of δ26Mgsili with progressive weathering. However, it is recent studies show that Mg isotope fractionation between secondary clay minerals and dissolved Mg variates span positive to negative in different secondary clay minerals, challenging Mg applied as a weathering proxy. In this study, we find a decrease trend of δ26Mgsili with increase of weathering intensity of deep time samples. Combining our samples and modern weathering profile observation, we suggest that the trend is caused by formation and following dissolution of Mg-rich secondary clay minerals such as chlorite and vermiculite with extremely heavy Mg isotope composition. A three stages weathering model described by mixing of different Mg-bearing mineral component is developed to explain Mg isotope fractionation mechanism. In preliminary weathering stage, primary minerals dissolve and Mg poor secondary clay mineral formed causing in quantity loss of Mg and slightly increase of δ26Mgsili. Mg-rich secondary clay mineral massively forms at bottom of soil in transition weathering stage leading to abrupt increase of Mg concentration and δ26Mgsili. Further dissolution of Mg-rich secondary clay mineral in advanced weathering stage forms a decrease trend of δ26Mgsili with increase weathering intensity. Our weathering model is well applied in modern weathering profiles with different Mg isotope trend. The new Mg fractionation mechanism indicate δ26Mgsili-normalized Mg concentration, instead of previous δ26Mgsili, can be used as an effective weathering proxy in deep time, showing weathering stage, weathering intensity and other climate information.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-7: Tracing past climate and environmental change using novel isotopic approaches
Presentation Preference: Oral Preferred

Spatial variation in depositional environments and carbon isotope values across the Paleocene–Eocene thermal maximum in shallow eastern Tethys

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Keywords: Paleocene-Eocene boundary, Carbon isotopes, Carbonate microfacies, Southern Tibet, Shallow-water carbonate platform

The Paleocene–Eocene Thermal Maximum (PETM, ~56 Ma) is a large negative carbon isotope excursion (CIE) that testifies to a massive perturbation of the global carbon cycle and has been considered to be an ancient, deep-time analogue for present and future climate change (Zeebe et al., 2016). This study presents new sedimentological, biostratigraphic, and carbon isotopic data from Yadong area in southern Tibet to evaluate the impact of the PETM on carbonate platform. The PETM beginning at the boundary between nodular and thin-bedded limestones is maintained up to the top of the thin-bedded limestone and calcareous marl interval, and is followed by recovery at the base of thick-bedded limestone interval. Microfacies analysis testifies to a regression at PETM onset from open to restricted shallow marine environments, and shallowing continued through the PETM core. Restricted lagoonal deposition was renewed during PETM recovery. These environmental changes were associated with two major turnovers of shallow-water biota, we infer that sudden biotic change at PETM onset may have been caused by the increased nutrient input related to intensified continental weathering and hydrological cycle. The smaller magnitude of the CIE observed in proximal, shallower-water strata than in distal, deeper-water strata is ascribed to enhanced primary productivity.

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Paleosedimentary environment of upper Permian Linxi Formation in Zhalute Basin, Northeast China

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Keywords: Paleosedimentary environment, the upper Permian Linxi Formation,Zhalute Basin

Zhalute Basin is located in the eastern ridge uplift zone of the Daxinganling Mountains and western subsidence zone of the Songliao Basin. The area mainly expose upper Permian Linxi Formation and late Jurassic volcanic rocks. Trace elements of dark fine clastic rocks of upper Permian Linxi Formation in Zhalute area are systematically analyzed to discuss the paleoclimate, paleosalinity and paleoredox condition. Samples are taken from Taohaiyingzi outcrop section and LD2 well in Zhalute Basin.

The ratio of Sr/Cu of the mudstone of Linxi Formation in the Taohayingzi outcrop section in Zalut Basin is 2.00~3.28 (n=12), and average value is 2.41; the ratio of Sr/Cu of the mudstone of Linxi Formation in LD2 well is 3.83~27.27 (n=12) with an average value of 10.9, and seven samples values are < 10. The results indicate that the sedimentary period of Linxi Formation in Zhalute area should be warm and humid climate(Deng et al. 1993).

The B/Ga ratio of samples from Linxi Formation in Taohayingzi outcrop section is 1.74~3.62, with an average value of 2.68, indicating freshwater environment (Wang et al. 1979); the B/Ga ratio of the samples from Linxi Formation of LD2 well is 3.31~11.74, with an average value of 6.14, indicating brackish water to saltwater environment with a tendency of dilution from bottom to top. It overall reflects the water environment of Linxi Formation is freshwater environment to brackish water and saltwater environment.

The ratio of V/(V+Ni) of mudstone samples of Linxi Formation in the Taohayingzi outcrop section in Zhalute Basin is 0.75~0.88 (n=12), with an average value of 0.79; The V/(V+Ni) ratio of mudstone samples of Linxi Formation of LD2 well is 0.67~0.81 (n=12), with an average value of 0.74. It overall reflects the water environment of Linxi Formation is anoxic and reductive environment (Jones et al. 1994).

To sum up, the analysis show that the sedimentary period of the upper Permian Linxi Formation in Zhalute Basin is warm and humid climate condition, the water environment is freshwater to brackish and saltwater, with anoxic and reductive environment.

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Incision History of the Three Gorges, Yangtze River Constrained From Low-Temperature Thermochronology in the bedrock of Huangling Massif

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Keywords: The Three Gorges, Yangtze River, detrital apatite, detrital zircon, AFT, AHe ZHe

Abstract: The evolution of the Yangtze River has a great significance for understanding the development of reorganization of the river networks and modern geomorphological patterns in east Asia. The Three Gorges as the key link between the upper and middle Yangtze River, and the incision history of the Three Gorges is an important part of the development of the river. Low-temperature thermochronology, such as apatite and zircon fission-track and (U-Th)/He, is one of the most important tools for uncovering the burial and erosional histories of sedimentary basins due to its relatively low closure temperatures of ~ 60 - 250°CIn this study, we use the fission track and (U-Th)/He thermochronology of apatite and zircon to calculate the exhumation rate, analyze the development of uplift in the bedrock of Huangling Massif. Based on the results of exhumation rate and cooling history, we can provide new evidence for the incision of the Three Gorges.

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The spatial distribution of surface ocean primary productivity in the wake of Marinoan global glaciation

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Keywords: Nantuo Formation, Microbial sulfate reduction, Microbial iron reduction, Pyrite, Iron isotope, Sulfur isotope

Termination of the Marinoan global glaciation (~650 – 635 Ma) was followed by the diversification of eukaryotes (e.g., early animals) and oxygenation of deep oceans in the early Ediacaran Period. Previous studies suggest recovery of marine primary productivity immediately before cap carbonate precipitation but after melting of the Marinoan global glaciation. Pyrite concretions from the topmost Nantuo Formation in the Yangtze Block, South China, decrease in abundance from shelf to basin facies, while their high positive S isotope values argued the development of oceanic euxinia, which required ample supply of organic matter, presumably reflecting the recovery of marine productivity. However, pyrite contents and pyrite S isotopes alone cannot uniquely constrain the extent and spatial distribution of the surface ocean organic matter production. In this study, we conducted in situ pyrite Fe (δ56Fepy) and S isotopes (δ34Spy) of pyrite concretions collected from four sections of the Nantuo Formation, spanning from shelf to basin environments. Pyrite from different sections has distinct δ34Spy and δ56Fepy values. In general, δ34Spy values display an increasing trend from shelf to basins, whereas δ56Fepy values demonstrate an opposite trend with the lowest values in the basin sections. The opposite δ34Spy and δ56Fepy onshore-offshore gradients strongly argue against hydrothermal origin, yet verify the diagenetic precipitation of Nantuo pyrite in sediment porewater. Numerical models were developed to quantify the microbial sulfate reduction (MSR), microbial iron reduction (MIR) and pyrite precipitation processes. The modeling results provide an explanation for the shallow-deep decreasing of δ56Fepy values, indicating that both the fraction of MIR (fMIR) and the fraction of Fe2+ consumed by pyritization (fpy) increase from shelf to basin sections. In addition, high δ34Spy values and pyrite contents in the basin sections also imply more intense MSR and higher supplies of H2S from sulfidic seawater. Both MSR and MIR are associated with organic matter degradation, thus suggesting that the surface ocean primary productivity displayed an unusual increasing trend toward the open ocean, which was different from the higher productivity in modern near-shore regions. We speculate that the reversed onshore-offshore gradient of surface ocean productivity might be attributed to high P concentration in the post-glacial ocean. Terrestrial riverine P supply, on the contrary, might have diluted seawater P concentration in the near-shore regions. Therefore, our result indicates that the recovery of marine productivity in the aftermath of the Marinoan global glaciation may be not controlled by the availability of nutrients, instead, the immediate recovery of productivity might have been prohibited by, e.g., low seawater pH at a high atmospheric pCO2 level in the initial melting of the Marinoan global glaciation.

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Aqueous Medium Characteristics and Evolution of the Third Member of Shahejie Formation in Dongying Sag

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Keywords: Dongying Sag,Aqueous Medium Characteristics,Element Geochemistry, Sedimentary Environment Analysis

With the development of sedimentary geochemistry, the migration, accumulation and distribution of sediment elements and isotopes are important means to restore sedimentary environment. Element adsorption and exchange often occur between sedimentary rock and its surrounding water medium, so aqueous medium analysis can be used for paleo-environmental restoration. Through the element test of 8,721 samples from the third member of Shahejie formation in Dongying sag, the quantitative and semi-quantitative research on the paleo-sedimentary environment of the study area is carried out by core observation and geochemical data analysis. The single well aqueous medium database is established through key coring wells, which is used to analyze the relationship between the original geochemical parameters and the characteristics of aqueous medium. The method of sedimentary aqueous medium suitable for the study area is optimized. The element ratio method and element fitting method are applied to quantitatively analyze the characteristics and evolution of aqueous medium. The research shows that in the vertical direction, the element characteristics of the third member of the vertical from the bottom to the top are different. The gradually decreasing data include Ca, Mn, Sr/Ba, Ca/Mg, K/Na, V/Ni, Ni/Co, V/Cr, and etc; while the increasing one include Mg, Fe, Rb/K, Fe/Mn, and etc. It indicates a decrease in salinity and pH but an increase in Eh from bottom to top in the study area. In other words, the water body is desalinated, the alkalinity is weakened and the oxidation is enhanced. On the plane, the salinity presents the pattern of two low areas and one high area. The pH value presents two high value areas in the central strip and two low value areas on both sides. EH is distributed in a circular band, and the high value area is distributed at the edge of the depression. The central part of the depression has relatively large salinity, high pH and low eh, which indicates that the central area is in a saline, alkaline and strong reducing environment. The water medium environment with high salinity and strong reducibility is conducive to the preservation of organic matter. Most of the environment forms organic rich lithofacies and becomes a sweets spot. This study provides a method to quantitatively analyze the characteristics of aqueous medium through geochemical elements.

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Geological characteristics and significance of source rocks of Mesoproterozoic Changchengian System in north of Guyang County of the northern margin of Ordos Basin

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Keywords: North of Guyang County, Mesoproterozoic, Source rocks, Geological characteristics, Geochemistry

The development of effective source rocks is the key to Mesoproterozoic hydrocarbon accumulation in Ordos area. In this paper, the geological characteristics of source rocks in the Agulugou Formation of the Zhaertaishan Group of Mesoproterozoic Changchengian System in north of Guyang County were studied by means of field geological investigation, microscopic section identification and geochemical analysis. Researches show that the source rock is carbonaceous slate and a small amount of schist with quartz as the main mineral composition, followed by plagioclase, potassium feldspar and muscovite, and a small amount of siderite. The contents of organic carbon in the source rocks are high, and the value ranges from 0.17% to 21.62%, with an average of 5.53%. The type of organic matter is I kerogenand the second is II kerogen. The value of Ro ranges from 4.32 to 5.09, and the Tmax value is from 556℃ to 564℃. These results show that the thermal evolution of source rocks is highand is in the over-mature stage. Their NASC normalized REE patterns of the source rocks are characterized by LREE enrichment with obvious different value between LREE and HREE with distinctive negative Eu anomalies (δEu: 0.430.49). The content and ratio of trace elements indicate that the sedimentary environment of the source rocks of Agulugou Formation is an oxygen-deficient - anoxic closed environment with large water depth, weak hydrodynamic conditions and limited communication with the open sea and the sedimentary facies are desalinated lagoon facies in warm and humid climate.

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Geochemical characteristics and geological significance of major elements in the lower paleoweathering crust of Benxi Formation, Ordos Basin

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Keywords: Ordos Basin,Benxi Formation,weathering crust,major element,Paleoclimate feature

The geochemical composition of regolith can reflect its development processes and the background climatic characteristics of weathering processes, and geochemical compositions of the paleo-regolith formed in earth history can reveal the type of paleo-regolith and record paleoclimatic changes.Ordos Basin is a large petroliferous basin. After the Deposition of Ordovician, the basin was uplifted by caledonian movement, and the Silurian, Devonian and Lower Carboniferous deposits were missing. Moreover, the top of Ordovician experienced weathering leaching for 150 million years, forming a weathering crust karst zone with thickness of more than 50 meters. The development process of the weathering crust may record the paleoclimate characteristics from the late Ordovician to carboniferous of the Early Paleozoic. According to the compositions of major elements, enrichment in elemental migrations and coefficient of weathering distribution of the lower part of the Carboniferous Benxi Formation in the Ordos Basin, North China, this study suggests that: (1) The weathering crust belongs to aluminiferous bauxite type weathering crust. It is a type of rock rich in aluminum minerals and characterized by chemical deposition and mechanical deposition. The structure is coarse sugar, bean, clastic and oolitic and the main mineral composition of the rock is boehmite, boehmite and boehmite. The major element compositions of the weathering crust are dominated by the elements of SiO_2, Al_2O_3, TFe_2O_3, $CaOAl_2O_3$:$SiO_2$1.And the elements of Al_2O_3, TFe_2O_3, TiO_2, K_2O are relatively concentrated in the middle-toupper parts of the regolith while the SiO2 is slightly lost. (2) The vertical variations of geochemical proxies such as SiO_2/Al_2O_3, $SiO_2/(Al_2O_3+TFe_2O_3)$, chemical index of alteration (CIA) , residual coefficient and BA value indicate that the paleo-weathering crust formed in alkaline reduction "diving type" environment, controlled by the karst micro-topography, and the vertical upper sequence variation of aluminiferous rocks is complex . (3)The material source of the weathering crust is not only from the denuded strata above the ancient weathering crust, but also from the denuded ancient land around the basin. Comprehensive study area constant element geochemical characteristics of the ancient weathering crust, and combining to the late Carboniferous to the Permian ancient North China plate latitude migration characteristics, this paper holds that the weathering crust formed in warm humid subtropical to tropical climate and it's a silicon - aluminum clay weathering crust with low degree of desilication and aluminization. At the same time, this burial weathering crust structure plays an important role in the process of hydrocarbon accumulation, which is not only a good channel for oil and gas migration, but also an effective reservoir. Together with the overlying strata, the weathered clay layer forms a composite cap.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-7: Tracing past climate and environmental change using novel isotopic approaches
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Mercury evidence for two pulses of volcanism during the Late Ordovician–early Silurian

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Keywords: volcanism,mass extincition, environmental change, mercury isotope

Intense volcanism is proposed as a driver for the mass extinction and environmental changes during the Ordovician-Silurian (O-S) transition (Lefebvre et al., 2010; Yang et al., 2019; Rasmussen et al., 2019), but evidence of a direct link was largely lacking. Mercury (Hg) enrichments in the O-S sediments have been used as a volcanic proxy to link the timing of volcanism with the record of environmental change and extinction (Gong et al., 2017; Jones et al., 2017; Bond et al., 2020; Hu et al., 2021), but it remains unclear whether these elevated Hg resulted from volcanic emission. Here we present mercury (Hg) concentrations and Hg isotope data for Upper Ordovician−Lower Silurian sedimentary strata in South China. Our new Hg data reveal two intervals of high Hg concentration coupled with generally near-zero or weak positive Δ^{199}Hg values and less negative δ^{202}Hg values, consistent with volcanic Hg source (Thibodeau and Bergquist, 2017). Both increased mercury intervals correlate with negative carbon and sulfur isotope excursions, and anoxia, supporting a link between them. The two observed episode of volcanism also correlate with the two Late Ordovician mass extinction pulses, suggesting that volcanism may have driven the end-Ordovician mass extinction. In addition, our Hg record suggests that previously unconstrained volcanism and associated environmental changes may also have played a major role in the delayed recovery in the aftermath of the Ordovician-Silurian mass extinction.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-7: Tracing past climate and environmental change using novel isotopic approaches
Presentation Preference: Oral Preferred

Study on sedimentary facies characteristics and sedimentary environment change of modern sedimentary body in Xi'an section of Fenghe River

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Keywords: Based on the field survey, sample collection and analysis and google satellite image of modern river system in Xi'an section of Fenghe River, the river sedimentary system and geochemical element conte

Based on the field survey, sample collection and analysis and google satellite image of modern river system in Xi'an section of Fenghe River, the river sedimentary system and geochemical element content in Xi'an section of Fenghe River are analyzed, and the rock type, sedimentary facies type, sedimentary model and climate change of Fenghe river sedimentary body in this area are comprehensively studied. The results show that the lithology of the modern sedimentary body of Xi'an Fenghe river is mainly earthy yellow mudstone, gray white sandstone, argillaceous siltstone and a small amount of light gray fine conglomerate. It is a meandering river sedimentary system composed of three cycles. In this study, three subfacies were identified in the sedimentary body of Xi'an section of modern Fenghe River, namely channel filling subfacies, channel edge subfacies and flood basin subfacies; Four microfacies, i.e. riverbed retention sedimentation, point bar, estuarine fan and flood plain, develop three sets of different sedimentary sequences vertically: the lower sequence has anti rhythmic characteristics, and the middle and upper parts show obvious positive rhythmic sedimentation, indicating the process of hydrodynamic first increasing and then gradually weakening. By analyzing the changes of trace elements such as CO, Cr, Cu, Ni, Rb, Sr, V, Zn and Zr in sediments, as well as Sr / Cu, V / (V + Ni), V / Cr, Ni / Co and Sr / Ba, it is determined that the main environment during the deposition period is arid climate, accompanied by seasonal rainfall, and the water body is a brackish water environment with weak oxidation oxidation oxidation.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-7: Tracing past climate and environmental change using novel isotopic approaches
Presentation Preference: Oral Preferred

Differential paleogeomorphic changes in North China during the late Mesozoic: evidence from stable isotopes and clumped isotopes

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Keywords: late Mesozoic, North China, topographic steps, paleoelevation, clumped isotopes

At present, the topography of China is characterized by prominent contrasts (i.e., topographic steps) in the east-west direction, which is particularly pronounced in North China (NC). Western NC is dominated by plateaus and high mountains with elevations generally >1000 m, while eastern NC is dominated by plains and low mountains with elevations generally <500 m. The topographic contrasts shape the modern climate and vegetation regionalization to some extent and also may have affected the paleoclimate and ecosystem in deep time. However, the timing of when the topographic steps in NC were established are unclear. Evaluating the surface topographic evolution of NC could provide a clue to this issue and promote the interpretation of the paleoclimate in Eastern China. In this study, we constrain the paleoelevation evolution of both western and eastern NC (i.e., Ordos Basin and Hefei Basin, respectively) during the late Mesozoic by applying clumped isotopes (Δ_{47}) and stable isotopes ($\delta^{18}O$ and $\delta^{13}C$) to paleosol carbonates. Our results suggest that the Ordos Basin maintained high paleoelevation (>1.5 km) throughout the late Mesozoic, while the Hefei Basin experienced significant paleoelevation reduction during the Early Cretaceous. Combined with paleogeographic, geophysical, and paleoecological evidence, these findings suggest that the differential paleogeomorphic changes may have formed the initial appearance of the present NC topographic steps no later than Aptian time. This topographic change may have affected the paleoclimate patterns of NC, or even the whole of Eastern China, and caused a climatic transition from dry to humid during this period.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-7: Tracing past climate and environmental change using novel isotopic approaches
Presentation Preference: Oral Preferred

Characterizing the occurrences of Phanerozoic marine oncoids and their secular response to paleoceanography and volcanism

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Keywords: Phanerozoic oncoids, occurrence, formation process, paleo-seawater properties, volcanism

Throughout the Phanerozoic, marine oncoids, as microbially mediated carbonate coated grains, have been widely recorded in a variety of marine depositional environments. The marine oncoids are commonly thought as excellent indicators of paleoenvironmental and climatic conditions, and depositional settings. However, ambiguities still remain for the oncoids in terms of origins, formation processes and environmental meanings. To reach a better understanding of marine oncoids and their response to paleoenvironmental changes, we compiled Phanerozoic secular variation of the occurrence (abundance, size and morphology distribution) of marine oncoids, paleo-seawater properties ($\delta^{34}S$, $\delta^{13}C$, $^{87}Sr/^{86}Sr$, Mg/Ca. sea level,….) and volcanic activities, based on mass data from published literature. The initial results reveal a relationship between positive $\delta^{13}C_{carb}$ excursion and abundant occurrence of carbonate oncoids in the marine settings. Interestingly, associated and coeval with the positive $\delta^{13}C_{carb}$ excursion and abundant occurrence of onciods in marine settings, the $^{87}Sr/^{86}Sr$ and $\delta^{34}S$ can be increased or decreased. To interpretate the coupled features of $\delta^{13}C_{carb}$, $^{87}Sr/^{86}Sr$, $\delta^{34}S$ and oncoid abundance, we proposed two potential models related to continental weathering and volcanisms for the oncoid formation. In the first model featured by positive $\delta^{13}C_{carb}$, and increasing $^{87}Sr/^{86}Sr$ and $\delta^{34}S$, the oncoid formation may be related to enhanced continental weathering; while in the second model featured by positive $\delta^{13}C_{carb}$, and decreasing $^{87}Sr/^{86}Sr$ and $\delta^{34}S$, the oncoid formation may be related to volcanic activities. In the future work, more data (abundance, size and morphology) will be added to support the proposed models. We will also verify the models based on abundant occurrence of marine oncoids in the Cambrian and early Permian Period with different paleo-seawater properties.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-7: Tracing past climate and environmental change using novel isotopic approaches
Presentation Preference: Oral Preferred

ISOTOPE AND TRACE ELEMENT SIGNATURES OF PALEOENVIRONMENT OF GRYPHEA SHELL BANKS IN THE KALLANKURICHCHI LIMESTONE, ARIYALUR GROUP, CAUVERY BASIN, INDIA

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Keywords: Paleogeographic reconstructions, Kallankurichchi Limestone, Shell bank, O-isotope, Trace elements

To supplement the recent paleoenvironmental reconstruction of the Maastrichtian Kallankurichchi Limestone (KL) on the basis of field and petrographic data (Srimani et al., 2021), this paper adopts carbon and oxygen isotope geochemistry of successive growth laminae of LMg calcitic Gryphea species Pycnodonte. Thickness variation in the same lamina-successions is also taken into account. Sessile though the organisms were, their shells being highly convoluted were prone to postmortem rolling downslope. For that reason, the shells were collected only from shell banks cemented with micritic matrix to ensure that they surrogate for their endemic paleoenvironment. Samples were collected from shell banks at three different stratigraphic levels, two in the lower TST part and the other from the base of the upper HST part of the KL. The mid-level shell bank was sampled from two different localities, about 500m apart, to get an idea about lateral variation in paleoenvironment. δ13C strongly covaries with δ18O in all but one of the mid-level samples, ensuring unaltered δ18O isotopic signature from all the three shell banks. δ13C is most negative (up to -2.25PDB) in the oldest bank. This is well expected with highest influx of lighter C isotope at the base of the retrogradational part of the sequence. The pattern of age-related variation does not, however, match with lamina-thickness variation. This factor indicates that bioproductivity rate could not overcome the control of the then sea water isotopic composition. So, the observed C12 enrichment was possibly affected by the high rate of freshwater influx as indicated in already documented high content of detrital quartz in associated sediment. The shell bank paleotemperature, as calculated from the δ18O values (Median), was around 27.04^{o}C. In the mid-level the δ13C values tend to be more enriched in the heavier C isotope suggesting deepening and away from the carbonate basin margin. Concurrently the degree of dilution by detrital quartz dropped. As anticipated the temperature calculated from the shells is, on average, the lowest at the mid-level, around 23.5^{o}C (Md) on sea-bottom. At the topmost level, at the base of the HST, δ13C values again turns dominantly negative. Here too lamina-thickness variation in the targeted shell does not match, but detrital quartz content variation trend shows a strong spike. Hence the influence of fresh water influx on δ13C content seems overwhelming. Concurrently the shell bank paleotemperature increased considerably to about 24.53^{o}C (Md) because of shallowing. Depth-control on seafloor paleotemperature is thus apparent. Paleosalinity of sea water derived from the micritic matrix between the shells in the banks is generally considerably high, B/Ga and Sr/Ba ranging from 20.60-49.00 and 0.7-1.9 respectively. This high salinity of sea water, however, does not seem to correlate with the δ18O values of the shells.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-7: Tracing past climate and environmental change using novel isotopic approaches
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Large volcanism during the Cryogenian interglaciation: Evidence for Hg and Hg isotopic from Datangpo formation black shales

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Keywords: mercury, mercury isotope, Hg/TOC ratio, volcanism, Cryogenian interglaciation

Mercury to total organic carbon (Hg/TOC) ratios are a newly developed proxy of large volcanism in geological history. Here, we investigate Hg concentrations and isotopic composition of Cryogenian interglacial sediments in a drill core (ZK4411) collected from the Nanhua Rift Basin, South China, to understand whether large volcanism was a major driving force of the Cryogenian interglaciation. The anomalous high Hg/TOC ratios in the Datangpo black shales confirm the presence of large volcanism at the onset of the Cryogenian interglaciation. The near-zero to slightly positive Δ^{199}Hg values (0.04‰ ± 0.06‰, 1SD, n=21) in the Datangpo black shales support the deposition of volcanic Hg via wet Hg(II) deposition. Given large volcanism can emit large amounts of green house gases (e.g., CO_2) to trigger global warming and deglaciation, this study may provide a causal link between large volcanism and the termination of the Sturtian glaciation.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-7: Tracing past climate and environmental change using novel isotopic approaches
Presentation Preference: Oral Preferred

Zinc isotopes as a tracer for carbon cycle perturbations during onset of Carboniferous icehouse

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Keywords: TICE, Zn isotope, paleoenvironment

The earliest Carboniferous cooling is thought to mark the onset of the Late Paleozoic Ice Age (Liu et al., 2019), which is consistent with one of the most significant variations of global carbon isotope (δ13C) record during Phanerozoic (named as 'mid-Tournaisian carbon isotope excursion', TICE, Mii et al., 1999; Saltzman et al., 2002; Yao et al., 2015; Maharjan et al., 2018a,b). Increased organic carbon burial was thought to be the cause of the δ13C positive excursion (Saltzman et al., 2000) and led to the CO2 decline. However, the possible mechanism remains controversial, including the rapid subsidence and sedimentation rate related to the Antler foreland basin (Saltzman et al., 2000), intensified ocean circulation and upwelling caused by cooling (Yao et al., 2015; Liu et al., 2019), expanded ocean anoxia (Cheng et al., 2020), and silicate weathering which was enhanced by the seed plants (Chen et al., 2021). Additionally, it is unclear whether TICE was caused by single or several triggers and the links between them.

Zn is a key trace element for lives, and the Zn-C cycle can well reflect marine primary productivity and organic carbon burial. Primary producers prefer to utilize 64Zn, and thus would result in higher zinc isotope composition (δ66Zn) (Maréchal et al., 2000; Little et al., 2014). In contrast, lower δ66Zn values correspond to a relative increase in the 64Zn-enriched input from riverine/volcanic sources or previously buried organic-rich sediments or shrink of 64Zn removal (Liu et al., 2017; Sweere et al., 2018; Chen et al., 2020). Carbonate δ66Zn has been widely used to reconstruct paleoenvironmental changes such as magmatism, silicate weathering, and burial and oxygenation of organic matter (Liu et al., 2017; Sweere et al., 2018; Chen et al., 2020; Lv et al., 2022). Here, we present the first carbonate δ66Zn record, in combination with other geochemical data (e.g., organic δ13C, δ238U, and major and trace elements), from a well-preserved, shallow-marine carbonate succession (the Malanbian section) from the northeastern Paleo-Tethys Ocean region. The Malanbian section of the South China Block was the target of previous high-resolution carbonate δ13C studies, showing a ~6‰ positive excursion in the mid-Tournaisian (Yao et al., 2015; Chen et al., 2020). We delineate the architecture (single or double peaks) and potential process of TICE during this critical climate transition through integrated geochemical proxies and careful biostratigraphic correlation.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-7: Tracing past climate and environmental change using novel isotopic approaches
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Evidence of a Post-Shuram Recovery in Saudi Arabia? Insights from High-Resolution Geochemical Records

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Keywords: Ediacaran, Shuram, Gaskiers, Multiproxy, Isotopes

The Ediacaran Period records the rise of diverse metazoan assemblages coupled with profound environmental and geochemical events preceding the Cambrian Explosion. Despite numerous studies, the origin of these events, particularly the largest negative carbon isotopic excursion, also known as the “Shuram Carbon isotope excursion” remains enigmatic. In Saudi Arabia, Ediacaran carbonates are preserved in small, isolated half-grabens associated with the Ediacaran to early Cambrian Najd strike-slip fault system. However, these carbonates are relatively understudied compared to the prolific oil-bearing Phanerozoic carbonate successions in Saudi Arabia and other Ediacaran strata worldwide. Here, we examined a well-exposed up to 300 m thick Ediacaran carbonate exposure of Dhaiqa Formation in NW Saudi Arabia and conducted a high-resolution, geochemical study (δ13C and δ18O isotopes, mineralogical, elemental and TOC measurements) to decipher the occurrence, origin, and preservation of these events in Saudi Arabia and establish the possibility of correlating these events regionally and globally. Based on detrital zircon U/Pb geochronological data from interbedded diamictite strata (~570 Ma), the studied Ediacaran successions are thought to be deposited just after the Shuram-Wonoka negative δ13C anomaly event, following the Gaskiers glaciation. Overall, our results show a clear trend of recovery from the negative δ13C excursion, which has been reported in other basins across the Arabian Plate and other regions of the world. This finding highlights the possible preservation of post-Shuram recovery in Saudi Arabia and argues the origin of the Shuram excursion as a result of the Gaskiers glaciation. The correlation of these results with comparable data from different Ediacaran strata across Arabia and worldwide is promising in the sense of worldwide connectivity to the Ediacaran seas.

Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-7: Tracing past climate and environmental change using novel isotopic approaches
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Structural diagenesis of Cenozoic post-rift carbonates: Insights from a multi-proxy study in the Eastern Red Sea

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Keywords: stable isotopes, structural diagenesis, calcite vein

The Miocene post-rift sediments represent one of the thickest Red Sea Rift Basin deposits. Miocene sediments, historically grouped into the Raghama Formation, are exposed in the Umm Luj Basin, located in the northern part of the eastern coast of the Red Sea. The carbonates of the Raghama Formation were observed, in places, unconformably overly the Proterozoic basement and intensely fractured. Such fractures could provide insights into the structural evolution and paleo fluid flow of the Red Sea Rift Basin. However, little is known about the origin and timing of different structural-controlled diagenetic processes. This study focused on structural diagenesis of these post-rift carbonates by applying a multi-proxy geochemical analysis on calcite precipitated in veins and fault breccia and on the dolomitized host rock. The $\delta^{18}O$ and $\delta^{13}C$ isotopic compositions of calcite veins vary between -10.6 to -9.5‰ and -7.9 to -7.2‰, respectively. On the other hand, the precipitated calcite along the fault breccia indicates a heavier average isotopic composition of -6.8‰ for $\delta^{18}O$ and -4.8‰ for $\delta^{13}C$. Thus, we argue that the structural diagenesis history in the study area comprises two very distinct fluid circulation members. The first member is the deposition of lighter isotopic composition calcites, indicating vein precipitated at higher temperatures due to increasing depth or associated with hydrothermal fluids and followed by closed-system recrystallization, indicated by the high-magnesium vein that the dolomitized host rock may be buffered. The second member of a fluid flow corresponds to the heavier isotopic calcite member representing a brecciation on the near-surface regime. Our results bring a new understanding of paleo fluid circulation and also highlight the potential of the carbon and oxygen isotope proxy for structural diagenesis studies.

Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-7: Tracing past climate and environmental change using novel isotopic approaches
Presentation Preference: Oral Preferred

Pb-Pb dating and Sr-C isotope stratigraphy of the Proterozoic Kaladgi Basin, India

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Keywords: Chemostratigraphy, Geochronology, Ediacaran, Mesoproterozoic, India

The Kaladgi Basin is one of the several Proterozoic sedimentary basins of India. Located close to the current western margin of peninsular India, the basin has a binary evolutionary history with an angular unconformity separating the older deformed and younger undeformed rock sequences of the Kaladgi Supergroup, named the Bagalkot and Badami Groups respectively. Whereas the timing of deposition of the Bagalkot sediments is somewhat well constrained (>1150 Ma), that of the Badami sediments and hence, the age of closure of the basin remains tentative. Considering that the supergroup contains four marine carbonate formations which may have recorded some of the important global events of the Proterozoic, we carried out ^{206}Pb-^{207}Pb dating of the topmost carbonate horizon (Konkankoppa Limestone), and C-O-Sr isotope systematics in all the carbonate formations. The dating yielded a depositional age of 604 ± 25 (2σ) Ma for the Konkankoppa Limestone, thus pushing timing of active sedimentation in the basin well into the Ediacaran Period. The near primary $^{87}Sr/^{86}Sr$ of 0.70781 (Mn/Sr = 1.7) of the limestone is consistent with this age. These data also confirm the existence of a long duration hiatus, > 500 Ma, between the deposition of the Bagalkot and the Badami Groups. The extended sedimentation history of the Kaladgi Basin refutes a claim that the sedimentation in all the Proterozoic basins of peninsular India ended by 1000 Ma.

The $\delta^{13}C$ of all the carbonate formations appears to have preserved the primary marine signature as inferred from Mn/Sr <10, $\delta^{18}O$ > -10‰, and the absence of any relationship between $\delta^{13}C$ and $\delta^{18}O$. Limited (0 ± 2 ‰) variation of $\delta^{13}C$ of the Bagalkot carbonate horizons, suggests a steady state organic carbon burial, whereas, wide variation of $\delta^{13}C$ in the Konkankoppa Limestone, -3.5 to +2 ‰, hints at a dynamic organic carbon burial scenario; both being consistent with the C-isotope stratigraphy of the Meso-Neoproterozoic times.

Session T10-8: Towards unravelling the 'Dolomite Problem': Multi-tracer geochemical approaches and novel perspectives

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-8: Towards unravelling the 'Dolomite Problem': Multi-tracer geochemical approaches and novel perspectives
Presentation Preference: Oral Preferred

Restoration of dolomite reservoirs process based on laser U-Pb dating technology: A case study of Ordovician Majiagou Formation, Ordos Basin

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Keywords: U-Pb dating,Ordos Basin,Ordovician,dolomitization

Aiming at the problem of multiple solutions in the diagenetic pore evolution process of dolomite reservoir. Taking the Ordovician Majiagou Formation in Ordos Basin as an example, this paper studies the formation process of weathering crust karst type and mound-shoal type dolomite reservoirs of Majiagou formation by using laser ablated U-Pb in-situ dating technology and combined with carbon and oxygen isotope composition analysis and test data. The results are as follows: First, five groups of 14 age data were obtained from the dating test of 8 reservoir samples. The age of the first group of surrounding rock matrix dolomite is 444.0 ~ 494.0 Ma; The age of canine dental or leaffillings in the second group was 440.0 ~ 467.0 ma; The age of the third group of dolomite silt filler is 316.5 ~ 381.0 Ma; The age of the fourth group of grain dolomite fillings is 354.0 Ma; The age of the fifth group of grain calcite fillings is 292.7 ~ 319.0 ma; Second, the formation of matrix dolomite of Majiagou Formation is related to sedimentary or penecontemporaneous dolomitization, while the dolomitization of the cements is a little later, which is the origin of infiltration reflux-early burial dolomitization; Third, the weathered crust karst dolomite reservoir on salt has successively experienced diagenesis such as penecontemporaneous dolomitization, compaction, weathered crust karst, filling and fracture. The gypsum mold hole forms the supergene karst stage, which is filled with minerals such as seepage dolomite silt and calcite, and the porosity is reduced from 10-40% to 3-8%; Fourth, the subsalt dune beach dolomite reservoir has undergone diagenesis such as penecontemporaneous dolomitization, compaction, seabed cementation, penecontemporaneous dissolution, seepage and reflux dolomitization, filling and fracture. The primary porosity of the reservoir is 10 ~ 30%, which is reduced to 0 ~ 6% after seawater cementation. The porosity is restored to 5-15% by penecontemporaneous dissolution, and then filled with grain dolomite and calcite, The porosity finally decreases to 2 ~ 6%. The dolomitization and pore evolution restoration methods can be used as a reference for pore evolution restoration of other basins or reservoirs.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-8: Towards unravelling the 'Dolomite Problem': Multi-tracer geochemical approaches and novel perspectives
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Assessing the impact of multiple fault zone overprint on Devonian carbonates (Rhenish Massif, Germany)

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Keywords: Dolomitization, Diagenesis, Petrography, U-Pb dating, Geochemistry, Clumped Isotopes

Dolomitic rock (dolostone) is a major topic in carbonate research and a complex archive of its palaeoenvironment and diagenetic pathways. Combining field and laboratory techniques (transmitted light- and cathodoluminescence microscopy, U-Pb dating, MicroXRF mapping, fluid inclusion analyses and clumped isotope thermometry, $^{87}Sr/^{86}Sr$, $\delta^{13}C$, $\delta^{18}O$), we assess the complex diagenetic succession and subsequent tectonic, hydrothermal and meteoric overprint of Paleozoic carbonates of the Middle-Late Devonian Massenkalk in Western Germany. The well-known geological and tectonic framework of the Massenkalk allows for an in-depth study of different alteration types in directly comparable lithologies. The aim is to better understand the impact of tectonic, hydrothermal and meteoric alteration events (Variscan and Post-Variscan) on multiple generations of hydrothermal dolostones and their precursors. Cathodoluminescence microscopy documents a complex paragenetic sequence ranging from marine calcite cements to multiple hydrothermal dolomites and meteoric/vadose calcites in partly dedolomitized carbonates. Fluid inclusion and clumped isotope analyses reveal temperatures between 20 and 230 °C representing individual events of fluid flow. Patterns in oxygen and carbon isotope data suggest a conservative behavior of precursor limestones and early hydrothermal dolomites during burial diagenesis. Later hydrothermal dolomites were altered by meteoric dedolomitization.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-8: Towards unravelling the 'Dolomite Problem': Multi-tracer geochemical approaches and novel perspectives
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

DOLOMITIZATION OF THE UPPER PERMIAN CHANGXING FORMATION IN YUANBA GAS FIELD, NE SICHUAN BASIN, CHINA

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Keywords: Geochemistry,Dolomitization,Reef-shoal Facies

The reef-shoal dolomite is the main reservoir of Upper Permian Changxing Formation in Yuanba gas field, NE Sichuan Province, Southern China. Dolomites vertically distribute in the upper member of Changxing Formation and laterally among reef cap, inter-reef shoal and back reef shoal facies. Different types of dolomites have similar ratios of 87Sr/86Sr(range from 0.7071 to 0.7075)which are consistent with those of dolomitic reef limestone, indicating dolomitizing fluids mainly came from synchronous seawater. Dolomitization occurred in a shallow burial low-temperature environment judged from the dolomitizing fluids temperature (40°-55°C) which is calculated from dolomite-water fractionation equation.

Even in an open-flow environment, different properties of dolomitizing fluids emerge because of the palaeogeomorphology and sea level fluctuation. (1)Relict bioclast medium-coarse crystalline reef cap dolomite has obviously negative δ18O, high Fe, Mn and slow crystal formation characteristics, suggesting the mixture of meteoric water and seawater involved in the reef cap dolomitization. (2)Microcrystal dolomite of inter-reef shoal has high δ18O, significantly high Fe, Mn, Sr and low order degree. It is closely related to the evaporated brines, though data may indicate a complex source of dolomitizing fluids. (3) Finely- medium crystalline dolomite of back reef (or shoal) owns a very low Fe, Mn value and high content of MgCO3, together with the rapid crystal formation, all of which demonstrate the normal water dolomitization features.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-8: Towards unravelling the 'Dolomite Problem': Multi-tracer geochemical approaches and novel perspectives
Presentation Preference: Oral Preferred

A clumped isotope diagenetic framework for the late Ediacaran dolomites

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Keywords: Δ47,Sulfur isotope,Magnesium isotope,Diagenetic systems,Bacterial sulfate reduction,Hydrothermal fluid

Early marine dolomites have been considered as potentially reliable archives for the reconstruction of past ocean physico-chemical conditions. However, this interpretation comes with significant challenges as not only can diagenetic alterations occur, but such dolomite frequently exhibits diverse fabrics with a consequent large geochemical variability. This study assesses whether the late Ediacaran dolomite (Hamajing Member, Dengying Formation) in South China can preserve geochemical representative of the original seawater in which they were formed. These dolomites contain five different fabrics (stromatolitic, micritic, oolitic, saddle dolomites and cements) and show a large variation in clumped isotopic values. Here, we aim to establish a diagenetic framework (closed versus open systems) for each dolomite fabric by combining clumped and oxygen isotopes. First, the influence of the solid-state reordering on such varied fabrics is evaluated by assuming two types of burial histories ("deeply buried" and "Hydrothermal pulse"). The results can not well account for the measured clumped isotopes in various fabrics. Therefore, the variability of clumped isotopes in the difference fabrics is mostly attributed to the alteration of diagenesis in the burial stage. In order to decipher the extent of diagenetic alteration, a quantitative framework has been established using variable water-rock ratios. Under such diagenetic framework, the micritic and stromatolitic dolomites show a closed-system behavior (low water-rock ratios = 0.06 – 0.3), while the fabrics of ooids, saddle dolomites and marine dolomite cements are buffered by hydrothermal fluids (high water-rock ratios = 1.4 – 5) during late diagenesis. This diagenetic framework highlights the extent of water-rock reactions plays a critical role in the fabric-specific variability of dolomite. This study indicates that the complex signals in early marine dolomite should be carefully evaluated when being considered as a palaeoproxy.

Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-8: Towards unravelling the 'Dolomite Problem': Multi-tracer geochemical approaches and novel perspectives
Presentation Preference: Oral Preferred

The in-situ U-Pb isotopic dating and clumped isotopeΔ47thermometry and their application in geological reconstruction for hydrocarbon accumulation history: A case study from Sinian Dengying FormationSichuan Basin

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Keywords: laser-ablation in-situ U-Pb isotopic dating, clumped isotope thermometry, carbonate crystal with hydrocarbon inclusions, Sichuan Basin, Sinian Dengying Formation

Traditional methods for reconstructing hydrocarbon accumulation history in ancient marine carbonate reservoirs, such as geological analysis, fluid inclusion study, and speculation based on formation time of hydrocarbon-bearing palaeo-uplifts and traps, generally have large uncertainties and may result in ambiguous results. To upgrade the toolkit for the reconstruction of hydrocarbon accumulation history, we develop a new method by investigating samples from the Sinian Dengying carbonate gas reservoir in the central paleo-uplift of the Sichuan Basin, southwestern China. The key innovation of this method is to constrain absolute ages of hydrocarbon accumulation with the application of the carbonate mineral in-situ U-Pb geochronology. This new dating technique involves two key steps: investigate abundance and distribution patterns of liquid and gaseous primary hydrocarbon inclusions with optical microscopes; choose carbonate crystals appropriate for U-Pb geochronology, which are inclusion-free but contemporaneous with those containing hydrocarbon inclusions. In this study, three stages of hydrocarbon accumulation were identified in the Dengying gas reservoir by U-Pb dating of dolomites: late Silurian. The first stage of oil accumulation occurred at (416±23) Ma; late Permian to early Triassic. The second stage of oil accumulation occurred between (248±27) Ma and (246.3±1.5) Ma; Yanshan–Himalayan period. The third stage of gas accumulation occurred between (115±69) Ma and (41±10) Ma. The hydrocarbon accumulation history of the Dengying gas reservoir reconstructed in this study is consistent with the tectonic-burial history, basin thermal history and hydrocarbon generation history, indicating that the new method is a reliable way for reconstructing the hydrocarbon accumulation history.

Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-8: Towards unravelling the 'Dolomite Problem': Multi-tracer geochemical approaches and novel perspectives
Presentation Preference: Oral Preferred

Formation Mechanism of the Terminal Ediacaran Dolomite Cements: Implications for reconstructing Neoproterozoic seawater chemistry

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Keywords: Ediacaran, Dengying Formation, Dolomite Cement, Magnesium Isotopes, Seawater chemistry

The Ediacaran marine dolomite cement has been considered as the premium material that records seawater chemistry. However, with various types and debatable origins, dolomite cement was underutilized for reconstructing seawater chemistry. There are two viewpoints regarding the origin of the Ediacaran marine dolomite cements, one is primary precipitation from seawater, which holds clues of ancient seawater geochemical signals, and another is mimetic dolomitization of early unstable carbonate minerals. Thus, it is still controversial whether marine dolomite cement can be used as an effective proxy for reconstructing the ancient seawater geochemical compositions. In order to explore the formation mechanism of different types of dolomite cements in the Dengying Formation as well as deciphering the unique seawater chemistry of the Precambrian ocean, we investigated the dolomite cements from the Ediacaran Dengying Formation from the Sichuan Basin. The Ediacaran dolomite cement can be divided into two types, i.e., later diagenetic crystalline dolomite (including bladed dolomite, silty-fine dolomite, medium-coarse dolomite) and fibrous marine dolomite (including fascicular fast dolomite, fascicular slow dolomite and radial slow dolomite). The length-slow cements are considered as primary dolomite based on optical characteristics, well-preserved chemical bands and cathodoluminescent bands, while length-fast dolomites are speculated to be formed by mimetic dolomitization. The δ^{26}Mg values of micritic-micro dolomite matrix and fascicular fast dolomite cement are similar (-1.9 ~ -2.0‰), inferring a same origination by mimetic dolomitization of high-Mg calcite or aragonite precursors. The δ^{26}Mg values of the fascicular slow dolomite (-1.8 ~ -1.9‰) and radial slow dolomite (-1.9 ~ -2.0‰) show a certain difference about 0.2‰, suggesting different Mg isotopic fractionation caused by the change of precipitation rate. The δ^{26}Mg values of later diagenetic crystalline dolomite vary greatly, with enriched Fe, Mn and Sr contents, indicating alterations of diagenetic fluids during burial stage. Thus, the primary length-slow dolomite, directly precipitated from the Ediacaran "Dolomite Sea", can be used as robust seawater chemistry archives.

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Session T10-8: Towards unravelling the 'Dolomite Problem': Multi-tracer geochemical approaches and novel perspectives
Presentation Preference: Oral Preferred

The response of Mg isotopes to dolomitization during sea-level fluctuations: Constraints on the hydrological condition of massive dolomitization system

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Keywords: Edwards group, Cretaceous seawater chemistry, Albian, dolomites, Texas

Marine dolomitization processes are characterized by complex variations in hydrological conditions and pore-fluid chemistry. Deposition of massive dolomitized carbonates on the Comanche Platform of south Texas, USA, during the Albian coincided with multiple fluctuations in sea level, thereby providing an ideal setting to study the response of magnesium isotopes to dolomitization during eustatic sea-level change. In this study, we conducted Mg, C, and O isotope analyses and complimentary mineralogical and petrographic investigations of dolomitized massive carbonates of the Albian Edwards Group in the Comanche Platform. Petrographic observations indicate that the carbonate rocks in the studied units were not altered by deep burial diagenesis or hydrothermal fluids. Based on our petrographic observations and the trace element and C-O isotope data, we infer the dolomites were formed via syn-depositional dolomitization during a period of low sea level. The δ26Mg values of the dolomites increase rapidly from −2.5‰ to −1.8‰ in the basal part of the unit, reflecting a change in fluid chemistry caused by dolomitization in a restricted marine environment. Subsequently, δ^{26}Mgdolomite values gradually decrease back to their initial value of approximately −2.5‰ due to seawater replenishment during transgression. The observed variability in dolomite δ^{26}Mg values reflects changes in the connectivity of the platform with the open ocean during marine transgressions. However, the δ^{26}Mgdolomite values do not vary with the high-frequency eustatic sea-level change recorded in the lithological variations, indicating uniform hydrologic conditions of the massive dolomitization system despite the hydrodynamic variations in the sedimentary environment. Therefore, we propose that massive dolomitization systems are mostly fluid-buffered and, as a result, Mg isotopes of dolomites can be used to trace changes in the paleo-marine environment, such as basin connectivity.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-8: Towards unravelling the 'Dolomite Problem': Multi-tracer geochemical approaches and novel perspectives
Presentation Preference: Oral Preferred

Constraining selective dolomitization by Mg isotopes: A study of mottled limestone in the middle Permian Qixia Formation, Sichuan Basin

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Keywords: Mg isotopes, fabric-selective dolomitization, Qixia Formation, penecontemporaneous exposure

Traditional geochemical methods play important roles in understanding the enigma of 'dolomite problem', however, cannot provide unique constraint on the dolomitization process and sources of Mg^{2+}. Recent years, Mg isotopes have opened a new window in unraveling the 'dolomite problem'. To further promoting the application of Mg isotopes in the study of dolomite genesis, we measured Mg isotopic composition of selective dolomitized limestone from the middle Permian Qixia Formation in Sichuan Basin. Based on petrographic observation, dolomite mottle and calcite matrix were micro-drilled respectively for geochemical analysis. The carbon and oxygen isotopic compositions of the dolomite mottles ($\delta^{13}C$ = -0.12 ~ 3.48‰ and $\delta^{18}O$ = -10.26 ~ -3.2‰) are similar to calcite matrix ($\delta^{13}C$ = -1.54 ~ 3.52‰ and $\delta^{18}O$ = -8.71 ~ -3.69‰) indicating that the fabric-selective dolomitization might be penecontemporaneous with limestone deposition. The Mn, Fe and Sr concentrations of dolomite mottles show that fabric-selective dolomitization occurred at a subaerial oxidic environment. The $\delta^{26}Mg$ variation pattern supports penecontemporaneous exposure and early diagenetic dolomitization process. At the relatively high sea-level, the lime wackestone to packstone deposited, and then the sea-level dropped, subaerial exposure leaded to the formation of karstified cavities, where selective dolomitization was constrained. The limestone precipitation - subaerial dissolution - dolomitization cycle occurs repeatedly with the fluctuations of sea-level and results in the selective dolomitization of the mottled limestone.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-8: Towards unravelling the 'Dolomite Problem': Multi-tracer geochemical approaches and novel perspectives
Presentation Preference: Oral Preferred

Origin of dolomite in the lower Triassic Feixianguan Formation, Northeastern Sichuan Basin: Evidence from magnesium isotopes

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Keywords: Dolomite problem, magnesium isotope, the Feixianguan Formation, Sichuan Basin

The origin of the dolomite from the lower Triassic Feixianguan Formation(FXG Fm.), Sichuan Basin remains controversial. Previous studies suggested the FXG dolomite was formed by multiple dolomitization processes, e.g., meteoric mixing zone dolomitization, seepage-reflux dolomitization and burial dolomitization. Here, We analysed the third member of the FXG Fm. at the Hekou section, NE Sichuan Basin, which is composed of oolitic dolomite, sandy dolomite and micrite dolomite. Based on detailed sedimentary facies analysis, we recognized three lithofacies and two sedimentary facies associations (ooid shoal and back-shoal lagoon), suggesting a shallow carbonate platform margin environment with periodic eustatic change. Meanwhile, multiple shallowing upward cycles of sedimentary sequences can be recognised by facies assemblage. We also measured the major and minor elements (e.g., Ca, Mg, Fe, Mn, Sr, Al, etc.), carbon and oxygen isotopes ($\delta^{13}C$: -1.3 to 0.7‰; $\delta^{18}O$: -9.1 to -4.5‰) and Mg isotopic compositions of the dolomite ($\delta^{26}Mg$: -2.23 to -1.93‰). The stratigraphic variation of $\delta^{26}Mg_{dol}$ is coincident with the depositional cycles, suggesting the dolomitization might be periodic and coupled with the sea-level oscillation. As dolomitization fluids experience changes in $\delta^{26}Mg$ values during dolomitization processes, the intra-cycle stratigraphic $\delta^{26}Mg_{dol}$ profile reflects the dolomitization processes. Our study indicates that the dolomitization pattern of the FXG dolomite is penecontemporaneous sabkha model coupled with seepage-reflux dolomitization model. When sea-level fell, the ooid shoal facies gradually evolved as back-shoal lagoon facies, and with the intensified evaporation, microcrystalline dolomite began to formed via penecontemporaneous sabkha model. Such process is characterized by a downward decreasing $\delta^{26}Mg_{dol}$ profile of the lagoonal dolomite. Meanwhile, the dense porewater flowed back and infiltrated downwards, resulting in the dolomitization of the underlying oolitic dolomite layers. Such process is collectively known as seepage-reflux model, supported by a downward increasing $\delta^{26}Mg_{dol}$ pattern of the shoal facies. In sum, our study provides a testable approach to investigating the formation mechanism of the lower Triassic FXG dolomite.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-8: Towards unravelling the 'Dolomite Problem': Multi-tracer geochemical approaches and novel perspectives
Presentation Preference: Oral Preferred

Origins of the Lower Ordovician Dolomite and Main Controlling Factors for Reservoir Formation in the Tarim Basin

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Keywords: origin of dolomite, geochemical proxies, petrological observation, main controlling factors of the development of the dolomite reservoir, Lower Ordovician, Tarim Basin

The Ordovician in the Tarim Basin, NW China is rich in oil and gas resources. Limestone and related reservoirs are mainly developed in the Middle and Upper Ordovician, and a large amount of oil and gas has been proved and produced. However, a massive dolomite occurred in the Lower Ordovician (including the Penglaiba Formation and the third and fourth member of the Yingshan Formation (collectively referred to as the Lower Yingshan Member), which have been confirmed by exploration to be able to form large-scale reservoirs, but no massive oil and gas discoveries have been made. In order to further clarify the origin of the Lower Ordovician dolomite and the main controlling factors of the development of the dolomite reservoirs, a systematic petrological and geochemical analysis was made. The results show that the Lower Ordovician dolomites are mostly distributed in thick layers and blocks in a large area, and vertically the lower strata are mostly dolomite, while the proportion of dolomite in the upper strata decreases; the lithology is mainly medium-fine crystalline dolomite, a small amount of very fine crystalline dolomite and grain dolomite. The residual grain structures or phantoms are usually observed in the medium-fine crystalline dolomite and very fine crystalline dolomite; combined with geochemical parameters such as carbon and oxygen isotopes, strontium isotopes, trace elements, rare earth elements, fluid inclusion measurements, and cathodoluminescence, it is believed that the Lower Ordovician dolomite in the Tarim Basin was formed in the early diagenetic period, and the middle and late diagenetic periods were superimposed with buried dolomitization; the development of the dolomite reservoirs is mainly controlled by high-energy facies, exposure dissolution and dolomitization.

Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-8: Towards unravelling the 'Dolomite Problem': Multi-tracer geochemical approaches and novel perspectives
Presentation Preference: Oral Preferred

Linking penecontemporaneous subaerial exposure and dolomite formation: Evidence from modern dolomite crusts forming in Brejo do Espinho, Brazil

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Keywords: dolomite crust, Mg isotopes, early diagenesis

The occurrence of modern microbial dolomite crusts in Brejo do Espinho (LBE), a hypersaline coastal lagoon located approximately 100 km east of Rio de Janeiro, Brazil, has been well documented in surficial deposits exposed aerially during dry periods when lagoon water levels are lower. This lithified dolomite serves as an exceptional modern analogue for decoding the penecontemporaneous diagenetic lithification processes and associated dolomite formation mechanisms. A previous study proposed that the early lithification of the crust during subaerial exposure under intensified semiarid conditions promotes the formation of well-ordered stoichiometric dolomite (Bahniuk et al., 2015). However, very limited information exists on the penecontemporaneous subaerial exposure and its influence on biogeochemical processes that are favorable for dolomite formation.

In this study, three samples of modern dolomite crusts with different lithified states (well lithified and less lithified) were collected from the border of LBE. All of the crusts had experienced repeated penecontemporaneous subaerial exposure during the annual dry season. Petrological analysis indicates that the crusts comprise co-occurring high-Mg calcite (HMC) and poorly to well-ordered dolomite. These lithified crusts mainly consist of micritic dolomite peloids or clotted peloids, as well as discrete aphanitic micro-laminae, whereas microsparitic dolomite crystals are predominantly distributed in well-lithified crust and surround the micritic peloids. In order to investigate the geochemical fingerprints recorded during the early diagenetic process, we measured elemental compositions and the C-O-Mg isotope values of the crusts. Low Fe and Mn concentrations reflect the formation of dolomite under aerobic conditions (Land, 1980), while higher Sr concentrations of well-lithified crust (mean value ~3000 ppm), which are contrary to Sr loss during the dolomitization process, indicate primary bacterial induced dolomite precipitation (Sánchez-Román et al., 2011). In general, the Mg isotopic composition (δ^{26}Mg) of the LEB crust (mean value -3.02‰) is lighter than other published values (Shalev et al., 2021), possibly indicating different dolomitization processes and Mg sources (including EPS bonded Mg^{2+}, porewater and dissolved HMC) for the different dolomite samples. The average ^{18}O value for the three different LBE crusts is 1.1‰ VPDB, indicating equilibrium with a relatively evaporated water. Additionally, there is no significant difference in the δ^{13}C values among the three different LBE crusts, which show more negative δ^{13}C value (mean value -8.6‰ VPDB) than the unlithified carbonate mud in LBE (δ^{13}C = -1.2‰ VPDB) (Bahniuk et al., 2015), suggesting the incorporation of ^{13}C depleted organic carbon during early biogeochemical diagenesis.

Thus, we propose that the biogeochemical processes related to decaying microbial mats under oxic conditions played an important role in the diagenetic dolomite formation. During the penecontemporaneous subaerial exposure, the respiration of aerobic bacterial communities produces CO_2 which lowers pH (Sánchez-Román et al., 2008) and increases the dissolution of primary HMC. Meanwhile, microbial degradation of EPS liberates bonded Mg^{2+}. At the same time, supersaturation due to strong evaporation and evaporative pumping of porewater represent different steps towards the enrichment and stabilization of Mg^{2+}. Finally, these combined

processes induce the transition of HMC to dolomite (micritic dolomite) or direct dolomite precipitation (microsparitic dolomite).

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-8: Towards unravelling the 'Dolomite Problem': Multi-tracer geochemical approaches and novel perspectives
Presentation Preference: Oral Preferred

Evidence for primary organogenic dolomites in the late Ediacaran Dengying Formation, South China

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Keywords: Shibantan Member, microbial mats, organic matter, massive dolostone, microbialites

Dolomite forms massive dolostones in Paleozoic and Precambrian sequences but rarely occurs in Holocene sediments which are commonly associated with microbial mats in highly evaporitic and alkaline environments such as coastal sabkhas, hypersaline lagoons and inland saline lakes. Although dolomite is difficult to precipitate at low temperatures under abiotic conditions, previous laboratory experiments have demonstrated that extracellular polymeric substances (EPS) can break the kinetic barriers for dolomite nucleation. However, unlike modern dolomites that have been extensively reported, confirmed occurrences of ancient primary dolomite are rare, likely due to poor preservation of primary sedimentary textures in Precambrian dolostones. In this work, we conducted a comprehensive mineralogical study of Late Ediacaran carbonates of the Shibantan Member, Dengying Formation in the eastern Yangtze Gorges area, South China. The Shibantan carbonates are characterized by calcite layers intercalated with millimeter-thick, dolomite-rich layers that contain up to 50% dolomite and exhibit an anastomosed structure akin to microbial mats. The dolomite-rich layers typically contain well-ordered, micritic-microlitic dolomite rhombs that are closely associated with organic matter. Microstructures resembling EPS were found between the dolomites within microbial mats, while small amounts of Mg-containing carbonate mineral nanoaggregates were also preserved, which closely resemble primary dolomites in modern microbial mats. Based on these observations, we propose that the Shibantan dolomites were formed by the gradual ordering of proto-dolomite or high magnesium calcite through a microbially induced transformation. The positive correlation between the occurrences of microbialite and dolostone abundance in both the Precambrian and the Phanerozoic supports the involvement of microbial mediation in the formation of massive dolostones. In microbially-dominated, anoxic oceanic environments with a relatively high Mg/Ca ratio, growth of organogenic primary dolomite in microbialites, along with subsequently superposed dolomitization events, likely have controlled the formation of some massive dolostones in the geological history.

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Session T10-8: Towards unravelling the 'Dolomite Problem': Multi-tracer geochemical approaches and novel perspectives
Presentation Preference: Oral Preferred

U-Pb dating, elements, and C-O-Sr-Nd isotopes of dolomite veins and rock acoustic emission in the Sichuan Basin, China: Implications for genetic mechanism of natural fracture in carbonate reservoirs

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Keywords: Fracture, Carbonate reservoirs, fracture dolomite cement, U-Pb dating, C-O-Sr-Nd isotopes

Natural fractures in carbonate reservoirs can significantly improve the permeability of the carbonate reservoir by acting as seepage channels. Moreover, the fractures themselves can provide space for oil and gas storage and control the development of solution pores and caves. Therefore, they are important to the evaluation of the distribution of hydrocarbon sweet spot sites in carbonate reservoirs. The Deng IV Member of the Gaoshiti-Moxi Block in the Sichuan Basin is a typical carbonate reservoir with large natural gas reserves. Since the Paleozoic, the Gaoshiti-Moxi Block has experienced multi-stage tectonic movement and many natural fractures have developed. Previous studies on the gas bearing property of the Dengying Formation in the Sichuan Basin mainly focused on the regional structure, reservoir lithology, pore structure, and sedimentary characteristics, paying little attention to natural fractures. Moreover, the formation time and mechanism of the natural fractures remain unknown, restricting the efficient development of gas extraction in the Dengying Formation. Using fluid inclusions of fracture dolomite cement, C-O-Sr-Nd isotope, rare earth elements, and U-Pb dating and combined with rock acoustic emission test, the present study accurately traced the origin of fluids filling these fractures, and constrained the time of fracture formation. Based on high temperature and high pressure triaxial rock mechanics experiment, the history of paleotectonic stress in the Gaoshiti-Moxi Block was reconstructed to reveal the fracture formation mechanism of carbonate reservoirs in the Deng IV Member. Micron CT imaging was used to clarify their contributions to the reservoir capacity and connectivity. The results show that tectonic fractures in the study area developed in three stages: Stage I, the Early Cambrian Yangtze Plate was extensively uplifted. The central Sichuan paleo-uplift was under the strong dynamic background of NEE-trending extension, leading to the oblique crossing of fault strikes along the NEE principal stress direction, existing SEE direction, and near-EW direction and the occurrence of a local dextral shear stress field near the fault zone. This further led to the formation of NWW-trending relaxed shear fractures within or near the existing fault zone. In this context, fluids from the Deng IV Member invaded NWW-trending relaxed shear fractures during ~558–550 Ma. Stage II, the Late Silurian Yangtze Plate collided with the Cathaysia Plate, forming compression-torsion stress field and then NEE-trending shear fractures in the Gaoshiti-Moxi Block. In this context, fluids from the Deng IV Member and the underlying Dengying III Member invaded NEE-trending relaxed shear fractures during ~425–420 Ma. Stage III, the Late Permian Sichuan Basin was wholly uplifted under the influence of the Emei taphrogeny, where the central Sichuan paleo-uplift was under an EW-trending tensile stress environment. Consequently, near NS-trending tensile fractures formed in the Gaoshiti-Moxi Block under the near EW-trending tensile stress field. In this context, high temperature fluids related to basaltic magma of Mount Emei invaded near NS-trending tensile fractures during ~258–250 Ma. Micron CT imaging revealed that the development of fractures increases the reservoir capacity and connectivity of carbonate reservoirs, which are important factors for the formation of high-quality hydrocarbon bearing reservoirs.

Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-8: Towards unravelling the 'Dolomite Problem': Multi-tracer geochemical approaches and novel perspectives
Presentation Preference: Oral Preferred

Early diagenesis and dolomitization of island carbonates in the South China Sea: Lessons from Calcium isotope signature

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Keywords: Reef carbonate, calcium isotope, carbonate diagenesis, dolomitization

Carbonate rocks in reef islands can be used to investigate how their isotopic compositions are modified by water-rock interactions during diagenesis, which is an important consideration when using these rocks as archives of paleo-environmental conditions. We investigated the diagenetic history of reef carbonate sediments in a core (well NK-1) from the margin of Meiji Reef in the South China Sea using stable Ca isotopes (δ44/40Ca). We present a model for diagenetic alteration that quantitatively explains the observed δ44/40Ca variations under different diagenetic conditions (i.e., meteoric versus marine diagenesis). The model can account for changes in the fluid advection rate, sedimentation rate, carbonate recrystallization rate, and seawater δ44/40Ca values. Our results identified significant stratigraphic variability in carbonate δ44/40Ca values, which are the consequence of variable types of diagenesis or the relative importance of seawater- versus sediment-buffered diagenetic conditions. An extreme excursion to lower δ44/40Ca values, along with low δ13C and δ18O values, was likely caused by a low advective fluid flow rate when the carbonate sediment was deposited, exposed at the surface, and diagenetically altered. The observed Ca isotopic fractionation was associated with regional tectonism and sea-level changes during reef development. Our results also suggest that the δ44/40Ca fractionation factor between carbonate and seawater for dolomite may be lower than that of its precursor calcite by up to 0.6‰. As such, the Ca isotope systematics of dolomite in reef island settings may be not close to equilibrium during its formation. This study has significant implications for the δ44/40Ca variations in ancient carbonates that have been used to document secular changes in seawater δ44/40Ca values, as well as paleo-environmental reconstructions based on reef limestone and dolostone archives.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-8: Towards unravelling the 'Dolomite Problem': Multi-tracer geochemical approaches and novel perspectives
Presentation Preference: Oral Preferred

Formation mechanism of selective dolomitization in stromatolites from the Tonian Weiji Formation, North China

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Keywords: selective dolomitization, stromatolite, Tonian

Selective dolomitized carbonates are common in the Phanerozoic, especially in the Cambrian and Ordovician carbonates. Previous studies conclude that selective dolomitization is related to diagenetic process. Bioturbation, Mg2+ bearing fluids reflux and depositional environment change may induce selective dolomitizations. In the Precambrian, the selective dolomitic carbonates are also recorded in stromatolite from the Tonian Weiji Formation. The Tonian Period marks a critical interval of Earth history as it connects the relatively static Mesoproterozoic Era and the extremely dynamic Neoproterozoic Era. Dolomitic stromatolites from the Weiji Formation are possible archives for decoding selective dolomitization and paleoenvironmental changes. In this study, we applied systematic petrological and geochemical analysis to stromatolitic carbonates in the Weiji Formaiton, Jiangsu Province.

In the Weiji Formation, three types of dolomitization are recognized on the basis of petrographic and geochemical data. Types I and II are selective dolomitization in dolomitic limestones. In Type I, dolomitization occurs selectively in the matrix. In Type II, dolomitization preferentially occurs in dark stromatolitic laminae. In Type III dolomitization, both the matrix and stromatolites are pervasively dolomitized to form dolostones. Under the guidance of petrographic observations, sample powders were collected by using a hand-held micro-drill for elemental compositions analysis, carbon and oxygen isotopes analysis. Magnesium to calcium ratios (Mg/Ca, mol/mol) of dolomitic samples show positive linear relationships with carbonate associated ferrous iron (Fecarb) and manganese (Mncarb). Carbon (δ13Ccarb) and oxygen (δ18Ocarb) isotopes also have a positive linear relationship. Rare Earth Elements of dolomitic samples are characterized by LREE depletions, MREE enrichments, positive yttrium anomalies, and a lack of europium anomalies. Geochemical results suggest an early diagenetic dolomitization, which possibly occurred in the iron reduction zone and under the influence of bottom seawater. The selective dolomitization processes are mainly controlled by heterogeneous compositions and primary structures of stromatolites. Iron-bearing rings in dolomite of dark-layers in type II stromatolites indicate that organic matter degradation and microbial activities may play an important role in dolomitization processes. Fecarb, Mncarb, δ13Ccarb and δ18Ocarb data of stromatolites show that dolomitization fluids in the Weiji Formation may have originated from mixed bottom seawater and pore water, indicating that early Neoproterozoic seawater or pore water may be enriched in ferrous iron.

Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-8: Towards unravelling the 'Dolomite Problem': Multi-tracer geochemical approaches and novel perspectives
Presentation Preference: Oral Preferred

Solid evidence suggests Neoproterozoic fibrous dolomite cement precipitation postdated matrix dolomitization

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Keywords: Dolomitization, fibrous dolomite cements, carbonate U-Pb dating, clumped isotopes, diagenesis, Neoproterozoic "dolomite sea"

The higher abundance of dolomite in the Neoproterozoic compared to that of the Phanerozoic has been linked to elevated marine Mg/Ca ratios, and a hypothesized "dolomite sea" that promoted widespread syn-sedimentary fibrous dolomite cements precipitation. Here we provide new uranium-lead (U-Pb) chronology, clumped isotope thermometry ($T_{\Delta47}$), combined with $\delta^{13}C$ and $\delta^{18}O$, and trace element geochemistry measurements for different types of dolomites, include bulk dolomite matrix (BD), fibrous dolomite cement (DC1), and late sparry dolomite cement (DC2 and DC3), in three Neoproterozoic dolostone profiles from China. The Ediacaran U-Pb ages coupled with nearly identical, low $T_{\Delta47}$ temperatures (average at ~50 ºC) for BD and DC1 dolomites, imply that these dolomites were either syn-depositional or early diagenetic. Some DC1 dolomites yield slightly younger (~20 to 50 Ma) U-Pb ages than the BD dolomites, suggesting that they were early diagenetic products formed after matrix dolomitization. The estimates of $\delta^{18}O_{water}$ values for dolomitizing fluids suggest that both DC1 and BD dolomites were precipitated from highly evaporated seawater. In contrast, DC2 and DC3 dolomites filling in vugs and fractures have much younger U-Pb ages (mostly <525 Ma), higher $T_{\Delta47}$ temperatures (>95 ºC), and lower Sr and U contents, consistent with the paragenetic sequence based on petrographic evidence that they were deeper burial diagenetic products. A synthesized diagenetic model with evaporative dolomitizing water evolved from anoxic, ferruginous to sub-oxic and/or oxic, non-ferruginous conditions is responsible for the decrease of Fe and Mn concentrations in global DC1 and BD dolomites throughout of the Neoproterozoic time. This study suggests that the widely distributed Neoproterozoic fibrous dolomite cements may be a later diagenetic feature, and thus calls into question their use in paleoclimate reconstruction, and as a principle line of evidence for the Neoproterozoic "dolomite sea" hypothesis.

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Session T10-9: Understanding the redox state of the mid-Proterozoic oceans and atmosphere

Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-9: Understanding the redox state of the mid-Proterozoic oceans and atmosphere
Presentation Preference: Oral Preferred

Compositional evolution of glauconite within Proterozoic Gandikonta Formation, Cuddapah Basin, India and its implications

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Keywords: Authigenic Fe-silicate, Glauconite, Precambrian, Shallow-marine, Geochemistry, 'Pseudomorphic' replacement

Authigenic Fe-silicates are a rare occurrence in Precambrian and therefore holds significant information about the ocean geochemistry. An integrated approach involving petrography, mineralogy and geochemistry reveals the origin of authigenic shallow marine-originated glauconitic sandstones of Proterozoic Gandikonta Formation, Cuddapah basin, southern India. X-ray diffractograms confirm the Fe-silicate as 'glauconite' with characteristic basal reflection (001) at 10.03Å. Petrography reveals dark green colour glauconite in two modes of occurrence as completed 'evolved' and a partially 'evolved' varieties. Partially 'evolved' variety exhibits the replacement texture within K-feldspar, mica and quartz grains while completely 'evolved' variety leaves no trace of substrate. Mica-replaced glauconite exhibits effects of pressure solution. A thin rim of iron oxides often concurs the glauconites. Geochemical studies further reflect the 'evolved' to 'highly-evolved' stage of maturation with K_2O content of glauconite ranging from 6.72% to 9.56% while the Fe_2O_3 (total) content varies from 4.56% to 18.87%. The avg. Al_2O_3 content of glauconite is 21.18% and the avg. SiO_2 content is 50.56%. The chemical composition of glauconite in Gandikonta Formation are comparable to many Precambrian equivalents. The high K and Si content reflects the replacement of K-feldspar and quartz by glauconite respectively. The simultaneous addition of Fe with constant K corroborate the 'pseudomorphic' replacement of substrate. The low Fe_2O_3 (total) content of glauconite may be related to either non-availability of Fe Precambrian shallow seas or weakly sub-oxic depositional condition. In either case, Precambrian glauconites differ from their Phanerozoic counterparts by the significantly lower content of Fe_2O_3 (total) and shallower depositional setting.

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Session T10-9: Understanding the redox state of the mid-Proterozoic oceans and atmosphere
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Mesoproterozoic oxygenation event: from shallow marine to atmosphere

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Keywords: Mid-Proterozoic, Gaoyuzhuang, North China, Cr isotope, Sulfur isotope, Eukaryote

Oxygen availability is crucial for the evolution of eukaryotes in geological history, but the redox conditions of the mid-Proterozoic atmosphere–ocean system remains vigorously debated. Previous geochemical studies suggested a very low mid-Proterozoic atmospheric oxygen level probably below 0.1–1% of the Present Atmosphere Level (PAL) with weakly oxygenated surface ocean, which may have suppressed the early evolution of eukaryotes in the ocean. A recent study, however, revealed a pulsed oxygenation event that was recorded in shallow marine carbonate of the middle Gaoyuzhuang Formation (at ~1.57 Ga, North China) with atmospheric pO_2 up to ~4% PAL based on iodine speciation, and is associated with the earliest known multi-cellular eukaryotic fossils. To elucidate whether this pulsed oxygenation was limited to local shallow seawaters or could also reflect an increase in atmospheric oxygen, chromium (Cr) and carbonate-associated sulfate (CAS) sulfur isotopes in the middle Gaoyuzhuang Formation were studied in two sections of the North China Platform. The results show a positive shift in authigenic Cr isotope from -0.18‰ to +0.66‰, followed by a decline to -0.16‰. This suggests a rise in atmospheric oxygen sufficient to initiate oxic Cr cycling and isotope fractionation (pO_2 > 0.1–1% PAL). This positive Cr isotope excursion was associated with a transient positive shift in $\delta^{34}S_{CAS}$ from ~20‰ to ~50‰, and a subsequent decline to ~10‰, providing independent evidence of atmospheric oxygenation. This oxygenation may have enhanced oxidative terrestrial weathering, increasing sulfate input to the ocean, and thus stimulated bacterial sulfate reduction and pyrite burial in deep anoxic seawaters. This is broadly consistent with previous results of carbonate I/(Ca+Mg) and Ce anomaly, but also reveals a lag between shallow seawater and atmospheric oxygenation. Fluctuated redox conditions and decoupled oxygenation between shallow seawater and atmosphere during the mid-Proterozoic may help to account for the current debate.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-9: Understanding the redox state of the mid-Proterozoic oceans and atmosphere
Presentation Preference: Oral Preferred

Ultrafine fabrics and organominerals as indicator of microbial dolomite in deep time: An example from the Mesoproterozoic of North China

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Keywords: Mesoproterozoic dolomite nucleation, Extracellular polymer substances (EPS), Nanoglobules, Utrafine fabrics, Organo-mineralization, Anoxic-suboxic conditions

Both laboratory experiment and modern environment studies show that primary dolomite can precipitate at low temperature (≤ 60°C) only when microbes were involved. Vast dolomites in mid-Proterozoic have long been suspected to be the results of microbial mediation, but direct evidence is rare. To reveal their origin, an integrated study was conducted on dolostone of the Mesoproterozoic Wumishan Formation (~1.48 Ga) of North China using multiple techniques. The results show that the Wumishan dolostone contains abundant multiscale organominerals that associated closely with fossilized extracellular polymeric substances (EPS) and putative bacteria. These micro-fabrics are strikingly similar to those recognized in dolomite precipitates produced in laboratory culture and modern sabkha environment, suggesting microbial origin. In the Wumishan samples, nanoglobules (60–200 nm) are well preserved, they preferentially attach to EPS filaments and tend to merge into polyhedrons (3–8 μm) that in turn coalesce into microspheres (20–60 μm). EDS analysis revealed a successive decrease in carbon from nanoglobules to microspheres with the increases of Mg and Ca contents, implying an increased mineralization. Nanoglobules may have derived from EPS degradation in nucleation, and served as seeds for subsequent growth of polyhedrons. Microsphere, as a basic building block in dolostone, can transform into rhombohedral crystal via neo-morphogenesis. Petrographic and XRD analyses show that the dolostone is dominated by ordered dolomite and was formed in peritidal environments with thriving microbial community. Iodine species, redox sensitive elements, Ce anomalies, and C−O isotopes suggested that the environment was dominated by anoxic to suboxic conditions, with low P but high Si contents in seawater.

Our study offered direct evidence of microbial origin for the Mesoproterozoic dolostone, providing new insights into the “Dolomite Problem”. The massive development of microbial dolostone in the Mesoproterozoic points to a specific ocean chemistry, where low oxygen and active bacterial metabolisms may have played crucial roles in precipitating dolomite. The coexistence of abundant microbial components and multiscale organominerals can be taken as textural evidence for microbial dolomite and signatures of life-environment interactions in deep time.

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Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-9: Understanding the redox state of the mid-Proterozoic oceans and atmosphere
Presentation Preference: Oral Preferred

Constraining the redox landscape of Mesoproterozoic mat grounds: A possible oxygen oasis in the 'Boring Billion' seafloor

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Keywords: Pyrite, Sulfur isotope, DAR model, Wumishan Formation, North China

The Earth's middle age or the 'Boring Billion' (~1.8 to ~0.8 Ga, billion years ago) represents one of the most enigmatic intervals in Earth's history, characterized by the absence of significant carbonate carbon isotope excursions and the sluggish evolution of eukaryotes. It is widely accepted that the atmospheric O_2 level was extremely low (<1% PAL or <10% PAL) and the ocean remained predominantly anoxic with the development of sulfidic (H_2S-enriched) continental margins. It is suggested that 2-10% of seafloor euxinia was sufficient to deplete some micro-nutrients in the ocean inventory, such as Mo and Cu, which are essential for nitrogen-fixation for eukaryotes. However, recent studies report multicellular fossils and episodic/sporadic inception of oceanic oxidation in Mesoproterozoic. These findings imply the possible occurrences of oxygen oasis that provided habitable niches for eukaryote evolution. Such oxygen oasis likely developed at shallow marine seafloor covered with microbial mat, where O_2 produced by benthic cyanobacteria resulted in the oxygenation of seafloor. Therefore, in order to constrain the habitability of Mesoproterozoic oxygen oasis, it is essential to reconstruct the O_2 fugacity in the seafloor. In this study, we analyzed pyrite sulfur isotopes and pyrite contents of the Mesoproterozoic Wumishan Formation (~1.4 Ga). The Wumishan Formation is composed of cyclic deposition of, in a shoaling upward sequence, the subtidal calcareous shale, massive thrombolitic dolostone, and microbial laminated dolostone. Both microbial laminated dolostone and thrombolytic dolostone precipitation involved with microbial activities, and thus might record the redox condition of putative oxygen oasis in the Mesoproterozoic oceans. We apply the One-Dimensional Diffusion-Advection-Reaction (1D-DAR) model to simulate syndepositional pyrite formation in sediments. Sedimentation rate can be well constrained by the sedimentary cycles. The modelling results indicate that more than 60~80% of H_2S that was generated in microbial sulfate reduction (MSR) was reoxidized, and that organic matter supply, both from surface water and seafloor, was limited. Thus, our study indicates that the seafloor could be substantially oxygenated in Mesoproterozoic, even when the atmospheric O_2 level was extremely low. Shallow marine seafloor covered with microbial mat may function as the oxygen oasis, providing habitable niches for the evolution of eukaryotes.

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Session T10-9: Understanding the redox state of the mid-Proterozoic oceans and atmosphere
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The Mesoproterozoic Oxygenation Event

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Keywords: Mesoproterozoic, Oxygen, North China, Yanliao Basin, Xiamaling Formation, Gaoyuzhuang Formation

Oxygen, one of the most essential elements for the survival of eukaryotes, plays a crucial role in the emergence and evolution of eukaryotic life. The accumulation of oxygen is one of the most important characteristics that distinguish Earth from other planets in the solar system, which is also considered to be the key factor influencing the birth and evolution of complex life forms. The oxygenation process of the Earth surface has long been viewed to be episodic with two critical intervals occurring in the early Paleoproterozoic (2.45–2.10 Ga) and the late Neoproterozoic (0.80–0.54 Ga), with a 1.3-billion-year-long low oxygen period in between. Recently, increasing independent works carried out by different scientific teams in the Yanliao Basin, North China are demonstrating that the atmospheric oxygen concentrations had reached >4% PAL (present atmospheric levels) at least during 1.59–1.56, 1.44–1.43, and 1.40–1.36 Ga. These estimated values are higher than the previously recommended values of <0.1–1% PAL. Such a scenario discovered in the Yanliao Basin is consistent with the synchronously deposited strata in Australia and Siberia, pointing to a Mesoproterozoic oxygenation event (1.59–1.36 Ga) between the two major oxygenation intervals during the Proterozoic. This Mesoproterozoic oxygenation event is coupled with the break-up of the Columbia (Nuna) supercontinent, the formation of organic-rich shales and Fe-Mn deposits, and the early innovation of eukaryotic algae, indicating that the geological and biological co-evolutionary processes control the Earth surface system.

Scientific Themes: Theme 10. Sedimentary Geochemistry
Session T10-9: Understanding the redox state of the mid-Proterozoic oceans and atmosphere
Presentation Preference: Oral Preferred

Identifying different microbial degradation of organic matter in the late Mesoproterozoic ocean with in-situ micro-Raman analysis

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Keywords: Shennongjia Group, micro-Raman, I-1350/I-1600, degradation of organic matter

Microbial degradation of organic matter is one of the main drivers of the biogeochemical cycles and provides principal insights into the sedimentary environment. However, it is a big challenge to identify the different microbial degradation processes of organic matter in deep time. Here, we illustrate that micro-Raman spectrometry of organic matter collected from limited strata intervals would provide insights into microbial degradation. Over 800 individual micro-Raman spectra of organic matter and 10 micro-Raman imaging are acquired from the Taizi formation (~1250 Ma) of the Shennongjia Group in South China. The Raman spectra data suggest that the organic matter is typically disordered but substantially different in the Taizi Formation. Specifically, the intensity ratio of *I*-1350/*I*-1600, a parameter reflecting the structure of organic matter, displays distinct temporal variations. The upper Taizi Formation is characterized by lower *I*-1350/*I*-1600 values, varying from ~0.8 to 1.0, relative to those of the lower Taizi Formation, which is located from ~1.0 to 1.8. No correlation is observed between the *I*-1350/*I*-1600 ratios, peak metamorphic temperatures, $\delta^{13}C_{org}$, and TOC contents. We attribute the diverse forms of kerogen structures observed in the Taizi Formation to different microbial degradations, which alter the functional groups of organic matter. The higher *I*-1350/*I*-1600 values indicate more recalcitrant organic matter, which might be caused by more severe aerobic microbial degradation.

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Session T10-9: Understanding the redox state of the mid-Proterozoic oceans and atmosphere
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Cyclostratigraphic calibration of the ~ 1.56 Ga oxygenation event recorded in the Gaoyuzhuang Formation, north China, and its implications

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Keywords: Mesoproterozoic, north China, Milankovitch cycles, Gaoyuzhuang Formation, negative carbon isotope excursion, oxygenation event

Earth oxygen concentration is closely interrelated to tectonic activity, biodiversity and climate evolution. The Mesoproterozoic earth, which between the GOE (ca. 2.43-2.22 billion years ago) and NOE (in late Neoproterozoic), experienced frequent redox environmental fluctuations. Recent studies of the upper part of Gaoyuzhuang Formation (Fm) (ca.1.60-1.54 Ga) in north China suggested that the Earth then experienced an oxygenation event that is characterized by a negative carbon isotope excursion, and it may have caused the expansion of eukaryotic life. But the duration of the events, which hint their origin mechanism, remains uncertain. Here we report a floating astronomical time scale based on the extracted Milankovitch cycles from the carbonate-dominated strata of the Member three of the Gaoyuzhuang Fm, in which the oxygenation event was reported. High-resolution magnetic susceptibility (MS) and anhysteretic remnant magnetization (ARM) series were obtained from the stratigraphic sections in the Jixian and Yanqing regions, north China. Rock magnetic experiments suggest that the magnetic parameters were dominated by input flux of the exogenous paramagnetic minerals, flux of which was likely controlled by the orbital-forced climatic changes. Our results demonstrate that the negative $\delta^{13}C_{carb}$ excursion and the interpreted transient oxygenation event had a duration of ~1.7 myr and ~ 6.2 myr, respectively. In the Yanqing section, the calculated duration of this corresponding pulse oxygenation event detected by I/ (Ca+Mg) is ~6.2 myr, and the short-term oxygen-filled atmosphere period is ~1.5 myr. By comparing Yanqing and Jixian Section, the large multicellular eukaryote fossils appear in the strata that is ~6.7 myr younger than the beginning of oxygenation event, ~3.3 myr younger than the oxygenation of deep water, and ~2.2 myr younger than the $\delta^{13}C_{carb}$ curve reaches its minimum.

