Diagenetic Controls on Reservoir Pore Structure of Tight Sandstones: Examples from Upper Triassic Yanchang Formation Chang 8 Sandstones in Jiyuan Region, Ordos Basin, China

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The eighth member of Upper Triassic Yanchang Formation (Chang 8) is the major oil reservoir units in Jiyuan oil field, however, the sandstones are characterized with low porosity, low permeability and strong microscopic heterogeneity, which are commonly attributed to variations in diagenetic alterations during its lengthy and complex geologic history. This article addresses the controls exerted by diagenetic alterations on the modification of pore-network characteristics (porosity, pore types, sizes, shapes, and distribution), with the aim to unravel the formation mechanisms of this complex pore structure, and to improve the quantitatively characterization and classification evaluation for Chang 8 sandstone reservoirs. Detailed petrological study by thin section, X-ray diffraction, scanning electron microscopy, core analysis and mercury injection capillary pressure analyses have been used to investigate the lithogology characteristics, diagenesis, diagenetic minerals and their coupling impacts on petrophysical properties. The results show that Chang 8 sandstones comprise fine to medium-grained ubarkoses, feldspathic litharenites, the pore types are dominated by remaining primary intergranular pores secondary porosity and micropores, the pore structure is characterized by small pore throats, high capillary pressure and a tiny pore throat radius. Destructive diagenesis as compaction, cementation and micro-porosity continued to decrease the pore-throat size, while dissolution enlarges pores and pore throats. Comprehensive Coefficient of Diagenesis, considering the combined effect of diagenesis, shows strong statistical correlations with threshold pressure, sorting coefficient and even reservoir quality index, *RQI*. Comprehensive Coefficient of Diagenesis, is an integrative modulus of diagenesis and physical property, generally the higher the values, the better the pore structure is, it is suitable for quantitatively characterization for pore structure in tight sandstones, such as Chang 8 oil layers in Jiyuan oi field.

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Diagenetic Controls on Reservoir Properties of Deeply Buried Tight Gas Sandstones: Examples from Lower Cretaceous Bashijiqike Formation in Keshen Area, Kuqa Depression in the Northern Tarim Basin of West China

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The deep buried Lower Cretaceous Bashijiqike tight sandstones are important gas exploration targets in Keshen Area, Kuqa Depression of Tarim Basin, exploration practice proves that there still contains excellent clastic rock reservoirs with depth of over 7900m, reservoir quality is a critical risk factor in this ultradeep reservoirs. Mineralogic, petrographic, and geochemical analyses have been used to investigate the diagenesis, diagenetic minerals, diagenetic evolution and their impact on reservoir quality with the aim to unravel the mechanisms to maintain anomalously high porosities in sandstones buried to such a great depth. The sandstones are dominantly fine-medium grained, well sorted lithic arkoses and feldspathic litharenite, averaged as Q42.1F32L25.9. Most primary pores have been lost by mechanical compaction or carbonate cementation, and reduction of porosity by mechanical compaction was more significant than by cementation. Dissolution of framework grain contributes to the enhancement of reservoir quality.

Eogenesis mainly includes mechanical compaction and calcite and possibly clays precipitation; Mesogenesis is typical of framework grains dissolution by CO2 and organic acids and subsequent precipitation of clays and quartz; infiltration of meteoric water related to Teleogenesis would result in flushing of the framework grains. The special burial regime as early-stage shallow burial with late-stage rapid deep burial model contributes to porosity preservation in eogenesis, and the overpressure caused by intense structural compression in middle Himalayan movement can certainly retard compaction and help preserve porosity in the late rapid deep burial stage. Anomalously high porosity are mainly found in medium grained, well sorted sandstones with low clay and carbonate cements content, of which the porosity are preserved primarily and enhanced secondarily.

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Distribution of Diagenetic Alterations within a High Resolution Sequence Stratigraphic Framework: Evidence from the Forth Member of Upper Triassic Xujiahe Formation in Central Sichuan Basin, China

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The Upper Triassic Xujiahe Formation hosts one of the most important petroleum systems in the Sichuan Basin, it can be divided into two super long-term sequence cycles (SLSC1, SLSC2) and five long-term sequence cycles (LSC1-LSC5), the forth member of Xujiahe Formation (Xu-4) is interpreted as a regional lake transgression-lake regression sedimentary cycles consisting of base-level rising and falling semi-cycles, corresponds to the 3rd order sequences. It is bounded by a sequence boundary (SB1) of super long-term base level cycle on the bottom and SB2 of long-term base level cycle on the top. The spatial and temporal distribution of diagenetic alterations and minerals has been constrained in relationship to the sequence stratigraphic framework of the Xu-4 sandstones. Mineralogic, petrographic, geochemical analyses combined with ECS logging data are used to investigate the diagenetic alterations, diagenetic minerals, diagenetic evolution and their impact on reservoir quality.

Sequence stratigraphy-related diagenetic minerals include carbonates, feldspars dissolution, precipitation of carbonate cements is presumably to be enhanced to the relatively long residence time of the sediments at shallow depths below the SB2 (top of Xu-4 sandstones), high content of carbonates below the SB2 are actually observed in ECS logging and thin sections. However, the fairly low $\delta^{13}C$ values of calcite cement suggest that carbon was partly derived from alteration of organic matters in Xu-3 source rocks, since local distributed carbonates above the SB1 can also be detected in ECS logging profile. Sandstones adjacent to sequence boundary are porous, intergranular pores by framework grains dissolution are commonly observed in this zone. Other minerals as quartz overgrowth and clay minerals show no obvious distribution pattern related to sequence stratigraphy due to the high diagenetic evolution level of the Xu-4 reservoirs.

Loss of depositional porosity was greater due to compaction than to cementation in both the base level rising and falling cycles, and loss of depositional porosity caused by both compaction and cementation are great in sandstones of base level falling cycles than that of base level rising cycles. Porosity are preserved primarily in sandbodies of base level rising semi-cycle, of which the framework grains are coarse grained, well sorted and grounded, they have undergone the most feldspar dissolution coupled with its adjacent to SB1, thereby further enhancing reservoir quality. While for sandbodies of base level rising semi-cycle, the framework grains are finer grained, poorer sorted, due to the less feldspars dissolution and carbonates precipitation below SB2, the reservoir property is poor. Linking diagenesis to sequence stratigraphy framework allows a better understanding of the parameters controlling the spatial and temporal distribution of diagenetic alterations, and hence of reservoir quality.

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Large-scale seismically-induced lacustrine sediment disturbance in an active intraplate seismic zone: Lake Témiscouata, northeastern Appalachians (eastern Canada)

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Mass-movement deposits are common in lacustrine basins located near active seismic zones. In eastern Canada, disturbed lacustrine deposits have been associated with past seismic events in the intraplate Western Québec Seismic Zone (WQZ) and the Charlevoix-Kamouraska Seismic Zone (CKSZ). With five major earthquakes that occurred during historical times (AD 1663: M>7; 1790: M=6; 1860: M=6; 1870: M=6.5 and 1925: M=6.2) and hundreds of minor earthquakes, the CKSZ is the most active seismic zone in eastern Canada. Here we present new high-resolution multibeam bathymetric, subbottom profiler and sediment core data collected in Lake Témiscouata, southeastern Québec, the largest lake located within the influence of the CKSZ. The occurrence of mass-movements in the highly cohesive glaciolacustrine deposits of the lake produced a peculiar sublacustrine landscape consisting of steep slide scars and residual mounds and very narrow residual crests. Our data indicate that postglacial times were marked by recurrent seismically-induced mass-movement events that cannot be individually identified in the sedimentary record due to the highly disturbed stratigraphy of the lake and to the absence of postglacial background sediments between events. The most recent recorded mass movement is a distinct debris flow sediment layer on the lake floor. This layer was deposited very shortly after a large-scale mass-movement event across the entire lake basins that occurred ~1300 cal BP. The presence of silt layers in gyttja overlying these disturbed units suggests that the region was affected by other seismic events following this event.

New ilmenite-zircon placer province in Early Paleozoic paleobasin on the northwestern Russian platform

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Heavy mineral ilmenite-zircon bearing placer deposits (heavy mineral sands - hereafter HMS) are of the most important source of titanium and zirconium which determine level of technological development of industry.
HMS consists of well-sorted weathering resistant minerals that had high-grade separation in coastal and shallow-water conditions. Preliminary destruction of unstable minerals is favorable for the process of HMS formation. Due to long joint transportation the heavy minerals (ilmenite, zircon, rutile, leucoxene, monazite) are of the same hydraulic equivalence (fall velocity in the water) with minerals of light fraction (mostly quartz). So, separation of transported sediments and concentration of the heavy minerals occur only during horizontal movement of the particles on the surface of the bottom within the limits of the current velocity of 10–18 cm/s.
There are two types of HMS placer deposits: present-day (Pleistocene to Holocene) coastal placers and ancient (Cenozoic to Mesozoic sometimes up to Paleozoic) buried placers mostly of coastal and shallow submarine genesis. Buried HMS deposits are located in three megaprovinces: Australian (Murray and Eucla basins), East European and West Siberian of Eurasia.
Reference pattern of the burial HMS of economic importance is Malyshev placer of Miocene age in the east of Ukraine which is on of the largest in the world and unique on content and quality of ore minerals. Magmatic and metamorphic rocks of Ukrainian shield which contain placer-forming minerals were disintegrated in weathered crusts and became the source of HMS deposits. Eroded material was transported to Miocene basin and separated in coastal and shallow sea conditions.
New forecasted HMS province is localized on the north-west of Russian plate closely to the south-east border of Baltic Shield. Host deposit consist of well-sorted mostly quartz Cambrian-Ordovician sands (COS). It is Early Paleozoic structural and lithological analogue of Cenozoic East Ukrainian placer province. Research of distribution of HMS in the territory of Russian Plate reveals consecutive decreasing of HMS age from Devonian in the central part to Miocene-Pliocene in the south that reflect tectonic and structural regularities of development of the Plate. Early Paleozoic HMS on the north part of the plate corresponds to this trend.
COS Formation outcrops along narrow sub-latitudinal paleocliff ("glint"); in the southern direction the sequence is overlaid with cover of platform deposits. Researched of the outcrops do not reveal placer deposits of economic importance, but concentration of heavy minerals rise in south-east direction up to economic value, where the sequence plunge down under the cover deposits.
Reconstruction of paleoconditions of the basin reveals that hydrodynamic in the west part of basin was too intensive for separation of heavy and light minerals, and in the south-east part it decrease to the value of effective separation.
Thus, based on method of geological analogy (similarity of the studied Formation to large-scale HMS deposits of economic importance), paleohydrodynamic reconstructions and growth of HMS concentrations in south-east direction, we can forecast new ilmenite-zircon placer province in Cambrian-Ordovician sands on the north-west of Russian plate beneath sedimentary cover. Availability of this area for HMS was confirmed by research of core samples of separate drilling holes that reveals heavy mineral concentration of economic importance in the south-east slope of Baltic Shield.

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Understanding of the diversity of earthquake turbiditic flows in a single lake: the case of the Lake Hazar on the East Anatolian Fault

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The East Anatolian Fault (EAF) is a major left-lateral strike-slip fault accommodating with the conjugate North Anatolian Fault the westward extrusion of the Anatolian Plate away from the Arabia-Eurasia collision zone. The East Anatolian Fault ruptured over most of its length during the 19th century in a series of magnitude ~7 earthquakes. During the 20th century this fault was less active with only two events of magnitude greater than 6. This absence of large earthquakes has resulted in relatively little attention being paid to the East Anatolian Fault compared to the North Anatolian Fault, which has ruptured during the last century in several earthquakes of Ms~7. To constrain the seismic history of the East Anatolian Fault in its central part, we focus on the Hazar Lake, occupying a 20 km long pull-apart basin. Short cores and long sedimentary cores were collected at three different sites to retrieve a paleoseismic record. Small correlative coarse-grained sedimentary events are identified in all cores. The age of the events is inferred combining radiocarbon and radionuclide (137 Cs and 210Pb) dating. We present here detailed analyses of three sedimentary events assigned respectively to the historical earthquakes occurring in 1789, 1513-1514, 1285. The source of the sedimentary events is different at the three sites. We combine X-ray imagery, magnetic susceptibility, grain-size and XRF measurements with thin section analysis to investigate the nature of sedimentary events. The analyses show first that the three sedimentary events are different. The magnitude of the terrigenous signal varies significantly. Second the correlative events have a different expression at the three sites. So each site has a different and specific sensitivity. In particular, an individual event can be composed of several coarse-grained sub-events of different magnitude with a time lapse in between greater than a week. The latter is reveals by the presence of bioturbation in particular by chironomids in individual thin sand layers. Thin section also shows that subevents are gradded. Each coarse-grained layer is thus a separated turbiditic flow. The site with the highest sensitivity is the one located near the near-shore steep submarine southern slopes overhanged by the steep subaerial slopes of the Hazar Mountains. The rivers draining the Hazar Mountains are ephemeral and provide a restricted sedimentary supply. In addition, seismic reflection data show that the submarine slopes do not to accumulate a significant sedimentary load. However on these steep slopes, an earthquake intensity of 6 or less is enough to trigger a slope failure and the associated turbiditic flow. We conclude that the different sub-events at this site may record a complete earthquake sequence, i.e the main-shock and its foreshocks and aftershocks.