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Session T10-9: Understanding the redox state of the mid-Proterozoic oceans and atmosphere
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Dynamic seawater redox status in the early Mesoproterozoic: Evidence from trace elements and sulfur isotopic compositions of carbonate associated sulfate in multiple sections

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Keywords: Mesoproterozoic, Gaoyuzhuang Formation, Redox, Sulfur isotope

The early Mesoproterozoic (1.6 - 1.4 Ga) is a critical stage for oxygenation of Earth's surface and early eukaryote evolution. However, the relationship between both is vague. Here, we provide new carbonate associated sulfate (CAS) sulfur isotopic compositions ($\delta^{34}S_{CAS}$) and trace elements from the 1.6 to 1.55 billion-year-old Gaoyuzhuang Formation in multiple sections, Yanshan Basin, North China, to investigate the temporal and spatial variation of ocean redox conditions. New and collected $\delta^{34}S_{CAS}$ data from four sections (Pingquan, Kuancheng, Qianxi and Jixian sections) reveal similar sulfur isotopic excursions, but the differences in absolute values indicate spatial heterogeneity of sulfur isotopic compositions, which may link to marine low-sulfate concentrations and oceanic redox stratification. The most elevated $\delta_{34}S_{CAS}$ values appeared at the top of the Second Member of the Gaoyuzhuang Formation, followed by distinct negative excursions at the bottom of the Third Member, suggesting a dynamic sulfur cycle and seawater redox status during this period. Combined with previous reported carbon and sulfur isotopes and some redox proxies (e.g., Ce anomalies, manganese-rich deposit, I / (Mg + Ca) and Fe speciation), we suggest that at least two oxygen rising events occurred in the Gaoyuzhuang Formation: (1) the bottom of the Second Member and (2) the bottom or middle part of the Third Member. Different sections show asynchronous oxygenation pulse, indicating that the redox status was spatial heterogenous within the Yanshan Basin. The spatial heterogeneity may be controlled by facies and paleogeographic locations. Considering the decimeter-scale multicellular eukaryote occurred in the middle part of the Third Member, it is consistent with the oxygenation pulse, we argue that oxic bottom water condition may be a critical factor for early eukaryote evolution.

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Session T10-9: Understanding the redox state of the mid-Proterozoic oceans and atmosphere
Presentation Preference: Oral Preferred

Pulsed oxygenations during Mesoproterozoic in North China Platform

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Keywords: Wumishan Formation, pulsed oxygenation, I/(Ca+Mg), C-S isotopic

Mid-Proterozoic (1.8–0.8 Ga), the critical stage for the origin and early evolution of eukaryotes, is a transitional period in the Earth oxygenation. However, the oxygen levels in the atmosphere-ocean system during this period remain debated, and thus limited our understanding to the co-evolution of life and environment. Recent studies revealed several episodes with “high” oxygen levels during mid-Proterozoic, but the possible causes for these short-lived oxygenations are still controversial. In order to further constrain the redox conditions in mid-Proterozoic atmosphere and shallow seawaters, thick peritidal carbonate successions (up to ~3000 m) in the Wumishan Formation (ca. 1.52–1.47 Ga) on the North China Platform have been chosen as target. Using petrographical and multiple geochemical proxies on three well-exposed sections, two pulsed increases of I/(Ca+Mg) (>2.6 mmol/mol) in Member I (~1.52 Ga) and lower part of Member IV (~1.48 Ga) were identified, respectively. Accompanied with the two intervals, negative Ce anomaly (~0.7) and low Mn/Sr ratio were also recognized, indicative of pulsed oxygenation in shallow seawater. This interpretation is also supported by sedimentological evidence that shows abundant water-column precipitated carbonate muds in the oxygenated intervals but rich seafloor precipitated aragonites in the neighboring intervals. The former requires moderate oxygenated conditions to remove carbonate inhibitors from water column through oxidation (e.g., Fe2+), while the latter requires the presence of Fe2+ under more anoxic conditions to inhibit carbonate precipitation from water column. The increase of δ34SCAS by ~30‰ during the latter stage of each pulsed oxygenation, possibly indicates atmospheric oxidation events, which led to the increase of sulfate input from oxidative weathering on land, and promoted elevated bacterial sulfate reduction and pyrite burial. According to the high I/(Ca+Mg) ratios (much higher than the Precambrian baseline 0.5 mmol/mol), and a semi-quantitative calculation, an oxygen level of >2.5% PAL was estimated for these two intervals. The negative shift in δ13Ccarb by 1.5‰ associated with the late stages of the intervals are likely caused by rapid remineralization of dissolved organic carbon with the expansion of oxygenated seawater, which is one of the significant causes to push the oxygenated seawater back to anoxic. The pulsed oxygenations identified in this study (~1.52, ~1.48 Ga), together with previously recognized short oxygenations (e.g., ~1.64, ~1.58, and ~1.44 Ga), likely imply that the mid-Proterozoic redox conditions were highly dynamic, with several intervals of high oxygen levels against an overall low backdrop. This study may shed light on oxygenation processes and give new perspectives on co-evolution of life and environment in mid-Proterozoic.

Theme11

Geoscience Programs & New Technology on Sedimentology

Session T11-1: Seismic sedimentology for non-marine basins

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-1: Seismic sedimentology for non-marine basins
Presentation Preference: Oral Preferred

Application of multi-attribute fusion technology in channel sand body recognition and boundary characterization : A case study of T gas field in East China Sea Basin

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Keywords: Seismic sedimentology,Seismic attributes,Channel sand body,Multi-attribute clustering,RGB fusion

Shallow water delta is a special sedimentary system in the interactive environment of rivers and lakes. The lithology combination changes rapidly in space and is sensitive to the change of water depth, which often forms the coexistence of thin interbeds and thick sandstone deposits. It is a key and challenging work to accurately identify and characterize channel sand body using seismic data under the condition of no enough wells in the sea area. In this study, the shallow water delta deposition of Paleogene Hua Gang Formation in T gas field area of East China Sea Basin is selected as an example. The author explores the method of using seismic multi-attribute fusion technology to accurately characterize the river channel in shallow water delta system. Six types of thirty-eight seismic attributes reflecting different geological information are extracted for river channel identification in the target area, and the most sensitive attributes to geological conditions are selected in each class of attributes. The physical meaning of various attributes is analyzed to identify the differences between different river structures. The multi-attribute clustering analysis based on FCM algorithm is used to reduce data dimension and reduce redundancy. Three seismic attributes that reflect the boundaries of geological bodies and lithological characteristics are selected for RGB fusion to highlight the overall characteristics of river distribution in this area, and enhance the characterization of the boundaries of channel sand body. It provides practical value for the next favorable target prediction of channel sand body.

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Session T11-1: Seismic sedimentology for non-marine basins
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Various structural slope-breaks types and their petroleum geological significance

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Keywords: Structural slope-break, Sequence architecture, Sedimentary features, Reservoir distribution

Yinggehai Basin is a Cenozoic transition-extension petroliferous basin in the orientation from northwest to southeast that has experienced multi-stage tectonic movements, by which the accommodation space evolution has been controlled. The long-term activity of syn-sedimentary faults formed complex and diverse types of structural slope-break, which affects the sedimentary processes and infills. Five types of structure slope-break have been classified with the discussion of their control on petroleum accumulation. The slope-breaks are developed controlled by the No. 1 boundary fault of the Yingdong slope zone, which includes: flexure slope-break, multi-step flexure slope-break, flexure fault terrace slope-break, multi-step fault terrace slope-break, and fault-controlled steep slope-break (Fig. 1).

Type is developed in MeishanFormation, Huanliu Formation, and Yinggehai Formation. The sedimentary infills are similar to type , which is featured by lowstand slope fans, basin fans, and highstand distal gravity fans. Type is mianly developed in Huangliu Formation during the accelerated thermal subsidence period, and the boundary faults are inactive. The whole Huangliu Formation is characterized by large-scale axial gravity flows and submarine fans. Type is developed in Sanya Formation and Meishan Formation. During the sedimentary period of the Meishan Formation, the study area is also in the thermal subsidence period, but the boundary fault activity is further weakened, and the sedimentary infilling is composed by the lowstand gravity flow fans and highstand deltas. Type is mainly developed in Sanya Formation within the thermal subsidence period, boundary fault activity is weakened, and the secondary small faults are sporadically developed, which controls the distributions of lowstand fan deltas. Type is mainly developed in Lingshui Formation, which is in the fault-depression transition period, the boundary fault activity is relatively strong, and the fan delta deposits are dispersed in lowstand, highstand, and transgressive systems tracts.

The research results present a case reference for the classification of structural slope-break types and have a certain significance for the distribution and prediction of oil and gas reservoirs in the study area.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-1: Seismic sedimentology for non-marine basins
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Research on provenance and sedimentary system of Qintong Sag, Subei Basin, China

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Keywords: seiemic frequency division technology,provenance,seismic facies,seismic attributes,sedimentary system,Qintong Sag

In order to meet the demand of oil exploration in Qintong Sag.It is necessary to understand provenance and sedimentary facies. Previous studies believed that the provenance of the 3rd Member of the Funing Formation of Qintong Sag came from the Western Wubao low uplift, the southern Taizhou uplift and the southwestern slope do not provide provenance, the exploration potential in the middle and southeast of the sag has been neglected. But we found that the sedimentary facies and sand body distribution in central Qintong Sag,are quite different from previous views, so as to determine the provenance and sedimentary system, firstly, the sequence division model is determined based on logging and 3D seismic which was managed by frequency division technology. Sedimentological methods such as the distribution characteristics of sandstone composition maturity, heavy mineral content and sandstone granularity, the variation tendency of the angle of progradational reflection and seismic facies distribution are used to qualitatively or semi-quantitatively characterize provenances at different times. Combined with the distribution of seismic facies,seismic attributes, loggingand logging lithology combination characteristics to determine the sedimentary facies distribution, and finally determine the sedimentary system. The 3rd Member of the Funing Formation is divided into two third-order sequences, the lower sequence can be divided into LST, HST and TST, the upper sequence is divided into LST. Provenance studies showed that the compositional maturity and heavy mineral content are low in northwest, southeast and north, but high in central and southwest,the granularity of sandstone distribution showed that The granularity of sandstone is lower in northwest, southeast and north, and higher in central and southwest.The angle of progradational reflection is the largest,when the seismic survey line of low TST about 15° , the seismic survey line of the HST and LST strikes about 310°~330°30° and 60°. Those analysis suggests that there are three provenance systems in Qintong Sag,the provenance of the central Qintong sag comes from the Taizhou uplift in the south of the study areanot the Wubao low upliftthe provenance of the north sag comes from the Liangduo uplift. There are six types of seismic facies. In general, progradational reflection and filling reflection are only found in the south and southeast of the study area, continuous,high to moderate amplitude,medium frequency parallel reflection are mainly developed in the northwest, the scale of progradational reflection and filling reflection gradually decreases from the early stage to the end stage of strata, it shows that this period is a process of lake level rise and hydrodynamic weakening.Fan delta and shallow lake subfacies are mainly found in the central area of Qintong Sag. Combined with the research of provenance and sedimentary facies, the multi-source sedimentary system of Qintong Sag was established for the first time.It is pointed out that the southern direction of the study area is the development area of high-quality reservoirs. The fan delta sedimentary system in the southeast is a favorable area for exploration.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-1: Seismic sedimentology for non-marine basins
Presentation Preference: Oral Preferred

Prediction of high-quality clastic rock reservoirs under the constraint of source and sink in the middle and deep layers of the Paleogene, Bohai Sea

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Keywords: High-quality reservoir, source-sink, clastic rock, Paleogene, middle-deep layer, Bohai Sea

In recent years, the middle and deep layers have gradually become the focus of oil and gas exploration in the Bohai Sea. Middle-deep reservoirs are characterized by deep burial and strong physical heterogeneity. Especially for reservoirs buried deeper than 3000m, the porosity is generally less than 15%, the permeability is less than 10mD, and it has entered the stage of low porosity and low permeability. However, there are also a large number of high-quality reservoirs with porosity greater than 15% and permeability greater than 10 mD in low-porosity and low-permeability reservoirs. Such reservoirs have become the key targets for oil and gas exploration in the middle and deep layers (over 3000m deep) in the Bohai Sea. Accurate comprehensive seismic interpretation data is particularly important. Various types of clastic rock deposits such as delta and sublacustrine fans are developed in the middle and deep layers of the Bohai Sea. Based on the analysis of cast thin sections, physical properties, and various analytical and laboratory data, the conditions for the development of high-quality reservoirs in the middle and deep layers are as follows: (1) coarse-grained parent rock rich in potassium feldspar is the material basis for the formation of high-quality reservoirs; (2) relatively Large-scale convergence system-long extended main valley-steep provenance area is the paleogeomorphological condition for the formation of large-scale thick sandstone; (3) delta distributary channel/underwater distributary channel/mouth bar microfacies and sublacustrine fan main Channel/proximal channel microfacies are the main types of sedimentary facies for the development of high-quality reservoirs; (4) Atmospheric freshwater leaching (early dissolution pores) - dissolution (diagenetic dissolution pores) - reservoirs and source rocks are connected by faults (Enhanced dissolution and development of fractures) are the main diagenetic conditions for the formation of high-quality reservoirs after burial. On the basis of clarifying the development conditions of high-quality reservoirs, a set of methods for predicting high-quality clastic rock reservoirs has been formed: (1) Restoration of parent rock and paleogeomorphology in the provenance area to obtain the real parent rock and paleogeomorphology of the provenance area; (2) Use the seismic structure to characterize the elements of the source-sink system and quantitatively count the parameters, classify them according to the size of the paleogeomorphic conditions that form high-quality reservoirs, and finely characterize the distribution and thickness of sedimentary microfacies of various sedimentary bodies, and carry out sand-rich analysis. (3) Use seismic data to find and characterize all kinds of faults running through sandstone and source rocks; (4) Combine the above-mentioned parent rock-paleomorphology-sedimentary microfacies-faults together to predict high-quality reservoirs .

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-1: Seismic sedimentology for non-marine basins
Presentation Preference: Oral Preferred

An active-learning-based lithology prediction technology and its application in seismic sedimentary analysis

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Keywords: seismic sedimentary, active-learning, lithology prediction

Seismic sedimentology based on stratigraphic slices has greatly improved the accuracy of the analysis on thin sedimentary layers. However, conventional attribute slices from the data set of 90-degree phase shift or wave impedance inversion can not reflect the thickness, but the morphological characteristics of a sedimentary body. This affects the sedimentary facies maps and results to share.

A lithology prediction method based on active learning is proposed to improve the accuracy of sedimentary analysis. The active learning method is generally divided into two parts: a learning engine (or a basic learning model) and a selecting engine (or a query function). The learning engine is responsible for maintaining a benchmark classifier and learns from the labeled sample set provided by the system with the help of a supervised learning algorithm to improve the performance of the classifier. The selecting engine is responsible for selecting a sample set that has not unlabeled using a committee-based query function, and then send the set to a human annotator to label. The samples after labeled by the human annotator will be added to the labeled sample set. The learning engine and the selecting engine work alternately. After many cycles, the performance of the benchmark classifier will be gradually improved, and the whole process will be terminated when the preset conditions are met. Model prediction results show that the method we proposed can provide good prediction results in the case of less samples, and its prediction accuracy is better than the conventional semi-supervised learning method.

Meandering river deposits were developed in the Keshang Formation in the Fengnan area of the Junggar Basin, where drilling data found that the oil-bearing sandstone layer is 2-10 m thick. When analyzing the seismic sedimentary characteristics of the target layer, we used the active learning method to predict the lithology. By using the lithologic body, we obtained the stratal slice of the oil-bearing sandstone layer. In order to make the stratal slice reflect both the shape and the thickness of the sandstone layer, we improved the stratal slice technology. In other words, we first determine whether the seismic attribute of slice is sandstone or mudstone. If the attribute indicates sandstone, we further analyze whether the lithology of sampling points above and under the slice is sandstone. If so, the thickness of the sandstone can then be calculated. On the improved stratal slice, both the shape and the thickness of the sandstone body can be clearly characterized. We employed the active learning method and novel stratal slice technology to predict the thickness of the sandstone layers drilled in 9 wells in the study area, and obtained an accuracy of 80%.

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-1: Seismic sedimentology for non-marine basins
Presentation Preference: Oral Preferred

Identification of seismic architectural characteristics of onshore meandering river reservoir based on Seismic Sedimentology

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Keywords: Seismic sedimentology, Seismic architecture, Meandering river reservoir, Chengdao Oilfield

Reservoir architecture is an important basis for studying the sedimentary evolution of underground reservoir and the distribution of remaining oil. Taking meander-river reservoir of Guantao Formation in Chengdao Oilfield as an example, characteristics of the evolution of subsurface meander-belt deposits were studied by seismic sedimentology. Seismic lithology is performed using 90° phase wavelet and frequency fusion; lithofacies are classified by combining seismically derived lithology (shaliness) and core and wireline-log description of lithology, grain size, and sedimentary structures; seismic geomorphology is conducted on seismic stratal slices. Five meandering belts were defined in the target layer, and the sediment at the bottom is characterized by the transformation from braided river to meandering river. Five fluvial architectural elements are recognized, including fluvial valley, floodplain, meander belt, sand fan, chute channel. According to logging while drilling technology of Schlumberger, the shape model of underground point bar is established. The seismic architecture, which reflect the shapes of the point-bar sandbodies in the superimposed regions between point bars, are identified by seismic forward models. Based on the seismic architecture between point bars, distribution characteristics of point bars in the meandering belt are identified and predicted by numerous continuous seismic profiles. The identified superimposed architecture between point bars and morphometric parameters of point bars are useful for the model of the target reservoir and streamline adjustment of well site.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-1: Seismic sedimentology for non-marine basins
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Seismic sedimentary interpretation and sedimentary evolution analysis of Jurassic Shaximiao Formation in Qiulin area, central and western Sichuan Basin

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Keywords: Seismic sedimentary,Fluvial facies,High resolution sequence,Sedimentary evolution, Sichuan Basin

The channel sand bodies of Jurassic Shaximiao Formation in Qiulin area of central Sichuan and western Sichuan are frequently superimposed in longitudinal period and interlaced in transverse direction. In this study, seismic sedimentology was used to characterize the sedimentary system types and temporal and spatial evolution law of Shaximiao Formation in this area, and to clarify the spatial distribution characteristics of channel sand bodies. Firstly, the isochronous interface in Shaximiao Formation is identified and the sequence stratigraphic framework is established based on high-resolution sequence stratigraphy. On the basis of establishing isochronal framework, the sedimentary facies types in this area were identified by integrating core, logging, analysis and seismic information. Then, the sandbody distribution of Shaximiao Formation was accurately characterized by using high-precision 3D seismic data, 90° phase transformation, stratigraphic section, frequency division pixel imaging, and three-dimensional interpretation of superimposed channel, and the depositional system and temporal and spatial evolution law of the area were clarified. The results show that :(1) the Shaximiao formation can be divided into two third-order sequences and five fourth-order sequences based on the widely developed phyllolimic shale in Sichuan basin as isochronous interface; (2) The Shaximiao Formation in this area is dominated by fluvial facies with obvious dual structure characteristics of fluvial facies. Delta facies and lacustrine facies are developed at the bottom and top of the first member of Shaximiao Formation. (3) Two river geomorphic types, strip-straight river and arched medium-low bend meandering river, were mainly identified in several stratum sections, and the coexistence of multiple river types was found in some stratum sections. The channel developed in high accommodating space is relatively isolated and small in scale. Low capacity allows rivers to interweave and become larger. The variation of the tolerable space controls the superposition patterns of sand bodies in different system tracts. The top of Shaximiao 1 submember and the top of Shaximiao 2 submember are in the lowest period of accommodating space, the development scale of channel sand body is relatively large, and they are the most favorable exploration and development intervals.

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Session T11-1: Seismic sedimentology for non-marine basins
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Seismic Sedimentology of Shallow Water Delta of Lianggaoshan Formation in Wubaiti Area, East Sichuan

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Keywords: Lianggaoshan Formation, shallow water delta, seismic sedimentology

The Jurassic strata have been stripped away in the anticline areas of the east Sichuan tectonic zone, but the Lianggaoshan Formation is well preserved in the widely syncline areas. The giant thick sand mudstone of the overlying Shaximiao Formation can serve as a good cover. Frequent hydrocarbon shows are seen in the Jurassic Lianggaoshan Formation in east Sichuan, but the exploration of the Lianggaoshan Formation in the east Sichuan syncline area is seriously under-recognized, which restricts the next exploration direction of the Jurassic. The old shallow seismic data have low coverage times and serious acquisition footprints; the sand body is thin, the impedance difference with the surrounding rock is small, and the geophysical response characteristics are hidden, making it difficult to characterize the sand body and quantitatively predict and describe the reservoir. To this end, on the basis of high-fidelity and high-resolution "double-high" target processing, using frequency division interpretation, multi-attribute RGB fusion, waveform classification and technology based on neural network control, and quantitative prediction of geostatistics, the research on Seismic sedimentology of the Lianggaoshan Formation in eastern Sichuan. The research results show that: (1) The two-division lake transgression-regression system tract division method is used to identify the shale with the largest lake flooding surface; The Lianggaoshan Formation is divided into two third-order sequences, and the upper section of Liangshan is further divided into four fourth-order sequences. It is determined that the Lianggaoshan Formation in the Wubaiti area mainly develops a shallow water delta system. (2) Adopt a comprehensive research idea from macroscopic to microscopic, qualitative to quantitative, and from fine characterization of appearance to insider heterogeneity evaluation. Imaging, depicting the boundary of the distributary channel sand body; The shallow water delta of Lianggaoshan Formation in Wubaiti area is mainly composed of fine-medium sandstone with high maturity, and the overall sand body is characterized by thin thickness and tight lithology. There are various distribution types of sand bodies, that is, there are distributary channel-type sand bodies dominated by river-controlled deltas, and there are also distributary sand bars controlled by lake waves. (3) Using the "sparse pulse" blind well algorithm and the "co-simulation" geostatistical algorithm, the inside of the channel sand body is finely described, and the evaluation idea of facies-controlled sand search, finding the best in the sand, and selecting the rich in the best is formed. It is concluded that the use of seismic sedimentology technology has clearly described the shape and inner reservoir characteristics of the delta distributary channel and distributary sand bar in the eastern Sichuan area, and achieved fine characterization of thin sand bodies less than λ/8. Well-configured delta front sand bodies formed by faults are favorable exploration and development targets. It points out the direction and provides technical and theoretical support for the exploration of Lianggaoshan Formation sand bodies in the eastern Sichuan area.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-1: Seismic sedimentology for non-marine basins
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Source-Sink Sedimentary Characteristics Analysis and Sandbody Identification of Deep-water Gravity Flow System

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Keywords: Deep-water gravity flow deposition, Source-conduit-sink, Wheeler transform, Seismic configuration; Sedimentary paleogeomorphology

Deep-water gravity flow deposits and their huge oil and gas exploration potential are the hotspots in the exploration of lithologic oil and gas reservoirs. The Baiyun deep-water area is located in the continental slope deep-water area of the northern continental margin of the South China Sea, where gravity flow channels and deep-water fan deposits are developed under the control of the continental shelf slope break. Gravity flow sand reservoirs have strong lateral heterogeneity, and are affected by the strong reflection of overlying limestone, making it difficult to define lithologic trap boundaries. In addition, thin sand bodies are affected by tuning effects, making it difficult to accurately predict the reservoir characteristics by conventional inversion methods. In this paper, the three-level "source-conduit-sink" coupling analysis is used to explore and study the gravity flow deposition in the Baiyun deep water area to guide the identification of gravity flow sand bodies. Firstly, the seismic data obtains multiple frequency division data volumes through wavelet transformation, performs F-X filtering, optimizes frequency bands for frequency reconstruction, highlights stratigraphic interface, carries out stratigraphic interpretation of key sequence interfaces and system and system domain interfaces, conduct research on the response of relative sea level and sequence interface, establish the sequence stratigraphic framework in the Baiyun deep water area, and describe the gravity flow deposition model of the deep water continental slope. Secondly, on the basis of Wheeler transformation, the seismic configuration analysis in the Wheeler domain is carried out, and the well-seismic combination is carried out to correlate the sedimentary lithology of the well with the paleospace seismic configuration, and establish a quantitative version for the seismic configuration interpretation of the reservoir sand body. Finally, Finally, through the analysis of sedimentary paleogeomorphology, continuous stratigraphic slice analysis, gradient structure tensor attributes, etc., study the sequence sedimentary interior and the "source-canal-sink" sedimentary structure response relationship, and analyze the supply background, transportation pipeline, depositional microscopic interior, depositional process, storage conditions and trap properties of the lobes of the continental slope gravity flow channel and the deep-water fan, to identify the distribution of gravity flow sand bodies. The third-level "source-canal-sink" coupling study of deep-water gravity flow deposition organically combines the profile configuration elements of sequence stratigraphy, the paleogeomorphic elements of source-sink analysis, and the plane seismic configuration elements of seismic deposition. Analyzing the distribution of depositional systems and reservoir architectural units from the perspective of depositional process and depositional origin provides a new idea for depositional analysis and reservoir sand body identification.

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Application of "source-canal-sink" ternary seismic sedimentary analysis in thin interbedded reservoir prediction——Taking A gas field in Xihu sag as an example

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Keywords: source-canal-sink, thin-layer interference, K-means clustering, Huagang Formation

The Huagang Formation of the A gas field in the central and southern part of the central inversion structural belt in the Xihu Sag has a fluvial-delta depositional environment and is a typical facies-controlled low-permeability gas reservoir. The favorable reservoir is the distributary channel. The gas abundance is higher, so the fine characterization of reservoir traps is of great significance to increase the reserves and production of the A gas field. The study area has thin interbedded sediments of sand and mud, with low seismic vertical resolution, severe interlayer interference, strong heterogeneity of planar channel reservoirs, and difficulty in identifying sand body boundaries. In view of the above problems, this paper adopts the "source-canal-sink" ternary seismic sedimentary analysis idea on the basis of previous research, firstly analyzes the paleogeomorphology and provenance of the study area through Wheeler domain transformation, and establishes a seismic configuration template. Two types of geological targets, such as distributary channels and distributary bays, were identified; secondly, surface block slices were used to eliminate interlayer interference, and 3 slices reflecting the distribution characteristics of river channels in different stages were extracted, and K-means artificial intelligence multi-attribute clustering technology was used to make research. Finally, combined with the seismic configuration template, the topography and semi-quantitative sand body configuration interpretation were carried out to clearly describe the early, middle and late channel sedimentary plan of the H5 sand formation in the target area. The results show that the Huagang Formation in the study area was flat during the depositional period, and developed two provenance areas, axial and lateral; the H5 sand formation in the target layer as a whole is a vertical superimposed complex of migratory channels, and three early, middle and late are identified. Period channel: In the early stage, the NW-trending source crossed channel was developed, converging to the southeast, in the middle stage, the lateral migration channel was developed, which was vertically stacked, and the axial single channel was developed in the late stage.

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Session T11-1: Seismic sedimentology for non-marine basins
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Seismic sedimentology fine characterization of deep-lake turbidites in continental lacustrine basin based on genetic knowledge --taking 3rd member of Shahejie Formation in Niuzhuang Sag of Jiyang Depression in China as an example

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Keywords: deep-lake turbidites,Seismic sedimentology,Jiyang Depression,Sedimentary characteristics

Geological knowledge gained through years of exploration and development suggests that there are three types of gravity flow deposits in Niuzhuang Sag: slump, detrital flow and turbidity current.The development location and scale of different types of gravity flow are different. On the basis of understanding the sedimentary law of deep-lake turbidites in this area, combining with drilling, logging, logging and seismic data, the main sand body in Niuzhuang oilfield is divided and compared.By means of fine calibration of well seismic synthetic record, selection of regional well backbone profile and fine interpretation of regional marker layer sand group, the major cycle correlation of turbidite deposition is carried out to complete the work of regional stratigraphic series.The deep-lake turbidites types, lithologic assemblage characteristics and distribution of different sand body genetic models are defined:In the northern fault trough belt, clastic channel and turbidity fan are mainly developed. The lithologic assemblage features are thick interbedded sand and thin interbedded sand respectively.In the southern restricted step-fault zone, slump sand bodies are mainly developed, and tThe lithologic assemblage features is isolated thick sand bodies.In the southern open fault step, the inner fan of debris flow and outer fan of turbidity flow are mainly developed, which are characterized by the lithologic combination of sand and mud thin interbedding. Based on actual seismic data and forward modeling, the seismic facies characteristics of different sand body genetic models are clarified.The typical seismic profile of gravity flow in the northern fault trough zone has the characteristics of strong amplitude, continuous and parallel reflection.The gravity flow in the southern restricted step-fault zone is characterized by strong amplitude and pod-like intermittent reflection.The gravity flow in the southern open step-fault zone has the characteristics of weak amplitude, medium continuity and disorderly reflection.Further, according to the characteristics of seismic data in the study area, the seismic data that can best reflect the sedimentary characteristics of turbidite sand body is selected. By analyzing the quality of seismic data, the forward model of turbidite sand body is designed according to the genetic type.Therefore, appropriate processing parameters are defined to obtain better quality seismic data. Through the well-seismic combination method, multi-well sand body is fully used to fit and match the optimal seismic attributes, and seismic sedimentology technology is used to complete the fine characterization of turbidite sand body combined with inversion prediction results.

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Seismic sedimentology interpretation of reservoirs with complex acoustic impedance contrast between sandstone and mudstone

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Keywords: fluvial-deltaic system,seismic sedimentology, seismic lithology,AVO attributes

Abstract: The acoustic impedance contrast between sandstone and mudstone is the basis for using 3-D seismic data to predict lithofacies and interpret sedimentary facies, but in sandstone reservoirs in complex sedimentary environment, the spatial variation of the acoustic impedance contrast between sandstone and mudstone brings multiple solutions to seismic lithology prediction. In this study, we took the ancient fluvial-deltaic system in the East China Sea Basin as the main object to conduct the research where had three types of sandstone with different acoustic impedance from mudstone: low-AI (type A) sandstone, overlapped-AI (type B) sandstone, and high-AI (type C) sandstone. The spatial variation law of the acoustic impedance relationship between sandstone and mudstone is summarized by the petrophysical analysis of well logs. And then a seismic lithological prediction method was proposed by the identification ability of different elastic parameters on the above three types of sandstone. The study found that: 1) The burial depth controlled the acoustic impedance relationship between sandstone and mudstone, and with the burial depth increasing three types sandstone were developed sequentially (type A - type B - type C);2) The western part of the study area was dominated by A-type sandstone. The central and eastern parts were dominated by B-type sandstone, and C-type sandstone was developed in the deep southeast; 3) AVO attributes G was used for interpretation of B-type sandstones, and seismic attributes from post-stacked seismic -90° phase shift data was used for interpretation of A-type sandstones ,and seismic attributes from post-stacked seismic 90° phase shift data can interpret C-type sandstones better;4) The ‘stratification- Partition’ seismic lithology prediction method was established to interpret the planar distribution of fluvial-shallow water delta sedimentary system in the study area. The results show that a river-dominated area developed in the northern part of the study area was characterized by stable skeleton drainage system and large channel sand body, and in the south shallow-water deltaic deposits was developed characterized by multistage superimposed and contiguous sand bodies. The sedimentary model of the fluvial-deltaic system was established to predict the reservoir in study area, and the reservoir prediction results were verified by drilling.

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2D convolutional neural network driven seismic multi-attribute method for sand thickness prediction in sparse well area

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Keywords: 2D convolutional neural network,shallow water delta,seismic multi-attribute, sand thickness, sparse well area

The prediction of sand thickness by seismic attributes is an important method for the study of sedimentary facies in oilfield exploration, but the lack of effective methods to construct the nonlinear relationship between seismic attributes and sand thickness and the lack of samples in sparse well areas restrict the prediction accuracy and reliability. Tianwaitian area in the Xihu Sag is taking as an example to explore the method of seismic multi-attribute prediction of sand thickness distribution in shallow water delta in sparse well area. Cluster analysis is used to optimize seismic attributes; the method of two-dimensional image valuing is taken to improve the reliability of seismic attribute value; virtual samples obtention from image rotation symmetry is used to expand the sample set. Based on the above process, 2D convolution neural network model is built to predict the plane distribution of sand thickness in the study area. The result is compared with BP neural network and SVM. The results show that the two-dimensional image value and virtual sample construction method of well point seismic attributes effectively solve the problem of insufficient sample size in sparse well area. On this basis, the 2D convolution neural network method can significantly improve the prediction accuracy. This method provides an effective solution for the prediction of sand thickness of complex clastic rock reservoir combined with well seismic in sparse well area.

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Study on sedimentary microfacies and sand body prediction of tight reservoir based on well seismic reservoir data

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Keywords: high-resolution 3D VSP and 3D seismic, sedimentary microfacies, Waveform indicating inversion, sweet sand body

The study area is located in an oil field in a basin in eastern China. It belongs to a low porosity and low permeability structural lithologic reservoir with tight sandstone under the sedimentary background of the lower Cretaceous delta front. Structure controls reserves, sedimentation controls reservoir types, and facies belts and physical properties control reservoir quality. Due to the low density of actual well pattern (well spacing greater than 400m), large spatial variation and uneven distribution of sedimentary microfacies, tight sand thickness (3-20m), physical parameters (porosity 11% - 23.4%, permeability 0.5-206md), and insufficient resolution of previous seismic data, it is very difficult to accurately describe tight sandstone reservoir.

Joint acquisition and processing based on the high-resolution 3D VSP and 3D seismic, this paper adopts the "well seismic reservoir" integrated reservoir fine description technology series, that is, the well point logging sedimentary microfacies (based on core thin section, logging facies analysis, etc.) calibration constrained seismic sedimentary facies technology, high-resolution seismic reservoir feature interpretation technology (fine structural analysis, paleogeomorphic restoration, multi-attribute analysis, etc.) Waveform indicating thin reservoir inversion prediction technology, sweet sand body distribution optimization technology based on production data, etc., qualitatively + quantitatively identify and predict four types of reservoir sedimentary microfacies, and characterize the spatial distribution of (3-10m) thin sand body and effective sweet sand body.

Based on the geological results and production data of structure, sedimentary microfacies, sand body prediction, the sweet sand bodies of the tight reservoir of the target strata in this area are finally classified and zoned, and 13 sweet sand body distribution areas above 5m are newly delineated, with the geological reserves of 25 million tons. Penetration rate of sweet sand body in horizontal well increased from 45% to 95%, which well guided the horizontal well drilling; The coincidence rate of well seismic of reservoir sedimentary microfacies and thin sand reservoir characteristics has increased by 30%.

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Precise Depicting Thin Fluvial Channel Sand Bodies Based on High-Precision Frequency Division Technique

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Keywords: Thin fluvial channel sand body, Frequency division, Zero-crossing time, Tuning frequency, Thickness

Prediction of thin-bed geometry and stacking patterns using seismic data is always a challenge. The identification of thin fluvial channel sand bodies in the complex sedimentary environment and the lateral heterogeneous depiction of reservoirs are key issues in the current seismic processing. In this paper, based on the comprehensive analysis of high-precision frequency-divided seismic data and high-precision horizon data, a case study of predicting thin fluvial channel sand bodies is carried out. At the zero-crossing-time points, a thin bed's reflection makes no contribution to the composite response. Therefore, for different frequency-divided seismic data volumes with 90° phase, we find out the stratigraphic slices that can reflect the distribution characteristics of single sand body from consecutive amplitude slices. Different thicknesses of fluvial channel sand bodies correspond to different tuning frequencies. Based on the frequency division by using high-precision wavelet transform and ZCTs at the tuning frequencies, we can estimate the thin sand bodies thickness and obtain the lateral distribution of each thin bed according to different tuning amplitudes in seismic reflection corresponding to components of tuning frequencies. Two synthetic examples (one simple model with two sand bodies and one complex model with six sand bodies) and field data examples justify the feasibility and reliability of the proposed method in characterizing interbedded fluvial channel sand bodies.

In this paper, we first perform the high-precision frequency-division process to obtain the seismic data volumes with different dominant frequencies. Then, we introduce the zero-crossing-time (ZCT) amplitude slice with its potential in depicting thin fluvial channel sand bodies. Next, the thickness of fluvial channel sand bodies at their tuning frequencies can be accurately estimated from their ZCTs. Finally, we use two sets of synthetic 3D seismic data and one field data set to discuss the identification of thin sand bodies from consecutive amplitude slices. Notably, more precise horizons will help us obtain better results.

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Study on Sedimentary Model and Quantitative Reservoir Prediction of J Oilfield in Bohai Area

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Keywords: sedimentary model, regularity of reservoir distribution, seismic facies; seismic attributes, reservoir prediction, increase reservoir production

In the early stage of development, the J Oilfield in Bohai Area is faced with problems such as few exploration well data, large well spacing, unclear understanding of provenance direction and sedimentation model, and rapid lateral changes in reservoir, which seriously restrict the implementation of development plan. Making full use of core, drilling and logging data to carry out sedimentary facies research, it is considered that the second member of Shahejie Formation in the J Oilfield mainly develops braided river delta front subfacies with far provenance in the northwest direction. Four types of sedimentary microfacies are identified, including underwater distributary channel, tributary bay, mouth bar, and distal bar. Through seismic facies, seismic attributes and seismic forward modeling technology, the superimposed characteristics of the braided river delta front sedimentary sand bodies with five different branch provenances on the plane of the J Oilfield and the plane distribution range of the sand bodies in each period are finely described. Then the fine sedimentary model of the study area is established. Based on the constraints of the sedimentary model and through the optimization and correlation analysis of seismic attributes, a set of techniques and methods for quantitative prediction of reservoir thickness by fusion of multiple seismic attributes are explored. The error range between the predicted reservoir thickness and the actual drilled reservoir thickness of the development wells is within 6 meters, which improves the accuracy of mid-deep reservoir prediction in J Oilfield. Through the study of fine deposition model and quantitative prediction of reservoir thickness, the risk and potential of oilfield are fully recognized, which guides the implementation of well location deployment and development plan to successfully realize the high efficiency evaluation of oilfield potential. Oilfield development practices have confirmed that the newly-added proven petroleum geological reserves in the J Oilfield exceed 8 million cubic meters, and more than ten new development wells have been added. The average productivity of a single well exceeds the pre-drilling design by 1.7 times, and a double harvest of reserves and production has been obtained. This research result has a good reference significance and enlightenment for the development of similar oilfields.

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Session T11-1: Seismic sedimentology for non-marine basins
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Reservoir prediction of channel sublacustrine fan in the third member of Shahejie Formation, Laizhouwan Depression, Bohai Sea

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Keywords: channel sublacustrine fan, deposition and reservoir prediction, faulted lacustrine basin, the middle sub-member of the third member of Shahejie Formation, Laizhouwan Depression

Large channel sublacustrine fan lithologic traps are in the third member of Shahejie Formation in Laizhouwan Sag, Bohai Bay Basin, with good reservoir forming background and great exploration potential. However, the sedimentary characteristics of sublacustrine fan are not clear, and the reservoir distribution is difficult to be delineated, which restrict the exploration process.

Therefore, under the guidance of seismic sedimentology and sedimentology theory, a method of optimizing attributes based on seismic facies analysis of different gravity flow channel types was proposed, and the distribution of sublustrine fan was described in detail with plane section, and favorable reservoir development area was finally established. It is recognized that the sublacustrine fan channel has the chaotic characteristics of medium and weak amplitude, which is obviously different from the parallel and continuous strong amplitude reflection of lacustrine mudstone. Based on this, coherent properties of frequency division dip angle, seismic structure attribute based on gray level co-occurrence matrix and waveform classification technique of neural network were selected to characterize the boundary of sublustrine fan and the inner channel.

The development of sublacustrine fan was mainly controlled by fault slope break and palaeogeomorphology.The gravity flow formed a watercourse fan body spreading NE, which advanced and extended to the low potential direction of palaeogeomorphology perpendicular to the strike of fault slope break.The gravity flow advances and extends to the low potential direction of the palaeogeomorphology perpendicular to the fault slope break, forming a watercourse fan body spreading in the northeast direction.The microfacies from south to north shows as "confined channel complex →superimposed channel complex and flank edge → interchannel → deep lake mud".Under the slope break of F1 fault, influenced by the pre-existing limited geomorphology, two restricted channel complexes developed in the first slope break zone, which were wide and thick..A plurality of single channels with small width are developed in the interior, and the single channels are superimposed and cut each other.Under the slope break of F2 fault, the landscape gradually slow, with the increase of transportation distance, the channel's effect on the fluid is gradually weakened, Sandy debris flow gradually diffuses to both sides and transforms into high-density turbidity current.Moreover, the diverging effect of the internal waterway gradually increases, and the main waterway gradually changes from a relatively straight branch waterway with flanks to a curved branch waterway.The thickness and availability of the reservoir also deteriorate from south to north.

The sedimentary distribution characteristics of sublacustrine fan reservoir in this area are clarified, which provides a basis for exploration and well distribution.The bohai channel sublacustrine fan sedimentary model was established, which enriched the sedimentary types of paleogene sublacustrine fan in Bohai Sea.The technical combination of this kind of reservoir prediction is established, which will guide the reservoir prediction of related types in Bohai sea area effectively.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-1: Seismic sedimentology for non-marine basins
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Application of Cauchy constrained inversion method in microfacies characterization of shallow water deltas - Taking Pinghu Formation in a depression in the East Sea as an example

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Keywords: Sea-land transition, Weak reflection coefficient,Cauchy constrained inversion, Sedimentary microfacies characterization

Shallow water deltas are developed in a depression slope belt in the East China Sea. Under the background of sea-land transition, the lithology changes quickly in lateral direction under the influence of rivers and tides. Meanwhile, due to the impedance superposition of middle-deep sandstone and mudstone, the difference of seismic reflection coefficient is small, which makes it difficult for conventional inversion technique to meet the requirements of fine characterization of the lithology. Therefore, fine characterization of sedimentary microfacies in the study area is difficult.In this paper, Cauchy constrained inversion method is applied to lithology identification that contributes to describe the sedimentary microfacies, which firstly combines the longitudinal low-frequency trend of rock physics with the transverse sensitive seismic information of different lithofacies, to establish optimized model that is more consistent with regional geological knowledge. As to solve weak seismic reflection coefficient problem, forward three-parameter Cauchy prior distribution was put to regularize the inversion parameters and the long tail feature of Cauchy distribution was used to protect the weak reflection information, which can improve the prediction accuracy of thin reservoir inversion. The application of three-parameter Cauchy constraint inversion in the target area indicates that the technique can effectively improve the vertical and lateral resolution of lithology prediction. Finally, based on the data of core, single well and interwell, Cauchy constrained inversion results are used to describe the sedimentary microfacies in each system tract of Pinghu Formation and analyze their evolution characteristics.