From Sturtian to Marinoan: sedimentary record from the Fulu Formation, South China

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There are two Neoproterozoic global glaciations, the Sturtian and Marinoan in chronological order. In South China Block (SCB), the younger Marinoan glaciation is represented by the Nantuo Formation that is distributed throughout the whole SCB. In contrast, the older Chang'an glaciation, which was correlated with the Sturtian glaciation, is restricted in deep basinal environment in northern Guangxi and southeastern Guizhou provinces. In the basinal settings, the interglacial deposition is represented by the Fulu Formation, the only depositional window in SCB recording the sedimentary history between the Sturtian and Marinoan glaciations.

The Fulu Formation unconformably overlies the Chang'an diamictite, and begins with the deposition of ferruginous silty mudstone with regional occurrences of banded iron formation. In the Fulu section, the lower most Fulu Formation is composed of ~60-m-thick purplish ferruginous silt mudstone, which was deposited in low energy offshore environment as indicated by horizontal beddings. The ferruginous mudstone unit is underlain by ~ 67-m-thick pebbly inequigranular sandstone of low textural maturity. The size of polymictic clasts varies between 0.3-0.5 cm, with occasional occurrence of large clasts up to 20 cm in size. The pebble sandstone unit develops parallel and swash beddings, suggesting the deposition in foreshore facies with occasional presence of ice rafting. The overlying 173.6-m-thick rhythmite unit consists of repeated units of intercalated centimeter-thick well-sorted coarse sandstone and siltstone, the former of which is laminated with development of cross bedding. The rhythmite unit is probably deposited in regions close to the ice front, experiencing high frequency invention-retreat glacial cycles. The rhythmite unit is sharply truncated by ~10-m-thick polymictic diamictite. The size of polymictic clasts within the diamictite unit decreases gradually upward, and is finally replaced by well-rounded, but poorly sorted mud gravels, ranging in size from 0.5-5 cm. The deposition of diamictites unit represents an ice-proximal glaciomarine deposition during a glacial climax. The diamictite unit is overlain by a siltstone unit of ~ 90 m thick. The thin-bedded siltstone is intercalated by sandstone layers of various thicknesses, which contains either poorly sorted polymictic clasts or mud gravels. The siltstone unit is the typical ice-distal glaciomarine deposit. The boundary between the Fulu and Lijiapo (Nantuo) formations was traditionally placed at the top of the siltstone unit, above which massive pebbly sandstone intercalated with pebble-free sandstone\siltstone layers imply the deposition in an ice-proximal glaciomarine condition.

In summary, the sedimentological evidence indicates that the deposition of Fulu Formation is strongly influenced by glaciations. From the ferruginous mudstone unit at the base of the Fulu Formation to the diamictite unit represents a sequence of deglaciation – ice-distal glaciomarine - ice front - ice-proximal glaciomarine sedimentation. And transition from the siltstone unit in the top of Fulu Formation to the Lijiapo Formation implies shifting from ice-distal to ice-proximal glaciomarine deposition.

Our study suggests that the interglacial interval between the Sturtian and Marinoan global glaciations is not glacial free, instead, glaciations might have influenced up to 30°in latitude, where SCB was located during late Neoproterozoic. We also speculate that high latitude areas, possibly mid-latitude regions as well, might have been ice-covered for ~800 million years throughout the whole Cryogenian, and the two global glaciations, the Sturtian and Marinoan, represents two extremes when extension of glaciations to tropics.

New high-resolution analyses of Arctic varved lakes and their potential to decipher strong climate signals

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Current warming in the Arctic appears to be unprecedented since at least the last 2000 years (PAGES 2k Consortium. 2013). It is becoming critical to obtain high-resolution records of climate to better understand its natural variability in the past but also to strengthen the future climate projections. Annually laminated sediments (varves) are excellent candidates to track past environmental changes. This paper focuses on two varved lakes from Melville Island (Cape Bounty East Lake (CBEL), western arctic) and Ellesmere Island (South Sawtooth Lake (SSL), eastern arctic), and presents new techniques to retrieve sedimentological data at high-resolution.

At CBEL, a 436-cm varve sequence was analysed using 86 thin sections. For each of the 2845 varves counted, particle size distribution (PSD) was extracted with a new software developped at INRS, University of Québec. The method makes possible the scanning of particle size at (sub) annual resolution. Comparison of coarse grain size with the annual largest rainfall recorded at the nearest weather station yielded a significantly positive correlation (R=0.85) (Lapointe et al. 2012). This correlation was much weaker for varve thickness (VT) (R=0.40). Furthermore, the long-term evolution of PSD and VT is strikingly different as shown by the weak correlation (R=0.29).

In an attempt to find known cyclicty in the 1750-year varve record of CBEL, the method of the wavelets was applied on the grain-size dataset, i.e. coarse grain size (98^{th} percentile). A persistant power band located at ~200 year period was found from AD 940 until recently. Spectral density and multitaper method revealed strong peaks at 170, 212 and 227 year. These dates are similar to that of the Suess solar cycle (~210 year). On the other hand, no such cyclicities were detected using the VT dataset.

This suggests that time series analyses may be influenced when performed on parameters influenced by core compaction with increasing depth, i.e. varve thickness, while parameters that are not depth dependent, e.g. annual sediment fluxes and granulometry, seem to be stronger.

In order to test wether the differences in cyclicities are due to climate or to the analysed parameters, we performed wavelet analysis using the VT of the 2828-year varve record of SSL. It shows a 90-year persistant power band over the last 600 years. Interestingly, the first ~600 years correspond to the very well defined and horizontal layers from the 90-cm gravity core. We will also discuss the results obtained on grain size on the SSL record.

PAGES 2k Consortium (2013). Continental-scale temperature variability during the past two millennia. *Nature Geoscience*.

Mud-rich carbonate mounds through space and time: paleozoic (Canada) and mesozoic (Morocco) case studies

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Phanerozoic mud-rich carbonate mounds are diverse geobodies with variable dimensions, geometry and macrofacies and are geographically and chronologically widespread. By studying the relative importance of accretionary modes in terms of biomineralization, organomineralization and marine cementation we have established a continuum from organomineralic to cement-rich counterparts. The contribution from skeletons (e.g. bryozoans, polychaetes, corals) varies from insignificant to important as a function of paleogeography, water depth and level of adaptation. Telescoped environmental conditions within cryptic niches, as well as early diagenesis and ephemeral substrates, could play a critical role in mounds formation, mound taphonomy and therefore their preservation through geological time. The approach adopted compares the accretionary mechanisms and the early diagenesis of various mudmounds of different ages and from different depositional environments. The data is based on field observations, comparative petrography (macrofacies and microfacies) and geochemical character (stable isotopes of carbon and oxygen; rare earth element distribution) associated with the different carbonate phases.

At the Chute Montmorency locality (Middle Ordovician, Quebec), bioherms are lenticular bodies where *in situ* trepostome bryozoans have built a classic reefal framework. Accretionary mechanisms rely mainly on biomineralization whereas organomineralization takes place within intra-reefal cryptic spaces. Cementation is absent. At the Anticosti Island locality (Lower Silurian, Quebec), mud-rich buildups have two distinct facies, both characterized by an abundance of marine cement. The crinoid-fenestrate bryozoan mudstone-wackestone facies is distinguished by volumetrically important polymud fabric and both shelter cavities and stromatactis. In this facies, biomineralization is of minor importance whereas organomineralization and, to a lesser extent, marine cementation within stromatactis are responsible for the net accretion. Regarding the fenestrate bryozoan cementstone facies, the contribution of biomineralization remains minor and organomineralization is absent. In this case, net accretion is the result of extensive marine cementation. At the Foum Zidet locality (Upper Sinemurian, Morocco), mounds contain well preserved, calcified siliceous sponges locally used as substrate by encrusting communities. Thus, mounds accretion combines organomineralization and, to a lesser degree, biomineralization whereas marine cement precipitation is lacking. At the Jebel Assameur locality (Bajocian, Morocco), mud-rich buildups contain important concentrations of scleractinian corals and coral debris. Accretionary processes consist of biomineralization resulting in classic patch reefs. Organomineralization and biomineralization are restricted to cryptic spaces and cement precipitation is minor.

Detailed study of these five localities, and comparisons with fifteen more examples from the literature, allow for the discussion of the evolution of parameters controlling mounds formation and mounds preservation. Other than environmental and paleoecological variation, the kinetics of various natural reactions ongoing at/or near the seafloor appears to be an important factor that determines the resulting carbonate fabric.

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Geochemical and geophysical characterization of the Opalinus Clay (Mont Terri underground rock laboratory, Switzerland)

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Located in the Jura Mountains (St-Ursanne, NW of Switzerland), the Mont Terri underground rock laboratory is a research facility investigating the Opalinus Clay formation, particularly for the deep geological disposal of radioactive waste. The Opalinus Clay is characterized by mudstones accumulated in a shallow epicontinental shelf sea during the late Toarcian and Aalenian. Three distinctive sub-facies of the Opalinus Clay have been described in the past, i) a shaly facies, ii) a carbonate-rich sandy facies and iii) a sandy facies. Within the framework of the SO (Sedimentology of Opalinus Clay) experiment, which is part of the Mont Terri Project, this master thesis is investigating a 27 m-long core (BDM-B2) crossing the three different sub-facies, in order to reconstruct the paleoenvironmental and paleoclimatic settings.

Different logging methods combined with a detailed facies description have been used to identify small-scaled facies variations. In order to improve the stability of fragmented hard-rock core sections during logging operations, the BDM-B2 core has been embedded in transparent polyethylene tubes filled with an epoxy resin. Geochemical logging at 1 cm resolution has been performed with the ITRAX XRF core scanner at the University of Bern. Moreover, the gamma-ray density, the p-wave velocity and the magnetic susceptibility have been measured with the GEOTEK Multi-Sensor Core Logger with a resolution of 0.5 cm.

The XRF results and the lithological descriptions confirmed the occurrence of three major sub-facies with distinctive mineralogical characteristics, but identified also the importance of smaller-scaled facies variations within each sub-facies. On the basis of the logging data, boundaries between the sub-facies could be refined and variations in paleoenvironmental and depositional settings could be reconstructed.

In order to establish a solid paleoenvironmental framework for the Opalinus Clay formation at the Mont Terri location, clay mineralogy, TOC measurements and detailed thin section analyses will be performed. Additionally, surface micro-texture analyses on Quartz grains will help in identifying the main sediment transport mechanisms.

Outcrop analogues providing quantitative constraints on small-scale facies distribution and geobody architecture in Cretaceous carbonate platform settings

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Sub-seismic scale facies distribution patterns and geobody architecture pose a major obstacle when assessing reservoir properties in the subsurface, as they may frequently lead to reservoir heterogeneity and can alter fluid flow, while proving difficult to characterise using the conventional combination of seismic surveying and wellbore data. In carbonate platform settings such geobodies commonly include bioherms and buildups, as well as grainstone clinoforms. The presence of such elements can result in drastic changes of the sedimentological and petrophysical parameters of the rock over small distances, and is particularly challenging to predict as mature fields move into enhanced oil recovery. Finding and identifying analogous outcrops is a proven approach for describing such geometries, with digital outcrop models becoming an increasingly popular tool, given their potential for integration in various subsurface reservoir models and flow simulators.

A combination of state-of-the-art outcrop digitalisation lidar-scanning techniques and traditional fieldwork methods is utilised in this study in order to describe sub-seismic-scale sedimentary geobodies. These include field based mapping of geobodies, sedimentary logging and sampling, with georeferencing using GPS, allowing precise placement of elements in later stages of data processing. With supporting microfacies analysis and modal analysis data, the resulting digital outcrop models can be supplemented with lithological parameters such as back-stripped porosity.

Both strike and dip sections of the Cenomanian-Turonian Congost Formation and the Santonian Sant Corneli Formation are well-exposed in the Tremp area of the south-central Pyrenees, allowing detailed study and construction of digital outcrop models to quantify observable internal geometries. Both formations were deposited on carbonate platforms that were established during the multiple tecto-sedimentary cycles that resulted from the onset of the Alpine Orogeny. Sets of bioclastic grainstone and packstone clinoforms, up to several 10s of metres in length and few metres in thickness, are observable in the outcrops of the Congost Formation, prograding onto the underlying deeper-water sediments and pinching out basinwards. Mixed coral-rudist buildups with diameters reaching up to 10 m, as well as laterally extensive biostromes of elongate rudists are characteristic for the Sant Corneli Formation. These are commonly interbedded with foraminifera-rich calcarenites, which may display internal clinoform-type bedding surfaces, interpreted as the result of changing dominant environmental controls on sedimentary processes.

Together, the investigated outcrops provide valuable examples of how the construction of digital outcrop models can contribute to understanding the distribution of carbonate sedimentary geobodies. The quantitative data derived from these models can be integrated into stratigraphic forward models and geocellular reservoir models through upscaling, as well as fluid flow simulations in subsurface environments. Subsequently, it is expected to contribute towards reduction of reservoir risk by allowing better insight on how small-scale changes in facies affect reservoir heterogeneity and how they can be better predicted through the implementation in seismic forward models.