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Session T11-1: Seismic sedimentology for non-marine basins
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Early Cretaceous Sequence Stratigraphy and Sedimentary System in Doseo Basin, Chad

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Keywords: Doseo Basin,Early Cretaceous,Sequence stratigraphy,Seismic sedimentology,sedimentary system

Seismic sedimentology is an emerging fringe subject that uses seismic data to study sedimentary rocks and their formation processes. It is an effective tool for high-frequency sequence and sedimentary system research in the stage of oil and gas exploration and development. Exploration of Chad's Doseo Basin is currently in early stages. Under the guidance of the theory of seismic stratigraphy and seismic sedimentology , We carry out seismic facies analysis in the 2D seismic data area, and 90° phase conversion, stratigraphic slicing, frequency division interpretation, etc. in the 3D seismic data area. Combined with drilling and coring data, the sequence stratigraphy, sedimentary system types and distribution of the Lower Cretaceous in the Doseo Basin are systematically analyzed. The research results show that the Doseo Basin is a narrow and long dustpan-shaped fault depression characterized as “northern fault besides southern stratigraphic overlap”, and can be divided into two depressions , an uplift and two slopes. Eight sequence boundaries can be identified in the Lower Cretaceous, and seven third-order sequencesSQ1~SQ7can be devided, which are represented by two water transgrassive-water regressive cycles. During the depositional period of SQ1 and SQ2, the topography of the basin fluctuated greatly, the sediment supply was sufficient, and the grain size of the sediments was relatively coarse. The sediments mainly came from the northern, central and southern paleo-uplifts. The sedimentary system of alluvial fan-fluvial-braided river delta was mainly developed in the southern fault terrace belt. In the northern steep slope zone, there were nearshore subaqueous fans and fan delta deposits, but no sublacustrine fans. During the depositional period of SQ3 and SQ4, the paleo-geomorphology tended to be flat, and the sediments mainly came from the east and south of the lake basin, extending a long distance to the northern steep slope zone. Normal delta deposits were developed in the southern fault terrace belt. The northern steep slope zone was dominated by the development of fan delta and nearshore subaqueous fan deposits which were superimposed with semi-deep lacustrine mudstone, and sublacustrine fans developed in front of the fan delta. The northeastern part of the basin developed braided river delta deposits that flow into the lake along the long axis of the basin. During the depositional period of SQ5 and SQ6, the lake deposition further expanded, and the delta depositional system took the dominant position. During the deposition of SQ7, the lake gradually shrank, and the lake basin was dominated by fluvial coarse clastic deposits. The sedimentary filling evolution of the basin shows that the delta front sand bodies in the central low uplift belt and the southern fault terrace belt, the fan delta front and nearshore subaqueous fan sand bodies in the northern steep slope belt are the most favorable reservoir for oil and gas exploration. Using seismic stratigraphy and seismic sedimentology methods to study the sequence framework and the distribution of sedimentary systems in the new exploration area provides an important basis for the subsequent exploration and development of the Doseo Basin.

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-1: Seismic sedimentology for non-marine basins
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Prediction of the thin interbedded sandstone reservoir base on seismic sedimentology: A case of Dongying formation in Zhuangxi area, Zhanhua Sag,Bohai Bay Basin

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Keywords: Thin-interbedded reservoir, Seismic sedimentology, Seismic meme inversion, Spacial distribution of sandbody, Reservoir thickness prediction

Seismic sedimentology is a new multidisciplinary subject, which develops on seismic stratigraphy and sequence stratigraphy, and plays an important role in the prediction of thin reservoirs in terrestrial rift basins. Zhuangxi area is a typical terrestrial rift sub-basin with strong tectonic activity, multiple sediment source areas and rapid lateral change during the sedimentary period of the Dongying Formation. The thin sand-mud interbed reservoir is the main one of the Dongying Formation. The scouring and overlaps of multi-stage sandbodies cause complex internal reservoir architecture and seriously restrict the development of this area. The present study successively employes sequence stratigraphic framework building, sandbodies plane distribution analysis and reservoir thickness prediction to explore the thin sand-mud interbed reservoir whose total thickness is less than the limit of the vertical seismic resolution. The resolution of the original seismic data of the study area is 25 meters (the dominant frequency is 25Hz), which is challenging to carry out the fine stratigraphic division. Therefore, the sequence stratigraphic framework builds on the frequency raising and widening data, and the sedimentary face types in this area are identified by combining with logging and core data. The results show that the Dongying Formation in Zhuangxi area is divided into five third-order sequences (SQ5, SQ4, SQ3, SQ2, SQ1 from bottom to top), which mainly developes braided river delta, shallow braided river delta and gravity flow sedimentation. Controlled by the paleotopography of rift sub-basin, the sedimentary genetic types of sand bodies in steep slope zone are mainly underwater distributary channel of braided river delta, river mouth bar and slump turbidite fan, and the sedimentary genetic types of sand bodies in gentle slope zone are mainly underwater distributary channel of shallow braided river delta and beach bar. Then the spatial geometry of sandstone and evolution of the sedimentary system are defined by reservoir seismic sedimentology analysis through 90°phase conversion, stratigraphic slicing and color blending. The results indicate that the lake level decreases gradually during the period of the Dongying Formation and accompanies by the sedimentary evolution from prodelta to braided fluvial river delta front or shallow braided river delta front from bottom to top. The sandbodies of SQ2 and SQ1 sequences are distributed in sheet shape with a large scale. The sandbodies of SQ4 and SQ3 sequences are roughly distributed in a banded shape in the trend of the NE-SW direction. The sandbodies of the SQ5 sequence are distributed in point shape with the smallest scale. Based on the present results, five to ten meters thin sandbodies are accurately predicted longitudinally through seismic sedimentology and seismic meme inversion which can make full use of the lateral variation information of seismic waveform to establish a crosswell model and has good inter-well prediction ability to predict the thickness of thin interbed.

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Session T11-1: Seismic sedimentology for non-marine basins
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Application of Seismic Sedimentology in the Study of the Shallow Water Delta in the Kangning Gas Field, Ordos Basin

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Keywords: sedimentary evolution,seismic sedimentology,shallow water delta,Ordos Basin

Kangning Gas Field is located in the eastern Ordos Basin, at present, the Kangning Gas Field has entered the stage of full-scale development, with strong reservoir heterogeneity and frequent vertical stacking of sand bodies. The drilled production wells reveal that the gas layer thickness in the Kangning Gas Field changes rapidly, and the drilling productivity varies greatly. However, the resolution of the seismic data in the study area is low, and the main frequency is about 32 Hz, which is difficult to meet the requirements of sedimentary microfacies analysis. In response to the above problems, this paper takes sequence stratigraphy, modern sedimentology, seismic sedimentology and other disciplines as the theoretical basis, and takes the fourth member of the Permian Shihezi Formation (H4) as the research object to carry out a fine characterization of the shallow water delta sedimentary system and guide the efficient exploration and development of the Kangning Gas Field.

Seismic sedimentology research is an important means for the exploration and development of lithologic reservoirs and the fine carving of sedimentary microfacies. Using seismic sedimentology in the fine study of the shallow water delta sedimentary system in the Kangning Gas Field, this study established a technical system for the characterization of shallow water delta channel sand bodies. That is, (1) the well-seismic combined sequence stratigraphic framework is constructed under the guidance of sequence theory, (2) the seismic lithologic stratigraphic significance is given by the phase adjustment technology, (3) the distribution law of sand bodies is clarified by means of seismic stratigraphic slices, (4) the frequency division attribute finely describes the distribution of sand bodies with different thicknesses.

From bottom to top, H4 Member is divided into three sand layer groups, corresponding to the lowstand, water transgression, and highstand system tracts respectively. The H4 Member developed shallow delta plain facies, mainly including braided distributary channels, sand bars and inter-channel deposits. A channel sand body characterization technology system based on seismic sedimentology, and a corresponding sedimentary evolution model had been established. The distribution of sedimentary facies has the characteristics of " distributary channel dominates, developed sand bars, and lateral migration". The superposition of multi-stage sand bodies during the low-stand and water-transgressive periods is the core cause of the distribution of thick sandstone and glutenite in the H4 Member. Distributary channel microfacies and sand bar microfacies are the main sedimentary facies belts contributing to productivity, providing favorable storage space for the formation of lithologic reservoirs. The study of shallow water delta sedimentary system based on sedimentology and seismic sedimentology is of great significance for guiding the exploration and development of lithologic reservoirs.

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Session T11-1: Seismic sedimentology for non-marine basins
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Discussion of seismic diagenetic facies of deep reservoir in the East China Sea Basin

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Keywords: Seismic diagenetic facies, Stratal slicing, Seismic sedimentology, Supervised learning, Tight sandstone, Xihu sag

Evaluation of seismic diagenetic facies is an effective interpretation procedure to characterize the spatial distribution of diagenetic facies in deep tight sandstones in offshore sparse well areas. Based on petrographic and seismic data, research on seismic diagenetic facies was used in the proposed workflow to predict the spatial distribution and distribution characteristics of seismic diagenetic facies for the third (H4c) sub-member of the fourth (H4) member of the E3h Formation in the Xihu Sag, East China Sea Basin, Eastern China. Herein, two discriminant functions between the core-derived diagenetic facies and the seismic elastic parameters of shear modulus, p-wave impedance, and porosity data volume were established using the supervised learning method, and seismic data X and seismic data Y containing diagenetic facies information were evaluated. Based on the linear function between seismic data X and seismic data Y, a new seismic data volume was calculated and a comprehensive index of diagenetic facies was proposed to describe the distribution of diagenetic facies. The comprehensive index of diagenetic facies can better identify the spatial distribution of diagenetic facies. The results of seismic diagenetic facies research mainly focused on (1) the spatial distribution of diagenetic facies and (2) the distribution characteristics of diagenetic facies. Based on core-derived diagenetic facies, typical stratal slices, and sedimentary microfacies, the spatial distribution of seismic diagenetic facies in the two sublayers of the H4c sandstone was accurately interpreted. The northern part of the H4c1 and H4c2 sublayers mainly developed quartz-cemented facies and a small amount of chlorite-coated quartz facies. The southern part and the surrounding areas of the H4c1 and H4c2 sublayers primarily developed tightly compacted facies. The area near four (F1, F2, F3, and F4) faults in the H4c1 sublayer mainly developed a small amount of dissolution facies, whereas the area near the F2 and F4 faults in the H4c2 sublayer primarily developed a small amount of dissolution facies. Furthermore, the distribution characteristics of seismic diagenetic facies were investigated from the perspective of sedimentary microfacies and diagenetic facies. The chlorite-coated facies is mainly distributed in the subaqueous distributary channel sedimentary microfacies. The dissolution facies is primarily distributed in the subaqueous distributary channel and sheet sand sedimentary microfacies near the faults. This study shows that the research of seismic diagenetic facies using petrographic data and seismic data can better predict the spatial distribution of diagenetic facies of deep tight sandstone.

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Seismic sedimentology study of Shihezi Formation in Kangningxi areaOrdos Basin, China

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Keywords: Ordos Basin, the west of Kangning Area, Shihezi Formation, seismic sedimentology, shallow braided river delta

The thin sand body reservoir of Shihezi Formation in Ordos Basin is rich in natural gas resources. Traditional research methods are difficult to depict its sedimentary microfacies and predict the distribution of favorable reservoirs while seismic sedimentology can accurately characterize the temporal and spatial distribution and evolution of its thin sand bodies. Integrating data from the comprehensive study of seismic sequence and drilling and logging sequence shows that Shihezi Formation in the west of Kangning area can be divided into four third-order sequences and nine fourth-order sequences under the guidance of sequence stratigraphy theory. Guided by sedimentology theory, it is clear that the sedimentary period of Shihezi Formation was basically in shallow water environment, and the sedimentary facies was mainly shallow braided river delta in the study area after a detailed investigation of regional geological background data as well as core data, drilling and logging data and seismic facies analysis. The seismic sedimentology research on key sequences is carried out under the guidance of seismic sedimentology. Firstly, we use the spectral inversion technology to increase the frequency of three-dimensional seismic data, and then establish the good correspondence between thin sand body and seismic reflection by 90 degree phase shift. Finally, we use frequency division, stratal slices, RGB attribute blending techniques and lithology calibration to study and depict the sedimentary facies of key sequences (SQh6, SQh4, SQh3 and SQh2). During the depositional period of SQh6 and SQh4 of Shihezi Formation, the lake level decreased slowly and underwater channels bifurcated and merged and oscillated frequently; in SQh3 sedimentary period, the inner front of shallow Braided River Delta continued to develop, but the underwater channel widened; In SQh2 sedimentary period, the delta advanced as a whole. Combined with the study of gas testing data, porosity and permeability data and stratal slices, we predict the zone of favorable sand bodies of key sequences, which is mainly determined by the distribution area of favorable sedimentary microfacies and thicker single sand body thickness (generally greater than 3m).

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-1: Seismic sedimentology for non-marine basins
Presentation Preference: Oral Preferred

Geological modeling of fan Delta Reservoir guided by seismic sedimentology and constrained by evolution and origin information --A case study of the upper fan-delta front subfacies of Es31 in Gangzhong Oilfield

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Keywords: fan delta, Seismic sedimentology, geologic modeling, gangzhong oilfield, origin and evolutionary information

The ES31 formation in the eastern Gangzhong area of beidagang secondary structural belt in Huanghua Depression is characterized by fan-delta deposition, rapid change of sedimentary facies, significant difference of lithologic assemblage, unclear understanding of the law, and strong heterogeneity within the reservoir, which restricts the understanding of uneven distribution of oil and gas and seriously affects the formulation and implementation of subsequent development plans. Therefore, taking gangzhong area as an example, the fan delta distribution in the study area was characterized by integrating core, well logging and seismic data. Under the guidance of depositional model, strata sections were extracted to analyze the evolution process of genetic units. This information is transformed into probability body to control geological modeling, and the geological model constrained by genetic and evolutionary information is established with the identification results of well data as hard data. Six lithofacies and four lithofacies combination types are identified. There are two fan delta groups in the study area, which are formed by the convergence of several channels. The two fan delta groups are gradually connected laterally along the provenance direction, forming the continuous distribution of fan Delta front sedimentary belt. By analyzing the sedimentary model of the study area and extracting the genetic and evolutionary information from the well and seismic data, the three-dimensional geological model of braided river reservoir is constrained to improve the rationality of the geological model.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-1: Seismic sedimentology for non-marine basins
Presentation Preference: Oral Preferred

Thin bed prediction from interbeded backgrounda new approach base on seismic sedimentology

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Keywords: thin-bedded reservoir, stratal slicing, seismic sedimentology, AVF, Junggar basin

Thin inter-bed< λ/4 in thicknesswhere λ is the length of waveform reservoir is important in non-marine postrift basins. However, thin bed prediction from the interbedded background is a challenging work for the seismic interpreters because of the limitation of seismic vertical resolution. Interference from other thin layers in seismic reflections has great negative impact on the thin-bedded reservoir prediction. To deal with this, Zeng proposed to analyze the changes of thin inter-bed by using slice sequence and then obtain the distribution of each thin layer. Li analyzed the interference process of thin interlayer and predicted the thin layer by decreasing slice interval to 0.2ms for searching zero-value slices without interference. Based on the zero-value slicing idea, we propose two novel approaches that can improve the accuracy of thin-bedded reservoir prediction by suppressing the interference with the help of seismic sedimentology. The proposed methods can accurately predict the plane distribution of an individual sand body within thin-bedded strata which is indistinguishable from a seismic profile. By using the amplitude versus frequency (AVF) attribute estimated by wavelet transform, the first method, named as Minimum Interference Frequency (MIF) slicing, can find a constant seismic frequency by which the adjacent layers show the minimum influences on the stratal slice of target layer. An optimal slice can be then obtained by dividing seismic data with the constant frequency mentioned above in frequency domain. Moreover, the second method, superimposed slicing, can suppress the interferences of thin beds by weighted stacking the multiple stratal slices of neighboring layers. The weight coefficients are estimated based on the spatial relation between the adjacent and target layers. A field example from Junggar Basin, Northwestern China, is carried out to validate the effectiveness of the two proposed methods in detecting an oil-bearing layer with a thickness of 6m from a thin-bedded reservoir with three sets of thin layers. A comparison with the well-log curves suggests that the proposed methods bring us a better prediction of thin-bedded reservoir than the traditional slicing approach.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-1: Seismic sedimentology for non-marine basins
Presentation Preference: Oral Preferred

Recent progresses in seismic sedimentology: improving thin bed prediction in lacustrine basins

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Keywords: Seismic sedimentology, seismic geomorphology, seismic lithology, stratal slicing

Depositional systems in lacustrine basins are dominated by seismically thin sand bodies. Most of hydrocarbon plays contain a large number of interbedded, thin (1-10 m) sandstone reservoirs. Standard seismic sedimentology uses seismic lithology (shaliness, relative impedance, etc.) to generate seismic-geomorphologic (stratal slice) volume for sedimentary study at seismic scale. In the thin-bed domain, however, seismic sedimentology faces challenges. In thin-bedded sequences, seismic geomorphology is compromised if chronostratigraphic assumption of seismic reflections and stratal slices is violated; seismic lithology is limited by seismic resolution (for geologists, it is typically restricted to dominant seismic resolvable limit at a quarter wavelength).

In recent years, there have been notable progresses in both aspects of seismic sedimentology. The most significant development in stratal slicing is the hybrid stratal slicing, i.e., to combine auto-tracking and proportional slicing (Wang et al., reviewing). In the seismic lithology side, progresses have been seen in reducing sidelobe and tuning effects and in improving resolution. Ni et al (personal communication) Tested stratal slicing at the minimum interference frequency and by suppressing interference by subtraction. Frequency fusion (Zeng, 2017; Zeng et al., 2021) reduces tuning with higher resolution (at least double the dominant frequency) and a wider sandstone body imaging range (1/16-1 wavelength). Seismic wavelet effect can be partially reduced by model-based seismic inversion. The Most promising development, however, is machine-learning based inversion or estimation (e.g., Hampson et al., 2001; Das et al., 2019), which train seismic traces for lithology logs (e.g., gamma ray) with many benefits. Models and field-data applications in lacustrine basins will be presented to support this study.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-1: Seismic sedimentology for non-marine basins
Presentation Preference: Oral Preferred

Sand supply mechanism and its hydrocarbon significance in Paleogene of the northern Huanggekou Sag, Bohai Bay basin, China

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Keywords: the Bonan Upliftbasin evolution, parent rock recovery, provenance evolution, reservoir cap assemblage

The Bonan Uplift is a submarine low uplift located between the Huanghekou Sag and the Bozhong Sag. In Paleogeneas the parent rock areathe parent rock type and distribution of the Bonan Uplift were not clear, making it difficult to understand the reservoir forming conditions of the northern Huanggekou Sag. Firstly, the uplift's evolution history and provenance characteristics were recovered based on different main fault depression periods of the two adjacent sages. Secondly, the provenance direction and the deposit range were studied and predicted using the paleogeomorphology characteristics and well seismic data. Finally, the Bonan Uplift's provenance evolution and its favourable role on hydrocarbon accumulation were discussed. The results suggested: (1) From Paleocene to Eocene, a large area of the Bonan Uplifted was denuded and supplied sediments southward to the Huanghekou Sag; (2) From Late Eocene to Early Oligocene, as the Bozhong Sag rifted strongly, the Bonan Uplift rotated, tilted and subsided, resulting in weakened sand supply capability; (3) The Bonan Uplift's provenance role varied in different geological periods, forming superior Paleogene reservoirs in the northern and central parts of the Huanghekou Sag, which is favorable for the vertical petroleum preservation.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-1: Seismic sedimentology for non-marine basins
Presentation Preference: Oral Preferred

Application of seismic sedimentology to characterize the S2S and thin sandbodies in Chinese continental basins

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Keywords: Seismic sedimentology, Key technology, Sequence framework, Source to sink, Thin sandbodies, reservoir architecture

Seismic sedimentology is a new interdiscipline of sedimentary geology and geophysics based on seismic stratigraphy and sequence stratigraphy. It revolutionizes the research perspective of sedimentologists and petroleum exploration scientists: from interpreting conventional seismic facies with seismic vertical resolution to studying sequence stratigraphy, source-sink systems, sandbodies distribution and reservoir architecture by making full use of seismic horizontal resolution (with stratal slices).

Different types of continental basins are developed in China, and multiple source-sink systems and thin sandbodies of multiple genetic types are developed under the complex sequence framework. It has been proved that seismic sedimentology plays an irreplaceable role in characterizing the source-sink systems elements, depicting thin sandbodies, predicting lithologic traps and exploring and developing oil and gas resources in thin sandbodies in continental basins.

The key technologies of seismic sedimentology include wavelet phase and seismic frequency adjustment, frequency division processing, rock physical relationship analysis, seismic parameter selection, stratal slice processing, RGB fusion, comprehensive analysis of seismic geomorphology and sedimentology. According to the characteristics of seismic lithology and seismic geomorphology reflected by stratal slices, the distribution and evolution process of system tracts in different sedimentary sequences, the characteristics of various elements of source-sink systems, the distribution of sedimentary systems and thin sandbodies, reservoir architecture, and the prediction of reservoir quality and the distribution of stratigraphic lithologic traps can be explained.

Seismic sedimentology is helpful to establish high-precision stratigraphic framework, characterize sequence framework, architecture and evolution of system tracts, and indicate the spatial and temporal distribution of lowstand systems tracts, transgression systems tracts and highstand systems tracts. It also can characterize the elements of source-sink systems, depict the catchment area and geomorphic characteristics of the source area, the types and scale of transport channels, and the relationship between the development of sedimentary sandbodies and the source area and transport channels. Seismic sedimentology can show the spatial and temporal distribution of thin sandbodies of genetic types such as rivers, deltas, beach bars, subaqueous fan and gravity flow deposits developed in continental rifted basins in different geomorphic units and different tectonic stages, and it is helpful to predict potential sand-rich units. Seismic sedimentology can characterize the sandbodies architectures of different sedimentary types, depict the sandbodies morphology and its association with mudstone interlayer, which lays a geological foundation for the precise exploration and development of oil and gas fields.

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-1: Seismic sedimentology for non-marine basins
Presentation Preference: Oral Preferred

Inspirations of seismic sedimentology from shear wave 9-component 3D seismic data in Qaidam Basin, NW China

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Keywords: Shear wave 9-Component 3D seismic, Seismic sedimentology, Seismic geomorphologic microfacies, Seismic lithologic reservoir property, Qaidam Basin

The first large-scale (82.5km^2) shear wave 9-component 3D (9C3D) seismic survey in the world was conducted by Qinghai Oil Field and BGP in Taidong area, Qadam Basin. The 9C3D seismic survey offers an opportunity to investigate structural, stratigraphic, and lithologic gas reservoirs for its super high quality. Comparing with conventional P-wave seismic data, the 9C3D data can reflect real structural features despite of interference from the unconsolidated sediments and the natural gas. Furthermore, the vertical resolution of the 9C3D data is doubled than the conventional P-wave data.

Seismic sedimentology, i.e., seismic geomorphology and seismic lithology, is firstly performed on the 9C3D seismic data. In the aspect of model-driven seismic geomorphology, a lacustrine-fluvial system is firstly recognized in the Taidong area, and then the evolution of sedimentary microfacies from K13 to K3 is reconstructed as well. In the aspect of data-driven seismic lithology, some key factors e.g., reservoir thickness, porosity, permeability, gas saturation, are calculated for the current target layer by the 9C3D seismic data and 28 wells (20 wells for calculating and 7 wells for verifying).

In the seismic geomorphology, -90° phase rotation, frequency decomposition, RGB blending, and stratal slicing are used. Water level deepens from K13 to K6, and then become shallow from K6 to K3. Microfacies change from underwater fluvial system with numerous channels in K13, to fluvial-lacustrine with a few channels, to shore-shallow lake with few channels, to shallow lake with no channel but beach and/or bars in K6. From K5, lateral heterogeneity become strong with the water level decline. It changes from lake to fluvial in the top of K5 with an obvious channel, and then to probably semi-restricted environment in K4 with a concentric circle phenomenon in the east area, which is quite similar with Salar de Uyuni in Bolivia.

In the seismic lithology, seismic attribute generation, principal component analysis, machine learning, and random fitting are utilized to calculate reservoir thickness, porosity, permeability, and gas saturation by the 9C3D seismic and well data for the sand layer numbered 4-1-4cd. It seems that reservoir thickness and porosity distribution obey microfacies, while permeability and gas saturation are controlled not only by microfacies but also by other factors e.g., digenesis and/or natural gas generation and migration.

Combination of seismic geomorphology and seismic lithology helps us to understand the facies evolution qualitatively, and the reservoir property and gas distribution quantitatively. In the meanwhile, combination of the new data (i.e., shear wave 9C3D seismic) and the new techniques (i.e., seismic sedimentology) enables us to reveal the forming environment of the world-wide renowned biogas in Sanhu area. The study is beneficial not only for the technique (shear wave and seismic sedimentology) progress and application, but also for the natural gas exploration and development in Qaidam Basin.

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Session T11-2: Sedimentological data and knowledge, artificial intelligence and data-driven discovery

2013

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-2: Sedimentological data and knowledge, artificial intelligence and data-driven discovery
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Machine Learning Based Proxy Model for Reactive Transport Modeling: Workflow and Implementation Example in Dolomitization Process Study

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Keywords: proxy modeling, Machine Learning, dolomitization model

Proxy-modeling (also known as surrogate modeling or meta-modeling) is widely used as a computational inexpensive alternative to the intensive numerical simulation in various applications, such as assisted history matching in reservoir simulation in petroleum industry.

In this study, the proxy modeling method is implemented in process-based reactive transport modeling (RTM). The conventional RTM integrates thermodynamic and kinetically controlled fluid-rock interactions with fluid flow through porous media in the subsurface and surface environment. RTM is usually conducted through numerical programs based on the first principle of physical processes. Thus, the calculation for complex chemical reactions in most available programs is in general computationally intensive.
Multiple RTM simulations are usually required for input parameter sensitivity analysis and model calibration. Therefore, it is highly desired to develop a computational efficient proxy modeling method with sufficient accuracy in an automated fashion to complement the process-based RTM and assist the sensitivity analysis or model calibration.

In this study, multiple machine learning methods, including neural network, Gaussian process and support vector regression methods are implemented as candidate methods for proxy modeling. The over all proxy modeling includes (1) base case RTM design and training model design, (2) proxy model construction based on machine learning, (4) surrogate model validation and evaluation, (5) prediction and other analysis work with the best calibrated proxy model.

The proposed workflow is illustrated with a simple 1D dolomitization model. Although different machine learning model procedures require different tuning and modeling efforts, the final well-trained proxy model can replace the original RTM with a satisfied accuracy and can be safely implemented in the task of sensitivity analysis or model calibration. Comparing with the conventional RTM, using proxy model can significantly reduce the computational time. It greatly improved the work efficacy such as rank the sensitivity of the parameters and to search the optimal solution for model calibration.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-2: Sedimentological data and knowledge, artificial intelligence and data-driven discovery
Presentation Preference: Oral Preferred

Automatic classification of microbial carbonate thin sections based on convolutional neural network

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Keywords: rock thin section, convolution neural network, microbial carbonate, image classification

Microbial carbonate is formed by inorganic or organic induced mineralization associated with microbial activity, different types of microbial carbonate have different macroscopic and microscopic structures, rock thin sections are usually manually identified by professionals, there are some problems such as low appraisal efficiency, disunity of judgment criteria and subjective factors. Therefore, an automatic classification method of microbial carbonate thin sections based on convolutional neural network is proposed.

Firstly, 200 microbiological carbonate thin sections from the northwest of Qaidam Basin were used as sample data, the thin section image can be divided into three types, including: clotted structure, granule structure and laminated structure. The image is preprocessed by multiple random transformations (rotation Angle, tangent Angle, random scaling, random horizontal flipping, etc.) , it is used to increase the number of samples and improve the generalization ability of neural network model training. Secondly, the convolutional neural network structure was established. The feature extraction part was composed of three convolutional layers and three pooling layers, and the classifier consists of two full connected network. The ReLU activation function is applied, the dense layer is classified by Softmax classifier. Finally, Adaptive gradient algorithm is used to optimize losses, the initial learning rate is 0.0001, K - fold cross - validation is used to train the dataset, After 400 iterations, The accuracy of training set is 95.3%, The classification accuracy of the test set was 91.2%, It is proved that convolutional neural network can replace manual to obtain efficient, accurate and reliable thin sections classification results.

The thin section data in this paper are only obtained from drilling in the Qaidam Basin, and the sample data are few. In the future, microbial carbonate rock thin section data for each basin will be added, the convolution neural network model with stronger applicability is established to achieve better classification effect.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-2: Sedimentological data and knowledge, artificial intelligence and data-driven discovery
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Multi-factor karst reservoir evaluation based on paleogeomorphological reconstruction, a case study from the 4th member of the Dengying Formation in the Sichuan Basin, China

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Keywords: Reservoir evaluation, Paleogeomorphological reconstruction, Random forest algorithm, Factor analysis, Deng IV member, Gaoshiti-Moxi area

The evaluation of reservoirs is of great importance in exploration practices, distribution of which is subjected to multiple geological factors. The carbonate platform of the 4th member of the Dengying Formation (Deng IV member) in the Gaoshiti-Moxi area (GMA), was uplifted above sea level during the episode II of Tongwan Movement and underwent prolonged karstification by meteosssric freshwater in the terminal Sinian, leading to a strong heterogeneity in reservoirs. Paleogeomorphic relief reflects hydraulic gradients that affect intensities of surface karstification to an extent, and the hydraulic gradients can be approximated by terrain slope gradients. Karst products (especially solution vugs and caverns) exist prevailingly in the Deng IV member, development of which mirrors internal dissolution intensities. Based on paleogeomorphological reconstruction in elevation method, the slope angles of single boreholes are calculated through digital elevation model (DEM). In accordance with single-borewell formation microscanner image (FMI) logging data, four electrofacies (viz. host rock, vug, fracture and cave) were identified in boreholes possessing FMI data. Matching the identified electrofacies with corresponding conventional logging curves as the training data, a model generalized for other boreholes without FMI data is established employing random forest algorithm, and thicknesses of the four electrofacies in each borehole are obtained to characterize the karstification intensity. Slope gradients and electrofacies thicknesses, together with multiple physical parameters depicting reservoirs in boreholes, are utilized for factor analysis. Four factors were obtained and fused into one comprehensive score in the light of their ratios of variance proportions. The favorability of reservoirs is described with the comprehensive scores of each borehole. It turns out that the most advantageous reservoirs are distributed in the vicinity of the platform margin in the west of the GMA, at which superimposition of several advantage factors may account for this. First is differentiation of deposition, porous mound-shoal complexes with rigid frameworks erect majorly in the platform margin. Karstification difference is the second, large scale caves are more developed in the mixing karst zone of seawater and freshwater in platform margin, complexes constructed upward with seaward steep slope may promote surface erosion and the developed matrix porosity of which can be preferential conduits of karst fluids for internal dissolution. The last reason is the transmeridional lateral migration of hydrocarbons from regional hydrocarbon-generating centre abutting the west of the GMA, contributing to earlier entrapment and accumulation in the mound-shoal complexes in the platform margin.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-2: Sedimentological data and knowledge, artificial intelligence and data-driven discovery
Presentation Preference: Oral Preferred

Petrophysical facies prediction using a LDA-assisted SSOM method for Paleogene Shahejie Formation in Bohai Oilfield

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Keywords: Petrophysical facies prediction, supervised self-organizing map, sedimental and diagenetic variations

The Shahejie Formation is an important oil and gas exploration and development target in Bohai Oilfield. It is composed of the superposition of multi-stage underwater distributary channel sand bodies. However, due to the differential carbonate cementation, the physical properties of the reservoir have strong heterogeneity within and between layers, which brings great difficulty to the deployment of injection-production wells in oilfields. Prediction of complex sedimental and diagenetic variations in sandstones are critical for hydrocarbon development. Integrated petrographic and petrophysical analyses are served here to categorize five petrophysical facies representing distinct mineralogical compositions, diagenetic processes, and pore systems. To upscale petrophysical features through correlating core petrophysical facies with geophysical well logs, linear discriminant analysis (LDA) was first employed to obtain eigenvectors that can best describe and distinguish petrophysical facies. The well logs that have stronger influence on the first and second eigenvectors and have less correlations with each other are selected to compress the feature space dimensions. The supervised self-organizing map (SSOM) predicable model was trained using dimensionally reduced well log database as input and core petrophysical facies as supervision to determine the nonlinear mapping relations between log response combination features and petrophysical facies group membership. The results showed that LDA assisted SSOM model yielded higher accuracy as compared with commonly employed linear and non-linear predictable model. The supervised LDA-assisted SSOM method as provided here can be gainfully used to predict petrophysical facies via conventional well logs.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-2: Sedimentological data and knowledge, artificial intelligence and data-driven discovery
Presentation Preference: Oral Preferred

Intelligent automatic identification instrument for rock slice

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Keywords: rock slice identification, Intelligent identification, identification instrument, Deep learning, Molecular spectrum

Rock thin section identification is the forerunner and basis of all research in geology and energy industry, but the traditional manual identification methods requires high experience and is greatly affected by subjective factors.

In this study, the method of establishing a mathematical model is proposed to analyze and simulate the process of geologists' identification of rock slices, and the model is calculated and solved based on various technical methods to obtain the identification results. On this basis, through the deep integration and digital synthesis of image recognition technology and mineral optical characterization technology, an intelligent automatic identification instrument of rock thin section is developed. For a given sample of ordinary thin slice or casting thin slice of clastic rock, The micro panorama is first automatically obtained, and then each segmented area of the panorama and its corresponding AI identification results are gradually realized, which is followed by the fingerprint identification and correction of single minerals in the thin slice sample through intelligent molecular spectrum. Finally, based on the overall processing and calculation of the AI & molecular spectrum identification results of each segmented area of the panorama, the thin section identification report and grain size thin section identification report of clastic rock are completed (including porosity value). 21 coarse sandstone thin section samples in HangJinQi area of Ordos Basin were selected and the stability, speed and accuracy were tested by using the intelligent automatic identification instrument of rock slice. The results show that the overall stability of the instrument system is good, the average identification time of each sample is 40-50 minutes, the average accuracy of image recognition part is 37-91% (weighted value), and the average pricision of image segmentation part is 16-83% (iou0.50). Compared with traditional manual identification, the identification instrument uses molecular spectrum to make the identification results of minerals more reliable. The micro panorama makes the field of view larger and more comprehensive, and the parameter calculation is more meaningful. If the accuracy of micro panorama segmentation and identification can be guaranteed, the rock and mineral identification instrument will have absolute advantages over manual identification.

Through the effective intersection and integration of multiple disciplines, this study makes it possible to use the instrument to test rock slices in standardized process, which provides a new development idea for the traditional research and has important scientific significance.

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-2: Sedimentological data and knowledge, artificial intelligence and data-driven discovery
Presentation Preference: Oral Preferred

Geostatistic recognition of genetically distinct shale facies in Upper Triassic Chang 7 section, the Ordos Basin, North China

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Keywords: Upper Triassic, Chang 7 section, Ordos Basin, Geostatistic decision tree, Shale facies, Black shale

The Ordos basin in North China may be one of the nonmarine basins with highest hydrocarbon generation per volume of sedimentary fill. It has great potential for unconventional oil and gas exploration, especially shale oil. When evaluating and predicting shale oil resources, the difference between different regions and different layers of shale is very obvious, so it cannot be calculated simply by average. A geostatistic decision tree was constructed based on a training set of 22 parameters (geochemistry, petrology, and sedimentology) for 110 shale samples from the basin, which can be used to implement genetic classification of subsequently collected shale samples. Three shale facies are identified by the decision tree. The properties of each facies are different, such as TOC, kerogen type and sulfur content. Genetic properties indicate formation conditions and provide base for the geostatistic assignments. The differential distribution of shale facies in the basin reflects their origins from different formation mechanism. Elements ratios, isotopes and biomarkers can be used to infer the sedimentary environment for each shale facies. Facies 1 mainly occurs in the upper Chang 7 section and shows evidence of quartz-rich source rock deposited under suboxic–anoxic condition. Facies 3 occurs at the lower Chang 7 section and shows evidence of clay-rich and pyrite-rich shale deposited under reducing dysoxic conditions with numerous higher plants input. Facies 1 and 2 constitutes the upper Chang 7 with interactive thick layers; Facies 2 and 3 constitute the lower Chang 7 with interactive thin layers.

Petrology, geochemistry and sedimentology of the shale facies suggest: Facies 1 represents the suboxic–anoxic upper Chang 7 proximal quartz-rich shale, which has lower TOC and sulfur content than other facies. The organic lamina is straight but rare. Kerogen is type I and dominated by sapropel. The content of saturated hydrocarbon in chloroform asphalt “A” extract is the highest. Facies 2 has higher TOC value, sulfur content and soluble hydrocarbon content than facies 1. It was formed in unstable hydrodynamic environment under weak anoxic condition. It is characterized by abundant laminas with various deformation structures and more alginite and vitrinite in kerogen. Anoxic lower Chang 7 distal sulfur-rich shale source rock make up organic-rich facies 3 (~7.0–17.0 wt. % TOC). This facies received more higher-plant input than the other facies. Well preserved algae shells are common in numerous and flat laminas. The content of chloroform asphalt of facies 3 is higher than that of other facies, but among which the saturated hydrocarbon content is the lowest, the aromatic, non-hydrocarbon and asphalt are the highest, suggesting the fluidity of hydrocarbon is the worst. Compared to others, this facies was formed in the environment where temperature is relative lower, water is relative deeper, productivity and salinity are relative higher, and the reducibility is relative stronger. A deeper understanding of shale classification and distribution is important for the accurate resource evaluation and optimal exploration planning of shale oil.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-2: Sedimentological data and knowledge, artificial intelligence and data-driven discovery
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Intelligent Identification And Application Of Imaging Logging Facies In Carbonate Reservoir

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Keywords: Carbonate Reservoir,Image Log Feature,Image Log Facies,Feature Extraction,Deep Learning

As an important part of petroleum exploration, carbonate reservoir has become the focus of research at present. Imaging logging technology plays an irreplaceable role in the study of carbonate reservoir sedimentation and structure. The imaging logging data have the characteristics of high longitudinal resolution and strong continuity. Therefore, the changes of rock mineral composition and structure model caused by the difference of deposition and tectonic action have obvious response characteristics in the imaging logging facies. In recent years, domestic and international identification and interpretation of imaging logging facies are mostly carried out by manual method. It is not only of huge workload, but also strongly influenced by human factors and large errors. With the development of artificial intelligence technology, automatic interpretation of imaging logging data by computer has become the development trend of logging in the future. But at the same time, how to improve the automatic identification accuracy of imaging logging facies by computer, in order to study the sedimentary and structural characteristics of carbonate reservoir based on imaging logging better is also the key problem to be solved urgently at this stage. In this study, the Tarim basin, Ordos basin and Sichuan basin are chosen for carbonate reservoir research and summarize in imaging logging characteristics. A set of suitable for Chinese typical carbonate reservoir of imaging logging facies identification chart is established for the follow-up contrast research of different carbonate reservoir sedimentary and tectonic characteristics. The features include fractures, caves, striations, stripes and gravels, and the logging image patterns are divided into 28 types, including light block, dark block, light and dark block truncation, etc. In addition, JAVA language and CIFLog software is used as the platform to realize the identification and extraction of imaging logging features and phase patterns. The carbonate reservoir imaging logging phase pattern database suitable for computer deep learning is formed, and convolutional neural network (CNN) technology is used to realize computer deep learning of imaging logging phase pattern samples. According to the classification of logging phase patterns, the feature extraction of 128 wells of electrical imaging logging data of carbonate reservoirs was completed, and a total of 5647 logging features were extracted and 20802 logging phase patterns were calibrated using image segmentation technology, and a database of typical imaging logging features and logging phase patterns of carbonate reservoirs was established. Based on this, the imaging logging facies of carbonate reservoirs in Changxing Formation, Maokou Formation, Qixia Formation, Longwangmiao Formation and Dengying Formation in Hechuan-Tongnan area of Sichuan Basin were identified. The identification accuracy reached 84% after comparison and verification, which has high practical application value.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-2: Sedimentological data and knowledge, artificial intelligence and data-driven discovery
Presentation Preference: Oral Preferred

Study on the performance of machine learning models and application in logging data interpretation -- A case study of the distribution of the sepiolite-talc combination in the Middle Permian Mao1 Member, Sichuan Basin

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Keywords: Sichuan basin,Mao1 Member,sepiolite-talc combination,2-dimensional distributions

The Middle Permian Maokou Formation is an essential exploration target in Sichuan Basin. With the discovery of unconventional natural gas in Maokou-1 Member (Mao1 Member), Mao1 Member is a new exploration heat in Sichuan basin. Researches unravel that sepiolite-talc combination is a crucial factor for unconventional natural gas in Mao1 Member (Song et al., 2022). However, the distribution of sepiolite-talc combination in Sichuan basin is still ambiguous and constrains the exploration in Mao1 Member. To delicately predict the distribution of sepiolite-talc combination in Sichuan basin (composing of (1) the existence of sepiolite-talc combination; (2) the contents of sepiolite-talc combination; (3) the geometric type of sepiolite-talc combination), this work collects and utilizes 1.8 million well-logging data from 245 wells. Training data are obtained from well Xt1 by microscopic, SEM, XRD analysis with coring samples. Strict comparasion of CatBoost, XGBoost, LightGBM, Random Forest, SVM, KNN, ANN incidactes that SVM and CatBoost models have excellent performances in the prediction of the existence of sepiolite-talc combination, XGBoost and ANN have excellent performances in the prediction of the contents of sepiolite-talc combination, and CatBoost is most suitable for the prediction of the geometric type of sepiolite-talc combination. Based on the results of best models, this work acquires 2-dimensional distributions of sepiolite-talc combination in Mao1 Members in Sichuan Basin. Code and technical details are accessible via https://github.com/KeranLi/multixgb.git.

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Session T11-2: Sedimentological data and knowledge, artificial intelligence and data-driven discovery
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Fracture identification in tight sandstones : Ensemble learning method with conventional well logs

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Keywords: Fracture identification, Tight sandstone reservoirs, XGBoost, Particle swarm optimization, Conventional well log

Fractures are of great significance to tight oil and gas reservoirs. Fracture recognized by using conventional well logs data is an economical and effective method for fracture zones identification. The classic approach to identify the fractures is crossplot. However, crossplot is not effective due to the weak and complex well log responses that fractures in tight sandstone reservoirs. To solve these problems, an ensemble learning method termed XGBoost (extreme gradient boosting) is introduced in this work, which is an improved algorithm of GBDT (gradient boosting decision tree). XGBoost has been proved to be powerful in classification, but limited by the setting of hyper-parameters. Therefore, PSO (particle swarm optimization), a heuristic algorithm, is introduced to optimize the hyper-parameters of the model. In addition, the XGBoost model is combined with an autoencoder to reduce the dimension of logging data to eliminate data redundancy. Consequently, the fracture identification method based on ensemble learning can be described as autoencoder-PSO-XGBoost. The wells of Chang 8 member in Binchang area, southwest of Ordos Basin is taken as validation. Caliper (CAL), acoustic log (AC), compensated neutron log (CNL), density (DEN) and resistivity log (ILM, ILD and LL8) were selected to evaluate the method. In order to highlight the superiority of the method, PSO-SVM (support vector machine) and MLP (multilayer perceptron neural network) are used as the comparative experiments. By comparing the experimental results with the prediction accuracy and F1-score, the proposed model is more reliable, the prediction accuracy is more than 85%, and has greater applicability in fracture identification.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-2: Sedimentological data and knowledge, artificial intelligence and data-driven discovery
Presentation Preference: Oral Preferred

AUTOMATED CORE DESCRIPTION SYSTEM APPLICATION FOR SEDIMENTOLOGICAL ANALYSIS

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Keywords: automation, core description, deep learning, computer vision, sedimentology, convolutional neural networks

The automated methods for core description have been developed for a long time. Different approaches have been used to meet the desired result: color distribution analysis and computer vision [1–5], machine learning [6–8], or deep learning [9–13] application. Recent developments in computer vision and machine learning allowed the creation of a system for automated core image extraction and description [14]. The system works with daylight core box images. Algorithms based on computer vision and deep learning have been applied to extract core column images from a core box with semantic segmentation [15] and automatically depth-reference them. These algorithms also helped to classify rocks into different rock and structure types [16]. The system works as a cloud solution. It was applied to various oil and mining industries' tasks — the system allows changes to the data produced by segmentation and classification algorithms. The speed of classification is about 10m\s. In this study, we overview the system application for sedimentological description. The quality of the images can be low (the minimum requirement is around 100dpi, which is about 390px for a 10 cm core column width).

After a classification algorithm was developed for 14 different types of rocks (3 rock types: sandstone, siltstone, shale\argillite, and five structures: bioturbated, rippled, laminated, massive, and cross-bedded) [17], it was uploaded to the system, and an expert applied it for a description of 10 different wells. An expert sedimentologist checked each well after classification and made some changes. The automated classification results have been reviewed and statistically analyzed compared to the expert's results. The classification accuracy on new data demonstrated a good accuracy\speed ratio. With a 7 - times well analysis speed increase, the minimum accuracy gained is 70%. Most lithologies have been detected correctly, but the structure was sometimes mixed. Also, some lithologies have not been included in the model (e.g., coal). The number of samples in the training set was small (less than 40 10x10 cm images), so the expert added these types to the system. The difference in NTG value measurement on the expert and algorithm classification results with a 1m sliding window is only 5%.

The automated core description application results are valuable for the industry in terms of their speed and NTG calculation. Also, it makes the life of an expert much easier. It allows him to concentrate on the results instead of the description. The overall description speed based on daylight core box images was 7-times increased. Another benefit of such a system application is automated depth referencing for the core images – the expert can interactively see the depth. The applied classification models help increase classification speed, improve the overall description quality, and be used as the first mandatory stage of initial preparation before the trip to the core storage or as a stand-alone stage for a quick core description. Even an untrained person can learn to classify different rock types while examining the results produced by an algorithm.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-2: Sedimentological data and knowledge, artificial intelligence and data-driven discovery
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Instance segmentation method to assist the identification of mineral particles in rock slices under microscope

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Keywords: Rock slice, Artificial intelligence, Convolutional neural network, Mineral identification

In recent years, a variety of artificial intelligence algorithms have achieved many results in solving regression problems and classification problems in the field of geoscience. The identification of mineral particles in rock slices is a classification problem in nature, and has good applicability with artificial intelligence algorithms. In the observation process of rock slices, the conventional method is to classify according to the experience of mineralogists. This manual classification method based on empirical statistics is very similar to the method of database comparison. The traditional rock slice classification method is limited by the experience of interpreters, which is a time-consuming and labor-intensive method. In this paper, an intelligent classification method is proposed. By segmenting different particles of rock slices under the microscope, each particle is marked, and then a database of mineral particles in rock slices is constructed. Then, the faster R-CNN algorithm is used to segment the rock slices image under the target mirror. Through verification, it is found that the model can quickly and accurately identify minerals such as quartz and feldspar. And the other side is more sensitive to calcite minerals. The experiments have achieved good identification results.

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Session T11-2: Sedimentological data and knowledge, artificial intelligence and data-driven discovery
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ML assisted sedimentological descriptions of core

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Keywords: Sedimentology, Core Description, Machine Learning

Sedimentological descriptions of core are often the crucial input for developing subsurface geological models as it provides numerous hard facts through direct measurements, observations, and interpretations. These core-based datasets typically are integrated with well logs and/or seismic for a better understanding of the geological/depositional model. Traditional manual core descriptions require significant amount of time and demand considerable experience of a sedimentologist. In order to reduce time and increase standardisation/ automatization, a project has been set up to develop a workflow using artificial intelligence (AI) and machine learning (ML) techniques for sedimentological data collection and core description. The main advantage would be collection of critical data from cores in a much faster and standardised format.

Over the recent years, several publications have documented the applicability of image recognition methods using AI, however, the sole dependency on core images ignores the vast amounts of measurements usually done on cores. The approach of this study is, therefore, to combine core images with a suite of diverse analytical datasets such as sedimentological, mineralogical, geochemical and geomechanical.

In the first phase of the study, the following sets of data have been used: slabbed white-light core images, tabulated analytical data comprising sedimentologial core description (lithology, texture, grain-size, sedimentary structures, bioturbation, lithofacies), spectral core gamma, routine core analyses data, XRD data and CoreDNA data (©Epslog Engineering). The main challenge in this approach was to combine the datasets with different dimensionalities. Nevertheless, preliminary results and learners from this ongoing study would be shared. Furthermore, the way forward would be discussed in order to achieve the ultimate goal of developing an automatized ML-based workflow that delivers core description/data such as lithology, texture, physical rock properties and lithofacies.

Ideally, depending on the complexity or heterogeneity of the rock, the resulting core description would only need minor revisions by senior staff for the basic sedimentological interpretation. A secondary aim of the project is also predictions of rock and reservoir properties.

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-2: Sedimentological data and knowledge, artificial intelligence and data-driven discovery
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Sedimentary Characteristics, Sediment Accumulation and its Geological Significance of Quaternary Sediments in Xiangqu Drainage Area of the Yarlung Tsangpo River Basin

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Keywords: Quaternary, Sediment Accumulation, Yarlung Tsangpo River, Remote Sensing, Kriging Interpolation

The Quaternary sediments are synchronic records of tectonic and climatic activity. The sedimentary characteristics and total sediment accumulation can effectively reveal the climatic and tectonic information of the study area. However, it is difficult to obtain the total Quaternary sediment accumulation by traditional stratum profile measurement. This paper takes the Quaternary sediments of Xiangqu drainage area, a tributary of Yarlung Tsangpo River, as an example, and proposes a kriging interpolation-pixel integration method based on the remote sensing interpretation maps of Quaternary sediments. According to the method, the total sediment accumulation in Xiangqu drainage area is about 84 cubic kilometers, of which the alluvial and diluvial sediments are 2.7 cubic kilometers and 8 cubic kilometers respectively, with an average of 0.0629 cubic kilometers deposited per kilometer. It is equivalent to 0.066 cubic kilometers per kilometer of sediment accumulation in the wide valley section of the middle reaches of the Yarlung Tsangpo River calculated by previous authors, indicating that the Xiangqu drainage area is in a relatively slow uplift stage. The main lithology of alluvium sediments are coarse gravel, medium gravel, gravel, pebble, medium-coarse sand and sandy loam. The particle size becomes finer from bottom to top. The early deposition of coarse gravel may correspond to the period of reduced snowmelt in the glacial stage. However, due to the uncertainty of depositional age, the relationship between sediment distribution characteristics and total sediment accumulation and climate remains to be further studied.

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-2: Sedimentological data and knowledge, artificial intelligence and data-driven discovery
Presentation Preference: Oral Preferred

Application of Knowledge Graph to Align Phanerozoic Time Scales: from 1893 to 2022

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Keywords: Geologic time scale, Knowledge graph, Open data, Data-driven discovery

With the accumulation of the large amounts of deep-time Earth data, data-driven discovery is ready to apply. These data depend on three basic information: time, space and matter. Geological time scale is a high degree of condensation of deep time data. Nevertheless, valuable hidden knowledge based on different geologic time scales and distributed in various publications. There is a lack of extracting deep time standard in current sedimentological literature. Knowledge graph (KG), as a new type of efficient organization and knowledge representation, has received increasing attention in data-intensive research. To lower the barrier of understanding time concepts in intellectual processes of geologic data, we adopted the KG technique to international geologic time concepts (geologic time scale) in 60 Phanerozoic time scales from 1893 to 2022. A unified description framework is built for the versions through the existing geological time ontology, and graph database is used to store and visualize the timescale. We realized the functions of rapid retrieval, version alignment and version recognition.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-2: Sedimentological data and knowledge, artificial intelligence and data-driven discovery
Presentation Preference: Oral Preferred

Discriminating Qiangtang, Lhasa, and Himalayan sediment sources in the Tibetan Plateau by detrital-zircon U-Pb age facies

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Keywords: Tibetan Plateau, Provenance analysis, Multidimensional scaling, Detrital zircon age facies

In the last decades, a great progress in sedimentary provenance research has been made after the advent of detrital geochronology. Because of high closure temperature and excellent durability of zircon, the detrital-zircon U-Pb isotopic system has been most widely used, and a bounty of detrital zircon ages have thus been produced. In this study, 49,111 U-Pb ages of detrital zircons from 533 samples from the six major geological domains across the Tibetan Plateau were compiled. Multidimensional scaling (MDS) statistical analysis allowed a rigorous discrimination among detrital-zircon age spectra in numerous pre-collisional units from South Qiangtang, North Lhasa, South Lhasa and the Tethys Himalaya, and to establish the detrital-zircon age facies (DZF) characteristic of each of these domains. A test based on detrital-zircon data from stratigraphic units in the Bangong-Nujiang and Indus-Yarlung Zangbo sutures demonstrates that the identified DZF represent a reliable useful tool to effectively determine the provenance of sedimentary units contained in these two suture zones. Through this extensive compilation of zircon-age data from across the Tibetan Plateau we highlight the importance of this new approach to sedimentary provenance analysis.

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-2: Sedimentological data and knowledge, artificial intelligence and data-driven discovery
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

An Attempt to Build Semantic Knowledge Graph of Calcareous Nannofossil in the "Top-Down" Approach

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Keywords: Knowledge graph,Semantic technology,Calcareous nannofossil

Knowledge graph is a key technology for semantic translation and data integration, which is essential for geoscience coming to the fourth paradigm of data-intensive scientific discovery. Researchers have shown an increased interest in building knowledge graph of geoscience recently. The specific method, however, is still relatively obscure. We review the concepts of the semantic web and knowledge graph, propose a workflow for building semantic knowledge graph of calcareous nannofossil in the "top-down" approach based on UC Zone, NC Zone, CC Zone data. We give three examples, which are the construction of SPARQL endpoints to support online queries, the import to Protégé for checking logic structure, and the import to Neo4j for visualization, to illustrate the machine readability, compatibility and interoperability of the semantic knowledge graph. We hope this paper will be helpful to geoscientists who are interested in paleontology with few backgrounds of knowledge graph.

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-2: Sedimentological data and knowledge, artificial intelligence and data-driven discovery
Presentation Preference: Oral Preferred

An Age Database for DSDP/ODP/IODP Sediment Records

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Keywords: age model, database, DSDP/ODP/IODP

The study of the Earth's evolution helps to better understand our mother-Earth and locate resources needed, thus promoting the harmonious coexistence between man and nature. The Ocean Drilling Project (DSDP, ODP, IODP) has more than 50 years of history and has accumulated a large amount of data, which is an ideal material for studying the Earth's evolution from Jurassic to Neogene. The centralized and unified sediment time frame is a key to drawing a clear picture of the evolutionary history. The Neptune Sandbox Berlin database has collected a large amount of age-related data (biostratigraphy, magnetostratigraphy, cyclostratigraphy), however, it accounts for only about one-seventh of all sediment-related holes. There is still a large amount of data that exists in literature, voyage reports, and other databases such as Pangaea.de and LIMS, to be discovered and harmonized. Therefore, we established a semi-automatic data extraction and mining method to process age-related data from various sources and integrate it into a database, which ensures rapid growth of data and benefits the study of Earth material from Jurassic to Neogene ocean sediments.

Session T11-3: Development and applications of in situ analysis in sedimentology and geobiology

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Session T11-3: Development and applications of in situ analysis in sedimentology and geobiology
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

In situ multiple techniques uncovering the occurrence of a mini oxygen oasis in near-shore microbialites

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Keywords: Cambrian, LA-ICP-MS,LA-(TOF)-ICP-MS, Fe oxides

With the development of emerging in-situ analytical techniques in sedimentology, more and more details of element/isotopic spatial variation at microscale levels of rocks are being discovered. In the present study, We used multiple in-situ techniques (EPMA, SEM-Raman, and LA-(TOF)-ICP-MS) to depict the redox characteristics preserved in middle Cambrian oolites and microbialites. Firstly, we acquired redox-sensitive element concentration data of different components using the LA-ICP-MS technique. Then, we drew oxygen gradient maps in ooids, microbial carbonates, and their cements taking advantage of a novel semi-quantitative 2D element imaging technique (LA-TOF-ICP-MS). After carefully examining these data, we noticed that large quantities of clay-sized authigenic minerals were distributed in the microbial components. Further SEM-Raman study confirmed that these are mostly Fe oxides and concentrated in calcified microbial microfossils. Lines of element geochemical evidence support a weakly oxic surface ocean condition in the clean, stirring surface ocean condition at that time, and the authigenic Fe oxides widely-distributed in microbial microfossils may provide compelling evidence on a key source of O_2 producing engine in the surface ocean, i.e., oxygenic photosynthesis. This study also implies that the surface ocean might not be sufficiently oxygenated (like modern level), even in the middle Cambrian time.

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-3: Development and applications of in situ analysis in sedimentology and geobiology
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Apparent rock fabric number calculation technology and its application in carbonate lithofacies logging identification

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Keywords: carbonate lithofacies, Logging identification, apparent rock fabric Number, KNN algorithm,Longwangmiao formation

The development of carbonate reservoirs is closely related to sedimentary facies. The identification of carbonate rock fabric components by logging data is of great practical significance for the study of carbonate sedimentary facies. However, due to the strong diagenesis and the development of fractures and vugs in the carbonate strata, it has always been a difficult problem to use conventional logging data to identify lithofacies based on rock structure and composition classification with high accuracy. At present, the combination of effective logging parameters and machine learning methods has become an effective means to improve the identification accuracy. As an effective logging parameter, the apparent fabric number (ARFN), it has achieved good application results in carbonate formations. However, this technology is not suitable for deep ancient low-porosity carbonate. Although scholars have improved this, it is still limited to no transition zone and no waterflood effects. For this, in this paper, taking the Longwangmiao Formation in the GM area of the Sichuan Basin as an example, based on the Lucia rock type classification scheme, the lithofacies are divided into three categories: granular dolomite (including dolarenite and fine grannular dolomite), crystal powder dolomite and micrite dolomite (including micrite dolomite and argillaceous micrite dolomite). Based on rock-electricity relationship analysis and formation test data, through core calibration, the rock fabric number calculation formula of Lucia is improved to make it suitable for the low-porosity reservoirs and water layers. The improved apparent rock fabric number parameter is taken as one of the input logging parameters of the K-neighbor classification algorithm (KNN) to carry out lithofacies logging identification. According to verification of the core data, the average identification coincidence rate increased from 74% to 80%. This technology meets the production needs and effectively promotes the fine study of carbonate sedimentary microfacies of the Longwangmiao Formation in the GM area.

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-3: Development and applications of in situ analysis in sedimentology and geobiology
Presentation Preference: Poster preferred (Participation to ECS virtual poster competition)

Direct dating Paleo-fluid flow events in the Ordovician deeply buried carbonate reservoirs of the Tarim Basin, NW China

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Keywords: fluid flow, in-situ calcite U-Pb dating, fluid inclusions, isotope geochemistry, carbonate reservoir, Tarim Basin

Reconstructing fluid evolution history in old sedimentary basins is extremely challenging due to the prolonged evolution, lack of exact age constraints and absence of preserved fluids. By integrating in-situ calcite U-Pb dating, fluid inclusion analysis, measurements of major and trace elements and carbon-oxygen-strontium isotopes, and molecular composition analysis of petroleum, we have reconstructed the fluid evolution history during the Carboniferous in an Ordovician deeply buried carbonate reservoir in the Tarim Basin, NW China, with unprecedented temporal resolution. The bituminous calcite vein records at least five generations of calcite precipitation from basinal fluids that compositionally evolved from ~353 Ma to ~316 Ma, spanning over 37 m.y. The initial calcite cement was associated with an intrusion of hyper-saline brine, enriched in REEs. This was followed by influx of meteoric water to precipitate the second and third generations of cement, which are characterized by reduced salinity, anomalously high 87Sr/86Sr ratios and extremely low concentration of REEs. The fourth generation of calcite cement was formed in a deep-fluid system accompanied by oil charge as indicated by the presence of bitumen, oil inclusions and low δ13C and 87Sr/86Sr ratios. The fifth generation of cement was precipitated from equilibrated connate water, and has the lowest salinity and a comparable REE signature to the host rock. Oil charge event occurred around 326 Ma, which is much earlier than previously thought (~250 Ma) based on conventional fluid inclusion analysis coupled with basin modeling results, and may help optimize petroleum exploration strategy. While more work is needed to shed light on the fluid evolution of the entire Tarim Basin, this study demonstrates the effectiveness of combining in-situ calcite U-Pb geochronology, fluid inclusion analysis, elemental and isotopic geochemistry to elucidate high-resolution temporal fluid evolution in old sedimentary basins with a complex tectonic history, providing a new paradigm for studying geofluid evolution.

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-3: Development and applications of in situ analysis in sedimentology and geobiology
Presentation Preference: Oral Preferred

Deepening ocean chemocline triggers the rise of the Ediacaran early complex life

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Keywords: Sedimentary pyrite, Ediacaran, NanoSIMS, Sulfur isotope, Nanhua Basin of China

Conventional geochemical indexes have explored different models of the relationship between profound evolution of eukaryotes and deep-ocean oxygenation in the Neoproterozoic Era. To further address this causality, new traced methods integrating with detailed petrological and in situ geochemical analysis by using scanning electron microscope and nanoscale secondary ion mass spectrometry on Ediacaran sedimentary pyrite, were developed in the fossiliferous Lantian drill core, South China. Samples from the core (Member II and Member III) cover depositional intervals immediately after Marinoan Glaciation (~635 Ma) and host macrofossil 'Lantian biota' (~ 600 Ma). Our results show that pyrite in Lantian black shales is mainly syngenetic, occurring as spherical framboidal, euhedral/subhedral crystals, zoned pyrite aggregates with overgrowth surrounding framboidal or euhedral pyrite cores, and fossil-shape pyrite aggregates. Atomic S/Fe ratios for all forms of pyrite range from 1.9 ± 0.037 to 2.1 ± 0.175, approaching pure-pyrite standard values (2:1). Framboid has consistently negative δ34Spy values with an average of –25.6 ± 7.9‰. Euhedral/subhedral and fossil-shape pyrite have generally positive and variable δ34Spy values with an average of 13.5 ± 14.4‰ and 16.5 ± 4.4‰, respectively. Zoned pyrite has negative and highly variable values (–20.4 ± 10.7‰). Measurement of ratios of framboidal area to total pyrite area indicates that the framboid formation is roughly subject to the high TOC%, and intervals with high content of framboid usually have low bulk δ34Spy values. Euhedral/subhedral pyrite shows distinctive δ34Spy values across the drill-core: they have degrees of overlapped δ34Spy values with framboid in the lower Member II samples, but their δ34Spy values become clearly positive in the upper Member II and lower Member III. Panel distributing patterns of δ34Spy values in zoned pyrite cystals are distinctive in different sampling intervals: δ34Spy values have no significant difference cross the pyrite crystals in the lowest Member II sample, but show increasing value trend from core to overgrowth edge in sample from middle Member II. The δ34Spy values changes of euhedral/subhedral pyrite and zoned pyrite crystals could be attributed to changes of their HS– origins that was caused by gradually deepening chemocline with the increasing sulfate concentration in the early Ediacaran Nanhua ocean. Increasing seawater sulfate in bottom water impels the occurrence of sulfate reduction within sediment, and provided enriched 34S signal to support crystal growth. Sulfate can also penetrate marine sediments to support sulfate reaction with methane beneath the sediment, fosters the formation of the sulfate-methane transition zone, and then promote enriched δ34Spy pyrite formation in comparatively restricted environment. Out research supports the hypothesis that environmental oxygenation acts as a pre-requisite for the complex multicellular life's evolution. The early-Ediacaran deepening chemocline helps to transit sulfidic deep-water to be oxic-suboxic, allowing for the occurrence of "Lantian Biota" that consist of morphologically complex benthic macroalgae and putative animals.

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-3: Development and applications of in situ analysis in sedimentology and geobiology
Presentation Preference: Oral Preferred

Remarkable micron-scale isotopic heterogeneity revealed by SIMS: Implications for the Ediacaran Shuram excursion

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Keywords: Shuram excursion, secondary ion mass spectrometry, microbial sulfate reduction, anaerobic oxidation of methane, carbon isotopes, authigenic carbonate

The Ediacaran Shuram excursion (SE) records a global decrease in carbonate carbon isotope ($\delta^{13}C_{carb}$) values from +6‰ down to ca. –10‰, representing the largest $\delta^{13}C_{carb}$ negative anomaly in Earth history. While the SE is also widely recorded in the upper Doushantuo Formation of South China, it shows highly variable $\delta^{13}C_{carb}$ profiles among correlative sections. This inconsistent expression of the SE challenges the conventional view of a homogeneous marine dissolved inorganic carbon (DIC) reservoir. A potential process that could explain $\delta^{13}C_{carb}$ variability is local mineralization of isotopically distinct authigenic carbonates near the sediment-water interface during early diagenesis. However, a direct test of such authigenic carbonates is still limited. Here, following a recent study on the SE in intra-shelf environment, we revisited an outer shelf section, identified and analyzed μm-scale, syn-depositional authigenic calcite cements via integrated cathodoluminescence (CL), micro-X-ray fluorescence (μXRF), scanning electron microscope (SEM), energy-dispersive spectroscopy (EDS), and secondary ion mass spectrometry (SIMS). Our new SIMS results reveal remarkable micron-scale heterogeneity of $\delta^{13}C_{carb}$ in authigenic calcite cements, including extremely negative values down to –37.5‰ (VPDB). We interpret these calcite cements as methane-derived authigenic calcite (MDAC) resulting from microbial sulfate reduction (MSR) and anaerobic oxidation of methane (AOM) during early diagenesis. Based on the new results, we propose that the heterogeneous SE in South China — manifest on micrometer, centimeter, and basinal scales — was modulated by methane oxidation under variable local redox and water depth conditions. The SE, therefore, was coupled with different degrees of authigenesis of ^{13}C-depleted carbonates that were locally modulated by methane oxidation in individual basins, and globally triggered by enhanced seawater sulfate during an atmospheric oxygenation event. In light of this study, the potential role of redox variability in methane oxidation during the SE may have been underestimated. Our study demonstrates that integrated SIMS-SEM analysis can distinguish different generations of isotopically distinct carbonates otherwise undetected by conventional analysis, and is thus an effective approach to assess the origin and diagenetic history of $\delta^{13}C_{carb}$ anomalies in the sedimentary record.

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-3: Development and applications of in situ analysis in sedimentology and geobiology
Presentation Preference: Oral Preferred

Multi-element imaging reveals the environmental context of Precambrian carbonaceous compressions

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Keywords: Xiamaling Formation, Lantian Formation, μ-XRF, Multi-element imaging, Fossil preservation

Fossil life in the Precambrian is commonly preserved as carbonaceous compressions, where Pre-Cryogenian carbonaceous compressions mainly occur in organic-poor rocks. Black-shale-preserved carbonaceous compressions have become more common since the Ediacaran Period. To explore the depositional context of carbonaceous compressions, micro X-ray fluorescence spectroscopy (μ-XRF) was used to image elemental distributions in carbonaceous compressions and surrounding rocks in Mesoproterozoic and Ediacaran-aged rocks. The carbonaceous compressions preserved in the Xiamaling green silty mudstones (1.40 Ga) and Lantian black shales (0.63 Ga) were selected and scanned, respectively. The behavior of redox-sensitive elements (Mo, U, V, Zn, Cu) in the Xiamaling and Lantian rocks and carbonaceous compressions suggest that the overlying water conditions during their sedimentation were not sulfidic. However, the co-enrichments of Fe and S in Xiamaling and Lantian carbonaceous compressions indicate pyrite permineralization. The Lantian carbonaceous compressions have a higher pyrite permineralization degree and a lower organism decomposition degree than those of the Xiamaling carbonaceous compressions. We speculate that these differences are related to a higher sulfate reduction rate and a lower dissimilatory iron reduction rate in the sediments hosting the Lantian carbonaceous compressions. Such conditions might be achieved through rapid burial and encircling by clay minerals. Overall, our results shed new light on understanding the preservation processes of the Precambrian life and the influence o environmental factors.

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-3: Development and applications of in situ analysis in sedimentology and geobiology
Presentation Preference: Oral Preferred

Recent developments of SIMS analyses of Precambrian sedimentary rocks

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Keywords: Precambrian, Stable isotope Geochemistry, SIMS

Secondary Ion Mass Spectrometry (SIMS) or ion microprobe is capable of revealing high precision isotopic and elemental heterogeneity at the microscale in various mineral phases. Recent analytical improvements either on the detection part or on the source with the new generation of oxygen primary ion sources have opened new avenues for targeting very small mineral phases, which can be then used for either reconstructing ancient environmental conditions or as potential biosignatures. We will review here recent applications of SIMS analyses in sedimentary rocks from the Precambrian. We will show that micropyrites in microbialites can be used as a biosignatures for microbial Fe and S cycling. Moreover, we will show how combining bulk and SIMS isotopes can be used to decipher diagenetic from deposition conditions. High precision geochemistry at high spatial resolution is thus a powerful approach for reconstructing ancient surface conditions from the sedimentary record through time

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Session T11-3: Development and applications of in situ analysis in sedimentology and geobiology
Presentation Preference: Oral Preferred

Brachiopods from the Latham Shale Lagerstätte (Cambrian Series 2, Stage 4) and Cadiz Formation (Miaolingian, Wuliuan), California

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Keywords: Cambrian, brachiopods, Latham Shale, Cadiz Formation

A moderately diverse assemblage of brachiopods from the Latham Shale Lagerstätte (Cambrian Series 2, upper Stage 4) and the upper Cadiz Formation (Miaolingian, Wuliuan), California, is described in detail for the first time. The fauna includes both linguliform (*Hadrotreta primaea*, *Paterina prospectensis*, *Dictyonina pannula* and *Mickwitzia occidens*) and rhynchonelliform (*Nisusia fulleri* and *Wimanella highlandensis*) brachiopods, together with olenellid trilobites and hyolithids. The fauna differs from other Cambrian Konservat-Lagerstätten (notably Cambrian Series 2 Chengjiang and Guanshan Lagerstätten, eastern Yunnan) in that the brachiopod shell valves in many cases are still preserved with their original mineralization. Moreover, the excellently preserved shale-hosted valves even include cases with exquisite epithelial cell moulds, otherwise only seen in acid-etched material from carbonate rocks. The pitted ornamentation in the *Dictyonina pannula* closely resembles those described from Ordovician linguliforms. The unusual preservation of *Nisusia fulleri* provides important clues for ancestral composition of the brachiopod shell. The two articulated rhynchonelliform species probably represent the oldest records of this group from the west Laurentia. The fauna may also represent the earliest onset of the transition from the Cambrian Evolutionary Fauna (CEF) to the Paleozoic Evolutionary Fauna (PEF).

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-3: Development and applications of in situ analysis in sedimentology and geobiology
Presentation Preference: Oral Preferred

The utility of NaOCl-etching before the in-situ analysis of pyrite

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Keywords: Etching, NaOCl, pyrite, in-situ analysis

Pyrite is widespread in a variety of rocks and ores. It is not uncommon that one pyrite grain is multi-generation indicated by compositional zoning (concentric). Significant information regarding the evolution of sedimentary environments or metamorphic/hydrothermal fluids can be obtained through systematic in-situ analysis (e.g., sulfur/iron isotopic composition, trace element concentration, etc.) of the pyrite growth zones (e.g., Peterson and Mavrogenes, 2014; Liu et al., 2021). It is critical to reveal internal zoning prior to in-situ analysis, otherwise spot sampling can mix multiple growth zones. Hypochlorite etching is a conventional chemical method immersing pyrite grains cast in epoxy mounts or thin sections in NaOCl solution (8–12.5 % NaOCl) for several minutes. The rinsed pyrite grains display colorful surfaces under the reflected light microscopy, and zoning can be revealed by distinct colors (due to trace element variations). The stained color is attributed to the optical interference by a thin layer of elemental sulfur on pyrite surface (Fleet et al., 1993). The spot size of in-situ analysis should then be adjusted to the various thicknesses of the growth zones. This method is fast, effective, efficient, and economical.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-3: Development and applications of in situ analysis in sedimentology and geobiology
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Hydraulic Fractures Evaluation and the Effects of Gravel Heterogeneity Based on Cores

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Keywords: Hydraulic fractures, Core, Gravel heterogeneity, Propagation mode, Fractures evaluation

The method of experimental and numerical investigation on hydraulic fracture (HF) propagation mode and geometry is indirect, the insight wasn't be verified by the direct information underground, which hit a bottleneck for improving hydraulic fracturing treatment. This study establishes an evaluation of the glutenite HF by integrating cores, imaging logging, and CT scans based on a slant well recovering core. A total of 335 HF are identified from 323.19 m cores, and are divided into two types according to the HF surface feature and propagation mode: (i) shear fracture: the HF partially or completely penetrate the gravel, the fracture propagation mode is straight and the fracture surface is a plane or nearly plane; (ii) tensional fracture: the HF deflects around the gravel, the fracture propagation mode is tortuous and the fracture surface is rough and irregular. The result showed that the HF is dominated by shear fracture. The density of shear fracture is higher than that of tensional fracture. 109 HF occurrence is identified by imaging logging. The dip of the fractures is dominated by high angles, and the strike is 90°~120°, which is consistent with the direction of maximum principal stress. The impact of gravel size, supporting types, and orientation on HF propagation is investigated. It is indicated that in the case of larger gravel size, the HF tends to penetrate gravel and consequently, result in the development of shear fracture; the HF is prone to penetrate sandstone-supported conglomerate than gravel-supported conglomerate; the greater the acute angle between the gravel long axis direction and the HF propagation direction, the easier the HF penetrates gravel. The factors of the abundant shear fractures development in the study area are analyzed, which is mainly controlled by the growth of cobble and the distance of the HF from fracturing wells. The research in this work provides some references for the glutenite hydraulic fracturing treatment and experimental and numerical investigation in future.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-3: Development and applications of in situ analysis in sedimentology and geobiology
Presentation Preference: Oral Preferred

A pilot study using LA-TOF-ICP-MS in imaging microscale carbonate diagenesis

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Keywords: Oolite, microbialite, in-situ element analytical technique, trace element mapping

Numerous sedimentary and diagenetic characteristics are typically controlled by mineral precipitation and alteration at the microscale level. High-resolution spatial mapping of element concentrations may provide clues on specific processes, e.g., cementation, recrystallization, and dolomitization, and would be helpful for studies of carbonate sedimentation and diagenesis. Recently, numerous in-situ element analytical techniques have been carried out in the field of carbonate sedimentology (e.g., SEM-EDS, EPMA, and μXRF), and the results show well-illustrated maps of major elements and some trace elements with relatively high contents (>100 ppm). Here, we reported an up-to-date laser ablation (LA)-based element imaging technique to determine the characteristics of major, trace, and rare-earth element spatial distribution (with concentrations ranging from >1 % to ppm levels) in several samples of microbialites and oolites. This element mapping analysis was performed using an imageGEO 193 nm LA system (Elemental Scientific Lasers) and a coupled time-of-flight (TOF) ICP-MS instrument (TOFWERK, icpTOF R). The rectangular area for LA imaging was set using a series of aligned and combined lines with a width of 7/10 μm. For calibrating carbonate samples that generally contain extremely low trace-element contents, the reference material of this study involved carbonate pellet MACS-3 (USGS) and OOID (unpublished laboratory internal standard, made from pure Bahamian ooid sands). All isotopes that can be measured by TOF-ICP-MS (n >100) were performed in the present study, and ^{25}Mg, ^{34}S, ^{43}Ca, ^{51}V, ^{52}Cr, ^{55}Mn, ^{57}Fe, ^{58}Ni, ^{59}Co, ^{63}Cu, ^{88}Sr, ^{138}La, ^{140}Ce, ^{208}Pb, ^{232}Th, and ^{238}U were focused and shown with good imaging performance to indicate specific diagenetic characteristics.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-3: Development and applications of in situ analysis in sedimentology and geobiology
Presentation Preference: Oral Preferred

Silica effect on dolomite crystal sizes during formation and burial

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Keywords: Recrystallization, adsorbed silica, dolomite, Synchrotron high-resolution XRD, EPMA

The formation mechanism of dolomite ($CaMg(CO_3)_2$), especially primary dolomite, has been a long-lasting problem. Although carbonate is prone to recrystallization during diagenesis, micritic dolomite is commonly observed in the rock record. Our recent work demonstrated that an increase in dissolved silica could inhibit precipitation of aragonite, which is the dominant product in modern seawater, and enhance Mg incorporation in high magnesium calcite (HMC) and disordered dolomite. Crystal sizes observed during synthesis experiments showed that dolomite is precipitated as nanometer-size crystals with silica adsorbed on the surface. Therefore, we propose that silica adsorption will affect crystal sizes during growth and possibly during early diagenesis. This work examines crystal size changes through annealing experiments with different silica concentrations and applies to the micritic dolomite in the Byron Formation, the Lower Silurian Burnt Bluff Group, northeastern Wisconsin.

Analyzed with synchrotron-based high-resolution X-ray diffraction, our annealing experiments at 180 °C of dolomite nanocrystals in dissolved silica-bearing solutions show that adsorbed silica can substantially inhibit crystal growth in calcite, dolomite, and HMC during diagenesis. As we think the thick and homogenous dolostones in Byron Formation were precipitated in evaporative tidal flats to semi-closed lagoonal environments with a high dissolved silica concentration, a similar inhibition effect from adsorbed silica is responsible for explaining the micritic nature of these dolomite. EPMA results show that Silurian dolomite contains up to 400 ppm of SiO_2. Annealing experiments and EPMA results indicate that the adsorbed silica is the reason restricting dolomite crystal recrystallization during burial. Some of the Byron dolomite demonstrate micritic dolomite layers with oscillating grain sizes, likely due to different silica concentrations and adsorption amounts during deposition. This inhibition effect would provide a new explanation for the well-preserved Paleozoic and Precambrian micritic dolomite.

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-3: Development and applications of in situ analysis in sedimentology and geobiology
Presentation Preference: Oral Preferred

Multiple analytical techniques uncovering fluid evolution of hydrothermal flows in the fold-thrust system

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Keywords: LA-ICP-MS, trace elements, hydrothermal fluid, fold-thrust system

Tracing the source and evolution of hydrothermal fluids in the fold-thrust system is still challenging due to the complicated tectonic activities and the frequent mixing of different flows. Although previous work established a two-stage model of hydrothermal flows (overpressure-driven and topography-driven) (Qing and Mountjoy, 1992; Machel, 2004), few of studies could provide compelling petrological and geochemical evidence to verify the source and evolution of hydrothermal fluids especially at a microscopic scale. In this study, we used a promising tool, i.e., in-situ LA-ICP-MS, coupled with other petrological and bulk-rock analytical methods, to elucidate the stages and characteristics of hydrothermal fluids recorded in luminescence-zoned dolomite of the Upper Ediacaran Dengying Formation in the eastern part of the Upper Yangtze Platform. The samples of hydrothermal dolostone were collected from three different areas (spaced approximately 3–5 km apart). From the wall rock to center, identical generations (D1–D3), especially D2 generation that includes seven luminescence zones, were identified in dolomite cements in different areas/occurrences. High-resolution in-situ measurements of trace element contents on different components further support the wide range of hydrothermal flow activities recorded in these dolomite cements. In addition, the features of REE compositions from D2 to D3, and the two-endmember mixing trends in bulk samples (strontium, carbon and oxygen isotopic compositions) provide solid evidence on the evolutionary processes of hydrothermal fluids from the overpressure- to topography-driven stages. Based on the combination of petrological, bulk-rock and in-situ methods, this study provides a template for understanding the evolution of hydrothermal flows in the fold-thrust system.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-3: Development and applications of in situ analysis in sedimentology and geobiology
Presentation Preference: Oral Preferred

Soft part preservation in hyolithids from the lower Cambrian (Stage 4) Guanshan Biota of South China and its implications

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Keywords: Hyolitha, Digestive tracts, Taphonomy, Konservat-Lagerstätten, Cambrian Series 2

Hyoliths, known globally from the Cambrian to the Permian are generally recognized as early lophotrochozoan animals of uncertain phylogenetic position. The calcareous exoskeleton of hyolithids, one of the two subgroups of hyoliths, consist of four elements including a conical conch, an external operculum, and a pair of curved enigmatic helens, but their ecology and internal morphology have long been considered controversial. Here we present for the first time, remarkably preserved hyolithids with helens and interior soft tissues from the Guanshan Biota (Cambrian, Stage 4) of Shijiangjun section, Wuding County in eastern Yunnan Province of South China. Preserved soft tissues and organs encompass the digestive tract, muscle scars and connective tissues between the operculum and conch. Three modes of soft part preservation in hyolithids from the Guanshan Biota are described: (1) preservation through pyritization, (2) sediment-infilling of guts, and (3) bacterial biofilm pseudomorphs (expressed as large internal hollow cavities), resulting from endogenous bacterial decay of soft parts. Such differential preservation of hyolith guts indicates different taphonomic modes for the soft parts of Cambrian animals in the Guanshan Biota. The newly collected material yields the oldest preserved guts in hyolithids from Konservat-biotas, and reveals new evidence for reconstructing hyolithid anatomy, such as the articulation mechanism of the opercula and the internal structures in the conch. Comparisons with younger well-preserved hyolithid specimens indicate that the gut anatomy of hyolithids was evolutionarily conservative from the early Cambrian through to at least the Ordovician.

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-3: Development and applications of in situ analysis in sedimentology and geobiology
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Provenance characteristics and sedimentary-tectonic evolution of Triassic Yanchang Formation in Jiyuan area, Ordos Basin—The evidence from U-Pb age in zircons

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Keywords: Detrital zircons, LA-ICP-MS, Provenance analysis, Sedimentary-tectonic evolution, Yanchang Formation, Ordos Basin

The Yanchang Formation of the Upper Triassic in the Jiyuan area in the central and western parts of the Ordos Basin is one of the main oil and gas enrichment areas in the basin. However, the tight sandstones of the Yanchang Formation have long been controversial on mineral genesis, formation age, tectonic setting and sediment source. The distribution and variation characteristics of detrital zircon ages were studied using LA-ICP-MS dating and geochemistry testing of the detrital zircons from sandstones in this study. The source of detrital zircons of different age components is identified, and difference of tectono-paleogeographic environments is analyzed. The main conclusions can be drawn as follows. Cathodoluminescence images show that most detrital zircon have a zonal structure. Rare Earth Element distribution models show that the sandstone is rich in HREE and is short of LREE, and all of models are left-dipping patterns. The Th/U values of detrital zircon show that most of the values are greater than 0.4, and a few are less than 0.1.The above geochemical testing results show that the source of detrital zircon is mainly magmatic rocks, followed by metamorphic rocks, and the ages of detrital zircons are reliable.The age results show that there exist three age stages of the Yanchang Formation detrital zircons, i.e., 228- 379 Ma, 1650- 1915 Ma, 2400- 2560 Ma, corresponding to the tectonic movements of indosinian, Hercynin, middle- late Lüliang movement and early-middle Wutai movement.By comparing the isotopic ages for the plutons in and around research areas, the tight sandstone of the Yanchang Formation in the central and western parts of the Ordos Basin derive from the Daqing Mountains-Wula Mountains, Yinshan Mountains and Jining areas in the north-northeast of the Ordos Basin.The sedimentary rocks source from gneissic granite in the late Neoarchean, ancient TTG gneiss and granulite in the early Paleoproterozoic, the khondalite belt in the Lüliang Movement, and the magmatic rock in the Indosinian and Hercynian.

Session T11-5: Technological and methodological advances in sedimentology

ID: T11-50038

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-5: Technological and methodological advances in sedimentology
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Intelligent identification and characterization of complex lithofacies in fluvial tight sandstone reservoir

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Keywords: Tight sandstone reservoir, Lithofacies type, Radial basis-multilayer perceptron neural network, Intelligence

The 8th member of Shihezi Formation in East II Block of Sulige Gasfield, Ordos Basin, is a typical fluvial facies deposit, which has experienced the sedimentary evolution from braided river (lower submember of the 8th of Xiashihezi Formation) to meandering river (upper submember of the 8th of Xiashihezi Formation) from bottom to top. However, the fluvial tight sandstone reservoirs are highly heterogeneous, and the sedimentary and reservoir characteristics of different river types are of great differences. This leads to the key technical problems such as the annual reduction of single well productivity and the difficulty of reservoir optimization in the later stage of development. In order to solve these neck problems, it is urgent to conduct fine anatomical research on reservoir structure (lithofacies units and their combinations) and heterogeneity characteristics constrained by lithofacies. Through the observation and description of core lithology and bedding, this study identified eight lithofacies types: massive bedding gravelly facies, trough cross bedding coarse sandstone facies, plate cross bedding coarse sandstone facies, plate cross bedding medium sandstone facies, parallel bedding medium sandstone facies, cross bedding fine sandstone facies, wavy bedding silty sandstone facies and massive bedding mudstone facies. Through core calibration logging and sensitivity analysis of logging curves, an intelligent lithofacies identification sample database is established, and a radial basis function multilayer perceptron neural network (RBF-MLPNN) joint model suitable for different river lithofacies characteristics is established based on data-driven method. The coincidence rate of this model for the intelligent identification of single well lithofacies in the 8th member of Shihezi Formation reservoir has reached 89.06%, which is significantly higher than that of other methods. This method considers the influence of different river-type lithofacies characteristics on the distribution of logging data, overcomes the shortcomings of existing lithofacies identification methods that are low in accuracy and difficult to popularize, and solves the problem of difficult identification of complex lithofacies. This method provides an effective way for the fine anatomical study of reservoir structure and heterogeneity characteristics of tight sandstone reservoirs in Sulige area.

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-5: Technological and methodological advances in sedimentology
Presentation Preference: Oral Preferred

Research of multi-temporal-spatial-scale variation of suspended sediment in the Bohai Sea: Based on machine learning method

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Keywords: Suspended sediment, Bohai Sea, Machine Learning;

Based on comparison of multiple machine learning algorithms, a new data-driven method, named as SatelliteFixer, is established herein to predict missing value of satellite data, which could be helpful in long-term continuous data generation with relative high resolution for temporal and spatial analysis. Compared with K-Nearest Neighbor, Support Vector Machine and Deep Neural Network, Random Forest is ultimately selected on account of its sufficiently prediction on the fluctuations in observed data. After application on 2002-2019 MODIS data of Bohai Sea and part North Yellow Sea, a reasonable reproduction of suspended sediment concentration with daily precision in 18 years is obtained by trained SatelliteFixer though constraint relationship of in-situ observational cruise data. Model result indicated a well preformation on retrieving suspended sediment concentration, showing an obvious variation among study area. Using the more comprehensive and accurate data of suspended sediment distribution, it could be calculated that average concentration varies from 0.81 mg/L to 38.95 mg/L in 18 years influencing by environment factors including wind, wave, current and tide. Controlled by East Asian Monsoon, the seasonal fluctuation of suspended sediment concentration and distribution with high concentration center located near Yellow River estuary is corresponded with hydrodynamic movement trend, while the average value is higher in Spring than in Autumn all as transition periods. Benefit from meticulous depiction by daily suspended sediment value, typical area analysis indicates regional imbalance of suspended sediment concentration dominated by varied environment factors, such as staggering peak of maximum value in winter. The subtle signal of river sediment load is captured with unstable value in summer and early entry of turbid period, while the concentration comparison of stations in Laizhou Bay demonstrates the human activity influence on river including dam construction, artificial avulsion and water-soil conservation program. Under the influence of multiple factors, the suspended sediment concentration in study area has a downward trend over the entirety reflected by Mann-Kendall test.