Paleoenvironmental control on Upper Ordovician hydrocarbon source rock types in North-America

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Late Ordovician is a time of widespread deposition of organic matter-rich mudstones. In North America, these Upper Ordovician hydrocarbon source rocks are present everywhere on the ancient Laurentia continent, their precise age being slightly variable with the oldest and thickest ones (Mohawkian; Sandbian) at the continental margin and the youngest and thinnest ones (Richmondian; end-Katian) in the central part of the continent.
The Hudson Bay Basin is an intracratonic basin located in the center of Laurentia; this basin is the largest of the intracratonic basins in North America. The preserved succession covers the Late Ordovician to Late Devonian and is dominated by shallow marine carbonates, evaporites and shales. Three intervals of Upper Ordovician black shales are present in the succession, with a progressive younging and thinning of the shale intervals towards the Late Ordovician paleoequator at the northern margin of the basin. The organic matter rich shale (up to 35% TOC) are found in cyclic succession of peritidal carbonates with evaporites interpreted to record hypersaline conditions. The hypersaline setting is also supported by the shallow water and environmentally stressed conodont association that indicate maximum regression in the late Ordovician.
The Upper Ordovician source rocks are markedly different on their petrographic characteristics and biomarker signatures. Upper Ordovician source rocks at or near the continental margins are locally rich in *Gloeocapsomorpha prisca* with biomarker signatures indicative of Type I/II source rocks. To the contrary, the Upper Ordovician source rocks at the northern reach of the Hudson Bay Basin are lacking *G. prisca* and their biomarker signatures indicates sulphur-rich organic matter (Type II-S). Compared to slightly older source rocks at the continental margins, those in Hudson Bay have higher abundances of C_{19} + *n*-alkanes and acyclic isoprenoids, and lower pristane/phytane ratios. These geochemical signatures indicate the Hudson Bay Basin source rocks were deposited in hypersaline and highly reducing environments in which anaerobic bacterias reworked the organic matter. Hypersaline-reducing environments are also indicated by the presence of 1-alkyl-2,3,6-trimethylbenzenes (which form in the presence of sulphur bacteria) in the aromatic fractions of Upper Ordovician units. The Ordovician source rocks in the Hudson Bay Basin also have low C32/C34 ratios and distributions of 17∀(H) - 21β(H)-hopanes that are very similar to the Silurian hypersaline source rocks in the intracratonic Michigan Basin in central USA.
The intrinsic character and geochemistry of Upper Ordovician source rocks indicate continental-wide tectonic and environmental controls. The thick succession (up to 600 m) of calcareous black shales at the continental margins of Laurentia (e.g., Utica Shale, Cape Phillips Formation) are present in a succession of deepening-upward open marine facies (carbonate and clastics) capped by flysch in response to tectonic foundering of the margin linked to accretion processes. These are dominated by Type II organic matter. Away from the continental margins, the Upper Ordovician source rocks (e.g., Collingwood and Yeoman formations) are included in open marine carbonate successions, these are dominated by Type I/II organic matter. Finally, in the central part of Laurentia, the Hudson Bay Upper Ordovician source rocks (e.g., Red Head Rapids, Amadjuak and Boas River formations) are younger and thinner (5 to 15 m), they are found in eustatically-controlled, shallowing-upward succession culminating in hypersaline conditions resulting in the formation of sulphur-rich Type II-S organic matter.
Tectonic, paleogeographic and paleoenvironmental conditions controlled the characteristics of Upper Ordovician source rocks in North America. The presence of Type II-S source rock has economic significance as these will start to generate oil at lower burial temperatures compared to Types I and II.

Diagenesis and burial history of Permian carbonates in Northern South America. Evolution from equatorial Pangea depositional condition to Northern Andean burial and exhumation regimes

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After deposition, Palmarito strata in the Mucuchachi Basin of northwestern South America were affected by a range of diagenetic processes, taking place at different stages in the burial history. For the most part Palmarito strata are fine-grained, and there are few grainstones or cavity structures where coarse cements can be observed. The main post-depositional processes were compaction and cementation, as well as silicification and selective dolomitization. The latter has in some cases enhanced the porosity although elsewhere the most common primary intraskeletal porosity has been reduced. The Palmarito succession in the central and northeast part of the Andes has been affected by low-grade regional metamorphism; this is probably the result of intense tectonic activity in some regions and deep burial. However, in the south-western Venezuelan Andes the sediments are unmetamorphosed and this suggests a differential burial history for the basin here or a lower heat flow associated with the tectonic activity.

For this study conventional petrography was carried out of about 170 thin-sections and a microfacies scheme was generated as well as the paragenesis, mostly involving compaction, cementation and dissolution. The stable isotopes $\delta^{13}C$ and $\delta^{18}O$ are useful for understanding the evolution of these rocks from subaerial exposure through to burial and subsequent uplift. In addition trace elements : iron (Fe), manganese (Mn), magnesium (Mg) and strontium (Sr), provided information on the diagenetic processes and fluids involved. Cathodoluminescence was used to identify the different stages of cementation. However, there were few cements to study since most of the facies were lime-mud rich which limited the use of this practical tool. Also, thermal analytical methods were applied to enable the construction of the thermal history of these rocks.

Palmarito strata do contain evidence of early marine and meteoric diagenesis through to burial diagenesis with few stages of cementation. However, mechanical and chemical compaction is the most significant process that has affected the formation, and as a result, most of the primary porosity has been lost. Silicification and dolomitization has also affected Palmarito strata, replacing original or secondary calcite in later diagenesis. The succession in the central and northeast parts of the Andes has suffered low-grade regional metamorphism, that is probably related to more intense tectonic activity there with higher heat flow or a thermal event and deeper burial. However, in the south-western Venezuelan Andes there was no metamorphism, suggesting lower heat flow associated with minor tectonic activity.

The complex history of the Northern South America area has resulted in a complicated post-depositional overlapping of processes. The thermal history model suggests that the northern area of the Andes reached a level of low grade metamorphism. However, the southern areas were buried to a maximum of 3.5 km until the Oligocene when rapid cooling exhumation occurred due to uplift of the Venezuelan Andes as a result of the complex Northern Andes-Caribbean tectonic regime.

"Chemostratigraphical Characterization of Stratigraphic Sequences: Upper B Sandstones of Eocene Misoa Formation, Maracaibo Basin, Western Venezuela"

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The Misoa Formation (Eocene) is characterized by a monotonous succession of sandstones and shales with scarce faunal content. This unit has been divided into several operational bodies based on its lithological, electric and radioactive log character. Its rich oil content, expressed in the wells studied in the area, leads to the need for a better knowledge and understanding of its stratigraphic development, in order to enhance its exploitation. This works is focus on the upper informal units (B1, B2, B3, B4 and B5) where their lithological content of interbedded sandstones and shales, make difficult to generate accurate chronostratigraphic correlations.

Chemical analysis of 298 samples from three wells were developed to establish concentrations of major (wt%) chemical elements expressed in oxide SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, CaO, MgO, Na_2O, K_2O, P_2O_5, minor and trace elements (ppm) Ba, Ce, Co, Cu, La, Mo, V, S, Sn, Rb, Sr, Zr, Y, Cr, Ni, Pb and Zn, by using optical emission spectrometry with inductively coupled plasma (ICP-OES). In addition mutivariate statistical analysis was undertaken to conduct chemical characterization of informal units for each well. The use of inter-elemental ratio (V/Al) and V/(V+Ni) help to define maximum flooding surfaces (MFS) and flooding surfaces (FS), allowing to confirm the MFS-43 previously defined by seismic correlation in the study area.

These results point out those B-informal units have higher geochemical fingerprint that can be chemically correlated and used in other areas of interest at this level of the Misoa Formation. This method probe to be a valuable tool, to be applied reliably statistically in siliciclastic sequences with little or no biostratigraphic control in order to reduce the uncertainty of the stratigraphic model, also this method contributes to the definition of high-frequency stratigraphic surfaces (thirth, fourth, fifth and up to sixth order).

3D architectural complexity in coal-bearing successions: examples from Late Carboniferous fluvio-deltaic deposits of southeastern Kentucky (USA)

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The exploration of coal-bearing reservoirs for hydrocarbon resources, both conventional and unconventional worldwide, has increased the interest in similar fluvial/estuarine successions. In this context, East Kentucky offers excellent outcrop analogues for Carboniferous fluvial-dominated deltaic where facies associations, depositional environments and sequence-stratigraphic patterns can be observed in detail. Extensive roadcuts and a vast database of well/core data (coal and gas exploration), available at the KGS (Kentucky Geological Survey) make of East Kentucky an excellent field laboratory for studying clastic sedimentology and stratigraphy in coal-bearing successions.

The middle Pennsylvanian Pikeville and Hyden Formations are very well exposed along the US highways 23 and 119 in Pike County (SE Kentucky). The local stratigraphy is well known thanks to numerous studies focused on very extensive Pennsylvanian coal beds, used as stratigraphic markers for outcrop correlation. Both formations were deposited in a foreland basin adjacent to the then-active Appalachian orogeny. Fluvio-deltaic systems fed by the orogen prograded toward west and northwest across the basin, subject to periodic transgressions driven by high-amplitude glacio-eustatic base-level changes during the Late Palaeozoic Gondwanan glaciation.

Here we show preliminary results from two outcrops (Burning Fork and John's Creek) along the US119, allowing 3D interpretations and modelling, and covering respectively an area of 0.5km^2 and 0.15 km^2. They were studied through detailed logging at facies scale and high-resolution rock sampling for characterization of porosity and permeability and for QEMScan rock-typing analsyses. The dominant facies associations allow us to distinguish deposits from three main depositional environments: low- to high-sinuosity rivers in coastal plains; paralic (estuarine or deltaic) settings; shallow-marine settings. Successions are formed by vertically stacked, erosively based depositional sequences with thickness from a few meters to a few tens of meters, with general architecture comprising three main elements: river-dominated valley fills; transitional sediments of coastal to marginal-marine environments, including coalbeds; and extensive marine shales locally intercalated with prograding mouth-bar deposits.

Integrated with available subsurface datasets, logs will be used to derive 3D facies and architectural models (Petrel) of sandstone bodies, with an aim to link their properties to sequence-stratigraphic phase.

A MATLAB program for subsidence analysis and 3D modelling: a case study of Miocene sediments in the Vienna Basin

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A MATLAB program for analysing and 3D modelling subsidence of a sedimentary basin consists of three steps; 1) data input, 2) subsidence analysis, and 3) 3D modelling. For analysing and modelling subsidence we arranged sample borehole data to a set of 3D points based on map location (x, y coordinates) and depth (z_1, z_2, z_3, …) of stratigraphic boundaries and the subsided basement. Subsidence was analysed by using backstripping equations and additional data from boreholes and references. The process resulted in 3D Surface visualizations of total basement subsidence and tectonic subsidence.

The reconstruction of subsidence maps from the arranged data used the Thin-Plate Spline (TPS) to reconstruct a smooth surface from a set of 3D points. The basic physical TPS model is based on the bending behaviour of a thin metal sheet that is constrained by a sparse set of fixed points. MATLAB was used to calculate the TPS interpolation function. Our program evaluates the TPS interpolation function at intersection points of a grid on the xy-plane. An adjustable resolution of the grid ensures that all details of the surface are captured. The final surface is obtained by linear interpolation between the grid points. The reconstructed surface can be viewed as a solid area or contour plot. A colour map is used to encode the depth of the surface in order to emphasize its shape. This program is still under development and other interpolation methods will be tested, in order to increase its usability and accuracy.

The major functions of this program are illustrated by a case study from a 35 x 62 km^2 area in the Neogene Vienna Basin. The studied data were largely derived from about 100 boreholes in the area. The stratigraphic column and age range were divided into six stages based on the Miocene Central Paratethys Stages . At each stage, visualizations of total basement subsidence and tectonic subsidence were generated. The software tool provides a better insight into the data and into the tectonic evolution of the Vienna Basin. However, the modelling approach currently cannot integrate the displacement and timing of faults completely. It therefore gives partly fuzzy, non-complete contours over faults. In addition, differences in the timing of fault movements may have caused differences in sedimentation and subsidence rates in different areas through time.

Basin Evolution of the Vienna Basin – Insights from 3D subsidence modeling of the central and the northern parts

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This study analyzes a detailed quantification of subsidence in the central and the northern parts of the Vienna Basin by backstripping and 3D modelling technique to understand its tectonic evolution. Backstripping is a technique for progressively removing the sedimentary load from a basin, in order to reveal the tectonic driving mechanisms of basin. And, the 3D model is reconstructed by utilizing the Thin-Plate Spline Interpolation in MATLAB. The Vienna Basin is a tectonically complex Miocene pull-apart basin situated between the Alps, the Carpathians, and the Pannonian Basin System. About 100 boreholes were investigated in the basin, and sorted into 10 groups based on their position within the same block bordered by major faults. Compared to other publications on this topic, this study provides a more accurate analysis by the high density of considered boreholes, the geophysical evaluation of the porosity-depth relation, and the use of 3D modelling.

During the Early Miocene, subsidence was shallow and producing NE-SW trending depocenters during the development of a piggy-back basin. From the late Early Miocene onwards data show very high subsidence rates caused due to sinistral transtension, which initiates pull-apart basin system. Subsequently, the curves show decreasing overall subsidence, however subsidence decreases leading to distinct subsidence patterns in the northern and the central parts. In the northern part, the subsidence decreases markedly, whereas the central part is characterized by gradually decreasing pattern and prolonged tectonic subsidence.

There were two suggestions to explain the different subsidence patterns observed in the Vienna Basin. The first suggestion proposed a post-rift (thermal) subsidence for the central part. Thus, the Vienna Basin comprises a non-uniform extensional basin changing from thin-skinned extension in the northern part to whole lithospheric extension in the central part. It suggested also that the deep-rooted strike-slip faults reactivated the pre-existing fault planes which penetrated locally into the overlying thrust belt and created a new structural regime. However, there is no major thermal anomaly arguing for lithospheric extension and the heat flow is low. Additionally, in such a small size basin, the coexistence of two extension types seems highly speculative.