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-5: Technological and methodological advances in sedimentology
Presentation Preference: Oral Preferred

Transfer zones developed within fold-and-thrust belts under differential compression based on 3D numerical simulation results

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Keywords: 3D numerical simulation, Discrete element method, Fold-and-thrust belt, Transfer zone, Junggar Basin

The tectonic evolution and kinematic mechanism of fold-and-thrust belts have been studied in the field by using both physical analog experiments and numerical simulations. In this work, we study the growth and origin of the structural patterns in fold-and-thrust belts that develop under differential compression. The experiments are based on particle-flow simulations. Two simulations are configured to use four velocity modules, which can result in different shortening at the same time: (i) the homogenous module filled with brittle simulating sediment is used to investigate the structural response with a velocity difference and (ii) the module with ductile detachment at the front of each module is used to test how the weak layer affects deformation.

Two differential compression simulations were conducted in this work to investigate the structural styles and kinematic evolution of the differential shortening fold-and-thrust belts, which raises the following major points: (1) Resistance from the slower adjacent module can lead to back-thrusts prevailing in the faster module. Conversely, weak nucleation in the slower module is influenced by drag from the other side. The development of the piedmont thrust belt, gentle syncline, and pop-up structure is characteristic of the simulated ductile detachment. (2) Two strike-slip fault systems are recognized in the differential-compression simulation, Riedel shears at the foot of the backstop have a “flower structure,” which is composed of steep faults in the cross section, and the transfer faults in front appear flat thrusts with back-thrusts on the hanging wall. The different shortening distances concentrated near the backstops create Riedel shear (Naylor et al., 1986), following which the thrusts formed in front soon accommodate the compressive stress, which explains why the shear is limited to the toes of the backstops. Transfer faults that are oblique in front of the wedges transport material laterally. The uplifting of the hanging wall in the detachment simulation is characteristic of the ramp-flat fold sliding above the ductile detachment in the slower module. Material transportation in the shortening and lateral directions are the major kinematic mechanisms creating transfer faults in differential compression simulations. (3) The results of these simulations identify two factors that control the structural patterns of the south margin of the Junggar Basin. Oblique and curved fold-and-thrust belts are generated from the differential compression, and multiple rows of anticline, such as the Huoerguosi and the Anjihai anticlines, are related to the ductile detachment.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-5: Technological and methodological advances in sedimentology
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

A novel evaluation method of tight conglomerate reservoir based on petrophysical facies：A case study of Triassic Baikouquan Formation, northern Mahu Sag, Junggar Basin, China.

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Keywords: Keywords: Reservoir evaluation,Tight conglomerate, Petrophysical facies, Mahu Sag.

The determination of high-quality regions with highly porous and permeable areas in tight oil reservoirs has always been a challenging work due to ultralow petrophysics attributes. To date, extensive reservoir evaluation studies have been undertaken to locate the favorable zones for oil exploration and exploitation. However, the selected evaluation parameters depend heavily on experience or pure mathematical methods, lacking the geological controlling factors which determine the reservoir quality, and it is hard to carry out horizontal comparison. Hence, we propose a novel reservoir evaluation method based on petrophysical facies to undertake the reservoir quality assessment for the tight conglomerate-dominated reservoir of the Triassic Baikouquan formation in the northern Mahu sag, Junggar Basin. The lithological type and diagenetic features were firstly identified based on laboratory data. Subsequently, petrophysical facies types were recognized by the combination of lithofacies and diagenesis facies. Afterwards, capillary pressure curves of different petrophysical facies were clustered to clarify the reservoir quality variation in distinct geological origin. Consequently, the evaluation standard was established and the reservoir quality distribution was analysed and drawn out. These results indicate that the distributional status of the optimal reservoir (RT1) and the worst reservoir (RT4) are primarily determined by grain size, while RT2 and RT3 are predominantly controlled by dissolution and compaction. Moreover, an evident positive association exists between the reservoir property classification and the single well production capacity, which reveals that the utilization of petrophysical facies to assess reservoir property is reliable. It is concluded that reservoir evaluation based on petrophysical facies harbors the potential to be a pivotal tool for reservoir property assessment and prediction of favorable porosity and permeability zones.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-5: Technological and methodological advances in sedimentology
Presentation Preference: Oral Preferred

Advances of Optically Simulated Luminescence dating on marine sediments

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Keywords: OSL Dating, Marine Sediment, Coast, Deep Sea

Marine sediments record the history of the earth since they are generally subjected to rare disturbance by human activities in marine environment. In order to illustrate the geological stories recorded in marine sediments, the applicability and precision of geochronological methods must be taken into account. The luminescence dating has been applied to marine sediments since 1970s' due to its long time range and reporting the ages in calendar years. Many different types of coastal sediments have been dated, including beaches, beach ridges, raised beaches, beachrocks, marine terraces, aeolianites, foredunes, back-barrier dunes or dune cordons, palaeosols, tsunami deposits, storm deposits and estuarine and tidal-flat sediments. However, due to the absence of terrigenous quartz and feldspar in deep sea, the applications of luminescence dating are few reported.

In this presentation, some case studies of Optically Simulated Luminescence (OSL) dating on marine sediments from coast to deep sea will be reviewed as follows. 1)The samples acquired from marine terraces in offshore Hainan Island, southern China were detected to illustrate the relative sea level changes, and the late Holocene coastal sediments of Hainan Island might have been reformed by tropical cyclones with a highstand sea level. 2) The ages of gas hydrate reservoirs have been detected in northern South China Sea for better understanding the accumulation processes of gas hydrates. 3) Samples collected from Hole U1431A of International Ocean Discovery Program (IODP) Expedition349 have been detected to illustrate the palaeoenviromental changes in the central South China Sea over the past 115 kyr. 4) The OSL samples from IODP Exp. 316 in Nankai Trough have been applied for great earthquake recurrences and the results show that the Philippine sea plate subduction is faster than its current rate of ~4.5 cm/yr, resulting in more frequent great earthquake events than 180-200 yr recurrence interval during the past 1,300 year. 5) A new OSL dating material called siliceous sponge spicules for deep sea sediments recovered by IODP Exp. 369 will be established. The more applications of OSL dating on marine sediments can be expected in the future to provide high precision geochronological constrains for our geoscience community.

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Session T11-5: Technological and methodological advances in sedimentology
Presentation Preference: Oral Preferred

Image-based Pore Structure Characterization and Pore-scale Fluid Flow Simulation of Fine-grained Sandstones

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Keywords: Pore structure, Pore-scale fluid flow simulation, CFD

The understanding and management of oil and gas recovery depend critically on quantifying microscopic pore structure features and how fluid flow through tortuous pore systems. Here an integrated approach based primarily on image processing combined with MICP tests was served to investigate the geometrical and topological features of pore spaces and single-phase flow behavior in porous media. The pore spaces were extracted by segmenting 3D images (X-CT) and 2D images (thin sections and SEM) based on grayscale threshold or color threshold, and watershed algorithms was implemented to explicitly identify pores and throats. In addition, the connected and isolated pore spaces were distinguished according to whether connected paths can be generated in Y-axis direction, and single-phase flow simulation was performed using pore network models and traditional CFD methods respectively. Results show that the isolated pore spaces occur extensively scattered within the fine-grained sandstones, conversely the connected pore spaces are spatially concentrated. In 3D representation of pore spaces, 82.64% of isolated pore spaces are dead end pores, while 73.95% of the connected pore spaces are connected by at least two throats. Smaller shape factors and network tortuosity of connected pore spaces can be obtained, which indicate more irregular shapes and less curved paths for connected pore spaces. Pore and throat size distribution has been shown to determine pore structures and reservoir quality. The 3D images can provide broadly information about pore and throat size, but the limitation is that not all pores are captured in one single imaging experiments, due to finite resolution and sample volume of the experiments. The 2D images of different resolutions allow to capture geometrical features of pore spaces in different scales, but they cannot effectively reflect the realistic topology characters of pore spaces, i.e. the connectivity of pore spaces (2D) is significantly poorer than their real connectivity and it is substantially difficult to find connected paths in 2D images. Solving single-phase transport properties using pore network models is numerically efficient, which attempt to simply the pore geometries while retain pore topology features. Good positive correlation between coordination number and pore radius could be found in pore network model, which means that larger pores are more likely to be connected by throats and emerge better pore connectivity. The throat radius records a good positive correlation with fluid flow rate, which is consistent with the results of MICP tests, that is, a small number of large throats in low-permeability sandstones contribute the vast majority of permeability. The simulation results of CFD methods also show that the large pore throats in the sandstone constitute the dominant seepage paths.

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Session T11-5: Technological and methodological advances in sedimentology
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A comprehensive method for investigating 3D pore structures and its influence on fluid flow capacity of low-permeability sandstones

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Keywords: Pore structures, fluid flow, low-permeability sandstones

Pore structures determine the reservoir petrophysical properties and thus control fluid flow in sandstones. Detailed investigation of pore structures is vital for evaluating reservoir quality and improving the efficiency of oil/gas development. Poroperm analysis, mercury injection capillary pressure (MICP), and X-ray CT imaging were performed to probe the pore structures of the low-permeability sandstones. We then combined with numerical simulation to quantify the fluid flow behavior. Four types of pore systems were identified: residual intergranular pores, secondary dissolution pores, micropores and a minor amount of micro-fractures. The large pore throats are well developed in the pore system dominated by residual intergranular pores. The pore systems composed mainly of secondary dissolution pores exhibit a highly variable pore size distribution, and there coexists micro-scale pore throats and nano-scale pore throats. X-ray CT scanning experiments with different resolutions were conducted, and the resolution effects on pore structure characterization were revealed. The selection of imaging resolution must address the dilema between sample representativeness and scanning accuracy at the same time. For low-permeability sandstones with small grain sizes, the X-ray CT data with an imaging resolution of 1.0 μm is appropriate. Due to the limitation of image resolution and image processing technology, the image-based porosity and permeability is larger than the helium porosity and air permeability detected by laboratory experimental measurement. Finally, the controls of pore throat size, pore connectivity, and spatial combination of pore-throats on fluid flow capacity were clarified. The dominant flow channels are generally well developed in the sandstones with strong microscopic heterogeneity and good pore connectivity. Furthermore, the results are of great significance in predicting reservoir quality and fluid flow properties in low-permeability sandstone reservoirs.

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Session T11-5: Technological and methodological advances in sedimentology
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Sedimentary evolution of alluvial fan and fluvial facies under the sequence architecture of the Guantao Formation, Binxian uplift and surrounding areas, Jiyang Depression, China

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Keywords: Sequence architecture, INPEFA curve, Wavelet change, Guantao Formation, Binxian uplift

To the problems of the strong heterogeneity and the multi-solution of lateral comparison of alluvial fan and fluvial facies of the Neogene Guantao Formation in the Binxian uplift and the surrounding areas of the Jiyang Depression, a new stratigraphic division method combining high-resolution sequence stratigraphy with cyclic stratigraphy is established, revealing the sequence architecture and the sedimentary filling characteristics of the parasequence group within the third-order sequence in the study area. Using the INPEFA curve obtained by the maximum entropy spectral attribute analysis technique and the time-frequency features extracted by the wavelet transform method, combined with the well-seismic method, the identification of the high-resolution sequence stratigraphic interface and isochronous stratigraphic correlation of the Guantao Formation have been completed. Compared with the conventional logging division method, the trend inflection point of the processed curve can improve the accuracy of the identification of cycles at all levels, and the coupling between cycles and sedimentary facies sequence is better. The results reveal that the Guantao Formation corresponds to a third-order sequence, which can be divided into one long-term cycle (LNG), four medium-term cycles (from bottom to top, MNG1-MNG4), and 11 short-term cycles (from bottom to top, SNG1-SNG11). During the depositional period of the Guantao Formation, alluvial fans, braided rivers and meandering rivers were mainly developed. The sequence plays an important role in controlling sedimentary facies. With an increase in the ratio of accommodating space to sediment supply, alluvial fans have gradually evolved into braided rivers and meandering rivers. Alluvial fans and braided river deposits are mainly developed in the rising period of the LNG, while meandering river deposits are mainly developed in the falling period of the LNG. The transition between rising and falling periods was located in the middle and upper part of the Guantao Formation. As the base level rises, the sand bodies gradually decrease, and the Binxian uplift is gradually filled up. The integration of multi-scale methods has certain reference significance for the construction of sequence stratigraphic framework and sedimentary filling model in areas with strong heterogeneity and provides a reference for the subsequent sand body prediction and exploration and development of the Guantao Formation.

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Session T11-5: Technological and methodological advances in sedimentology
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Digital Processing and Recognition of Core Fluorescence Response Image

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Keywords: core fluorescence image,computer automatic identification,core

As important data for observing the structure of underground rock formations, the core fluorescence image is of great significance to the analysis of the meaning of its different color responses. Computer automatic identification can remove errors in human observation and improve the efficiency of related research and analysis.

The method I have used is

1. Based on the reflection color of the core box, the difference between the corresponding color of the core fluorescence and the core fluorescence is used to exclude the influence of light reflection on the results. The output fluorescence image is an RGB image. The pure reflection value without fluorescence response is (0, 0, 255), and the ideal and best organic matter fluorescence response value is (255, 255, 0), so the difference will not affect the fluorescence response of organic matter.

2. Convert the RGB image output by the computer into an HSV image, and obtain the one-dimensional feature vectors of three cut cores HSV=H*QH*QS+S*QV+V (H: Hue (0~360) S: Saturation (0~1) V: Brightness (0~1) QH, QV, QS are the quantification levels of H, S, V, respectively), and a fluorescence corresponding curve is obtained after averaging.

3. Coarse quantization of various corresponding colors, that is, the H component is quantized to 16 levels, the S component is non-uniformly quantized to 4 levels, and the brightness has a small distinction between colors, which is not considered, for the time being, to obtain 64 representative colors. Assign values to get the corresponding curve.

4. Use conventional methods to analyze the abnormality of the fluorescence response curve to obtain a standard plate of fluorescence response.

V. Application of fluorescence response standard plate for core fluorescence image recognition.

The core fluorescence response color is not only affected by the content of organic matter, but also by the comprehensive effect of many factors such as the content, size, and microstructure of bright crystal particles.

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-5: Technological and methodological advances in sedimentology
Presentation Preference: Poster preferred (Nonparticipation to ECS virtual poster competition)

Technical method for analysis of provenance system characteristics of Laiyang Group in Lingshan Island and its surrounding areas

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Keywords: Source system characteristics, Laiyang group, Lingshan Island, Tracer method of heavy mineral analysis source

Lingshan Island is located in the middle of Jiaonan uplift and Qianliyan uplift, on the suture line of Sulu orogenic belt, and is controlled by the collision between North China plate and Yangtze plate. Lingshan Island formation mainly develops turbidite of Laiyang Group of Lower Cretaceous, terrigenous clastic rocks, volcanic rocks and pyroclastic rocks of Qingshan Group. The strata of Laiyang Group mainly show the interbedding of gravity flow sedimentary rocks, siliceous rocks and siltstones. Its distribution is not limited to Lingshan Island, but extends parallel to the orogenic belt in the northeast and reaches Wulian fault in the south. The provenance system characteristics of Laiyang Group in Lingshan Island and its surrounding areas can be comprehensively analyzed by the following methods: (1) Paleocurrent direction analysis, which indicates the direction of restoring paleocurrent through many indicators of paleocurrent direction preserved in the strata, such as corrugation, oblique bedding, trough pattern, directional arrangement of gravel, etc. (2) The analysis of debris composition and the change of gravel detritus composition can indicate the evolution of provenance composition and tectonic setting of orogenic belt, and can also reflect the crustal uplift and subsidence in provenance area; (3) Trace method of provenance of heavy mineral analysis, which can be divided into heavy mineral combination analysis, heavy mineral corresponding index analysis, single mineral analysis, etc. Single mineral analysis, such as zircon U-Pb isotope dating and apatite trace element analysis, establishes the sedimentological relationship between sediments and provenance, effectively traces the background and properties of provenance, and can obtain the internal relationship between basin subsidence and important thermal tectonic events. Through these technical means and methods, the provenance system characteristics of Lingshan Island and its surrounding outcrop areas are analyzed, and the structural pattern change characteristics of basin and mountain ranges in the study area of Laiyang Group during the sedimentary period are discussed, which will provide some guidance for further understanding the relationship between Riqingwei Basin and Jiaolai Basin.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-5: Technological and methodological advances in sedimentology
Presentation Preference: Oral Preferred

Logs predication for high-quality shale based on support-vector-regression and Particle swarm optimization: A study case of Shahejie formation, Boxing Depression, Bohai Basin

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Keywords: shale, logs, lithofacies predication, SVR, PSO

The continental shale is characterized by strong vertical heterogeneity, usually with a laminated structure, which is composed of carbonate or siliciclastic rocks and organic-rich clay laminas. There are significantly different in the mineral composition, hydrocarbon generation potential, and pore structure. Thus, the division of lacustrine shale lithofacies needs to be based on the mineral composition (carbonate, quartz and feldspar, clay), rock structure, and the total organic carbon (TOC) and it is the foundation of reservoir evaluation and prediction.

The laminated structures are areally developed within the fourth member of Shahejie formation of Boxing depression. The laminated shale almost is carbonate laminas interbedded with organic-rich clays and little siliciclastic laminas. Logs data provide abundant and high precision geological information which is always used for prediction. Many methodologies have been applicated to predict the shale lithofacies including multiple linear regression (MLR), Kohonen neural network (KNN), and Bayes classifier. But these methods cannot work for the prediction of shale lithofacies in the study area due to the lack of measured data and the poor correlation between the minerals content and the logs.

In this research, we used X-Ray diffraction (XRD), TOC, and logging of well A to divide the shale lithofacies, and rock pyrolysis was used to identify the high-quality shale lithofacies. We selected AC (acoustic log), RT (true formation resistivity), GR (gamma-ray), and CNL (neutron log) as the feature parameters to fit the mineral content using the support-vector-regression (SVR) model. It was trained by particle swarm optimization (PSO). We used the model to predict the vertical shale lithofacies by the calculated mineral contents.

The measured data show that eight lithofacies are present in the study area: (1) organic-rich laminated sandy limestone; (2) organic-rich laminated limestone; (3) organic-rich laminated calcareous sandstone; (4) organic-rich laminated argillaceous sandstone; (5) organic-rich bedded sandy limestone; (6) organic laminated sandy limestone; (7) organic bedded sandy limestone; (8) organic massive calcareous sandstone. The organic-rich laminated sandy limestone is high-quality lithofacies. We identified several organic-rich laminated sandy limestones in well A. The results show that the mean absolute deviation (MAE) between predictive and measured values of mineral contents is 5% in the SVR model. This study shows that the SVR method is a powerful tool for shale lithofacies prediction in the background of measured data is small and the correlation between logs and mineral content is very poor.

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Session T11-5: Technological and methodological advances in sedimentology
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Virtual Digital Outcrop Under DDE

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Keywords: Digital Outcrop,UAV,DDE,UE4

The outcrop is the basic part of geological research, geologists usually visit the site to study its characteristics and infer the underground rock. The study of outcrops is not limited to the basic field, it is often used in the oil industry for reservoir modeling and to fill the gap between the seismic scale. The outcrop is often far away from the urban area and is located in difficult landforms. Scholars often face difficulties such as data collection, dangerous working environment, long working cycle and so on. In view of the importance of outcrop research in geology and its branches, the emergence of virtual outcrop model (VOM) enables research to be carried out in the laboratory. In the past ten years, LiDAR has been used as the main acquisition method for outcrop modeling, and its acquisition cycle and post-processing cycle are relatively long. In this study, UAV tilt photography is used as the outcrop acquisition method to model a profile with multi-precision blocks. With the support of UE4 engine, the 3D models with different precision are assembled, and the outcrop micro-geological information is fused with the scene roaming function by using UE4 development function. Result shows that: (1) On the basis of flexible and efficient acquisition, the modeling accuracy of UAV tilt photography can also meet the research needs; (2) The outcrop models with different precision and position can be spliced by UE4 engine, and the outcrop model is modularized. (3) The development function of UE4 can integrate the micro-scale information such as sedimentary structure, paleontological fossils and thin slices with the virtual outcrop model, and realize the roaming function, which can be used as the construction scheme of mathematical information database of outcrop profile, which is consistent with the purpose of DDE to "share global geoscience knowledge". (4) In teaching, it provides cognitive assistance for geological field practice.

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Fault propagation in pull-apart basin and its implication on depocenter migration: A discontinuum based numerical study

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Keywords: Strike-slip fault, pull-apart basin, depocenter migration, numerical simulation

The development degree and formation process of faults control the subsidence evolution in strike-slip pull-apart basin. In previous studies on the characteristics and evolution process of strike-slip pull-apart basin by physical simulation, there is a lack of correlation analysis between fault development process and basin subsidence process. Based on the discrete element method software PFC2D, this paper simulates the geometric morphology and deformation characteristics of strike-slip pull-apart basin evolution caused by strike-slip faults underlapping and overlapping. According to the curves of stress and displacement, the variation law of stress at different positions is explained. Combined with the characteristics of average stress distribution and contact force distribution in the basin, the influence of fault development on basin depocenter migration is discussed. The simulation results reveal that the fault extension process in the early stage of basin development in both cases is developed from the main fault endpoint to the opposite plate. In the late stage of basin development, underlapping model developed penetrating faults in the basin, and the new faults expanded outward. There was no large penetrating fault in the overlapping model, and the faults only expanded outward. The corresponding depocenter of the basin develops from both ends of the main fault to the interior, with the extension of the fault and then to the exterior. The fault propagation and basin depocenter migration of the KSG basin in North Africa correspond well with the simulation observation conclusion. The relevant research results can provide a theoretical basis for the analysis of similar basins and the judgment of the evolution stage of basin development.

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Cyclostratigraphy of xingouzui Formation in Jiangling Sag, Jianghan Basin and its sedimentary response to Paleocene-Eocene Thermal Maximum heat events

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Keywords: Jiangling Depression, Cyclostratigraphy, Xingouzui Formation, Absolutely Astronomical Time Scale, Deposition rate,

Jiangling depression is located in the west of jianghan basin, southern China is on the Yangtze continental block in the development of Cenozoic continental basin, the deposition of thick more continuous Cenozoic strata, after years of exploration, predecessors to the structure and evolution characteristics of jiangling depression had certain understanding, but for the regional stratigraphic age there is a big controversy, including new groove tip group basic assurance for floor age 56 Ma, However, the age of the top boundary is still uncertain, and the age difference leads to the uncertainty of the duration of the Xingouzui Formation, which affects the understanding of the structural evolution and hydrocarbon accumulation law of jiangling Depression. Based on spectral analysis of logging data from typical Wells in Xingou Zui Formation, Jiangling Depression, Jianghan Basin, the 405 kyr long eccentricality orbital period in the sedimentary record was identified and astronomically tuned. Floating astronomical chronoscales with duration of 8.921 Myr for well E9 and 5.504 Myr for well L8 were established. Based on the Eocene bottom age of the 2020 International paleomagnetic standard polar column of 56 Ma as the time anchor, a high-precision absolute astronomical age scale of 56-47.079 Ma was established for the Xingou Zui Formation. The deposition rates of The Xingou Zui Formation in Well E9 and Well L8 are estimated to be 9.98cm/kyr and 16.85cm/kyr, respectivelyIt is helpful to infer the distribution range of reservoir and source rock through the difference of different deposition rates for subsequent oil and gas exploration. In addition, a preliminary discussion was made on the reason why the long eccentricity signal of 405kyr was obviously weakened during the middle palaeocene extreme heat event in the xingouzui formation.

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Application of high frequency 3D sequence stratigraphy technique in prediction of carbonate deposition law

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Keywords: high frequency sequence, horizon cube, stratigraphic body, carbonate rock, sedimentary evolution

The concept of high-frequency sequence stratigraphic body is put forward for the first time, which is the further development and extension of seismic stratigraphy, sequence stratigraphy and well logging geology. The principle of spatial relative resolution and the concept of stratigraphic body is introduced and utilized; the calibration and application methods of high-frequency sequence stratigraphic body (HFSSB) are described in detail; at the same time, the technical flow, and analysis with application methods emphatically are introduced. Under the framework of this technology, taking S5 and S6 reservoirs in the Middle East oil field as an example, firstly the HFSSB is calibrated by high-frequency sequence stratigraphy of wells. In addition, 10 five-order cycles are further subdivided in the period of a transgressive and regressive sedimentary cycle. According to paleo-geomorphology restoration, based on the theory of relative spatial resolution, according to the reflection interface extracted from reservoir position of the high frequency sequence stratigraphic body, within the limited seismic wave group, following the vertical sedimentary time series, the reservoir properties of HFSSB are deeply decoded in space. Combined with the information of logging and geological calibration, the spatial distribution of s6-2 to S5-1 carbonate deposits is also successively analyzed in vertical direction, the horizontal attributes show that the sedimentary law and changes of tidal channel of shoal deposits are predicted more accurately than conventional method.

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Evolution of the hydrocarbon migration system of the Lower Enping Group in the Pearl River Estuary Basin

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Keywords: favorable area, fluid inclusion, hydrocarbon expulsion threshold, hydrocarbon migration, Lufeng sag

The Enping Group of the Paleogene System in the Lufeng south area of the Pearl River Estuary Basin has good potential for hydrocarbon exploration. It is characterized by a vertically large distribution of a crude oil type and a widely horizontal distribution of similar crude oil. With the complex characteristics of hydrocarbon distribution and migration, studying the evolution mode of this migration system on a dynamic scale is necessary. In this study, the key accumulation period was determined using existing logging, seismic, and microscopic data combined with fluid inclusion and burial history. Then, the system's migration path and the direction of migration in the key accumulation period were analyzed, and the migration system and evolution model in the study area were established. The results show two stages of accumulation in the southern Lufeng area: 19–8 Ma and 8–0 Ma. In the first stage, the reservoir mainly followed the transport of a far-source fault–sand–ridge coupling system and the traps on the migration path were favorable for hydrocarbon accumulation. In the second accumulation period, traps that developed near the oil-source faults were favorable for hydrocarbon accumulation. The favorable traps in the first accumulation period were distributed in the whole area. The traps in the southwest wells B921 and C1211 were larger than the first stage, whereas the favorable traps in the northeast and central parts were mainly distributed in B211D and its adjacent well area, with smaller and scattered traps. Favorable traps in the second accumulation period were mainly distributed in the eastern and central regions, around wells B211D and B161, whereas the traps in the southwest were not conducive to hydrocarbon accumulation due to the lack of effective transport system connection. The results of this study have a certain guiding significance for practical exploration.

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Modeling method of paleokarst restoration under multivariate constraints based on Digital Outcrop

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Keywords: Paleokarst cave reservoir,Multivariate constraints,Multipoint geostatistics,Digital Outcrop

A large area of deep carbonate reservoirs are developed in the platform basin of Tarim Basin. Different from the conventional clastic reservoirs, carbonate paleokarst cave reservoirs have their unique distribution rules. The traditional sedimentary facies modeling methods can not achieve good modeling results in this kind of reservoirs. Based on the investigation of typical karst outcrop in Yijianfang area, this paper uses modern measurement means such as UAV proximity photography and three-dimensional laser scanning to collect multiple data and construct an integrated digital outcrop model. Based on the fine identification and division of geological parameters of Digital Outcrop, a new method of paleokarst restoration modeling under the constraint of multivariate data is proposed. Taking the typical outcrop karst quantitative development model highly summarized as the training sample, combined with modern karst achievements, the karst development training image database is constructed. At the same time, the virtual well construction technology is used to construct the actual karst cave parameters with the virtual well method as the hard data-driven model. The multi-point geostatistics method under multivariate constraints is mainly adopted. Through the multivariate data fusion theory based on optimal parameter estimation, the three kinds of constraint data of fault parameters, fracture data and stratum attributes are fully integrated as the simulated trend constraint data. Combined with the training images and soft and hard data, the three-dimensional prototype geological model of paleokarst is constructed. The results show that the simulation results are more faithful to the hard data, and the restored paleokarst model is highly consistent with the karst development model of underground river type reservoir in Tabei reservoir.

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Dual-Energy CT: a new perspective for non-destructive analysis of sediment cores using stoichiometric calibration method

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Keywords: X-rays, sedimentology, medical CT, lacustrine sediment, chemical composition and electron density

Dual-energy CT (DECT) consists in imaging objects using two X-ray incident beams with different energies in order to discriminate and identify the different phases within a sample based on their density (specifically electron density, ρ_e) and elemental composition (effective atomic number, Z_{eff}). Here, a stoichiometric calibration method, originally developed for medical purposes and not requiring the previous knowledge of incident X-ray beam is applied to sediment cores, exploring the potential of this non-destructive technique for studying in 3D the inner changes in sedimentary composition, e.g. mineralogy and porosity.

Lacustrine sediment cores from the Canadian Artic containing pronounced sedimentary variations were tested. Cores were scanned using a medical CT instrument at 70 kV and 140 kV and chemical composition and electron density were calculated using the above-mentioned stoichiometric calibration protocol. ρ_e and Z_{eff} profiles were then compared to element profiles obtained from the same cores at the same resolution using a µXRF core scanner. Comparison of these profiles reveals elements having the strongest influence on two properties inferred with the CT-scanner.

Then, the prediction of sediment core chemical composition using DECT was tested, verifying the possibility to make this approach an alternative to current techniques.

In conclusion, dual-energy CT is a versatile method able not only to visualize non-destructively the inner structure of sediments but also shows promising prospect in identifying mineralogical and/or porosity changes in three dimensions.

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Characterization of Pore Structure and Connectivity of Sedimentary Rocks by Synchrotron Small-Angle X-ray Scattering (SAXS)

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Keywords: Longmaxi shale, small-angle X-ray scattering, closed pores, fractal dimension, absolute scattering intensity

Sedimentary rock pores are the storage space of many fossil energy. As a typical unconventional fine-grained sedimentary reservoir, the pore-throat configuration relationship of shale is more complex than that of sandstone and carbonate, which leads to the problem of low oil recovery in the process of exploitation. However, the complex pore-fracture network system is more conducive to the physical binding of carbon dioxide by rocks and promotes its dissolution and mineralization reaction, and also leads to shale reservoir being target fotmation for carbon dioxide geological sequestration. Therefore, revealing the pore structure and connectivity of shale is of great significance for the transformation of pore-fracture system in the process of oil and gas exploitation, and can be further used to guide the geological sequestration of carbon dioxide.

Small-angle X-ray scattering (SAXS) is a non-injection and non-destructive method that can be used to quickly and comprehensively characterize various parameters in shale pore systems at the nanoscale. In general the relative scattering intensities obtained irectly from SAXS can be used to calculate parameters related to the scatterer morphology such as the radius of gyration and particle/pore size distribution of the material, and therefore have a wide range of applications in nanoscience, structural resolution dependent on biological function, etc. Radlinski et al., (1996) was the first to use SAXS for the characterisation of pore distribution in porous media such as coal rock. When it comes to calculating parameters related to the mass density of a sample such as total porosity, specific surface area, etc., absolute scattering intensity must be used. Many scholars have investigated the process of absolute scattering intensity correction for weak scatterers such as biomolecules, but less research has been done on absolute scattering intensity correction for strong scatterers such as shales. In this study, the absolute SAXS intensities of typical fine-grained sedimentary rock samples, such as shales of the Longmaxi Formation in the Sichuan Basin, China, were calibrated by various methods under the Shanghai Synchrotron Radiation Facility. This study combined with the Debye-Porod theory on how to calculate porosity and specific surface area of porous media by absolute scattering intensity, reveals that the pore structure and connectivity characteristics of mud shale reservoirs are important for studying the diagenetic evolution of shale reservoirs, searching for shale oil and gas sweet spots, and predicting fracturing effects.

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SEDIMENTARY FACIES CHARACTERIZATION WITH AN INTEGRATED ANALYSIS OF HIGH-RESOLUTION BOREHOLE IMAGES, NUCLEAR MAGNETIC RESONANCE LOGS, MINERALOGIC LOGS, CORE AND CT DATA IN GLAUCONITIC SANDSTONES OF M2 SANDSTONE, ORIENTE BASIN-ECUADOR

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Keywords: glauconitic sandstones, image logs, nuclear magnetic resonance, CT, cretaceous

The main reservoirs in the Oriente Basin in Ecuador corresponds to the Hollin Formation and the U Sandstone and T Sandstone members of the Napo Formation. However, the last drilling campaign in the Cuyabeno field suggested that the M2 Sandstones Member of Napo Formation can become a potential secondary reservoir. However, secondary reservoirs as the M2 Sandstones Member of the Napo Formation are poorly known due to lack of information and more complex mineralogy. For example, the presence of glauconite could affect to gamma ray, resistive and density logs, which conventional petrophysical analysis can presents many uncertainties in this kind of reservoir. Hence, this sedimentological characterization is the result of the integration of novel technology as high-resolution borehole images, nuclear magnetic resonance, mineralogy, and core data. The core analysis includes porosity/permeability analysis, thin sections description, XRD analysis and computed tomography (CT) data. The core data was used to calibrate the interpretation of the high-resolution borehole, nuclear magnetic resonance and mineralogic well logs.

The core data is the main part of the interpretation for a sedimentological analysis. Nevertheless, on few occasions the core covers all the reservoir, and they are taken in a limited number of wells. In other hand, the well logs acquire information of the entire stratigraphic column. The combination of these data permit to elaborate a detailed sedimentological description of the geological formation.

The presence of glauconite and illite defined in the XRD data, thin section analysis, mineralogic logs and type of bioturbations suggests a shallow marine environment. The textures present in the image logs as cemented beds, and nodules, propose several diagenetic events in these sandstones, which can reduce the reservoir properties. And finally, the changes in the grain size present in the core are correlated with variations in mineralogy and pore size defined by mineralogic and nuclear magnetic resonance logs.

The integrated sedimentological interpretation together with detailed well correlations suggest that different sandbodies of the M2 Sandstone could be represent marine bars.

The result of this integration permitted to elaborate a robust sedimentological model of the M2 Sandstone. This detail analysis enhanced the petrophysical interpretation, and will be a input for the elaboration of a posterior geocellular model in order to develop this mature field.

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STUDYING VARVED SEDIMENTS BY MICRO-TOMODENSITOMETRY

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Keywords: Paleoclimatic reconstructions, Particle-size, Micro-CT, Varves

Particle-size analyses from thin sections of sediment cores extracted from lakes and oceans allowed to obtain robust paleoclimatic reconstructions. These reconstructions consisted of a detailed study of the structure and texture of varved sediments using image analysis of pictures taken at the scanning electron microscope. This method is destructive, laborious and requires long periods of sample preparation. This paper investigates the possibility to use X-ray micro-tomodensitometry (µCT) for such paleoclimatic studies. µCT allows the observation of objects whose sizes are of the order of several micrometres and has the advantage of being a non-destructive technique, facilitating the study of the internal structures of a wide variety of geological objects. A home-made sample holder was designed and built to scan cores that were previously studied by the thin sections method. Then, several instrumental acquisition and images 3D reconstruction settings were tested in order to identify the best possible configuration to 1) determine the limits of varves; 2) perform the varve counting; 3) estimate the annual mass accumulation rate by the estimation of each varve density; 4) access the morphology and size of sediment grains, which are, in favourable settings, revealing indices of the prevailing climatic conditions at the time of their deposition. These µCT results will be compared to the ones obtained by the thin sections method to evaluate the effectiveness of the method for paleoclimatic analyses.

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Measurement and sampling of dynamic near-seafloor flows in Kaikōura Submarine Canyon, offshore Aotearoa New Zealand

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Keywords: submarine canyon, sediment, flow, lander, mooring

Linking measurements of process to depositional products has been a long-standing challenge in sedimentology and stratigraphy. This has been particularly difficult in deep-sea submarine canyon and channel environments that experience dynamic and often unpredictable flows with varying sediment flux to the seafloor and along channels. Targeted studies along such systems including paired near-seafloor and seabed samples and measurements are needed to characterise and quantify sediment and organic carbon flux. Here, we present initial results of a pilot study in the Kaikōura Submarine Canyon, offshore northeastern Te Waipounamu South Island, Aotearoa New Zealand. The experiment focused on three locations along the submarine canyon floor from ~900 to ~1500 metres water depth with sediment traps mounted on a mooring (~15-16 metres above the seafloor) and on a benthic lander (~2 metres above the seafloor), with complementary multicores (across the sediment-water interface) collected at each site. Benthic landers deployed for few weeks allowed a detailed view of near-seafloor canyon sedimentary dynamics. Preliminary results suggest that sediment fluxes and organic carbon composition varies with distance down-canyon, distance above the seafloor, and over time. The new measurements were acquired following an earthquake-triggered canyon-flushing event in 2016 that overall caused significant erosion (up to 50 m in the upper canyon) but locally resulted in a complex pattern of erosion and deposition along the canyon system. Our new near-seafloor data provide detailed information on canyon dynamics following canyon-flushing that reveal the processes of canyon infill between such large events at much shorter time-and smaller space-scales.

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-5: Technological and methodological advances in sedimentology
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A Dynamic Model for ME Seamount Based on BIM+GIS

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Keywords: BIM, GIS, Model, Cobalt-rich crusts

Cobalt-rich crusts contain Mn, Co, Pt, Ni, Pb, Ti, Ce and other elements. The content of cobalt is very high. Co can be used to produce heat-resistant alloys, cemented carbide, anti-corrosion alloys, magnetic alloys, etc. It is a scarce strategic resource and the crusts are located in shallow water, so the development and extraction technology and investment costs are lower than those of deep-sea polymetallic nodules, making it a high-quality seabed mineral resource. The cobalt-rich crusts resource exploration contract signed between China and the International Seabed Authority at Caiwei and Jiaxie Guyots in the Magellan Seamount group has been implemented for eight years, during which a large amount of data such as geological sampling, geophysical survey lines, video survey lines, environmental exploration and related analysis have been acquired. Spatial modelling of various data, realizing full-cycle management of data and establishing digital mining area models are very important aspects of the follow-up work. The ME Seamount, which is adjacent to the crust mineral area, is one of the larger seamounts in the Magellan Seamount chain and is the most heavily investigated apart from the mineral area. BIM (Building Information Modeling) technology is a numerical tool applied to engineering design and construction management, which supports dynamic databases through the integration of informative models of data to be shared and transmitted throughout the life cycle process of planning, operation and maintenance. GIS provides an advanced spatial data management and visualisation environment. Based on BIM and GIS, Revit solid model and ArcScene surface model are produced on the basis of product data like DEM, survey stations, survey line data and resource assessment in ME Seamount. Then these two models are integrated into a geometric parametric model. The surface texture of the terrain is extracted from the DEM and the original image with orientation parameters, and the texture is pasted on the geometric model to build the ME Seamount geometric parametric model. The study shows that BIM+GIS-based data modelling of cobalt-rich crusts can help realise the full-cycle digital management of data collection and management, spatial analysis, resource evaluation and strategy support, etc. The technology can realise 3D visualisation of mine data at a lower cost and higher efficiency, and provide a visualisation tool for optimal mining management.

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A Deep-time Spatial Interpolation Method

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Keywords: Deep time, Spatial interpolation, Sediment distribution, Scientific Ocean Drilling

Resolving the spatial extension information of a stratigraphic column or borehole is an essential step toward understanding the distribution of sediment and its quantitative spatial-temporal evolution. However, due to the non-intuitiveness, non-parametric and irregular distribution of geological spatial information, some current spatial interpolation techniques have limited applicability in deep time geological research. Here, we systematically review the existing related methods and their applications of modern geographical spatial interpolation, each method has its specific assumptions and features. Based on the geological conditions and principles, we propose a “deep-time” spatial interpolation method, which can bridge the gap between deep-time and modern geological space. Finally, using the spatial interpolation method, we map a deep-time sediment distribution and quantitatively calculate the total amount of sediment based on the data from Scientific Ocean Drilling.

Session T11-6: Open session for other topics of sedimentology

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-6: Open session for other topics of sedimentology
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The Relationship Between Paleogeography and Sedimentary of Upper Urho Formation in Junggar Basin

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Keywords: Junggar Basin, Upper Urho Formation, Paleogeography, Sedimentary, Ancient Gullies

Recently the exploration of oil and gas in the Junggar Basin has gradually moved from conventional traps outside the source to inside, and has significant achievements. With the deeper exploration, several oil reservoirs have been discovered in Upper Urho Formation, and it turns to be the most important layer to increase production. Actually we found that the distribution of the sedimentary system in this area was obviously controlled by the paleogeomorphology. Based on the determination of the sequence stratigraphic framework of the Upper Urho Formation, we analyzed the data of core, slices, seismics, outcrops and logging datas to establish the paleogeology, and clarified the characteristics of sedimentary.