The second model presented that the Vienna Basin provides an excellent example of how thin-skinned extension can create a sedimentary basin. It explained that post-extensional (or thermal) subsidence within the basin is impossible, because the extension and the associated strike-slip faulting were restricted to shallow levels. It analyzed subsidence curves of the basin for two different cases; (1) for the northeastern part, where most of the subsidence and sedimentation is of Early Miocene age or older, and (2) for the south-central part, where most of the subsidence is of the Middle to Late Miocene age. The model, however, fails to explain why subsidence happened locally in different times, and the study analyzed uncorrected subsidence curves neglecting compaction of sediments.

Later studies of the Vienna Basin argue for polyphase thin-skinned extension and present that some extension and faulting have probably occurred until recently, or are still ongoing. In this study, 3D modeling allowed us to gain better insight into the data and helped to improve the theoretical models for the tectonic evolution of the Vienna Basin. It promotes approaches that active tectonics might influence on the subsidence patterns observed in the basin.

Calcified microbial reefs in the Cambrian Series 2 of the North China Platform: implications on the evolution of Cambrian calcified microbes

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The microbial reefs of the Zhushadong Formation (Cambrian Series 2) in Shandong Province, China are the earliest in the North China Platform and consist of various thrombolites that are classified into three types based on their mesostructures: rimmed, grainstone-patched, and dendritic thrombolites. The thrombolites mainly occur within various coarse-grained carbonate facies, such as crudely stratified oolitic grainstone, stromatolitic grainstone, and disorganized limestone conglomerate. Various calcified microbes are recognized in the thrombolites, including *Epiphyton*, *Kordephyton*, tube-shaped microbe, *Bija*, *Tarthinia*, *Renalcis*, *Amgaina*, and *Razumovskia*. The thrombolites in the Zhushadong Formation mostly formed as small patch reefs within the grainstone shoal with repetitive burial and exposure processes. Rimmed thrombolites and grainstone-patched thrombolites grew with abundant input of carbonate grains (forming grainstone patches). Dendritic thrombolite solely formed by calcification of microbes including *Epiphyton*, *Tarthinia*, and tube-shaped microbe. Rims (crusts) of rimmed thrombolite formed under very high energy conditions.

The calcified microbes in the Zhushadong Formation only occur in limited area (ca. 3 m thick interval, 1km^2 in area). On the other hand, calcified microbes, mostly *Epiphyton*, thrived and formed ca. 180 m thick microbialite-oolite-dominated successions during the Cambrian Series 3 (Zhangxia Formation). The calcified microbes were, however, more diverse in the Zhushadong Formation compared with those of the overlying Zhangxia Formation, which was most likely due to changes in depositional environments (abundant siliciclastic input and tidal effects vs. stable carbonate platform) and global changes within reefal environments (end-Cambrian Series 2 extinction of archaeocyaths and calcified microbes). Decrease in diversity of calcified microbes in the North China Platform, where archaeocyaths were absent, may help understand evolutionary trends of calcified microbes apart from the influence of archaeocyaths.

Transition in reefal environments and its relationship to major geological event during the middle to late Cambrian

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The reefs of the middle–late Cambrian (Cambrian Series 3–Furongian) have long been considered as microbialites that flourished in the aftermath of the archaeocyath extinction. This review shows that the Cambrian Series 3 and Furongian actually yield different types of reefs. The Cambrian Series 3 reefs were dominated by thrombolites and dendrolites, largely constructed by calcified microbe *Epiphyton* and *Renalcis*. On the other hand, the Furongian reefs consisted mainly of maze-like maceriate reefs and columnar stromatolites. The maceriate reefs most likely formed by siliceous sponges and calcified microbes including *Girvanella* and *Tarthinia*, whereas the columnar stromatolites mainly constructed by *Girvanella*, *Tarthinia*, and minor siliceous sponges. Other microbial reefs (e.g., non-columnar stromatolites) persisted during the Cambrian Series 3 and Furongian, mainly as small patch reefs or reefal crusts. Lithisitid sponge-microbial reefs initially formed in the Cambrian Series 3, but only occupied minor portion.

The Cambrian Series 3 and Furongian were separated by a major geologic event, characterized by positive carbon and sulfur isotope excursion (Steptoean Positive Carbon Isotope Excursion; SPICE), eustatic sea-level drop, major faunal turnover of trilobites, diversification of new organisms, closure of Burgess-shale type preservation, and increase in characteristic sedimentary facies such as flat-pebble conglomerate (or limestone pseudoconglomerate) and hardground. Evidence collectively suggests that there was a major overturn in the entire earth ecosystem. Reefs were significantly affected by the event. Calcified microbes *Epiphyton* and *Renalcis* most likely decreased greatly due to sea-level fall and extinction of associated fauna, and gradually substituted by sponge-microbial association of the maze-like maceriate reefs and calcified microbes (mostly *Girvanella*) of the columnar stromatolites.

Detection of disconformity by U-Pb geochronology of detrital zircons and the Korean early Paleozoic stratigraphy revisited

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This study reports the results of U-Pb ages of detrital zircons from the well-established lower Paleozoic platformal succession developed on the Precambrian gneiss and metasedimentary rocks in South Korea. Three stratigraphic units in the basal part of the succession are the Jangsan, Myeonsan, and Myobong formations. The unfossiliferous Jangsan (white to pink quartz sandstone) and Myeonsan (dark gray ilmenite-rich sandstone) formations are in fault contact, are considered to be coeval (Early Cambrian), and both strata are known to be conformably overlain by the dark gray fossiliferous fine-grained Myobong Formation (late Early-early Middle Cambrian). Detritus for both the Jangsan and Myeonsan formations was derived from local Paleoproterozoic-Archean sources, with detrital zircons ranging from 1.8 Ga to 3.5 Ga. The Myobong Formation, in contrast, contains abundant (80%) Mesoproterozoic-Neoproterozoic detrital zircons, but no potential source is known from the local provenance. Combined with the field-mapping results on the boundary between the Jangsan and Myobong formations, a significant change in provenance between the Jangsan/Myeonsan and Myobong formations suggests that the boundary between the Jangsan/Myeonsan and Myobong formations represents a disconformity, which indicates that contrary to the common stratigraphic concept, sedimentation was not continuous from the Jangsan/Myeonsan formations to the Myobong Formation. Along with similar zircon grain ages, features of the Myeonsan Formation such as the restricted areal distribution in the basin margin, the fault contact with the Jangsan Formation, and the presence of abundant gravelly clasts lithologically similar to that of the Jangsan Formation in the basal conglomerate bed all suggest that the deposition of the Myeonsan Formation post-dated the Jangsan Formation in a fault-bounded marginal marine basin. We interpret that the Jangsan Formation is of Precambrian in age, whereas the presence of trace fossils (*Skolithos* and *Laevicyclus*) in the Myeonsan Formation suggests the maximum depositional age being the latest Neoproterozoic. The results of this study reveal the existence of unappreciated two tectonic events, each occurred after deposition of the Jangsan Formation and after deposition of the Myeonsan Formation, and call for reevaluation of Precambrian-Paleozoic geologic history of the Korean Peninsula and further its correlation with East Asian tectonic blocks.

Upper Cretaceous carbonate gravity-flow deposits in south Albania: lithofacies, sequences and mega-structures, an integrated overview

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Being part of the NNW-SSE structural Ionian fold-and-thrust belt, the Upper Cretaceous carbonate deposits of the Ionian Basin expose a unique example of a gravity-flow system. Sediment input derived from the Apulian carbonate platform to the west, document a wide range of depositional processes building up the Upper Cretaceous sedimentary architecture. Our data provide a detailed view of the facies diversity. From inversely-graded coarse-grained decimeter-size clasts to finely grained laminated facies, a wide range of facies are documented, reflecting a wide diversity of depositional processes. Based on field observations and published studies on gravity-flow deposits, a number of typical stacking facies patterns were identified. They form carbonate sequences and document the composite nature of carbonate gravity-flow deposits. Large-scale slump deformations make up thick packages during the Maastrichtian. These mega-structures document a wide range of geometric features, allowing an assessment of type and degree of the soft-sediment deformation. Integrated in a three-scale classification (facies, sequences, and megastructures), the carbonate gravity system of south Albania can be described accurately regarding the settling of gravity-flow deposits and their syn-sedimentary deformations.

Keywords: Albania, Upper Cretaceous, facies, carbonate gravity-flow, slumps

Sedimentary evolution, facies and geometry of the Apulian carbonate platform during Upper Cretaceous in south Albania

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A 1220 meters thick succession of platform carbonates was studied in the south of Albania, on the Karaburuni peninsula, exposing the whole Upper Cretaceous interval. Dating is based on biostratigraphy relying on benthic foraminifera as well as Strontium Isotope Stratigraphy. Detailed sedimentological investigations unraveled ten lithofacies reflecting variations in depositional settings and evolution of the platform. The lithofacies are arranged in small-scale sequences recognizable in the field, that suggest a climatic and / or eustatic control of the sedimentation during the Upper Cretaceous. The variations in terms of facies and thicknesses of small-scale sequences in the Llogara carbonate succession records two evolutionary stages, namely (i) a Cenomanian and Early Turonian stage with shallow water conditions characterized by peritidal lithofacies and (ii) an Upper Turonian and Senonian stage when sedimentation rapidly evolved towards subtidal dominated setting. This paper unravels the sedimentary evolution of the cyclic carbonate platform during the Upper Cretaceous. Particular attention is attached to the integration of the studied area with neighboring platforms, towards a better understanding of the Upper Cretaceous sedimentary record over the peri-Adriatic region.

Sedimentary Evolution of the eastern edge of Apulia during the Upper Cretaceous (Ionian Basin, Albania)

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The petroleum potential of the Cretaceous to Eocene carbonate interval in Albania was discovered in the 60's. Since then, few studies attempted to unravel the sedimentary evolution at a reservoir scale. The Upper Cretaceous deposits of the Ionian Basin are composed of pelagic and gravity-flow facies. They broadly outcrop in the south of the country along three main thrust belts with a NNW-SSW orientation, surrounded to the east by the Sazani Zone, exposing the Apulian platform succession. Our study focuses on the sedimentary deposition during the Upper Cretaceous in the Ionian Basin. Field investigations coupled with bio- and chronostratigraphical methods were performed in order to highlight the Upper Cretaceous sedimentary evolution. Hemipelagites and low-density calciturbiditic deposits, typically accumulating until the Santonian, are gradually replaced by coarser and thicker calciturbiditic and debris-flow deposits during the Campanian. The carbonate transport-system brutally turns into a large-scale slump system, showing soft-sediment deformation structures at pluri-metric scale during the Maastrichtian. Four slumped levels are identified during the late Upper Cretaceous, with a first deformation level reaching up to 50 meters in thickness in the distal part of the basin. These major levels are consistent with tectonic triggers affecting the Apulian Platform during this period. The large scale outcrops studied in the field and the extension of eight defined units throughout the basin allows unraveling the foredeep evolution of the Ionian Basin during the Upper Cretaceous, thus revealing the architecture of this basin at a reservoir exploration scale.

Keywords: Albania, carbonates, slope, gravity-flow deposits, slump, basin evolution

New insights into the processes of glacial re-advance in a Sturtian snowball Earth event

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The Kingston Range is a glaciogenic sedimentary succession of early Cryogenian (Sturtian) age that crops out in the Death Valley area, California. Widely accepted to be a glaciation of pan-global extent, it has recently been established that ice sheets were characterised by grounding-line oscillations. In the type area (the Kingston Range), detailed facies analysis reveals a basal diamictite unit and an upper boulder conglomerate were deposited by ice-proximal efflux processes. Previous work suggested that an olistostrome unit punctuating the succession was deposited in response to tectonically-induced downslope mobilisation of material during an interglacial isostatic rebound event. Building on this previous work, this poster provides detailed insight into the relationship between the olistostrome and overlying strata, allowing processes of glacial re-advance following an inter-glacial ice minima to be elucidated, and correlated to ice advance sequences elsewhere in the Death Valley region[†].

The olistostrome unit comprises an assortment of facies including unbedded km-scale megaclasts and carbonate breccias with shales. The upper surface of the olistostrome unit is sharp, and overlying strata comprise at least 50 m of dropstone-free shales, punctuated by thin sandstones. The trend toward thicker graded beds upsection, in concert with the gradual appearance and then abundance of dropstones, testifies to the resumption of a direct ice sheet control on sedimentation. Stratigraphic organisation into thickening and coarsening upward bedsets over a multi-metre scale reveals the accumulation of a classic subaqueous fan complex dominated by a spectrum of high to low density turbidites, and with thick graded boulder-conglomerates at intervals. The finer-grained facies assemblage is heterolithic; current ripple cross-laminated sandstones intercalated with shales that bear delicate granule to pebble-sized dropstones in abundance. This intercalation suggests an origin through dilute turbidites ultimately sourced from meltwater plumes. These latter deposits are proposed to result from steady-state meltwater drainage, whilst the boulder-conglomerates may correspond to more energetic outburst events. These findings imply styles of meltwater release directly analogous to those observed at modern ice margins, rather than a dramatic and dominantly catastrophic emergence from a snowball Earth state.