Results show that: (1)Junggar basin was divided into 8 primary tectonic units and 42 secondary tectonic units. We can see a higher-to-lower characteristics when it goes from north to south. The highest part was the western uplift in the northwestern basin, and the lowest part was the thrust belt in the southern basin. (2)The sedimentary systems in Junggar basin contained steep slope-fan delta in the western and gentle slope-waved fan delta. The basin area was smaller in the first period of Urho Formation, and there displayed fan deltas along the edge of Junggar basin. The second period of Urho Formation was transgression with plenty of sources, therefore more sand bodies were deposited on the edge of the lake, and it was also a fan-delta period. There was a widely transgression in the third of the Urho Formation with less sediments in less main rivers, so only few sand bodies were deposited at the edge and mainly deposition was lacustrine mudstone. (3) The main transport channels of sand in this area were ancient gullies, and we found U-type and V-type ancient gullies here, most gullies were V-type. The gullies mainly distributed in northwest and east of basin, with perpendicular and parallel to the source direction. The characteristics of transportation channels were different between northwest basin and east basin, which leaded to different sedimentary models. In the northwest, we found most gullies were perpendicular to sources, and there was a severely altitude difference. The single thickness of the sand body was lager, and distributed widely, showing a continuous superimposition. In the east, we distinguished three groove systems: Shaqiuhe system, Shaqiu system and Shuangquangou system, and it turned that three lobes: Fubei lobe, Shaqiu lobe and Shuangquan lobe were controlled by three systems mentioned.(4)There's significant effect on sedimentary distribution caused by the paleogeology, different geomorphic pattern in different period and continuous sedimentary of sand body. This formed the situation of sand body largely distributed along ancient gullies. And we summarized the patterns of relationship between paleogeography and sedimentary.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
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Back-arc basin evolution in collision zones: Sedimentary records of early Permian subduction tectonics in Ailaoshan Orogenic Belt

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Keywords: ailaoshan,back-arc basin,Volcanic debris

Ailaoshan tectonic belt is located between Indochina-Simao block and South China block, which belongs to both Gondwana and South China continental tectonic units(Metcalfe, 2002; Metcalfe, 2013b; Zhao et al., 2017; Li et al., 2021) There are many related researches have been carrying out in the Paleotethys ocean closure(Fan et al., 2010; Jian et al.,2009a; Jian et al.,2009b; Xu et al., 2019) and the late collisional orogeny(Cao et al.,2012; Wang et al., 2019; Yu et al., 2020; Zheng et al.,2021), however, the trench-arc-basin evolution occurred in the early days of collision orogenic belt is rarely to be noticed. Meanwhile, Ailaoshan tectonic belt can be divided into three evolutionary stages, which have different tectonic attributes in different geological stages(Wang et al.,2000; Liu et al.,2011). The Ailaoshan ocean basin has been considered as a branch of the Paleotethys ocean and is of great significance to the evolution of the Paleotethys Ocean(Wang et al., 2000;Lai et al.,2012;Pan et al., 2012;Xia et al., 2020). In previous studies, the Ailaoshan ocean basin was believed to have been opened in the Late Paleozoic and closed in the Early Triassic(Li et al., 2013;Xia et al.,2016;Xu et al.,2020). However, by summarizing the research results, it is found that the main research object is arc volcanic rocks around the Ailaoshan tectonic belt(Fan et al.,2010; Liu et al.,2011;Li et al.,2013;Sun et al.,2016; Faure et al.,2016). Through the study of volcanic rocks, a series of discussions and explanations have been carried out on the tectonic attributes, suture positions and closure time of Ailaoshan ocean basin, but the opening time of Ailaoshan ocean basin is still controversial(Liu et al.,2018), the unique tectonic background of "early subduction evolution in collision tectonic belt" of Ailaoshan ocean basin has not been thoroughly discussed.

To test the initial subduction of the Ailaoshan ocean basin, we here report high-precision U-Pb dating and Hf isotope method to carry out the early subduction initiation time of the Ailaoshan Ocean, and the subduction direction by comparing with the detrital zircon age of the same period in the surrounding area, and established the early subduction mode of the ocean basin in the background of collisional orogenic belt.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
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Sedimentation, Structure, and Reservoir Properties in Prospective Offshore Geologic Carbon Sinks, Gulf of Mexico

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Keywords: Deep water, Gulf of Mexico, turbidite, salt tectonics, reservoir properties

Deep-water deposits in the upper continental slope in the Central Gulf of Mexico include many of the largest oil and gas reservoirs in North America and are potentially vast targets for CO_2-enhanced oil recovery and saline formation storage of CO_2. As part of the SECARB Offshore Partnership program, an assessment of the enhanced oil recovery and saline formation storage resource is underway in the Mississippi Canyon, Green Canyon, Viosca Knoll, and Atwater Valley areas of the central Gulf of Mexico. This region has long been a frontier for the development of deep-water drilling and production technology, and long-range planning is required to develop strategies for the implementation of CO_2-enhanced recovery and storage so that technology is ready to apply as reservoirs mature.

Data from more than 7,200 wells and 74 3D seismic surveys indicate that target reservoir strata are dominated by sandstone ranging in age from Miocene to Pleistocene and are distributed through a section that in places is thicker than 10 km. The region contains a spectrum of salt-tectonic structures, including large allochthonous salt sheets. Sedimentation is dominated by turbidite systems, and an intricate relationship exists between salt movement and sedimentation. Numerous minibasins have subsided between salt bodies, compartmentalizing the turbidite systems; minibasin, subsalt, and suprasalt reservoirs are abundant.

Turbidite sandstone occurs between thick mudstone units that are on the order of 100 m thick. Sandstone thickness is highly variable, and values form a distinct statistical population. These values have a log-normal distribution with a geometric mean of 7 m, and values between 3 and 19 m fall within the standard deviation; the maximum is 220 m. Sandstone thinner than 10 m is typical of mid to outer fan deposits, whereas thicker sand is characteristic of fan channels. Channels are deepest at the margins of the minibasins. Fan deposits thin away from the channels and commonly terminate basinward of the edges of the minibasins. This depositional heterogeneity contributes a component of stratigraphic trapping to what is otherwise a salt-structural regime. Porosity of reservoir sandstone typically ranges from 20-35%, and permeability is generally 100–1,100 mD. Porosity decreases with depth, and values indicate high reservoir quality throughout the section.

Reservoir pressure, temperature, and fluid chemistry vary systematically with depth and are primary considerations for CO_2 enhanced recovery and storage. Reservoir pressure is influenced strongly by active hydrocarbon charge, with normal brine-compensated hydrostatic pressure gradients forming the lower limit, and fracture gradient (19.9 kPa/m) forming the upper limit. Temperature gradient varies greatly and depends strongly on the distribution of thermally conducive salt and poorly conductive mudstone and sand. Brine concentration ranges from normal marine at the seabed to ~350,000 mg/L at depths beyond 20,000 ft. The storage resource is >4 Gt in maturing reservoirs and is terratonne-class in saline formations. Results show that there are many technical challenges, but assessment results indicate that the potential for CO_2-enhanced recovery and storage is vast and a strong driver for technology development and implementation.

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
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Early Pleistocene depositional setting at Dachangliang, Nihewan Basin, NE China

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Keywords: Quaternary, Asia, Ostracoda, Hominins, Paleolithic

The Nihewan Basin preserves the oldest record of hominin occupation in NE Asia, following the earliest locations outside of Africa. The sedimentology and stratigraphy of the early Pleistocene deposits of the Nihewan Formation, exposed in the northeast of the basin, were not adequately investigated so far. Three sediment sections up to 50-m thick were investigated to reconstruct their depositional conditions. The study included analyses of the lithological characteristics of the outcrops, and of grain size, magnetic susceptibility, and ostracod-assemblage data. The exposed sediments predominantly comprise varicoloured silt-sized materials, partially interbedded with calcareous and fine grained sand layers and minor contributions of clay-sized particles. Different sedimentary units typically have specific, homogenous lithological features. Sedimentary structures within the units include various stratification types such as cross-, horizontal and ripple bedding, and burrows, indicating a dynamic depositional setting. Prominent marker beds of white marl enable a lithostratigraphic correlation with the sediment section at the Majuangou site that contains four artefact layers of known age. Sediment accumulation of the studied sections apparently started ca. 1.7 Ma and lasted until ca. 0.9 Ma. The sediments in all sections reveal four sedimentary cycles which are accompanied by cyclical changes in magnetic susceptibility (MS). In each cycle, the grain size fines upwards, while MS values decrease. The ostracod assemblage represents 13 taxa with *Limnocythere flexa*, *Ilyocypris spp*. and *Heterocypris salina* as the most abundant species. In contrast to slightly darker coarser grained sediments, the white marl layers are dominated by *Cytherissa lacustris* and/or *Leucocythere dorsotuberosa.* The investigated sediments and ostracods suggest that the sediments at Dachangliang were mostly deposited in a wetland and/or alluvial plain setting which was at least two times interrupted by the establishment of a relatively deep lake at ca. 1.3 and 0.9 Ma.

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Sediment erodibility in the Yangtze Delta: spatial-temporal distribution and their sedimentary significance

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Keywords: sediment erodibility, Yangtze subaqueous delta, cohesive strength meter, critical shear stress, sediment activity

An accretion-erosion conversion is occurring in the mouth bar area of the Yangtze estuary under the decreasing sediment flux due to the construction of dams and soil conservation, this could threaten the development of the Yangtze subaqueous delta. The sediment erodibility is an important indicator of subaqueous delta vulnerability. In this study, shore cores were collected in the Yangtze subaqueous delta using a box-corer, and the critical shear stress of the sediment was measured using a cohesive strength meter (CSM) and an empirical formula; the activity of the sediment was analyzed by comparing the critical shear stress of the sediment with the bed shear stress simulated using a numerical model (FVCOM), thus discussing the present and future erodibility of the subaqueous delta. We found that the results of the empirical formula relied only on grain size differ significantly from the situ sediment, but the results of CSM that do not correlate with the empirical formula are more consistent with the situ sediment. The annual surface sediment activity ranges from 5% to 30% based on the CSM results indicate that the surface erodibility is not high. Meanwhile, the critical shear stress in this region increases with increasing water depth but the bed shear stress is the opposite, so there is a low probability of continued vertical erosion after surface sediment erosion. Therefore, the erodibility of the Yangtze subaqueous delta is lower than the mouth bar area, indicating no accretion-erosion conversion, and will not experience continuous vertical erosion under sediment starvation in the next decades.

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Diagenesis and Porosity Evolution of Tight Sandstone Gas Reservoirs in the Western Sulige Area

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Keywords: tight sandstone gas, pore evolution, diagenetic facies, western Sulige area

The purpose of this work was to explore the genesis of tight reservoirs and porosity evolution in the western Sulige area, Ordos Basin. Based on laboratory tests including observation of casting thin sections, electron microscope analysis and high pressure mercury injection, a theoretical calculation model was established, by which qualitative and quantitative analyses were made to the pore evolution of the gas reservoirs in the Su 48 area. The analysis results show that the reservoir lithology of He 8 member is mainly quartz sandstone and lithic quartz sandstone. The generation of the reservoirs was mostly in the early and middle diagenesis stage, and some reached the late diagenesis stage. The diagenesis sequence was as follows: compaction - siliceous cementation - chlorite cementation - clay mineral cementation - dissolution- carbonate cementation. The quantitative results show that compaction and cementation were the primary factorsleading to the decrease of reservoir porosity. The original porosity was reduced 22% by compaction and cementation dropped 9.81%, while the reservoir space was enhanced 3.88% by dissolution, finally resulting in todays tight sandstone reservoirs with average porosity 7.47%. Comparison shows that the calculated results are basically consistent with the measurements with relative error less than 3%. According to the action intensity of diagenesis, combined with the analysis of rock characteristics, the diagenetic facies of He 8 member reservoir in the study area can be divided into four types, i. e., weak -medium cementation strong dissolution facies, medium cementation medium dissolution facies, medium dissolution strong cementation facies and strong compaction tight facies Gas tests demonstrate that the gas production in the area of weak -medium cementation and strong dissolution facies is relatively considerable, which can be regarded as the main research area for continuous gas production.

Reference
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Presentation Preference: Oral Preferred

Lithofacies and diagenetic evolution implications for reservoir quality: A case study of the Triassic Chang 6 Member, Ordos Basin, China

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Keywords: Lacustrine shallow-water delta front sediments, Lithofacies, Diagenetic evolution, Reservoir quality, Carbonate cements;Ordos Basin

The Chang 6 tight sandstone reservoirs of the Upper Triassic Yanchang Formation in the southeastern Ordos Basin develop large lacustrine shallow-water delta front sediments, and its lithofacies and diagenetic evolution history are complex. Based on core observations, this research integrates casting thin sections, scanning electron microscope, cathodoluminescence, backscatter imaging, electron probe and fluorescence thin section observations and quantitative statistics, capillary pressure, porosity and permeability, homogenization temperature of fluid inclusions, **in-situ carbon and oxygen isotope analysis results of carbonate cements**, and other techniques to investigate the lithofacies, the characteristics and distributions of various diagenetic alterations, and their implications for reservoir quality.

Three types of lithofacies are identified in lacustrine shallow-water delta front deposits. Lithofacies I is gray white fine and medium sandstones, developed large-scale parallel bedding. Lithofacies II is gray fine sandstones, developed massive trough cross bedding. Lithofacies III is gray black muddy siltstones or siltstones, developed wavy bedding.

The various lithofacies have different initial petrological components, diagenetic alteration characteristics and reservoir qualities, and differ in oil-charging phase and intensity. The lithofacies I sandstones are arkose, and the sandstones experienced medium mechanical compaction, finite cementation, intensive dissolution and two phases of oil charging with high intensity. The lithofacies II sandstones are arkose and lithic arkose, and the sandstones experienced moderate to extensive mechanical compaction, relatively extensive cementation, relatively moderate dissolution and two phases of oil charging that the intensity is weaker than lithofacies I sandstones. The lithofacies III sandstones are lithic arkose, and the sandstones experienced rapid compaction densification, continuous cementation, limited dissolution and only early small-scale oil charging.

Mechanical compaction is the most significant reason for the decrease in primary porosity. The carbonate cementation and authigenic clay minerals further reduce the reservoir quality. The origin of microcrystalline calcite($\delta^{18}O_{PDB}$: -13.3 ‰~-10.0 ‰; $\delta^{13}C_{PDB}$: 0.4‰~2.1‰) formed in the eogenesis A stage is related to meteoric water in a shallow buried environment. The origin of sparry calcite I ($\delta^{18}O_{PDB}$: -19.8 ‰~-13.4 ‰; $\delta^{13}C_{PDB}$: -0.4‰~0.8‰) formed in the eogenesis A stage, sparry calcite II ($\delta^{18}O_{PDB}$: -21.8 ‰~-18.7 ‰; $\delta^{13}C_{PDB}$: -5.1‰~-0.4‰) formed in the eogenesis B stage, and ankerite ($\delta^{18}O_{PDB}$: -21.5‰~-16.8‰; $\delta^{13}C_{PDB}$: -4.6‰~-3.9‰) formed in the mesogenesis A stage is gradually correlated with the negative carbon fluid released during the thermal decarboxylation of organic matter. When the chlorite cement content in the reservoir is less than 4%, the primary intergranular pores can be effectively protected. Flaky and fibrous illite deteriorate the reservoir quality. The acidic diagenetic environment formed during the two phases oil charging process is the key factor for the dissolution of laumontite and feldspar. Laumontite cements effectively resisted the intensity of compaction in eogenetic stage, and its dissolution pores formed in mesogenetic stage greatly improved the reservoir quality.

Ultimately, combining the relationship between sedimentary facies and lithofacies with the distribution of different diagenetic processes, four evolutionary patterns are identified for reservoir quality in the lacustrine shallow-water delta front.

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Presentation Preference: Oral Preferred

TOC Prediction Using A Joint Unsupervised and Supervised Deep Learning Approach

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Keywords: Sweet-spot Prediction, Unsupervised Learning, Contrastive Learning-Convolutional Neural Network, Unlabeled Data

Abstract: Total organic carbon content (TOC) is important for sweet spot prediction and resource calculation. However, the prediction accuracy of traditional physical methods is low, while machine learning methods only use labeled samples (core TOC samples and well logging data) to predict TOC, leading to their performance reaching a bottleneck. Meanwhile, there is considerable unlabeled data (well logging data) in many oilfields. Therefore, based on this unlabeled data, we proposed a joint unsupervised and supervised learning approach, named Contrastive Learning-Convolutional Neural Network (CL-CNN) to predict TOC. In recent years, CL has been a research hotspot in the field of unsupervised learning, whose principle is to reduce the distance between similar samples and increase the distance between different samples as much as possible in the feature space. CNN is characterized by local connectivity and weight sharing, which has strong generalization ability and high prediction accuracy. CL-CNN model first applies CL to pretrain the initial parameters of CNN model on a large number of unlabeled datasets and then finetunes the resultant CNN model using the labeled data. The framework combines the advantages of CL and CNN to further improve the prediction accuracy and generalization ability. The proposed method was applied to predict the TOC of shale gas in the Sichuan Basin, China, including 121 core samples and 1224 well logging data (121 logging data for supervised learning and 1103 logging data for unsupervised learning) from the JY 10 well. Besides, the CL-CNN model was further verified by JY 10-10 well data. Experimental results demonstrated that the CL-CNN model outperformed many machine learning methods, such as Support Vector Machine (SVM), Gaussian Process Regression (GPR), Random Forest (RF), and CNN model because of its better accuracy (R^2=0.8958, RMSE=0.3353), generalization and low over fitting, which indicates the feasibility and effectiveness of the proposed method. The CL-CNN model can also be used as a general prediction tool for reservoir parameters such as porosity and permeability.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
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Analyses on characteristics and main controlling factors of the tight sandstone reservoirs in the Southeastern Ordos Basin

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Keywords: Tight sandstone reservoirsReservoir characteristics, Diagenesis, Ordos basin

With the continuous expansion of oil exploration and development, tight sandstone reservoirs have become the main target reservoirs of oil and gas exploration and development in China [1]. By means of thin section, scanning electron microscopy, X-ray diffraction, taking Shan 1 Member of Lower Permian Shanxi Formation in Yanchang Gas Field, southeastern Ordos Basin as an example, this study comprehensively studied the main controlling factors of tight sandstone reservoirs, which is of great scientific significance to guide the exploration and development of tight sandstone gas in the Upper Paleozoic in southeastern Ordos Basin. Shan 1 Member is mainly composed of medium sandstone and fine sandstone. The clastic mineral composition of sandstones in Shan 1 Member is mainly quartz (76.2%) and lithic (22.9%), with little feldspar (0.89%). The average content of interstitial materials in Shan 1 Member is 11.95%, including hydromica 3.5%, siliceous 2.6%, carbonate 3%, chlorite film 2.18% and kaolinite 0.63%. The sorting of sandstone grains is medium preference, and some reservoir sections are well sorted. The grinding circle is mainly subangular to subcircular. There is a positive correlation between porosity and permeability in most stratified sections in the study area, but there are also high permeability sections in some well-developed fractures or pore-throat connections. Pore types mainly dissolution pore accounted for 63% of the total pore types; secondly intergranular pore is mainly manifested in authigenic clay minerals such as kaolinite, illite and chlorite in crystallization in the process of the formation of the intergranular pores, feldspar and sialic acid and mineral dissolution of kaolinite intercrystal pore, accounts for about 16%; primary pores are hard to retain only a small amount of primary intergranular pore, it accounts for about 9% of the total pore types due to strong compaction; microcracks within the particles were observed under the microscope, including cracks that run through multiple particles and contraction joints of tuffaceous matter. Fractures are usually accompanied by dissolution, that is, after the formation of fractures, they become effective channels for fluid flow, thus causing formation solutions to form crack solution fractures on both sides of fractures, accounting for about 1.9% of the total pore types. The statistical analysis of grain size in this area shows that intergranular pore and face ratio are positively correlated with grain size, intergranular pore and face ratio are positively correlated with quartz content, and negatively correlated with cuttings content, indicating that the higher quartz content, the better porosity and permeability of the reservoir. Currently, the reservoir is in the middle diagenetic stage B. Mechanical compaction, late carbonate cementation and siliceous cementation are the destructive diagenesis, which are the main reasons for low porosity and low permeability of reservoir rocks. Kaolinite intercrystalline pore reservoirs provide important reservoir space and dissolution greatly improves reservoir performance.

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Presentation Preference: Oral Preferred

Microscopic characteristics and classification evaluation of tight sandstone reservoirs: A case study of Chang 9 oil-bearing layer in Nanliang area, Ordos Basin

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Keywords: Tight sandstone reservoir, Classification evaluation of reservoirs, Fractal theory, Ordos basin

The reservoir's storage capacity and seepage capacity are controlled by the microstructure of tight sandstone. As a result, it is critical to clarify the properties of microscopic reservoirs for oil and gas exploration and development. Taking the Chang 9 in the Nanliang area, Ordos Basin as an example, the microstructural characteristics of tight sandstone reservoirs were identified using nuclear magnetic resonance (NMR), high-pressure hg injection, X-ray diffraction, scanning electron microscope (SEM), and cathode luminescence. Then applying the fractal theory to classify the pore radius of tight sandstone reservoirs into three categories. The results indicate that strong compaction is the reason for the general densification of tight sandstone reservoirs. On the basis of strong compaction, cementation aggravates the densification of the reservoir, while dissolution improves the quality of the reservoir. In tight sandstone reservoirs, not only are there great differences between different reservoirs but also the microstructure within the same reservoir is extremely complex. With the increase of pore radius, the heterogeneity of pores increases gradually, in which macro-pores control the physical properties of the reservoir. According to the macro-porosity, tight sandstone reservoirs are categorized into three types, and the results are consistent with testing for oil. It is concluded that the combination of high-pressure hg injection, nuclear magnetic resonance and fractal theory can quantitatively characterize the microscopic property of tight sandstone reservoirs, and then determine the key factors affecting the quality of the reservoir, providing a reliable basis for the classification and evaluation of tight sandstone reservoirs.

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-6: Open session for other topics of sedimentology
Presentation Preference: Oral Preferred

Fluid-Rock Interaction Mechanism and Porosity Evolution of the First Stage of Huangliu Formation Reservoirs in Gas Field D with High-temperature and High-pressure, Yinggehai Basin

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Keywords: chemical thermodynamics, hydrodynamics, fluid-rock interaction mechanism, porosity evolution, the first stage of Huangliu Formation

Since the 1990s, many achievements have been made in the study of reservoir fluid-rock interaction in Yinggehai Basin. However, just like the research on other oilfields, most of the methods used in the previous research were traditional geological methods, which mainly focused on the petrological characteristics, diagenetic characteristics and reservoir performance of the reservoir. They were mainly static, and could not quantitatively combine the process of fluid-rock interaction with the evolution process of reservoir pores, which was difficult to meet the needs of oil and gas field exploration. The Gas Field D is a lithologic trap buried in middle and deep layers which developed in the northwest of the central mud diapir structural belt in Yinggehai Basin, north of South China Sea. It is a typical high-temperature and high-pressure gas reservoir. The vertical physical properties of the first member of Huangliu Formation of the target layer change greatly. To further explore the favorable reservoir in this gas reservoir has always been the focus of current work. In addition to sedimentation, high-temperature and high-pressure fluid-rock interaction under deep burial conditions is bound to have a significant impact on the first member of Huangliu Formation and control the distribution of favorable reservoir.

This paper discusses fluid-rock interaction mechanism, diagenesis model and porosity evolution of the first stage of Huangliu Formation reservoirs in Gas Field D with high-temperature and high pressure, Yinggehai Basin based on chemical thermodynamics and hydrodynamics. The results show that the minerals participating in reaction were feldspar, kaolinite, illite smectite mixed layer, illite, quartz and a few carbonate cements of diagenesis stage. Organic acid, high temperature thermal fluid and over-pressure from underlying formation supplied acid fluid environment of high temperature and high pressure for mineral reaction. From syngenetic period to early A stage of diagenesis, the system was open, the temperature of stratum was below 70℃, the illitization of kaolinite and smectite impeled largely unstable plagioclase to dissolve and K-feldspar was preserved; while part of quartz was expanded and carbonate was deposited locally. Correspondingly, the porosity evolution trended to reduce before stabilization. From early B stage to middle A stage of diagenesis, the system was semi-closed, the temperature of stratum was 70140℃, K-feldspar was largely dissolved, which impeled smectite sequentially illitizate, while albite was largely preserved and SiO_2 was deposited. In correspondence, the porosity evolution trended to reduce steadily. From middle B stage of diagenesis, the system was closed, the temperature of stratum was 140℃, kaolinite and K-feldspar reacted directly to form illite with K-feldspar basically consumed out, but kaolinite and illite coexisted with many remains of albite while part of quartz secondary outgrowth shows harbor-shape dissolution. Then, the porosity evolution trended to rejuvenize in part of the curve.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-6: Open session for other topics of sedimentology
Presentation Preference: Oral Preferred

Influences of structure and sedimentation on heterogeneity of fluid flow in sandstones: A case study of outcrops in the northwestern Tarim Basin, China

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Keywords: Red beds,Bleeding phenomena,Heterogeneity of diagenetic fluid,The Tarim Basin

The heterogeneity of fluid flow affects the migration and enrichment of oil and gas, oil recovery, and the distribution of remaining oil in reservoirs. Due to the reduction of underground fluid, the reddish-brown and red strata change to grayish-white, grayish-green even white, which is called the ‘bleeding phenomena’. Typical ‘red beds’ sedimentation developed in the Silurian and Devonian in the northwestern Tarim Basin. In the outcrops of these strata, the reduction of partial red beds to grayish-green reveals the heterogeneity of reducing fluid flow, which becomes a favorable case for the study of fluid migration controlled by structures (faults or fractures) and sedimentation. It is found that fluid preferentially migrates along lamina and lithologic interfaces in high porosity strata. In the profile of low porosity strata, irregularly distributed single-cell shape accumulation is formed first and then gradually migrates upward. Furthermore, it will be connected to cell aggregate and finally form a layered distribution. The fluid preferentially exists in the sandstone with high porosity and permeability, which is the primary manifestation of the heterogeneity of the interlayer. The wettability of micro-mineral particles also affects the migration of reducing fluid, resulting in the micro-heterogeneity of fluid activity. When there are faults and fractures in the formation, the fluid preferentially flows through the fracture network and mainly flows within a certain distance from fracture walls. According to the quantitative statistics, the scale of fracture and the width of the fluid seepage zone controlled by it are positively correlated. Under the influence of structures and sedimentation, fluid migrates through the fracture network system and porphyritic aggregates under buoyancy. On the plane, fluid migrates through high porosity and permeability sandstones, lamina, and lithologic interfaces. In three dimensions, it migrates in the network composed of the above dominant channels. The study reveals the heterogeneous differential migration mode of fluid and analyses dominant flow channels in the formation, which provides a geological model and parameters for reservoir modeling.

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-6: Open session for other topics of sedimentology
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Drawdown of marine sulfate levels at the onset of Marinoan glaciation

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Keywords: the Datangpo Formation, the Nantuo Formation, pyrite sulfur isotope, marine sulfate concentration, snowball Earth

Microbial sulfate reduction plays significant roles in regulating marine organic matter degradation and thus the variation of ancient marine sulfate level is closely coupled with the changes of global organic carbon burials as well as Earth's surface redox evolution in geological time. It is widely assumed that seawater sulfate concentration was extremely low during the Cryogenian Marinoan glaciation (ca. 650–635 Ma) which represents the most extreme icehouse condition in Earth's history. However, such a low seawater sulfate level has not been explicitly confirmed to date. To address this, here we carried out pyrite content and sulfur isotope (δ^{34}Spy) analysis of the Cryogenian non-glacial (the Datangpo Formation) and the Marinoan glacial successions (the Nantuo Formation) in the South China. Both the Datangpo and Nantuo Formation show relatively high values of δ^{34}Spy, ranging from +19.9 ‰ to +32.9 ‰, and low values of pyrite content (mean value=0.72 wt.%). Mineralogical analysis suggests these pyrites are dominated by euhedral crystals with rare occurrence of framboids, indicating an early diagenetic origin, i.e. pyrite formed in sediments with sulfate supplied from seawater. By using a one-dimensional diffusion-advection-reaction (DAR) model, we calculate marine sulfate levels during the transition from non-glacial to glacial period. The modeling results show that the seawater sulfate concentration is < 1 mM during the transition from the Datangpo to the Nantuo Formation, suggesting a shink of marine sulfate reservoir at the onset of Marinoan glaciation. We propose the low marine sulfate concentration was resulted from a decrease in chemical weathering prior to the initiation of the global glaciation. This study provides a quantitative constraint on marine sulfate levels during the snowball Earth event and may shed new light on our understanding of the marine biogeochemical changes during the Neoproterozoic global glaciation.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
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Presentation Preference: Oral Preferred

Centennial climate oscillations control pyrite sulfur isotopes via sedimentation rates-related AOM changes: Evidence from multiple sulfur isotopes of pyrite from East China Sea

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Keywords: pyrite, multiple sulfur isotopes, anaerobic oxidation of methane, sedimentation rate, climate change

Marine authigenic pyrite and its sulfur isotope plays a critical role in tracing remarkable Earth's surface environment changes. Determining the mechanism of large variations of pyrite sulfur isotopes in young sediments can help to recognize the fractionation effects of pyrite and understand how to use it in reconstructing of Earth's surface redox conditions. We studied the multiple sulfur isotopic compositions of the pyrite in chronological Holocene sediments from East China Sea inner shelf which show 34S in high (2.09 cm/yr) and medium sedimentation rate (1-1.32 cm/yr) layers are ~40‰ and ~25‰ heavier than that of low sedimentation rate (<0.5 cm/yr) layers. Mass-balance modelling and previous reported multiple sulfur isotopes of pyrite show our 34S-enriched pyrite was over grew by AOM-SR pyrite to OSR pyrite. The AOM-SR pyrite overgrowth is only found in medium and high sedimentation rate layers, we suggest the enhanced of AOM activity is controlled by sedimentation rate. Comparing with Holocene climate record, we found the sedimentation rate is controlled by East Asian Summer Monsoon through river sediment discharge and longshore current. Taken together, the multiple sulfur isotopic compositions of pyrite indicate climate changes via sedimentation rate-related AOM.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
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Analysis of seismic configuration based on "source sink" system -- Taking Paleogene of Panyu 4 depression in Pearl River Mouth Basin as an example

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Keywords: Seismic configuration, Wheeler domain transformation, Configuration attribute, Three dimensional lithofacies interpretation

In the practice of oil and gas exploration and development in the middle and later stage, aiming at the sea area data with complex continental sedimentation, few wells and low resolution of seismic data, the seismic configuration interpretation technology can effectively identify the distribution, style and superposition relationship of different levels of sedimentary configuration units in the sedimentary paleoenvironment. Taking the Paleogene Wenchang Formation of No. 4 depression in Panyu as an example, based on the analysis of the dynamic sedimentary process of the "source sink" system unit, using the prestack high-resolution seismic processing data, under the constraints of the high-frequency sequence stratigraphic framework, combined with the geological background and well data, the class III "source sink" system of steep slope, gentle slope and long axis type and the corresponding relationship between different seismic lithofacies and seismic configuration under it are established, using Wheeler domain transformation, approximate paleogeomorphic restoration The techniques of configuration attribute and three-dimensional lithofacies body interpretation have carried out fine seismic configuration interpretation for the third member of Wenchang Formation in Panyu 4 WA, Pearl River Mouth Basin, and then qualitatively and semi quantitatively described and described the spatial distribution characteristics, spatial configuration relationship and distribution mode of various sedimentary units under different convergence units.

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-6: Open session for other topics of sedimentology
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Seismic Sedimentologic Characterization of The Second Member of Shahejie Formation in Zhuangzi Area, Zhanhua Sag

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Keywords: Zhuangxi area, Palaeogeomorphology, Seismic sedimentology, Fan delta, Characterization

Zhuangxi area is located in the northeast of Zhanhua Sag and the north of Gubei Sag of Jiyang depression, which is a negative structural unit of Zhanhua Sag. Exploration shows that the area has a favorable prospect for oil and gas exploration and development. The second member of the Shahejie Formation in the study area is characterized by large burial depth, thin stratigraphy, and rapid changes in sedimentary facies, which restrict the understanding of oil and gas distribution. Based on the theory of sequence stratigraphy and in combination with the INPEFA technique, the second member of the Shahejie Formation in the study area is divided into two sand groups and six sub-layers. The provenance direction is determined by the sandstone percent content statistics, seismic attribute analysis, and paleomorphologic restoration. With a comprehensive utilization of core, logging and 3D seismic data, constrained by the isochronous stratigraphic framework, the seismic sedimentological characterization of six sub-layers in the second member of the Shahejie Formation was carried out using techniques such as seismic stratal slicing, phase conversion, frequency decomposion, and multi-attribute RGB fusion which are guided by seismic sedimentology theory. Research shows that: (1)The provenance of the second member of the Shahejie Formation is mainly from the Changdi buried hill in the east of the study area. (2)Under the control of geomorphology characterized by interphased groove and beams in near-source area, a continuous distribution of fan delta front deposition zone is developed in the second member of the Shahejie Formation along the Changdi Fault. (3)During the sedimentary period of the second member of the Shahejie Formation, the study area experienced the process from the initial fault-subsidence period to the strong fault-subsidence period. Fan delta develops in an inherited way, showing the characteristics of multi-phase progression. Practice indicates that the fine characterization of fan delta sedimentary facies belt can be realized by seismic sedimentology, which is of great significance to clarify the distribution of favorable facies belt and the evolution characteristics of sedimentary system.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-6: Open session for other topics of sedimentology
Presentation Preference: Poster Preferred (Nonparticipation to ECS virtual poster competition)

Subtle reservoirs and implications for hydrocarbon exploration in terrestrial lacustrine fan delta deposits: Insights from the Triassic Baikouquan Formation, Mahu Sag, Junggar Basin, Western China.

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Keywords: Keywords: lacustrine fan delta,sequence stratigraphy, sedimentary evolution, subtle reservoir, hydrocarbon reservoir models.

Large-scale lacustrine fan delta reservoirs containing mixed oil in the Baikouquan Formation (MA131 block, Junggar Basin) have abundant petroleum reserves. However, the reservoirs are subtle and it is challenging to identify such reservoirs in lacustrine foreland basins. High-resolution sequence stratigraphy, the sedimentary setting, and reservoir models are established by integration of wireline log data, cores, thin sections, and seismic data. A fifth-order sequence stratigraphic framework for the Baikouquan Formation is formed, which enables reconstruction of the sedimentary setting and further detailing of the reservoir model, such that the correlation to multistage progradation and retrogradation of the fan delta complex is possible. By core observation, eight microfacies are identified, among which sandy debris flows and distributary channels dominate approximately 80% of the depositional system. Stratal slices enable determining the northern Xiazijie and eastern Madong fan delta systems. The northern Xiazijie fan delta is widely distributed throughout sequences SSQ1–SSQ6, whereas the Xiazijie fan delta underwent, in general, gradual retrogradation during the formation of sequences SSQ6 and SSQ7. The eastern Madong gravity flow fan delta system only developed during the formation of sequences SSQ1–SSQ5 at the location of an abrupt slope break. There are nine categories of reservoir models in the area according to source rocks, faults, and reservoirs. Both geomorphology and climate played a significant role in controlling the sedimentary infill. Deep faults and an unconformity between the Permian and the Triassic of the Mahu Sag played a decisive role in controlling the hydrocarbon migration pathways. The faults, source rock, and microfacies jointly exert a significant control on hydrocarbon accumulation. Within the nearshore fan delta front, variable reservoir quality can be observed; Crucial factors in improving reservoir quality are fine grain size and relatively low clay content. This work may serve as a guide on subtle reservoir characterization in other basins.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-6: Open session for other topics of sedimentology
Presentation Preference: Oral Preferred

Geoarchaeological investigation of occupation deposits at the Upper Paleolithic Fodongdi cave site, Southwest China: Sedimentary process, paleoclimate change, site formation process and past human activities in the Late Pleistocene

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Keywords: Fodongdi cave site, Geoarchaeology, Micromorphology, Sedimentary process, Site formation process, Past human activities

The Fodongdi cave site which formed in the Permian carbonate of Baoshan-Shanbang terrane, is located in the northwest wall of Nantinghe sinistral strike fault, Yunnan Province, Southwest China. Recent excavations of the Fodongdi cave site have uncovered a ~4.45 m stratigraphic sequence (18,000-11,000 cal. BP, not to the bottom) containing abundant sedimentary features which experienced extensive post-depositional change and archaeological assemblages such as hearth, various tools and biological fossils. The stratigraphic sequence is well defined but complex, including roofspall deposits, aeolian deposits, alluvial deposits, chemical deposits, biological deposits, and anthropogenic deposits. Sedimentological and geochronological analyses suggest that sedimentary process varied markedly through time, both laterally and vertically. Through micromorphological and other geoarchaeological analyses of the stratigraphic sequence, especially three occupation phases, we identified the information of sedimentary history, paleoclimate change, the site formation process and past human activities in the Late Pleistocene. This study provides a good practice for micromorphological study of the cave site formation and reveals the distinct diachronic trends in the frequency of visits and the modes of occupation in Upper Paleolithic South China.

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Session T11-6: Open session for other topics of sedimentology
Presentation Preference: Oral Preferred

Probing event stratigraphy in an ultra-deep water hadal oceanic trench environment: Initial results from IODP Expedition 386 "Japan Trench Paleoseismology"

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Keywords: IODP, Deep-Sea, Japan Trench, Paleoseismology, Event Stratigraphy, Hadal Zone,

Hadal oceanic trenches - formed by the downward-bending of oceanic crust in plate subduction zones – are the deepest places on our planet and arguable one of Earth´s most challenging environments for sedimentological research. They act as terminal sinks for sedimentary mass and carbon, and form high-resolution archives to unravel the history of subduction zone processes, including the world's largest earthquakes that occur in such subduction plate boundary systems, and to investigate the deep-ocean elemental cycles.

International Ocean Discovery Program (IODP) Expedition 386, Japan Trench Paleoseismology was designed as a Mission Specific Platform Expedition, and, for the first time within IODP, to use Giant Piston Coring (GPC) technology to recover subsurface samples. In 2021, we successfully collected 29 GPCs at 15 sites (1 to 3 holes each; total core recovery 831 meters), recovering 20 to 40-meter-long, continuous, upper Pleistocene to Holocene stratigraphic successions of 11 individual trench-fill basins along an axis-parallel transect from 36°N – 40.4°N, at water depths between 7445-8023 m below sea level. These offshore expedition achievements revealed the first ever high-temporal and high spatial resolution investigation and sampling of a hadal oceanic trench.

The cores are currently being examined by multimethod applications to characterize and date hadal trench sediments and extreme event deposits, for which the detailed sedimentological, physical and (bio-)geochemical features, stratigraphic expressions and spatiotemporal distribution will be analyzed for proxy evidences of giant earthquakes and (bio-)geochemical cycling in deep sea sediments. Initial preliminary results presented in this ISC presentation show event-stratigraphic successions comprising several 10s of potentially giant-earthquake related event beds, revealing a fascinating record that will unravel the earthquake history of the different along-strike segments. Post-Expedition research projects further analyzing these initial IODP data sets will (i) enable statistically robust assessment of the recurrence patterns of giant earthquakes, while advancing our understanding of earthquake-induced geohazards along subduction zones and (ii) provide new constraints on sediment and carbon fluxes of event-triggered sediment mobilization to a deep-sea trench and its influence on the hadal environments.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-6: Open session for other topics of sedimentology
Presentation Preference: Poster Preferred (Participation to ECS virtual poster competition)

Distribution and evolution of sedimentary facies in Zhujiang Formation

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Keywords: Zhusan depression,Zhujiang Formation,drilling,logging,sedimentary facies

As one of the main battlefields of oil and gas exploration in the northern continental margin of the South China Sea, and there are large potentials of oil and gas exploration in the Zhu III depression, the Pearl River Mouth Basin. The sandstone section in the Zhujiang Formation is the main reservoir of oil and gas in the fault depression transition stage. In order to have a good knowledege of the distribution of high-quality sandstone reservoirs in the Zhujiang Formation, this study comprehensively analyzes the sedimentary distribution and evolution of the Zhujiang formation by using drilling, logging and seismic data in Wenchang sag. From bottom to top, there are two segments in the Zhujiang formation, the first member of Zhujiang Formation which can also be divided into two sub-facies and the second member of Zhujiang Formation; The sedimentation of the second member of Zhujiang Formation is characterized by the influence of tide. Tidal flat sedimentary facies mainly composed of uniform massive fine sandstone mudstone are developed at the bottom, and the sand rich sedimentation continued to advance into Wenchang sag; The continuous influence of tide made sand content increase obviously with the decrease of buried depth. The lithology gradually changes into pebbly sandstone and locally containing medium sandstone and mudstone, which entirely belonging to the sedimentary environment of sand flat sub-facies of tidal flat facies; In the lower sub member of the first member of the Zhujiang Formation, the rise of sea level made most of the study area in an underwater sedimentary environment. The grain size of the sediments formed at this stage is finer than that of the fan delta. The underwater distributary channel sand is dominated by medium sandstone and developed small cross bedding. Medium fine sandstone with parallel bedding and cross bedding predominated in river mouth bar deposits; Due to the continuous rise of sea level, the lithology of the upper sub-member of the first member of the Pearl River formation is characterized by deep-water fine-grained sedimentation, the sandbar deposits and neritic mud sedimentation is dominant; The lithologic traps formed by offshore sandbar deposits, which are widely developed in these fine-grained sediments, are the main objects of oil and gas exploration in the next step.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-6: Open session for other topics of sedimentology
Presentation Preference: Oral Preferred

Unlocking the mystery of Pliocene-Pleistocene global climate change: A proposal for drilling in the tropical Sunda Shelf

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Keywords: Carbon cycling, sea-level change, paleo-drainage system, Pliocene-Pleistocene, Maritime Continent, Sunda Shelf

The Earth has been cooling over the past 5 million years, leading to the development of Northern Hemisphere ice sheets and the followed frequent occurrence of alternating interglacial and glacial stages. Many hypotheses have been proposed to explain this cooling trend, but with no consensus. The emergence of the low-latitude Maritime Continent has been proposed to be a driver for such climate change during the Pliocene-Pleistocene epochs. To test this scientific hypothesis, we have proposed to drill in tectonically stable sedimentary basins on the tropic Sunda Shelf, the western part of the Maritime Continent, to reconstruct Pliocene-Pleistocene sea-level change, drainage system development, and carbon cycling.

The Sunda Shelf provides particularly well-suited conditions for comprehensive high-resolution studies to reconstruct major geomorphic changes on the Maritime Continent and to assess associated interactions with the global climate. As the largest tropical shelf in the world, the Sunda Shelf was completely exposed during sea-level lowstand periods, allowing the development of large paleo-drainage systems and widespread rainforests and marine vegetations. Sampling the paleo-river systems to determine their age and sedimentary environment will allow to reconstruct the eustatic sea-level fluctuations and the development of major drainage systems. The Sunda Shelf and adjacent land regions were covered by rainforests and marine vegetations during sea-level lowstand periods. The retrieved sedimentary sequences will be used to evaluate the contribution of the glacial exposure of this major tropical shelf region functioning as an enormous CO_2 sink and carbon sequestration.

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Session T11-6: Open session for other topics of sedimentology
Presentation Preference: Oral Preferred

Sedimentary and geochemical records of northwestern Australia during the Mid-Pleistocene and their implications for paleoenvironment

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Keywords: clay mineral, grain size, sediment source, Mid-Pleistocene Transition, Australian paleo-monsoon

Based on the analyses of clay mineral X-ray diffraction (XRD) and grain size test of sediment core form Site U1483 (13°05.24′S, 121°48.25′E, water depth 1,733 m) that was drilled offshore northwestern Australia during International Ocean Discovery Program (IODP) Expedition 363, evolution characteristics and dynamic environment characteristics of sediments in the Timor Sea area during the Mid-Pleistocene (1600ka~800ka) are reconstructed, and the transport process and dynamic mechanism of continental sediments into the sea on orbital scale are discussed.

The content of clay minerals shows obvious glacial-interglacial cycles. Smectite is the main clay mineral (30~70%, with an average value of 52%), and the content increases during glacial periods; while the contents of kaolinite (14~35%, with an average value of 23%), illite (11~29%, with an average value of 18%) and chlorite (2~16%, with an average value of 7%) show a similar pattern, which shares a mirror relationship with the change of smectite content, i.e. the content in glacial period is lower than that in interglacial period.

The grain size data shows that the sedimental particles are mainly silt and clay, with an average mean grain size of ~9.1μm, and the main distribution range is 4.8~17.6μm. The time series of grain size shows a glacial-interglacial cycle, which is related to the change of sea level. It is worth noting that the grain size has fluctuated severely and decreased during the Mid-Pleistocene Transition, which reflects that the hydrodynamic conditions variations at this period, indicating the fluctuating sedimentary environment as well, which provides an evidence for the environmental variations before the Mid-Pleistocene Transition.

By comparing with the potential source area, it is considered that the clay minerals dominated by smectite are terrestrial clastic origin, and most of them come from the material input of Fitzroy River and Ord River in the continent of northwestern Australia. During the cold and dry glacial periods, smectite content becomes high due to the strengthened physical erosion, delivered by the river to the sea inlet, and then transported to the shelf area by the southward Leuven current. Spectrum analyses also show that the change of clay mineral assemblage shares strong 100ka and 23ka periods, which is in consistent with the eccentricity (100ka) and precession (23ka) periods. The precession period reflects the intensity of weathering on the northwestern Australia, which is influenced by the power of river runoff that controlled by the rainfall distribution under the influence of Australian paleo-monsoon. It is inferred that the variations of clay minerals are controlled by sea-level changes and the Australian paleo-monsoon system regulated by orbital parameters.

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Session T11-6: Open session for other topics of sedimentology
Presentation Preference: Oral Preferred

Effects Between Grain Size and Slope to Speak the Depositional System

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Keywords: Terrain slope, detrital material, sand content (N/G), Uni-directional flow, "Mass-slope" coupling,

The three-dimensional distribution characteristics of the clastic depositional system and its genetic mechanism are the core content of establishing a sedimentary model and predicting the distribution of its sand bodies, which is also a critical scientific issue in sedimentology research. Most of the depositional systems from the source area to the catchment area, the topographic slope (height difference) is a normal transition process from steep to gentle, this process (Catastrophism and Gradualism) determines the response of fluid transport energy changes and sediment transport mode, resulting in changes in their flow patterns and deposition processes, resulting in the formation of different depositional systems or different phase zones of the same depositional system. Most of the scholars who have studied the clastic depositional system at home and abroad believe that its planar morphology and profile filling structure are closely related to the slope and slope shape of its deposition as well as the quality of clastic particles, but there is no unified and clear understanding of this quantitative law so far. Based on this point, the topography of the clastic sediment body is classified into three basic slopes: linear, up-convex, and down-concave, from the perspective of sediment dynamics in this paper. Moreover, according to the composition of the proportion of different debris particles, the composition of debris material is divided into five types from coarse to fine: gravel-rich, sand-gravel, sand-rich, sand-mud, and mud-rich. In this way, we analyze the response between clastic particle size and deposition pattern under different topographic slope changes and then reveal the mechanism controlling the sedimentary system's three-dimensional spatial distribution of sand content (N/G) under additional slope shapes/slope drops. The "mass-slope" coupling effect of the clastic sediment is proposed: a large number of flume experiments and field investigations have proved that the sediment formed in the context of linear and concave slopes has a negative geomorphic unit with a positive grain sequence; while the sediment formed in the context of convex slopes forms positive geomorphic units with inverse grain order; topographic features and slope descent mainly control the planar morphology of the sediment, and the rate of change of slope controls its essence, and the grain size is exponentially related to the slope. However, the superposition pattern of debris material under different slope drops is more the result of the mutual coupling of different debris material compositions and topographic slope. This theoretical understanding explains the phenomenon that the natural clastic depositional system is "small and numerous on steep slopes, large and few on gentle slopes, few fan-shaped waterways on steep slopes, and many rivers bend on gentle slopes, gravel on steep slopes, sand on gentle slopes, and more mud on the bay.

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Session T11-6: Open session for other topics of sedimentology
Presentation Preference: Oral Preferred

Seismic response and distribution of Lianggaoshan shale, Sichuan Basin, China

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Keywords: Shale oil, Seismic response, Lianggaoshan Formation, Sichuan Basin

Recently, well PA1 achieved a major breakthrough of shale oil in the Lower Jurassic Lianggaoshan Formation in Sichuan Basin, showing the huge exploration prospect of shale oil in the Basin. The exploration of shale oil in the Lianggaoshan Formation is still in its infancy, and systematic research has not been carried out. The distribution of favorable and high-quality shale is unclear, and the favorable exploration zone is uncertain. It is necessary to carry out comprehensive geological-seismic research to guide future shale oil exploration. On the basis of seismic sedimentology research, the seismic response characteristics of shale in Lianggaoshan Formation and its distribution at the basin scale are clarified for the first time. The results show that: (1) the seismic response of the shale-rich section is characterized by strong trough reflection; (2) the Lianggaoshan Formation developed two large-scale lake flooding, and high-quality shale developed in deep lake and semi-deep lake; (3) from lower section to upper section of Lianggaoshan Formation, the lake center migrated from east to northwest; (4) the shale in the lower section is mainly distributed in the central and eastern Sichuan Basin, with a favorable area of 37,000 km^2; the shale in the middle section is mainly distributed in the Guang'an-Longgang area and eastern Sichuan Basin, with a favorable area of 34,000 km^2.

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Paleogene giant sand injectites: a case study from the Eastern Russian Platform

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Keywords: Sand injectites, Paleogene, Russian Platform

The Paleogene quartz sands and sandstones of the Sosnov formation occurred in the Ulyanovsk-Syzran Volga region of the Eastern Russian Platform have been actively developing for a long time as they are known as a valuable source of industrial minerals, of which glass raw materials are of particular value. Predicting new deposits based on ideas on the coastal-marine origin of the Sosnov sands exhausted possibilities due to the lack of marine bedding in sands and extraordinary variability in their thickness. Thus, the current research aims to consider the Sosnov Formation is formed not in the coastal-marine environment but by injecting of deep-layered sands into the Paleocene opokas and diatomites.

We offer a new origin of the Sosnov formation which is based on the widely occurring geological phenomenon of sand injectites. Those are defined as a result of injection of loose fluidised sands into overlaying strata under the impact of pressure excess (e.g. Hurst et al., 2011).

The sand sill investigated in the Kuchury Quarry (the Ulyanovsk Region, Russia) reveals the considerable (over 33 m) thickness of the Sosnov pure quartz sands and sandstones. Probably, the loose quartz sands of the Bathonian (Middle Jurassic) Lukoyanov formation are supposed to be a source of the injected sand material. Complex of analytical methods is used to compaire both the Sosnov and Lukoyanov sands. It includes the sieve grain size, petrography, mineralogy, XRD, scanning electron microscope, electron microprobe, Raman spectroscopy, ICP-MS and X-ray fluorescence element geochemical analyses of rocks and minerals, U-Pb and Zircon Fission Track dating of detrital zircons, etc. The results obtained make it possible to provide provenance analysis of the Paleogene Sosnov sands (injected sands) and the Bathonian Lukoyanov sands (parent unit), reconstruct the Paleogene paleoenvironments in the Russian Platform (RP), and solve a problem of origin of the Sosnov rocks.

Study of the spatial distribution of the Sosnov sands according to drilling data and geological reports, reveals the sandy sills occur at different stratigraphic levels having the variable thickness (up to 150 m) and dimensions (over 20,000 km^2). Those mentioned can rank the sand body as gigantic injectite (Davies et al., 2006; Hurst et al., 2011; Løseth et al., 2012).

Considering the Sosnov sands intrude the Danian-Thanetian opoka and diatomite succession occuring throughout the study area, the age of sand injectites can be proposed post-Thanetian. Interestingly, it coincides with the Late Paleocene activity of the Main Zhiguli Fault extended sublatitudinally 90 km south of the Kuchurov quarry, which led to the uplift of the southern flank by 350-450 m (Davletshin et al., 2017). This tectonic event most likely triggered the formation of giant injectites in the adjacent territories.

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Presentation Preference: Oral Preferred

Effect of lamina structure on reservoir quality in fine-grained sedimentary rocks: The Lucaogou Formation in Jimusar Sag, Junggar Basin, China

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Keywords: lamina structure, reservoir quality, well logs, fine-grained sedimentary rocks

Fine-grained sedimentary rocks, as important reservoirs and source rocks for tight and shale oil and gas, have become a research focus. The development of laminae determines the accumulation and production of tight and shale oil and gas in fine-grained rocks. However, due to the limitation of resolution of conventional logs, it is difficult to recognize the features of centimeter-scale laminae. To close this gap, complementary studies including core observation, thin section, X-ray diffraction (XRD), conventional log analysis, and slabs of image logs were conducted to unravel the centimeter-scale laminae. Then the recognition models for laminae were built using well logs. The fine-grained rocks can be divided into laminated rock (thickness of lamina < 0.01 m), layered rock (0.01 m–0.1 m), and massive rock (no layer or layer spacing > 0.1 m) according to the scale of laminae from core observation. Then the laminated rocks can be further divided into binary, ternary, and multiple structure according to the mineral superposition assemblages from thin section observation. The typical mineral components, image logs, and NMR T_2 distributions of various lamina types are unraveled. The core can identify the centimeter to millimeter-scale laminae, and thin section can identify the millimeter scale to micrometer scale laminae, and additionally, they can detect mineral types and their superposition sequence. Conventional logs can identify the meter scale layers, while image logs and related slab images can identify the millimeter to centimeter scale laminae variations. Therefore, the slab of image logs combined with thin sections can identify laminae assemblage characteristics, including the thickness and vertical assemblage of laminae. Therefore the identification and classification of lamina structure of various scales on a single well can be predicted using conventional logs, image logs, slabs combined with thin sections. The layered rocks have better reservoir quality and oil-bearing potential than the massive and laminated rocks. In the laminated rocks, the binary lamina is better than the ternary and multiple layers due to high content of felsic minerals. The results above built the predictable model for multi-scale lamina structure using well logs. The results will provide insights into the lamina structure-controlled reservoir quality and oil mobility, and help sweet spots prediction in fine-grained sedimentary rocks worldwide.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
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Stratigraphic and sedimentologic review of the alluvial units deposited during the initial stages of development of the Montalbán subbasin (latest Cretaceous, Iberian Basin)

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Keywords: Cretaceous, Montalbán subbasin, Alluvial system, chronostratigraphy

During the Alpine compression, the rift system that conformed the Iberian basin was inverted, giving rise to the Iberian Ranges and many Cenozoic subbasins in the Northeastern part of the system. One of these Cenozoic subbasins, the Montalbán subbasin, presents more than 50 km in length with a triangle shape geometry that opens to the west. This subbasin forms a syncline structure, with Cenozoic deposits in the nucleus bounded by Mesozoic units from the Utrillas thrust (SSW) and the Montalbán anticline (NNE). The uppermost Cretaceous-Cenozoic units consist of 2 km-thick alluvial deposits varying from conglomerates and sandstones at the margins, decreasing its grain size to central areas of the system where lacustrine limestones appear. This succession was previously divided in 5 tecto-sedimentary units (T1-T5) that were correlated to other nearby subbasins found around the Montlabán anticline.

This study is focused in the Northwestern area of the Montalbán subbasin, adjacent to the Mesozoic flanks of the Montalbán anticline. Before this study, the uppermost Cretaceous units consisted of two lithostratigraphic units: (1) La Cañadilla Fm, Coastal limestones with rudists and foraminifera from the Middle Santonian-Early Campanian and (2) Fortanete Fm, lacustrine carbonates with charophytes, terrestrial gastropods and black pebbles. However, new dinosaur fossil sites recently discovered in the first units previously assigned to the late Paleocene-Eocene (T1-T2), opened the possibility to a general review of the chronostratigraphy of the subbasin. More than 26 new fossil sites have been discovered, of particular interest are the well-preserved caudal vertebra from titanosauridae. Moreover, eggshells, crocodrile? teeth and charophytes also represents the paleontologic potential of the area. In order to stablish the most possible precise chronostratigraphy, a detailed magnetostratigraphy study has been done along the 700 m-thick composite section of the newly defined Allueva Fm.

A detailed analysis of the sedimentology and paleoenvironment of the alluvial system that conforms the Allueva Fm has been developed. Based on 5 stratigraphic logs, dominant lithologies, grain size, sedimentary structures and roundness/sphericity a total of 6 lithofacies have been differentiated. Furthermore, analysis of relations between lithofacies resulted in the differentiation of 5 facies associations, each one representing different sub-environments of the alluvial system. The most proximal associations (FA1, FA2) are dominated by tabular conglomeratic levels with rounded intraclasts and both massive and laminated sandstones, related to the intermediate areas of the alluvial system. Lutite dominate associations (FA3, FA4) with intercalations of thin and isolated levels of conglomerates, sandstones and limestones are interpreted as intermediate-distal flood plains with high decantation of fine-grained lutite and sporadic lakes. Finally, limestone dominated association (FA5) is composed by continuous m-thick levels of limestones with large oncoids (up to 15 cm in diameter), and are related to the most distal areas where big and stable lake systems are stablished. The absence of viscosity fluxes such as debris flow deposits or extremely bad sorted and angulous intraclasts suggests that the study area only represents the intermediate and distal areas of the alluvial system.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
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Control of Mineral Composition on Reservoir Physical Properties in Deep-buried Clastic Rocks——A Case Study in Surrounding Area of Bozhong Sag

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Keywords: Bohai Sea, Paleogene, deep clastic rock, mineral composition, reservoir physical properties

Compared with other depressions in Bohai Bay Basin, the exploration degree and commercial success rate of Paleogene deep clastic rocks in Bohai Sea are the lowest. Many deep wells (> 3500 m) in the surrounding area of Bozhong Sag reveal the giant thick clastic reservoirs. Due to the large overall burial depth, the reservoir is obviously densified, only a few wells have high productivity. The differential evolution mechanism of reservoirs is a key issue that restricts exploration. Aiming at the differential evolution mechanism of the reservoir, this paper carried out experiments such as thin slice, scanning electron microscope, x-ray diffraction, compaction and dissolution Simulation. Studies have shown that the differential evolution of the reservoir is significantly affected by the provenance. The parent rock coming from granite, clastic rocks with low miscellaneous base content have good reservoir physical properties. While the clastic rocks with high miscellaneous base content have poor physical properties. If the clastic rock is mixed with some carbonate particles, its reservoir physical properties increase first and then decrease with the increase of carbonate particle content. The clastic rock with small amount of carbonate particles, developed strong dissolution, and good reservoir physical properties.The existence of a large number of carbonate particles will cause strong cementation and tightness in the early stage of the reservoir, and the productivity is still poor after fracturing. Appropriate amount of volcanic cuttings will improve reservoir physical properties. The dissolution of the rhyolite cuttings promote the development of secondary pores. With the content of volcanic materials increases, tuffaceous components will fill inter grain in the form of heterobase, which makes physical properties worse. It can be seen that different provenance systems control different mineral composition combinations, thereby controlling the physical property evolution of reservoirs. Through statistics and fitting calculation of a large number of measured physical properties and X-ray diffraction mineral composition, it is found that the upper limit of impurity content in deep high-quality clastic reservoir is about 13 %. The upper limits of carbonate and volcanic particles are 20 % and 39 %, respectively. On this basis, a reservoir physical property evaluation template of deep clastic rock in surrounding area of Bozhong Sag is established based on mineral composition ratio, which has a good prediction on the physical property of clastic rock reservoir in the area without well and the area with less well.

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Eocene mammal tracks in southeastern Tibetan Plateau

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Keywords: Southeastern Tibetan Plateau, Eocene, Artiodactyl tracks, Anoplotheriipus zeuctus

The uplift of the Tibetan Plateau has a significant impact on some groups of mammals in the aspects of their origin, radiation and evolution. Compared with intensive studies of Neogene mammals, the research of Paleogene mammals in the Tibetan Plateau is extraordinarily poor due to the scarcity of the Paleogene mammal fossils, which has restrained our recognition of the biota and paleoecology during the early uplift of the Tibetan Plateau. Fortunately, we have recently discovered some mammal tracks from the upper Baoxiangsi Formation of the Jianchuan Basin in southeastern Tibetan Plateau, including six artiodactyl tracks and two carnivore tracks. Previous chronological studies constrained the age of the tracks to the late Eocene. All tracks are preserved in purple red medium to thick-bedded fine-grained sandstones with ripple marks and rain prints, which represents shore lake facies. Based on the morphological analysis, the artiodactyl tracks documented here are referred to as *Anoplotheriipus zeuctus*. Moreover, combined with artiodactyl fossils that had been reported in the Baoxiangsi Formation, artiodactyl tracks are attributed to eoentelodonts. In contrast, mesonychids are the probable trackmaker of carnivore tracks. All mammal tracks reported here not only make up for the scarcity of mammal fossils during the Paleogene in Tibetan Plateau, but also provide new materials to discuss the biodiversity, paleoclimate and paleoenvironment of southeastern Tibetan Plateau during the late Eocene.

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
Session T11-6: Open session for other topics of sedimentology
Presentation Preference: Oral Preferred

Characteristics and origin of chlorite coats in the Oligocene gas sandstone reservoirs of the Upper Huagang Formation, Xihu Depression, East China Sea Shelf Basin

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Keywords: Clay coats, Chlorite coats, Crystal nucleation and growth, Braided channel sandstones, Xihu Depression, East China Sea Shelf Basin

Chlorite coats appear extensively in the braided river sandstones in the Xihu Depression on the East China Sea Shelf Basin. The origins of chlorite coats with different morphologies and chemical compositions were studied based on detailed analyses of sedimentary features and sandstone petrography. The present chlorite coats can be identified by two layers. The inner coats are mainly composed of chlorite and illite components transformed from detrital clay precursors. Illite components are generally recognized in the dentations or embayments of detrital grains and have a dense, parallel texture. These components are transformed from smectitic clay precursors and are distributed in both low-energy and high-energy braided channels. The chlorite components display as small, euhedral crystals and pile up to exhibit a chaotic texture, dispersing on detrital grain surfaces or as pore-filling aggregates, and are observed mainly in high-energy braided channels with abundant mud rip-up clasts. These components may originate from the thermally driven recrystallization of Fe-rich clay precursors, which are likely derived from the intense cut-bank erosion of adjacent floodplain mudstones that are more readily enriched in flocculated fluvial Fe oxides and hydroxides. The outer coats occur as well-developed chlorite crystals on the surface of detrital grains or inner coats but differ in their crystal sizes among different types of channels. These coats likely originate from direct precipitation from pore waters. Iron and magnesium are mainly supplied by the alteration and dissolution of volcanic material and smectite illitization within clay matrices or mud rip-up clasts. During the growth of chlorite coats, different types of braided channels significantly control their morphologies and chemical compositions. Transport abrasion and variations in hydrodynamic energy determine the clay precursors, which subsequently control the thickness and completeness of the chlorite coats. Moreover, the crystal sizes of the outer coats vary due to distinct material supply processes in different channels; in this study, two growth models were investigated: 1) The continuous growth model is suitable for a relatively closed diagenetic system with continuous supplementation of iron and magnesium. A sustained and relatively high chlorite supersaturation ensures continuous crystallization for the outer coats to reach large sizes; 2) the intermittent growth model is suitable for a more open diagenetic system that has difficulty maintaining a relatively high supersaturation state for chlorite precipitation, resulting in multiple crystallization processes on one or more layers of the finer chlorite crystals.

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Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
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Sequence stratigraphic framework and sedimentary evolution of the first member of the Zhujiang Formation, Qionghai uplift, Zhu III Depression, Pearl River Mouth Basin

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Keywords: sequence stratigraphy,sedimentary evolution,Zhujiang Formation,Qionghai uplift,Pearl River Mouth Basin

The zhujiang Formation in Zhu III depression of Pearl River Mouth Basin is widely developed in shallow sea delta sedimentary system. Qionghai uplift is located in the west of Zhu III depression, and its upper shallow sea shelf sand body is an important oil and gas reservoir. This paper makes full use of the core, well-logging and high-resolution 3D seismic data, and the unit is quaternary sequence to study the sedimentary characteristics of shallow sea delta of the first member of Zhujiang Formation in Qionghai uplift area of Zhu-3 depression, and its evolution law and main controlling factors were analyzed. The results show that the first member of Zhujiang Formation in Qionghai uplift area of Zhu IIIdepression can be divided into four quaternary sequences: PS1, PS2, PS3 and PS4.During PS3 and PS4, delta deposits were mainly developed, and fan bodies were NW-SE distributed, with underwater distributary channel, mouth bar and far sand bar. The PS1 and PS2 periods are characterized by the large-scale development of shallow sea sedimentary systems, with tidal sand ridges in the west and offshore sand bars in the east. The sedimentary system and sand body distribution of Qionghai uplift in Zhusan depression are controlled by the dual hydrodynamic action of river and tide. Sandstone and mudstone develop mutually, forming good reservoir and cap assemblage. The deltaic sand body is covered by transgressive mudstone, forming stratigraphic trap, and tidal sand ridge and offshore sand bar are favorable areas for lithologic trap development. In this paper, the study of shallow sea delta depositional system plays a positive geological significance for trap exploration.

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New perspectives on Opalinus Clay facies descriptions based on new drill cores in eastern Switzerland

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Keywords: Opalinus Clay, radioactive waste disposal, subfacies, depositional model

The Opalinus Clay, an argillaceous to silty claystone formation, is known in Switzerland as being the selected host rock for deep geological disposal of high-, intermediate- and low-level radioactive waste. Since the 1990s, various properties of the Opalinus Clay have been studied within the framework of the Nagra (National Cooperative for the Disposal of Radioactive Waste) deep drilling campaigns and the Mont Terri Project (international research program dedicated to the investigation of claystone). The Opalinus Clay succession was deposited during the Late Toarcian to Early Aalenian in an epicontinental sea covering central Europe.

The Opalinus Clay is relatively homogeneous at formation-scale compared to other Mesozoic formations in northern Switzerland. At higher spatial resolution however, sedimentological variations do occur. Besides m-scale lithofacies variations, high, intra-facies lithological variability occur at dm- to cm-scale. The facies diversity is primary attributed to regional differences in depositional, environmental and diagenetic conditions. In order to harmonize petrographic descriptions in an objective and quantitative way within all fields of research related to the Opalinus Clay, a subfacies classification scheme has been developed ((Lauper et al., 2018, 2021). The subfacies are distinguished by parameters such as texture (grain size, bedding, fabric and colour) and composition (nature and mineralogy of components). The five subfacies types can be further refined by additional attributes and sedimentary characteristics (biogenic, diagenetic, structural).

Subfacies descriptions are crucial to understand the lateral and vertical facies variability at regional scale. Moreover, accurate petrographic descriptions are a crucial prerequisite to many geotechnical studies and the predictive modelling of petrophysical properties.

The main goal of the present study is to define a subfacies classification model covering the entire Opalinus Clay succession of the Mont Terri rock laboratory and successions deposited further to the east where Nagra is currently investigating three potential sites for radioactive waste storage within the Opalinus Clay. Nine new drill cores are used to apply the subfacies classification scheme. The current subfacies classification scheme will be adapted considering regional facies heterogeneities. Based on the revised subfacies classification, facies and intra-facies variability will be captured. This will form the base for the revision of depositional models for the Opalinus Clay using a basin-wide approach.

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Evaluation method of gas hydrate and free gas system and its application in Shenhu Area, South China Sea

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Keywords: Shenhu area, Gas hydrate, Free gas, Well-to-seismic calibration method

As a new alternative energy source, gas hydrate has attracted wide attention all over the world. Since gas hydrate is always associated with free gas, the evaluation of gas hydrate and free gas system is an important aspect of hydrate reservoir exploration and development. In this study, based on identifying gas hydrate and free gas by well logging, the seismic reflection characteristics of gas hydrate and free gas are determined by accurate well-to-seismic calibration method. On account of seismic reflection characteristics, AVO attributes are used to identify gas hydrate and free gas qualitatively. Using pre-stack and post-stack inversion to get the ratio of P-wave impedance and P-wave-to-S-wave velocities, we determine the three-dimensional space distribution of gas hydrate and free gas, predict their effective porosity and saturation, and eventually achieve the meticulous depiction of gas hydrate and free gas in the body, which is necessary in subsequent estimation of gas hydrate and free gas resources. Results show that according to logging interpretation, gas hydrate of B-well is located in the depth range of 1460 – 1510 mbsl, and free gas is in 1510 – 1542 mbsl. Moreover, gas hydrate of A-well is located in the depth range of 1425 – 1512 mbsl, and no obvious free gas is identified. Gas hydrate is located above free gas and distributed continuously. In plane form, gas hydrate and free gas both present sub-elliptical distribution in NW-SE direction. Gas hydrate has an effective porosity of 0.30 – 0.40, an average saturation of 0.33 – 0.40 and an effective thickness of 3.0 – 10.5 m, whereas free gas possesses an effective porosity of 0.35 – 0.40, a saturation of 0.24 – 0.32 and an effective thickness of 2.0 – 5.0 m.

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Combining indicators analysis and chemometrics to trace the geographical origin of crude oil

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Keywords: Crude oil, Origin traceability, Chemometrics

Geographic traceability is crucial to global oil trade security. This study discusses the possibility of using multivariate statistical methods combined with multi-indicator analysis to identify samples from five major source countries of crude oil imports to China. The physicochemical properties and trace elements of crude oil were detected by Petroleum product standards and inductively coupled plasma atomic emission spectrometry (ICP-AES). Eight indexes (moisture, density, sulfur content, acid value, organochlorine, carbon residual, V, and Ni) were analyzed. Principal component analysis (PCA), hierarchical clustering analysis (HCA), Orthogonal projections to lateen structures- discriminant analysis (OPLS-DA), and other multivariate data analysis methods were used to determine the geographical origin of crude oil samples. Satisfying results have been obtained by using PCA to reduce the dimensions of the indicators of crude oil from different sources. It allows the reduction of 8 variables to 3 principal components and accounts for 80.06% of the total variance. The HCA shows five clusters corresponding to five sources of crude oil. This will help improve the utilization rate of crude oil with different characteristics, improve the quality of crude oil trade, and ensure the high quality of crude oil trade. For the sample set used for modeling, the model's accuracy was 97.19% after OPLS-DA optimization. These results show that multi-index analysis and stoichiometry are practical tools for identifying crude oil origin, filling the technical gap in rapidly identifying crude oil origin.

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Method of geological parameters cutoffs of determination based on the single well EUR of tight reservoirs

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Keywords: Heterogeneity,Uncertainty,Single well EURMinimum quantities of EUR, economic limit, cutoffs of geological parameters

Tight oil resources are abundant in China, the amount of recoverable resources is 1.94 billion tons and has become an important replacement field of crude oil production in China. Due to the heterogeneity and uncertainties of reservoirs, fracture, oil-bearing and adaptability of engineering technology, the method using static data of the conventional reservoir to determine the cutoffs of reservoir geological paramerters cannot meet for the needs of the profitable development evaluation of tight reservoirs. Highlighted single well information, the key parameter of the single well EUR affecting economic of tight reservoir was carried out, and combined with the analysis of main control factors of reserve uncertainty. A series of determination methods and process based on the single well EUR for the cutoffs of geological reservoir parameters of tight reservoirs was established. Considering the particularity of tight reservoir, the fracture development degree was added in the study of cutoffs of the geological parameters.Five paramerters, including single well EUR, net pay, effective porosity, initial oil saturation and fracture development degree, were selected for classification and subdivided into six types.By compiling the intersection diagram of single well EUR and net pay, the cutoffs of geological parameters were determined comprehensively by comparing the economic limit and the classification of reservoir geological parameters under the two scenarios. The method was applied to Chang 8 reservoir in Honghe oilfield of Ordos Basin, and its feasibility was verified.The practical application shows that this method can provide effective technical support to screen sweet spots and development deployment optimizing in tight reservoirs.

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
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The control of low sequence faults on reservoir quality and its practical production significance

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Keywords: Low sequence secondary fault ,Reservoir quality ,Production significance

Faults are of great significance to the basin and its internal structural evolution, sedimentation and oil and gas reservoir exploration and development. High sequence faults usually control the distribution of sedimentary sand bodies under the influence of regional structural background, which requires additional attention in the early exploration stage. However, with the continuous advancement of oil and gas field development process, low sequence faults are the focus of our attention, including the impact on reservoir quality and residual oil and gas distribution. Based on the data of seismic, drilling and logging, production performance and so on, this paper quantitatively analyzes the differences of reservoir physical properties under different stress segments along the fault strike in the second East Sulige area, and discusses the control effect of the fault on the distribution of remaining oil and gas. The results show that the physical property data of tension torsion section is obviously better than that of compression torsion section, which is considered to be caused by the change of rock composition structure of sand body caused by local tectonic stress and the formation of micro cracks in the sand body of reservoir; However, the fault sealing ability of the tension torsion section is poor, which often can not prevent fluid migration. From the actual drilling situation of well points, it can be seen that more oil and gas reservoirs are distributed in the compression torsion section, and only some dessert reservoirs can form small oil and gas reservoirs; The production dynamic data also show that under the same production measures, the high yield and rapid drop of tension torsion section is not conducive to long-term development. Based on the above understanding, it is considered that the tension torsion section is easier to form the early dessert reservoir section, and the compression torsion section can not be ignored in the process of residual oil development in the later stage.

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The application of waveform indicator inversion based on Fisher discriminant reconstruction curve in low permeability reservoir prediction — taking EP-A oilfield as an example

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Keywords: Waveform indicator inversion,low permeability reservoir,curve reconstruction,The Zhu jiang Formation,Fisher discriminant method

The prediction of low-permeability thin reservoirs has always been a difficult point in oil and gas exploration and development. The Zhu jiang Formation of EP-A Oilfield in Yang jiang Depression is a typical low-permeability thin reservoir. This kind of reservoir has the characteristics of rapid lateral change of sand body, poor continuity, small size of single sand body, low porosity and low permeability. The traditional seismic inversion method has low inversion accuracy for such reservoirs. In order to obtain high-precision inversion results and predict reservoir, seismic waveform indicator inversion method is used. High resolution reservoir prediction is carried out by using lateral variation of seismic waveform instead of variation function and well seismic combination. Firstly, based on the sensitive curve analysis, the elastic parameters and electrical parameters are reconstructed by Fisher discriminant method. The reconstructed curve can better identify conventional sandstone, low permeability sandstone and mudstone; Then, the optimal cutoff frequency is determined according to the main frequency and frequency width of seismic data; Finally, the waveform indicator inversion is carried out by using the reconstructed curve to obtain the inversion results and calculate the thickness of each main layer. The results show that the seismic waveform indication inversion improves the lateral and vertical prediction accuracy of the reservoir. It can successfully predict the sand body boundary and sand body thickness, The results are in line with the sedimentary geological law of the study area and provide a basis for guiding further oil and gas exploration and development.

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Origin and source of deep oils in the Dongying depression, Bohai Bay Basin: Insights from geochemical and geological analyses

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Keywords: Petroleum potential, Biomarkers, Oil-source correlation, Minfeng sag

The origin and source of oils from the Mbr 4 of the Shahejie Fm in the Minfeng sag, Dongying depression, Bohai Bay Basin are researched based on geochemical experiments, including TOC, Rock-Eval pyrolysis, gas chromatography-mass spectrometry (GC-MS) of saturated and aromatic hydrocarbon, the saturated hydrocarbon GC, whole oil GC and diamondoids quantitative analysis. Based on hierarchical cluster analysis of selected biomarker parameters, the crude oils from the Mbr 4 of the Shahejie Fm in the Minfeng sag are identified into 3 groups. According to the biomarker characteristics and depositional environment, the source rocks of the lower sub-member of Mbr 4 of the Shahejie Fm are further divided into the lower and upper part.

Group I oils from the lower sub-member of Mbr 4 of the Shahejie Fm in the Fengshen area are mature and high mature with low-medium thermal cracking degrees. These oils are characterized by low β-carotene/nC25 and C30 4-methylsterane index (4MI), and high oleane index (oleane/C30-Hopane, O/H), C27 diasterane/C27 regular sterane (C27Dia/C27), Regular sterane/17 α Hopane (S/H), and Gammacerane/C30 hopane (G/H), and medium Pr/Ph. This suggests that Group I oils contain important contributions from the mudstones between gypsum salt rocks in the upper part of the lower sub-member of the Mbr 4 of the Shahejie Fm. Group II oils are mature oils from the upper sub-member of the Mbr 4 of the Shahejie Fm in the Yanjia area with high 4MI and Pr/Ph, and low O/H, S/H, C27Dia/C27, and medium β-carotene/nC25 and G/H. These features are similar to the lacustrine mudstones in the upper sub-member of the Mbr 4 of the Shahejie Fm, indicating their genetic correlation. Group III oils from the upper sub-member of the Mbr 4 of the Shahejie Fm in the Yong'an area show the lowest maturity. Typical features of Group III oils include high β-carotene/nC25 and S/H, and the low O/H, Pr/Ph and 4MI, which are different from the source rocks in the Mbr 4 of the Shahejie Fm in the Fengshen area. Literature research suggests the mudstones in the upper sub-member of the Mbr 4 of the Shahejie Fm in the local Yong'an area are potential source rocks for Group III oils.

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Characteristics of hydrocarbon accumulation and exploration potential of passive continental margin basins around Indian Ocean

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Keywords: Passive continental margin basin, hyfrocarbon accumulation model, exploration potential

In order to enrich the theory of oil and gas accumulation in global passive continental margin basin, the tectonic evolution periods of the passive continental margin basin around the Indian Ocean are divided, and the characteristics of regional hydrocarbon accumulation and enrichment are analyzed. Two hydrocarbon accumulation models in two types of passive continental basin in East Africa are summarized. The models help to point out the exploration direction of frontier exploration basins. The study shows that the passive continental margin basins around Indian Ocean have experienced four tectonic evolution stages, pre-rift craton, rift, transition and drift, forming four sets of sedimentary, pre rift, rift, sag and continental marginal strata. Regional research shows that the long term rift-sag and restricted to semi restricted environment control the high quality source rocks in pre rift and rift stage respectively. Large provenance controls the high quality reservoir distribution of drift stage. Kerogen type and thermal evolution of source rock result in Indian Ocean is dominated by natural gas. The hydrocarbon accumulation models of transformed basin and extensional basin are established. Through the models, the exploration potential of frontier exploration basins in East Africa is definited.

Scientific Themes: Theme 11. Geoscience Programs & New Technology on Sedimentology
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Constraint of interstitial materials on the Paleogene Huangliu Formation reservoirs with low to medium permeability in the Dongfang 13 block, Yinggehai Basin

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Keywords: submarine-fan,low permeability reservoir,calcareous material ,argillaceous material

The submarine-fan reservoirs in Dongfang 13 block of Yinggehai Basin is characterized by medium porosity and low permeability, and the reservoir rock type is mainly feldspathic lithic sandstone. Interstitial materials have an important influence on the development of reservoir physical properties.The earlier understanding shows that sedimentation is one of the main controlling factors of the low permeability eservoirs in the study area, and the influence mechanism of the interstitial materials such as calcareous and argillaceous material on the low permeability reservoirs in dongfang 13 block is more obvious.

Based on thin section petrographic analysis, combined with core, physical property test data, logging interpretation results and seismic attribute slices, the main controlling factors of low permeability reservoir in the study area are studied in detail. The results show that:(1) The reservoir interstitial materials in the study area are mainly composed of calcareous and argillaceous materials. Take a certain depth section of the study formation as an examplethe content of calcareous material and argillaceous materials in the reservoir is 7% and 38% respectively, and the content of calcareous material is mainly iron calcite, which is more than 70%, followed by dolomite and micrite. The argillaceous components are mainly clay and a small amount of felsic clastic grains of corresponding grain size.(2) Calcareous material is distributed unevenly in the form of silty iron calcite, cementing metasomatic particles and affecting the original physical properties of the reservoir.(3) From the perspective of thin section scale, the distribution of illite and chlorite plays a decisive role in reservoir permeability, which is banded along the layer and has poor vertical connectivity. The pore type is mainly cast hole, and the reservoir permeability is generally less than 20mD. If the llite and chlorite is randomly distributed, the overall connectivity of the reservoir is poor,and the permeability is often less than 1mD.

Based on the influence of calcareous material and argillaceous material base on low permeability reservoir, this research work tries to explain their origin and formation mode, which has guiding significance for the future favorable reservoir development.

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Sedimentological record of alternate bar in embanked river: case study of the lower reaches of Natori River, northeastern Japan

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Keywords: Alternate point bar, Transport-depositional processes, Suspension, Typhoon Hagibis, Natori River

To examine the transport–depositional processes of fluvial clastic sediment in the embanked river, we investigated the sedimentological record based on the eroded outcrop exposing along the high-water level riverbed in the lower reaches of Natori River flowing down in the Sendai Plain, Miyagi Prefecture, northeastern Japan. The sedimentological record observed in embanked river (Utsugawa and Shirai, 2020; Shirai and Utsugawa, 2021) of which the water flow and clastic transportation are restricted has not been reported enough.

The Sendai Plain is an alluvial plain surrounded by the Neogene volcanic rock hill, and the east side of this plain faces the Sendai Bay and the Pacific Ocean (Shimazu, 2016). After the World War II, by construction of the continuous embankments the floodplain was separated from the embanked floodplain (Shimazu and Utsugawa, 2020). Nowadays there are alternate point bars which the elevation from water level are approximately 2 to 5 m. Typhoon Hagibis caused flooding of the river and the flood stage was above approximately 2 m on the high riverbed on October 2019. After that, in the lower reaches of Natori River, the exposed outcrops of high-water level riverbed were surveyed on December 2019 and February 2020.

The sedimentological characteristics were almost similar at the sites as described below; (i) at the bottom, subrounded–rounded gravel layer was covered by silty sand layer. The gravel size is similar to the clast deposited near the current riverbed. (ii) The silty (slightly soiled) very fine–fine sand layer was almost massive due to bioturbation. Man-made materials (e.g., plastic bag, can, glass bottle) were often included. (iii) The surface was capped by sand layer derived from suspension of flooding on October 2019. The thickness was only several to ten centimeters. At the flood, although the large amount of detritus containing wood debris was delivered from upstream, the deposited wood debris was few in number on the surface. It means that the wood debris was caught on the forest developed at the upper side of the point bars.

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Sedimentological study and Revised lithostratigraphic framework of the lower Anti-Atlas Supergroup: Ourty Series (Igherm Inlier, Western Anti-Atlas, Morocco)

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Keywords: Morocco, Anti-Atlas Belt, Igherm Inlier, Proterozoic, lower Anti-Atlas Supergroup, lithostratigraphy.

In the western part of the Moroccan Anti-Atlas, the lower Anti-Atlas Supergroup contains a sedimentary succession deposited along the northern margin of the West African craton. It is composed of sedimentary units and associated, mafic intrusive and extrusive rocks. Similarly, it is developed in the Igherm inlier where the Ourty Series includes pelite-carbonate and thick quartzite sequences, and mafic intrusive rocks. Based on sedimentological and lithostratigraphic studies, we have subdivided the Ourty Series into several units with the total thickness ranging between 2 to 3 km. Lithostratigraphic correlation of the sections in separate parts of the Ighrem Inlier and correlation with the lower Anti-Atlas Supergroup in the Anti-Atlas Inliers identified from the base to the top the following, five higher-rank units. 1) The ca. 2030-1706 Ma Tasserda-Taghatine Group of the Tagadirt Igzouln area that corresponds to interbedded coarse quartzites, shales, sandstones, and limestones cut by dolerite sills. This unit was deposited in fluvial to shoreface sedimentary environments. 2) the ca. 1745-1650 Ma Oumoula (Mimount) Formation of the Labaste-Taghout area that consists of quartzites and pelites also cut by a set of doleritic sills; the sedimentary structures indicate fluvial to littoral, backshore, depositional environments. 3) The ca. 1650 Ma to >883 Ma Tizi n'Taghatine Group, recognized in the Tizi N'Tilin area, is composed of limestones alternating with mud-rich horizons grading to shales interlayered with quartz sandstones. It was deposited in shoreface to offshore depositional environments. 4) The ca. 883 Ma Tachdamt Formation consists of mafic volcanic rocks exposed in the Ourti Boyarf area. 5) The ca. 700 Ma Bleida Formation, developed in the Tizgui N'Oufla-Assaka area, consists of shales and quartz sandstones interbedded with aleurolites of laminated, volcanic layers and limestones alternating with shaly horizons. The facies analysis of the latter unit indicates shoreface to offshore depositional environments. The compilation of published and our own field data have led to a revised lithostratigraphy for the lower Anti-Atlas Supergroup in the Ighrem Inlier.

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Influence of inherited paleorelief (palimpsests) during the late Permian marine transgression on distribution of evaporitic sediments - an example from SW Poland

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Keywords: Zechstein, evaporates, carbonates, sediment distribution, differential compaction

Basing on over 500 boreholes the maps of the top-surfaces of several sedimentary/stratigraphic units were created - lower Permian sandstone, upper Permian (Zechstein): dolomite (Ca1), anhydrites (lower and upper), salt (Na1). Then, for 218 of boreholes, located within or in vicinity of the copper mines area, in which the above mentioned sedimentary units were recognized, an agglomerative hierarchical clustering was performed based on one minus the Pearson correlation coefficient, using different methods. The Pearson correlation coefficient was calculated for the groups obtained. In case of Ca1 and lower anhydrite, additional maps of thicknesses were created due to the additional information from hundreds of shorter boreholes made from mine drifts.

The Zechstein Sea overflooded the area of aeolian accumulation. Due to the water invasion onto the palaeorelief of ancient dunes, less-more parallel seifs, the oversaturated sandy material was partly fluidized and replaced down the dune slopes, what significantly reduced their primary highs. Nevertheless, the reworked topography continued to be an important factor influencing distribution of early transgressive marine sediments, e.g. between flooded dune crests, on the interdune areas, a significantly higher amount of fine grained mud was deposited what is documented by its larger thickness. Later deposited carbonates of the Ca1 horizon had been formed as rigid plate which covered still uncompacted muds. Those pre-lithification deformation is documented by occurrence of numerous intrusive sand dikes which cut the both horizons and are variously deformed due to later differential compaction.

An analysis of the Ca1 thickness variation map identify a fragment of the east-west oriented carbonate platform, a structure recognizable regionally within the Zechstein Basin. Along the edge of this carbonate platform, a barrier developed with thickness above 100 m. High resolution map present at least partly, the correlation of Ca1 horizon thickness with recognized sandstone elevation. Northwards from the barrier edge, the top surface of carbonate unit successively slopes down what reduces the thickness to c.a. 15 m on a distance of few km. Further northwards thickness is reduced slowly to few meters. Further, due to water depth decreasing, sulfate sedimentation began. On the carbonate platform top surface the sulfates thicknesses vary between few and c.a. 40 m. On the barrier's slope of Ca1 a sulfate platform developed with regular thicknesses c.a. 60-80 m. On the high resolution map of the lower A1 thicknesses, correlation between growing values of anhydrite thicknesses and sandstone elevations positions is observed. That may suggest the presence of (slight?) palaeo-relief undulations, which may have been influenced the distribution of the sulphates during its deposition. Correlation is observed in the zones with relatively low Ca1 thicknesses. That might suggest it was probably a result of syndepositional mud compaction. In the region where the salt is now present, a negative correlation with the lower anhydrite is observed, probably as chlorides were deposited in salt pans surrounded by elevations built of sulphates. In general, the thickness of the evaporites increases towards the depocenter of the Zechstein Sea Basin. A part of the visual observations are supported by statistical correlations.