[†]See Busfield & Le Heron: Evolution of a glacially-sourced subaqueous fan complex: proglacial to ice contact facies in the Kingston Peak Formation, Sperry Wash, California

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Neoproterozoic ice sheets and olistoliths: multiple glacial cycles in the Kingston Peak Formation, California

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The Kingston Peak Formation is a diamictite-bearing succession that crops out in the Death Valley region, California, USA. An exceptionally thick (>1.5 km) outcrop belt in its type area (the Kingston Range), provides clear insights into the dynamics of early-Cryogenian ('Sturtian') ice sheets in Laurentia. Seven detailed logs allow the lateral and vertical distribution of facies associations to be assessed. We recognise (1) diamictite facies association (ice-proximal glacigenic debris flows), (2) lonestone-bearing facies association (ice-marginal hemipelagic deposits and low-density gravity flows with ice-berg rafting), (3) pebble to boulder conglomerate facies association (ice-proximal co-genetic glacigenic debris flows and high-density turbidites), (4) megaclast facies association (olistostrome and hemipelagic sediments subject to ice-rafting), and (5) interbedded heterolithics facies association (low-density turbidites and hemipelagic deposits). The stratigraphic motif allows three glacial cycles to be inferred across the range. Ice-minimum conditions interrupting the Kingston Peak are associated with the development of an olistostrome complex, succeeded by a thick accumulation of boulder conglomerates deposited during ice re-advance. The data testify to a strong glacial influence on sedimentation within this ancient subaqueous succession, and to highly dynamic ice sheet behaviour with clear glacial cycles during the Sturtian glaciation.

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Earthquake induced soft sediment deformation (seismites): new data from the Early Triassic Guryul Ravine section (Kashmir).

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At the classical Guryul ravine section of Kashmir, the Permo-Triassic (P-T) boundary is located about 3 m above the base of the Khunamuh Formation. Brookfield et al. (2013) proposed that the deposits straddling the boundary between the Khunamuh Formation and the underlying, Permian Zewan Formation are Siberian Traps-induced seismites overlain by tsunamites. These deposits have been subject to a divergent re-interpretation by Krystyn et al. (2014), who rejected a Siberian-Traps origin.

Here, we report the discovery of highly contorted beds at the top of a 7 m. thick, thin-bedded, light beige nodular lime mudstone, a new lithological unit recorded in the Early Triassic Khunamuh Formation, 120 m above the top of the Zewan Formation. These contorted beds, about 1 m thick, are showing typical earthquake induced soft sediment deformations, similar to the latest Permian in the lower part of the section. This new nodular limestone is of early Spathian age as indicated by our conodont sampling and crops out at the base of a cliff-forming limestone interval named Niti Limestone throughout the Tethys Himalaya area since the 19th century.

It is interesting to note that both latest Permian and early Spathian seismites occur at a marked lithological change, i.e. a shift in the depositional settings. The latest Permian seismite occurs on a delta ramp with mixed quartzose sand, silt and shelly carbonate lenses, storm influenced deposits, followed by an abrupt contact with the overlying deeper, thin- bedded and siliceous clay mud turbidite deposits and rare lime mud lenses. The early Spathian one is intercalated at the top of a distal ramp nodular limestone deposits, just at the change to the shallower thick-bedded Niti limestone.

The latest Permian seismic activity coincides with a platform drowning during a transgressive phase and the early Spathian one occurred during a platform uplift, also during a transgressive phase. Both may conceivably have been driven by recurrent phases of syn-sedimentary block faulting of the northern Indian passive margin. In this, we agree with the conclusions of Krystyn et al. (2014) that any relation between the local occurrences of seismites-tsunamites and the eruption of the Siberian traps is unlikely.

Yet, we must keep in mind that both coincide also with global shifts in the geochemical, sedimentological, paleontological and climate records.

Specific Features of the Mineral Composition of Titanium-Zirconium Placers in Russia

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In the world consumption of mineral deposits, complex coastal-marine placers (CMP) are virtually the single source of whole rutile, more than 95% of zircon, and more than 70% of ilmenite. In Russia, we have a number of well-explored placer deposits (with demonstrated reserves) that can satisfy the internal consumption for some tens of years. CMP deposits in Russia are characterized by lower concentrations of ilmenite, rutile, zircon, and other minerals; worse geographic-economic and mining-technological conditions (thick overburden); and worse mineralogical-technological properties of sands (high clay content and fine-grained structure).

We analyzed specific features of the mineral composition of the Ti-Zr placers in Russia; the mineral composition and grain size distribution of sands therein; physical, chemical, and morphostructural properties of minerals; and other parameters. The most important conclusions obtained from the chemical analysis are related to the contents of useful components and hazardous admixtures. Contents of the major oxides vary within a relatively narrow range.

Results of detailed investigation show that heavy minerals of various placers and even different sectors of a single placer can be represented by varieties with different physicochemical properties and other specific features. These differences are most essential for the ore minerals. The majority of titanium-zirconium placers is characterized by the presence of significantly altered ilmenite with properties strongly differing from those of the unaltered variety. Signs of alteration of mineral grains are diverse and interrelated (color, luster, surface, density, size, hardness, crushing strength at static loading, surface electric resistance, and so on). The degree of ilmenite alteration can qualitatively be estimated on the basis of its chemical composition, in which the TiO_2 content usually exceeds the theoretical value. The degree of alteration inversely correlates with the specific magnetic susceptibility.

The rational geological study of titanium-zirconium placers envisages an operative and low-cost prognosis of technological properties of new deposits discovered in the course of regional surveys with the application of methods of technical mineralogy. Investigations of the mineral composition of placers have demonstrated that ore sands of each placer province are characterized by specific features: placers of the East European province are characterized by the abundance of hazardous admixtures (phosphates and chrome spinels), ingrowths of ore and nonore minerals, and microinclusions of minerals (with other physical properties) inside the ore mineral grains, placers of the West Siberian province are marked by the fine-grained structure and clayey composition of sands, fine-grained structure of ore minerals, and a relatively low content of hazardous admixtures, placers of the North Caucasian province are characterized by a low content of the clayey fraction, relatively coarse-grained structure of sands and ore minerals, high degree of sorting, and low content of hazardous admixtures. Based on the analysis of specific features of the mineral composition of ore sands in five placer deposits of Russia, we developed criteria for the assessment of technological properties and dressability of titanium-zirconium placers at various stages of geological exploration.

Based on the analysis of specific features of the mineral composition of ore sands in five placer deposits of Russia, we developed criteria for the assessment of technological properties and dressability of titanium-zirconium placers at various stages of geological exploration.

Free gas zone as a primer for submarine failure: a case study from offshore Mauritania

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The study area is located ~75 km offshore of Mauritania. Here the representative architectural elements include gullies and canyons, demonstrating the predominance of gravity-driven sediments. We use three-dimensional (3-D) seismic data to examine a particularly well imaged mass transport complex (MTC), which sits immediately on the present base of the gas hydrate stability zone (BHSZ). This rarely documented spatial relationship between the BHSZ and a submarine failure provides compelling evidence that gas buoyancy may be a viable mechanism for submarine failure. The buoyancy is provided by the inter-connected gas column underlying the incipient failure plane and could have a significant impact on the excess pore pressure which could reduce the effective stress and move the Mohr circle to the left, making it closer to the failure envelope. We propose that the buoyancy pressure of methane below the BHSZ was the primer for failure rather than hydrates dissociation. The adopted 3-D seismic imaging workflow starts with manual or automatic picking on selected cross profile, followed by auto-tracking one specific reflection and ends with the calculation of the seismic attribute. Four key reflections were interpreted on the seismic data: seabed, top of MTC, base of MTC and BHSZ. Their attributes have been extracted and revealed through RMS and dip magnitude map. The RMS map is used to testify the existence of free gas while the dip magnitude map is to examine the vertical pathways (e.g. chimneys and faults).The related observation results are: a) Three separated areas of high amplitude anomaly (HAA) are located immediately under the present BHSZ and interpreted as the free gas zone (FGZ). Their current distribution is related in part to the geometry of the failure. b) Free gas exists extensively under the MTC. Based upon the height of the present gas column we estimate that gas columns were sufficient to reduce the shear strength to the degree that the upper section of the MTC was critically stressed and primed for failure. c) The chimneys penetrating the BHSZ vertically are absent in the area of the failure and elsewhere common which suggests the reduction in the preserved overpressure. Mass transport associated with hydrates is commonly attributed to hydrate dissociation. Here we propose an alternative mechanism that methane migrating through high-permeability pathways including chimneys and faults accumulated in a succession of strata directly overlain by the present BHSZ. The entire free gas zone had provided sufficient buoyancy to prime the submarine failure.

Lacustrine slope apron deposits -- A type of sedimentation ignored in faulted lacustrine basin

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The sedimentary models of coarse grained conglomerates always were interpreted as fan delta or submarine fan in the steep zone of fault lacustrine basin, but these two kinds of model are not sufficient to meet the growing sandstone fine prediction demand as the acceleration of oil and gas exploration and development. Our study reveals another coarse grained conglomerates model: Lacustrine slope apron. The establishment of lacustrine slope apron model is based on the contrastive analysis of more than two thousand meters core section (more than 100 wells) in 4 lacustrine basins or depressions (Subei basin, Yitong fault depression, Dongying north depression and Chezhen depression).

We described and interpreted twelve major types of lithofacies and occur into three types of lithofacies associations in the slope apron system: (1) Lithofacies association 1 forms disorganized conglomerate (Gmd) and massive conglomerate (Gm) up to 6-25m thick, alternating with dark gray mudstone(Fm1), constituting a positive rhythm which is dominated by multiple debris flow channels. (2)Lithofacies association 2 composed of disorganized conglomerate (Gmd), massive conglomerate (Gm), massive sandstone (Sm), trough cross-stratified sandstone(St) and horizontally stratified sandstone (Sh), coupletting with intercalation of mudstone(Fm1) and thin-bedded sandstone beds (Sdi), and is characterized by the combination of gravity flow sediments (Gmd, Gm and Sm) and traction current sediments (St, Sh and Sdi). (3)Lithofacies association 3 dominates by thick black mudstone (Lm2) interbeding thin massive sand with mudstone clasts (Sm) dominated by sandy debris flow and the thin normal graded sandy layer (Sg) dominated by turbidity currents.

Lacustrine slope apron model is with the characteristics as following:

a. Line source (multiple sources) (Fig. 9)
b. Multiple etching supply channels
c. Regular sandstone distribution: coarse debris flows depositions in proximal zone, debirs flows and traction currents mixed depositions in middle zone and sandy debites and turbidites in distal zone.
d. Presence of overall apron geometry and absence of fan geometry in map view.

Our model is also different from the submerged fan models (also called submarine fan), with emphasis on the high density turbidity current and Bouma sequence. Reasons are as follows:

a. The submarine is point resource but the slope apron is line resources.
b. The submarine fan sediments are typified by course conglomerates and pebbley sandstones, interpreted as the deposits of high-density turbidity currents and non-cohesive debris flows (Ineson, 1989), but the slope apron is characterized by mixed sediments of gravity flows and traction currents.

The significance of our model is it have been use to predict the distribution of sandstone reservoirs in Moliqing fault depresson and Shaobo are in Jiangsu North basin. The model may be applicable to other fault depression for predicting reservoir distribution.

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Anomalous ooid primary mineralogy in the Early Triassic: a clue on varied seawater chemistry?

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The Early Triassic period was situated at the second “aragonite sea” of the Phanerozoic, and the primary mineralogy of ooid was supposed to be aragonite and possibly high–Mg calcite specially. Meanwhile, high seawater Mg/Ca ratio and sulfate concentrations, as well as icehouse climate are regarded as the diagnostic features during the interval of “aragonite sea”. However, newly published papers show very low sulfate concentrations, extremely high temperature, and remarkable increased atmospheric carbon dioxide partial pressure presenting in the Early Triassic. As one reliable indicator of palaeoceanographic chemical conditions, on the other hand, widespread ooid deposits also show a series of anomalies in mineral compositions after the end-Permian mass extinction event. During the latest Permian, primary aragonitic ooids were still overwhelming in shallow-water sections. But anomalies in structures and original minerals occurred intermittently in the Dienerian, late Smithian and late Spathian times, including overgrown sizes and bimineralic components (alternately low-Mg calcitic and aragonitic layers, as well as aragonitic and high-Mg calcitic layers). Moreover, well–preserved, finely radial-concentric fabric ooids suggested as primary low–Mg calcite were recorded in the Spathian and afterwards. Observed trends in ooid mineralogy may imply an unexpected variation in seawater chemistry during the Early Triassic. Since the Mg/Ca ratio driven by mid–ocean ridges spreading rates (with timescale 100-200Ma) sustains a relatively stable trend, some shorter timescales (<5 Ma) factors are suspected exerting effects on varied primary minerals at that time, including atmospheric carbon dioxide partial pressure, carbonate saturation state, total alkalinity, as well as sulfate concentrations. The interaction of atmosphere (high concentrations of carbon dioxide), land (strongly terrestrial weathering), and ocean (anoxic and unstable carbonate saturation state) environments may contribute to the anomalies in ooid primary mineralogy.

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Lithofacies and Sequence Stratigraphy of an Eocene Calciclastic Lake Basin: A Case Study of the Shulu Sag in Bohai Bay Basin, North China

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1. Introduction - Unlike carbonate submarine fan deposits, the calciclastic deposits in the Eocene half-graben Shulu Sag had a different depositional mechanism and are composed of thick organic-rich calcilutites with interbeds of extraclastic calcirudites. Recent discoveries have shown good hydrocarbon potential in the tight extraclastic calcirudites but their spatial distribution remains unclear. Thus, the study of lithofacies and sequence stratigraphy of the carbonate succession may enable us to better understand the tight reservoirs and provide some insights for future exploration and development.
2. Methods - First we used detailed core description and thin section analysis to identify the lithofacies. Then a depositional model was developed based on sedimentary features and depositional geometries. Finally we established the sequence stratigraphic framework using 3D seismic, well log and geochemical data and discussed the controlling factors of the stratigraphic evolution via reconstruction of paleoclimate and tectonic history.
3. Results - The carbonate succession originated from the uplifted portion of the hanging-wall fault block, which is composed of Paleozoic carbonates and Proterozoic metamorphic rocks.
A total of six lithofacies were identified: (1) extraclastic rudstone; (2) extraclastic floatstone; (3) extraclastic calcirudite containing intraclasts; (4) interlaminated calcisiltite and calcilutite; (5) laminated calcilutite; and (6) massive calcilutite.
The extraclastic rudstone and floatstone are texturally immature and the maximum clast size reaches 1m. These two lithofacies indicate rapid sedimentation and are probably deposited by debris flows.
The extraclastic calcirudite containing intraclasts include both the Paleozoic carbonate fragments and redeposited calcilutite clasts. This lithofacies indicates reworking of unconsolidated sediments, probably by hyperpycnal flows.
The interlaminated calcisiltite and calcilutite contains silt- to clay-sized carbonate grains. The laminated calcilutite is composed of repetitive carbonate and clay laminae. These two lithofacies may result from alternating suspension settling and turbidity currents.
The massive calcilutite comprises micrite and clay minerals. This lithofacies indicates bioturbation or deep water settings with nearly unchanging conditions.
Based on sedimentary features and depositional geometries, the extraclastic rudstone and floatstone are interpreted as deposits formed in the fan delta plain and delta front while the calcirudite containing intraclasts is interpreted as deposits formed in the prodelta. The other three lithofacies are mainly deposited in the semi-deep to deep lake.
Five depositional sequences were identified. The LST is characterized by the progradation of fan delta and a large areal extent of the conglomerate deposits. The TST mainly contains semi-deep to deep lake organic-rich deposits which act as source rocks. The HST is also marked by the delta progradation but with a much smaller areal extent.
4. Conclusions - The calciclastic deposits resulted from the interplay between provenance and tectonics and were mainly deposited in the fan delta and semi-deep to deep lake environments. The facies distribution is controlled by the systems tract and the LST conglomerates may be the most favorable exploration targets.
Five episodes of faulting were identified, responsible for the formation of sequence boundaries. During periods of fault activity, new accommodation space was created in the central basin and the source area was lifted, resulting in unconformity along the basin margin.

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Carbon, Oxygen, Strontium and Neodymium Isotope Geochemistry of Middle Permian Lacustrine Carbonate Rocks in Lucaogou Formation, Xinjiang, Northwest China

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The Middle Permian Lucaogou Formation (Corresponding to Wordian Stage, Guadalupian Series), exposed in Hongyanchi section at Urumchi, Northern Xinjiang, NW China, is characterized by lacustrine dark gray dolostones, gray limestones interbedded with thick black mudstones and oil shales. The dolostones are mainly composed of micro-crystalline dolomite, ferrodolomite and quartz. The limestones, occured at the upper part of Lucaogou Formation, are mainly composed of very fine to coarse calcite with some irregular cherts. Both limestones and dolostones contain abundant organic matter, fossil fragments (including shells of ostracods and fish scales) and microfossils (calcispheres). Forty six bulk rock samples of dolostones and limestones from the Hongyanchi section were measured for their $\delta^{18}O$, $\delta^{13}C$, $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ values. The $\delta^{18}O_{PDB}$ of dolostones ranged from -10.76‰ to -2.26‰; the $\delta^{18}O_{PDB}$ of limestones ranged from -11.06‰ to -7.34‰. The $\delta^{13}C_{PDB}$ of dolostones ranged from 4.37‰ to 16.6‰; the $\delta^{13}C_{PDB}$ of limestones ranged from 3.64‰ to 7.20‰. The positive $\delta^{13}C$ values suggest the isotope fractionation by methanogens. From the bottom to the top, the values of carbon and oxygen isotopes increased gradually. $^{87}Sr/^{86}Sr$ ratios of the dolostones ranged from 0.705676 to 0.707362; the $^{87}Sr/^{86}Sr$ ratios of the limestones ranged from 0.705947 to 0.706167. The $^{87}Sr/^{86}Sr$ ratios of Lucaogou carbonate rocks are lower than those of Guadalupian seawater (0.706844 to 0.707135, Korte *et al*., 2006). $^{143}Nd/^{144}Nd$ ratios of the dolostones varied from 0.512044 to 0.513199; $^{143}Nd/^{144}Nd$ ratios of the limestones varied from 0.512704 to 0.512863. The neodymium ratios of Lucaogou carbonate rocks are close to that of bulk silica earth (Rollinsin, 1993). The neodymium ratios and the low strontium ratios indicate that hydrothermal flux from volcanism might participate in the formation of Lucaogou carbonates.

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Palaeogene carbonate microfacies and sandstone provenance (Gamba, South Tibet): the stratigraphic response to initial India-Asia continental collision

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The Palaeogene marine strata in the Gamba area of south Tibet comprise carbonates of the Zongpu Formation and siliciclastic rocks of the Enba and Zhaguo Formations, documenting the final stages of marine deposition in the Tethyan Himalaya. The ~350-m-thick Zongpu Formation was dated as late Danian to Ypresian based on larger benthic foraminifers. Thirteen distinct microfacies identify three sedimentary environments. Mudstone, wackestone with Udoteacean algae, bioclastic-peloidal packstone, packstone with Rotaliids and green algae and floatstone with *Alveolina* and *Orbitolites* were deposited in restricted lagoonal environments. Bioclastic packstone and grainstone with Rotaliids were deposited in high-energy shoal environments. Floatstones with Nummulitids or Alveolinids were deposited in shallow open-marine environments. The Zongpu Formation was accumulated on a carbonate ramp. It documents two deepening-upward sequences separated by an unconformity corresponding to the Palaeocene/Eocene boundary and marked by a conglomerate with limestone clasts. The overlying Enba Formation comprises greenish grey calcareous shales intercalated with litho-quartzose sandstones in the upper part and capped by subaerial litho-quartzose red beds of the Zhaguo Formation. Petrographic analysis and detrital zircon geochronology and geochemistry indicate that detritus in the Enba and Zhaguo Formations, deposited on top of the Indian passive margin, was derived from the Asian active margin in the north. These clastic units were thus deposited after the onset of the India-Asia continental collision in the early Himalayan foreland basin. Major lithological and paleoenvironmental changes occur at three stratigraphic levels: the Jidula/Zongpu boundary (~62 Ma), the Paleocene/Eocene boundary (~56 Ma) and the Zongpu/Enba boundary (~51 Ma). Our provenance study confirms that the India-Asia collision was already under way during deposition of the Enba Member (~51 Ma) and, along with facies analysis and general palaeogeographic considerations, indicate that Neo-Tethys was still wide open during the Early-Middle Paleocene. It is thus argued, consistently with previous studies, that the Paleocene/Eocene disconformity documented in the Gamba area as in the northwestern Tethyan Himalaya is likely to record flexural uplift consequent to initial underthusting of the Indian continental margin beneath Asia at, or just a little earlier than, 56 Ma.

Tectono-sedimentary system of the lower Urho Formation of the Permian of the Fifth and Eighth areas, northwestern margin of Junggar Basin, China

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Foreland basin strata provide an opportunity to review the depositional responses of alluvial systems to unsteady tectonic load variations at convergent plate margins. Tectonic elements that form the bounding northwestern margins of the Junggar Basin controlled both the deposition and structural development of the basin. Not only was it a significant provenance, but it also provided the tectonic load necessary to form the foredeep along the east side of the basin (Bird, Kenneth J., and Cornelius M. Molenaar). The lower Urho Group in northwestern margin of the Junggar Basin, one of the four hydrocarbon basins in western China, preserves a Neo-Hercynian record of sedimentation during initial foreland basin subsidence of the Zaire orogeny. Utilizing fluvial facies distributions and long-term stacking patterns within the context of a marginal-marine foreland basin provides stratigraphic evidence to distinguish a residual tectonic signature from eustatic sea level change events. Results from basin-wide facies analysis, corroborated with petrography, support a continental depositional system of alluvial fan-braided fluvial river-lacustrine depositional systems infilling of the foredeep during eustatic lowstands. Provenance data suggest that sediment was mainly derived from sedimentary rocks uplifted as part of the Zaire orogen, northwestern margin of the Junggar Basin. Tectonic elements that form the bounding northwestern margins of the basin controlled both the deposition and structural development of the basin. Not only was it a significant provenance, but it also provided the tectonic load necessary to form the foredeep along the east side of the basin. Along the northwestern margin, the north-west fault zone, Zhongguai Salient Area, western slope of Mahu Sag, and western slope of Changji Sag were clearly the dominating structural element affecting basin development. The fan deltafacies association is dominated by conglomerates, sandstones, and interbedded mudstone bodies of the Fifth and Eighth areas, northwestern margin of the Junggar Basin. Integration of subsurface and sandstone provenance data indicates significant, repeated paleogeographical shifts in alluvial facies distribution. Faulting, erosional truncation and lake-level fluctuation are interpreted from seismic-sequence analysis to have a small distribution of the Lower Urho in the basin margin. Long-term stacking patterns within the Fifth and Eighth areas are dominated by the fan delta. The transition is from fan delta plain at the edge of the basin to the fan delta front in the slope area. The bodies of the fan in the northern Eighth area extend widely to the lake basin. Controlled by the slope break belt, the basin floor fan developed along the slope break zone (slope fan).Reactivation along basement faults led to the development of a progradational fan. Our preliminary conclusion from this analysis is that oil and gas exploration in this area is benefitted by identifying the extension of the fan delta and the sublacustrine fan. Moreover, distinct wedges comprising composite sequences are bounded by successive shifts in alluvial facies and define three low-frequency tectonic accommodation cycles.

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Sedimentary records of Mesozoic strata in northern margin of the South China Sea and Eastern Tethys Domain

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The Tethys domain is a global structural realm besides of Gondwana, Euro-Asian and Pacific realm, which is the product of the opening and closing of Tethys Ocean. The geological and geophysical data reveals that Mesozoic strata are distributed mainly in the depressions on the northern margin of the South China Sea (SCS), which include the Shenhu- Dongsha-Penghu-Beigang uplift belt. There is an obvious regional unconformity surface within the Mesozoic strata. Thus, it is important to reveal sedimentation breaks during the Mesozoic Era and the basin evolution in the northern margin of the SCS.

Geophysical data has proved the existence of marine sediments in the northern South China Sea during the Mesozoic period, presuming that there are Tethys tectonic relics in the Mesozoic era. The characteristics of seismic profile are wedge-shaped, low amplitude, low frequency, and continuous seismic facies in Cretaceous strata, which indicated that top-cutting erosion phenomenon. It is a relatively stability of sedimentary environment in Jurassic period, as well as the regional distribution of strata. Thickness variations are minor and the depositional environments ranging from shallow to bathyal deposits.

According to the Mesozoic strata distribution of the SCS and its surrounding area, the area experienced two important marine transgression during the middle and late Mesozoic Era, one occurring in the Indosinian after the late-Early Jurassic, another occurring in Late Jurassic and early Cretaceous. The transgression took place from the Tibet Lhasa block to the north and south of North Tethys Sea, which belongs to the eastward extension of the Tethys.

The lithography, sedimentary facies and sequence of the Mesozoic both outcropped in land and occurred offshore may correlate well. The characteristics of stratigraphy and sedimentation based on the outcropped strata are helpful to study the related subjects of the Mesozoic offshore and can be a guide to petroleum exploration in the northern margin of the SCS.

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Study on the relationship between system properties of sedimentary environment and occurrence of source rocks in Huizhou Sag

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Wenchang and Enping Formation are two source rock series in Huizhou sag. On the basis of evaluation of organic abundance of source rocks, the different influence that systematic properties of sedimentary environment have on the occurrence of source rocks during these two geological periods are discussed according to the System Theory. Through the comparison of the Palaeotopographical features, redox condition, subsidence rates and sedimentation rates of these two source rock series, the systematic properties which are prone to form source rocks are recognized, and six conclusions are drawn: ① Source rocks of Wenchang Formation and Enping Formation have distinctive geochemical features. Source rocks of Wenchang Formation are middle-good source rocks which have high organic matter abundance; Coal-measure source rocks of Enping Formation have a wider distribution of Total Organic Carbon and are characterized by the section of mudstone of medium organic matter abundance, carbonaceous mudstone and coal. ② Palaeotopography that are prone to occur source rocks are different in these two periods. During Eocene, half-graben which are controlled by faults are good for the occurrence of source rocks; During late Eocene to early Oligocene, palaeotopographical types of “Analogous lagoon-tidal flat” and “shallow lake-fluvial” which are periodically covered by water , proximal to the source of organic matter supply and far from depocenter are prone to occur coal-measure source rocks; ③ Redox conditions of sedimentary environment have different impact on source rocks during these two period. Week-reducing to reducing conditions are advantageous for the occurrence of medium-good source rocks during Eocene. Source rocks of Enping Formation are formed in various redox conditions.④ Subsidence rates and sedimentation rates of Wenchang Formation and Enping Formation are different. Source rocks of Wenchang Formation are formed in the environment of moderate sedimentation rates. Sedimentation rates of 8.5~14.0cm/kyr are favorable for organic matter quickly going down to the reducing bottom of lake without being diluted by other particles or oxidized; Coal-measure source rocks of Enping Formation are formed near “Subsidence rate-sedimentation rate” balanced surface. Sedimentation rates of source rocks of are between 5.9~18.8cm/kyr and the upper limit of subsidence rates lie between 13.8 ~ 15.3 cm /kyr. ⑤ During Eocene, systematic properties of environment that are good for the occurrence of source rocks in Huizhou Sag are characterized by the half-graben which are controlled by faults, reducing environment and moderate sedimentation rates. ⑥ During late Eocene to early Oligocene, systematic properties of environment that are good for the occurrence of source rocks in Huizhou Sag are characterized by the palaeotopographical types of “Analogous lagoon-tidal flat” and “shallow lake-fluvial”, as well as the balance between subsidence and sedimentation.

Key words: Sedimentary environment; system properties; source rocks; palaeotopography; redox condition; subsidence rate; sedimentation rates; Huizhou Sag.

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Shoreline translation during transgressive-regressive cycles of the Lower Wilcox Margin, Gulf of Mexico Basin

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The Wilcox Group in the Gulf of Mexico Basin spans much of the Upper Paleocene and Lower Eocene, and extends from the Burgos Basin in northeast Mexico to central Alabama. It is an important reservoir of hydrocarbons and fresh water. Recent discoveries in deep-water Gulf of Mexico represent significant hydrocarbon resources in turbidite systems that are deep basin equivalents to the onshore Wilcox trend. Large distance of more than 250 miles between the shelf fluvial/deltaic systems and submarine fans implies a complicated transportation system during Wilcox deposition. In order to characterize cyclicity and shoreline translation of the Wilcox margin, this study identified thirteen repeated transgressive-regressive cycles on the basis of wire-line well log interpretation and core observation in the Houston embayment area. The thickness of each T-R cycle ranges from 40 m to 60 m, corresponding to a full cycle of transgressive and regressive shoreline shifts.

The heterolithic facies with abundant crinkled mud drapes, double mud layers, rhythmic bedding, and herringbone cross stratification indicate that the transgressive half cycle in the lower Wilcox mainly consists of tidal-dominated estuary deposits. The facies include fluvial/tidal channel-bar complexes, sub-tidal sand flats, and supra-tidal sand/mud flats. The brackish water estuarine facies primarily show a *Skolithos* ichnofacies assemblage with moderate intensity of bioturbation. However, the regressive half cycle is composed of storm/wave dominated delta and shore face deposits, typically well-sorted sandstone with wave ripples and hummocky cross stratification. These fully marine deposits yield a high diversity and intensity of trace fossils including expressions of the *Cruziana* and *Zoophycos* ichnofacies.

Shoreline translation during transgressvie-regressive cycles plays an important role in understanding sediment distribution and shelf construction. During the transgressive period, tidally influenced shorelines are indented due to the interaction of fluvial and tidal processes. During the regressive period, storm/wave influenced shorelines are more linear, due to strong wave energy reworking sediments. Quantified sedimentary facies and T-R cycles (thickness, proportion, and translation distance) were calculated in the lower Wilcox. The results suggest that the lower Wilcox estuarine shorelines were mainly tide-dominated in transgressions, but straight shorelines dominated by storm/wave in regressions.

Keywords: Shoreline, Tidal-dominated estuary, Trace fossil, T-R cycle, Lower Wilcox

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Role of sea-level change in deep water deposition and reservoir architecture, Early and Middle Permian, Delaware Basin

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Architecture and sedimentary characteristics of deep water depositional systems can reflect influence of sea-level change on depositional processes at the shelf, slope, and basin floor. Outcrops of the northern slope and basin floor of the Delaware Basin in west Texas are progressively exposed due to canyon incision and road cutting. The Bone Spring, Cutoff, Brush Canyon, and Bell Canyon Formations within the Lower and Middle Permian were measured to characterize gravity flow deposits on the basin slope and floor. Subsurface data from the East Ford Field and Red Tank Field in the central and eastern Delaware basin were used to study reservoir architectures. Depositional models of deep water gravity flows at different stages of sea-level change were constructed on the basis of outcrop and subsurface data.

In falling-stage system tracts, rapid sea-level fall and instability of shelf edge caused poorly-sorted sandy debris with clasts of reef carbonate from shelf edge to be deposited on the slope, and high density turbidities on the slope toe and basin floor. In low-stand system tracts, deep water fans that consist of mixed siliciclastic and carbonate facies on the basin floor are mainly comprised of debris and turbidities. However, in transgression and high-stand system tracts, channel-levee and elongate lobes of mud-rich calciturbidites deposition formed as a result of high deep water and less sediment supply.

Geological heterogeneities of depositional systems such as sand distribution and net-to-gross ratio play a major role in reservoir exploration and exploitation. The fan-like debris and high density turbidities, which associated with mass-transport complexes, are composed of coarser sandstone and carbonate clasts. These basin floor fans show high net-to-gross ratio of 79.2%, which suggests high quality reservoirs for hydrocarbon accumulation. Lobe-like deep water fans with moderate net-to-gross ratio of 57.2% facilitate the formation of more seals and interlayer beds in sandy reservoirs. However, the elongate channel-levee systems with muddy calciturbidites at the high sea-level stand have low net-to-gross ratio of 26.0%, which primarily indicate source rocks and minor reservoirs for hydrocarbon accumulation.

Keywords: sea-level change, debris flow, high density turbidities, calciturbidites, reservoir architecture

The geological implications of the Cenozoic heavy minerals in Boxing Sag, north of the Luxi Rise

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1 Introduction - Due to the lack of reliable analytical data, the understanding on Luxi Rise is still under debate and the disagreements are mainly focused on the regional exhumation rate, the temporal and spatial erosion variation and the resulted effect on adjacent basin. In this paper, the process of uplift and denudation of LuXi Rise is discussed based on the survey of clastic heavy minerals and their grouping patterns in Boxing Sag. The survey results are correlated with the outcrops of the adjacent area and the direction, composition and variety of the material source in study area.

2 Geological background - Located on the southwest of Dongying Sag, Boxing Sag is linked to Luxi Rise on south. As a secondary tectonic unit of the rift basin, Boxing Sag was developed during the Paleogene and the corresponding deposition here is comprised of Kongdian Formation, Shahejie Formation and Dongying Formation from bottom upward.

3 Methods and results of sample analysis - In this study, over 100 core samples were collected from more than 40 wells of Boxing Sag. All these samples are processed and tested in lab following Von Eynatten and Gaupp ‘s methods and 20 clastic heavy minerals were identified: zircon, apatite, anatase, rutile, barite, brookite, pyrite, sphene, garnet, pyroxene, hornblende, epidote, tourmaline, glauconite, chromium iron ore, leucoxene, ilmenite, hematite limonite, magnetite, monazite, et al. Among them, there are seven minerals and each of them shows a volume content over 10% of the whole and they are: zircon, garnet, epidote, apatite, red limonite, pyrite, magnetite and ilmenite.

Based on the survey of the Cenozoic detrital heavy minerals in Boxing Sag and their correlation with the source rocks in studying area, it is indicated that the local metamorphic heavy mineral combination which represented by epidote is close to that of Luxi Rise. The statement that one provenance of Boxing Sag is from Luxi Rise is also supported by thin section analysis. In addition, another local metamorphic heavy mineral combination represented by garnet is close to that of Sulu. The evidence that Sulu as another provenance is provided by the probe analysis.

As to the Paleogene depostion in Boxing Sag, the source rock of Kongdian formation and Shasi formation is comprised of Luxi metamorphic rock represented by epidote, Sulu metamorphic rock rich in garnet, volcanic and sedimentary rocks. Sha3 formation was mainly sourced from Luxi metamorphic and sedimentary rocks. From Plaeogen Sha2 to Neogene Guantao Formation, the lithology is pretty similar to that of Kongdian and Sha4 Formation. The source rock of Neogene Minghuazhen Formation mainly contains Luxi metamorphic and mafic igneous rocks.

In the study area, both Kongdian Formation and Sha4 Formation contain metamorphic rock from Luxi and that from Sulu, which implies that Luxi Rise is low enough at that time and the study area received material from by both Luxi and Sulu. The increasing Luxi source and the decreasing Sulu source since Sha3 period indicates a weakened effect on Boxing Sag from Sulu as Luxi uplifted acceleratedly. During the deposition period of Neogene Minghuazhen Formation there is almost no source rock rich in garnet sag any more, which suggestd that the Luxi Rise had experienced a substantial uplift and the effect of Sulu provenance to sag is almost cut off.

Key words: Heavy mineral; Provenance of source rocks; Sulu metamorphic belt; Boxing Sag; Luxi Rise

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Argillaceous parcel - a criterion for recognizing sandy mass-transport deposits: Deep-water massive sandstone of the Yanchang Formation (Upper Triassic), Ordos Basin, Central China

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Numerous examples of sandy mass-transport deposits (SMTDs) in deep-marine and deep-lacustrine environments have been documented in recent years by researchers worldwide. However, there are no accepted criteria for identifying the deposits of subaqueous mass-transport processes. In this context, through rigorous examination of several outcrop profiles in the Ordos lacustrine basin in central China, we propose that the "argillaceous parcels" in the deep-water thick massive sandstone of the Yanchang Formation are a viable criterion for recognizing deposition from sandy debris flows in delta front environments. The depositional features suggest that the sediments containing the feature were characterized by en masse emplacement (i.e., a Bingham plastic behavior) and were supported by the strength of the plastic medium at all times. Accordingly, the "argillaceous parcels" are one of the most significant criteria indicating sandy debrites as the origin of the deep-water thick massive sandstones of the Yanchang Formation. This diagnostic feature may be of use in identifying analogous SMTDs in other localities.

Keywords: argillaceous parcel, deep-water deposits ,sandy-mass transport deposits, sandy debris flow, Yanchang Formation, Ordos Basin, Central China

Cretaceous Climate in South China

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There are lots of small to medium Cretaceous continental basins in South China, in which variety of sediments and minerals can be used to analyze the paleoclimate. In this work, we tried to make interpretations of the Cretaceous climate in South China using paleosol type, clay mineral association, and carbon-oxygen isotope of lacustrine carbonate as well as atmospheric CO_2 level.

Four kinds of paleosols are recognized as argillisol, calcisol, oxisol, and spodosol based on observation of eleven cross sections in field. According to climate direction of paleosol type, observations suggest it was in aridity or semi-aridity of subtropic during the Aptian-Albian epoch in SW Zhejiang; and at the same time it was in semiaridity in tropic in SW Fujian. In the Cenomanian, it could become more moisture in SW Zhejiang, whereas the paleoclimate in SW Fujian in the Cenomanian might be similar with that in the Aptian-Albian.

Components of clay mineral illite, smectite, kaolinite, and chlorite were measured and analyzed from twelve observed sections to interpret the Cretaceous paleoclimate in South China. In total, the relative content of illite is over 80% in average through the Cretaceous; and abundant smectites present in some formations in western Fujian and Zhejiang, indicating an arid-semiarid climate of tropic-subtropic in the Cretaceous in SE China with interruptions of hot-humid in western Zhejiang and dry-cold in western Fujian and western Zhejiang. Kaolinites are increased to 8-15% in Nanxiong basin, implying an ascending of moisture in the late Later Cretaceous through the Early Paleogene.

Carbon and oxygen isotopic values of lacustrine carbonates were analyzed. $\delta^{13}C$ values range between -5‰ and 3‰, and $\delta^{18}O$ values are all negative (–19.3‰ ~ –7.4‰), likely indicatives of a brackish-salt environment and a arid-semiarid climate with strong evaporation during intervals of the late Berriasian and Valanginian age. Linear covariant ratios between $\delta^{13}C$ and $\delta^{18}O$ values demonstrate that lacustrine, palustrine, and pond systems were closed and evaporative under a regional arid-semiarid climatic setting.

$\delta^{13}C$ values of calcretes of the Lower Cretaceous pedogenic carbonates range from –7.0 to –3.0 ‰ and can be grouped into five episodes of increasing–decreasing values. The carbon isotope proxy suggests pCO_2 mostly in range 1000–2000 ppmV at $S(z)$=2500 ppmV and 25°C during the Hauterivian–Albian interval, being 4–8 times pre-industrial values and indication of compatibly hot climate. A high atmospheric CO_2 level is featured in the Early Cretaceous although rapid rises in pCO_2 are identified for early Hauterivian, middle Barremian, late Aptian, early Albian and middle Albian, and rapid falls for intervening periods.

In summary, the climate is characterized by arid-semiarid of tropic-subtropic in South China in Cretaceous, during which it was interrupted by wet-hot and dry-cold in the Early Cretaceous and it had been increasing in moisture in the Late Cretaceous through the Early Paleogene.

The characteristics of caves under different karst background in Tahe paleokarst reservoirs

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Tahe oilfield is the first oversize Paleozoic marine carbonate oilfield in China and the main oil-bearing formation of Ordovician is typical carbonate fracture-carvity reservoir. The carbonate fracture-carvity reservoir, with various types of reservoir space, has characteristics of very strong heterogeneity, while the cave plays the leading role in oil and gas preservation and permeation. In this paper, taking block 4 and block 7 of Tahe oilfield as an example, we divided the cave into horizontal pipe cave and isolated cave on the basis of genetic mechanism, and then discussed the characteristics of caves under different karst background in Tahe paleokarst reservoirs.

Utilizing the outcrops, cores, logging data, seismic data and geology patterns comprehensively. We identified different types of caves. Then based on the core observation of 18 cored wells, we calibrated logging curves and identified the filling types in different caves of 53 logging wells. Tahe block 4, the karst highland topography, suffering from leaching, weathering and denudation of Atmospheric water, develops fractures relatively. Affected by vertical corrosion controlled by the fault and lateral erosion controlled by water surfaces, both pipe caves and isolated caves are better development. Pipe caves extend horizontally, while isolated caves present oval-shaped irregularly. Tahe block 7, the karst slope landform, with the poor development of fractures and underground runoffs, develops the pipe cave mainly. Block, develops 3 period pipe caves controlled by three period water surfaces and the cave size is larger than block 4. Pipe caves are filled with sand and mud fillings and fluvial beddings are visible in cores. Detrital components are mainly carbonate rock fragments, including stalactites fragments, biological detritus, calcite crystal, microcrystalline limestone, calcarenite and so on, nd are also rich in silty sand and other external components. Laminated structures are developed in lime mudstones and tuffaceous sandstones. Isolated caves are mainly filled with Collapse breccia. Breccia, with the size in the range of 2mm-30mm, is supported by particulates, and the components are calcarenite or microcrystalline limestone. Meanwhile, terrigenous quartz sandstone, shale, iron calcite crystal chips and gray sand filled among the breccia. However, block 4 is unfilled or partly filled, while block 7 is full filled mainly.

Migration of the carbonate ramp and sponge buildup driven by the orogenic wedge advance in the early stage (Carnian), Longmen Shan foreland basin, eastern margin of Tibetan Plateau, China

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The marine Carnian Maantang Fm. overlies a flexural forebulge unconformity and records the initial establishment, drowning and migration of a carbonate ramp and sponge buildup along the forebulge margin of the Longmen Shan foreland basin. The Maantang Fm. is of wedge-shaped geometry, and is composed of oolitic and bioclastic limestone, siliceous sponge reef and shale in an upward-fining succession. The formation shows the establishment and drowning of a distal margin carbonate ramp and sponge buildup, deepening into offshore marine muds, followed by progradation of marginal marine siliciclastics. The formation also shows the transition from shale cratonward into carbonate rock southeastward. The sponge reefs and shoal were deposited on a carbonate ramp on the distal margin of the early foreland basin. The growth rate of sponge reefs is 0.04 mm/yr, equivalent to the rate of relative sea level rise of 0.01–0.05 mm/yr. The sponge buildup and oolitic shoal are divided into seven zones southeastward on the carbonate ramp along the basal unconformity. Their migration rate of 18 mm/yr from NW to SE coincides with the estimated orogenic wedge advance rate (5–15 mm/yr), a clear indication that the advancing wedge controlled the migration rate of foreland oolitic shoal–siliceous sponge reef. We have inferred that the tectonic load of the Longmen Shan orogenic wedge led to flexural subsidence and rising relative sea level in the foreland basin located at the western margin of the Yangtze craton, driving the growth and subsequent drowning of the oolitic shoal–sponge buildup in the early stage of the foreland basin. We propose that the drowning and migration process was the sedimentary response to the orogenic wedge advance towards the Yangtze craton, and to the rapid closure of the Carnian Songpan–Ganzi remnant ocean basin.

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Low permeability sandstone reservoir quality heterogeneity within a architectual element in the outcrop of Yanchang Formation, Ordos Basin, China

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The low permeability sandstone reservoirs have become popular targets in petroleum exploration and development in recent years. The low permeability sandstone reservoirs were studied widely on the distribution of more favorable reservoirs in the basin scale. The reservoir quality within a architectural element has not been studied until now and it has significant influence on the development effect especially for the continental reservoirs. This study presents results of internal low permeability sandstone reservoirs quality heterogeneity in distributary-channel and controlling factors of the quality heterogeneity by using one well-exposed distributary-channel outcrop in Yanhe Section of the Yanchang Formation in Ordos Basin, China. The 21 samples evenly taken in different parts along the accretion in distributary-channel outcrop based on the analysis of architecture. By experimental petrological analysis, pore throat structure analysis and physical property analysis results taken from the outcrop samples, significant variability in the content of reservoir quality, textual and diagenetic components is present.

Reservoir heterogeneity of distributary-channel sandstones is revealed in the analysis result of samples. Within the channel sandbody, the in-filling pattern and the distance from the mudstone of channel edge control the internal distribution of reservoir quality. The porosity and permeability decreases along its accretion direction overall and the channel edge parts which near mudstone are lower than the channel inside parts. The distribution contours of porosity and permeability tend to be parallel with the accretion surface within the same channel. The best reservoir in the single distributary-channel sandstone is commonly found in the early filling's lower part. In the distributary-channel outcrop in Yanhe section, the sample which gets from early filling's lower part' porosity is 8.51%, permeability is $0.26\times10^{-3}\mu m^2$, and the end of filling part sample' porosity is 6.52%, permeability is $0.046\times10^{-3}\mu m^2$.

Filling patterns and the distance from the channel edge mudstone play an important role in reservoir quality heterogeneity of distributary-channel sandstones from consideration of average composition and thermal history. It is revealed in the following two aspects. (1) In original pore diameter and the throat width resulted from depositional fabric, The original pore diameter and the throat width both decrease with the finer of grain size and more matrix content which are associated directly with filling patterns along the accretion direction. The anisotropic pore structure and matrix content are both reflected in the variation of permeability. (2) At diagenetic intensitisy, the variation of grain size and matrix content according to filling pattern has important control on the intensity of diagenesis. Finer the grain size and more the matrix content, the compaction intensity is stronger. And the pore diameter and the throat width results from compaction provide spaces for cementation and dissolution, especially the dissolution when the secondary solution pores are more seen in this area. Matrix content and the distance from the mudstone of channel edge have complex influence on cementation intensity and types. Laumontite and calcite are two main important cements in this area. The more matrix content the less laumontite cementation. Closer to the channel edge mudstone the calcite cementation is more intense and this leads to the best part of the reservoir quality is not always the coarsest part of the channel sandbody.

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Structurally controlled diagenesis and porosity modification of the Ordovician carbonate reservoirs in deep-buried Tarim Basin, northwest China

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Carbonate reservoir formation and distribution are generally related with sedimentary facies of high-energy and epidiagenetic processes. However, further data derived from petrological-mineralogical and geofluid records are presented here to improve our understanding of the origin of the Ordovician carbonate reservoir rocks deeply buried in the Tarim basin, northwest China. Syndepositional and early-stage diagenesis of the Ordovician carbonate in the Tahe of north Tarim basin and the Tazhong of Central Tarim basin, were mainly characterized by sustained and intense cementation in seawater, and the preserved carbonate reservoir distribution has only a limited genetic relationship with depositional facies. Therefore, late constructive diagenetic modification has been a key process allowing the Ordovician carbonates to become effective reservoirs for oil-gas accumulation. However, after epidiagenetic karstification, the late normal deep-burial diagenesis of the Ordovician carbonates of the Tahe region mainly resulted in multistage carbonate precipitation rather than dissolution, as inferred from the lack of evident retrograde dissolution related to decreasing temperature. On the other hand, from the Lower Ordovician to Upper Ordovician in the Tazhong, diagenetic records in the lower carbonate strata, including high-temperature fluid inclusions and special diagenetic minerals rich in ^{87}Sr, shows stronger thermal fluid modification than that in the upper carbonate strata, which suggests the thermal fluid was deeply sourced and led to the development of strong heterogeneity in the deeply buried carbonate reservoirs. The constructive modification of structurally controlled thermal fluid flow on the Ordovician carbonates mainly occurred along the transtensional fault systems developed during the Middle-Late Devonian and Permian and/or the pre-existing karst systems basically formed during the Middle-Late Ordovician and pre-Carboniferous periods.

Deepwater deposition mechanisms and significance for unconventional hydrocarbon exploration: A case study from the Lower Silurian Longmaxi shale in the Sichuan Basin, South China

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The deposition mechanisms of the Longmaxi shale in the Sichuan Basin in southern China, as well as their significance, were studied. Based on the detailed observation of outcrops and cores, using petrographic and scanning electron microscopy examination of thin sections and other data analyses, five depositional processes that are potentially responsible for the deposition of the Longmaxi mudstone have been identified: 1) suspension deposition, 2) upwelling, 3) turbidity currents, 4) gravity slumps and 5) storm currents. The lithofacies deposited by these different mechanisms have been characterized in detail. Suspension deposition mainly forms laminated shale, and siliceous shale is associated with upwelling, whereas massive mudstone and siltstone are mainly deposited by turbidity currents, gravity slumps and storm currents. The deposition model and a vertical sequence have been established based on a cored well (Well Yuye-1) and an outcrop (Hongyanxi Outcrop).

The deposition mechanisms have an important impact on the source rock and the reservoir properties. Suspension and upwelling can provide favorable conditions for the production and the conservation of organic matter and are conducive to the formation of high quality source rocks (TOC content up to 5.4%). The reservoir storage spaces are mainly interlaminated fractures and organic pores with good reservoir physical properties. Turbidity currents and storm currents may carry a large quantity of oxygen into the sea floor, resulting in the oxidation of organic matter, which is unfavorable for the preservation of organic matter. Gravity slumps inherit the primary characteristics of the lithology and the organic matter content. The lithofacies formed by turbidity currents and storm currents have relatively low TOC contents (mainly <1%). Structural fractures and intergranular pores can be the main reservoir storage spaces present. In summary, organic-rich shale and silicolite deposited by suspension deposition and upwelling are the key exploration targets for shale oil and gas. The widely distributed, multilayer tight sandstone can be important in the exploration for tight oil. A better understanding of the deposition mechanism and its impact on oil reservoirs may provide insight for finding favorable areas for exploration.

Keywords: Deepwater deposition; deposition model; unconventional hydrocarbon; Longmaxi shale; Sichuan Basin

Characteristics of Cenomanian cold seep carbonates in the eastern Tethys Ocean

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Cold seep carbonates with distinctive structures which are related to the seepage of methane hydrates and have played an important role in paleoenvironmental evolution and disturbance of the carbon cycle. We studied Cenomanian cold seep carbonates in southern Tibet. The carbonates are widespread in shale and shale/silty sandstone alternation successions in the Xigaze Forearc Basin and Tethyan Himalaya zone, which were parts of the northern and southern margins respectively of the eastern Tethyan Ocean in the Cretaceous. The morphology, mineralogy and compositon of the carbon and oxygen isotopes were studied in detail. The carbonates display nodular, tubular, chimney-like, and massive morphologies. They are mostly composed of micritic calcite, scarce shells, and framboidal pyrite. Depleted $\delta^{13}C$ values ranging from -7.89‰ to -29.35‰ indicate that the precipitation of the carbonate resulted from release of methane hydrates**.** The $\delta^{18}O$ values (from -8.61‰ to -14.74‰) indicate that the carbonates suffered strong alteration.

From margin to center, the $\delta^{13}C$ values and element compositions are significantly different. The $\delta^{13}C$ values are more depleted in the center than in the margins. We suggest that the margin is more significantly affected by the pore water of the surrounding sediments than are the central parts of the carbonates. Toward the centers, the Ca and Si contents increase and the Fe, Al, and K contents decrease. Therefore, we suggest that the influences by the surrounding sediments decreased from the margins to the cores of the carbonates. The depletion in Mn and occurrence of pyrite framboids indicate that the carbonates were deposited in a reducing environment. Based on these analyses, the formation of cold seep carbonates in the eastern Tethys Ocean can be divided into three stages as follows: formation of methane hydrates, release of methane hydrates, deposition of carbonates and interaction with surrounding sediments.

Our study provides firm evidence of relatively large-scale seafloor methane leakage in the Cenomanian at both the southern and northern margins of the Tethys Ocean. Furture research is needed to examine the reason for the methane release and its implications for the evolution of Cretaceous paleoenvironment and paleoceanography.

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Lagoon-sediment evidence of typhoon strikes in southeastern Hainan Island, China

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Recently the increasing economic losses and casualties caused by tropical cyclones have attracted media and public attentions around the world. Tropical cyclones, originated on tropical or subtropical sea surface, are deemed to be disastrous events whose intensity is of great sensitivity to details of regional and tropical climate changes. Amount of works have focused on various factors that influence the seasonal-to-decadal variation of tropical cyclones and the effect of climate changes on tropical cyclone activity, especially in the Western North Pacific (WNP). The results of Emanuel's research (2005) clearly show an upward trend to both longer storm lifetimes and greater storm intensities in the WNP and North Atlantic since the mid-1970s. However, studies based on plentiful tropical cyclone datasets showed that there were no statistically significant trends in typhoon intensity in the WNP in recent years. These contradictory results may be interpreted as the calibration problem because of a lack of instrumental records for a long time series.

Previous works show that low-energy coastal depositional settings, such as lagoons and lakes, can offer favorable environments for the preservation of storm-induced deposits, which provide the information of past intense tropical cyclones. Marine incursions into these lagoons or lakes during extreme storms disrupt underlying sedimentary sequences and damage coral reefs by enhanced typhoons- generated waves and storm surges. Consequently, Cores collected from these sites may contain several meters of fine-grained units interbedded with coarse-grained event layers as a mixture of coarse sediments, calcium carbonate shells, and shell fragments. Considered as distinctive sedimentary signature, these layers can be used to reconstruct past records of typhoon-induced storm events. Moreover, information about past typhoons can also be retrieved from historical archives in libraries and museums, particularly in the regions with a tremendous source of valuable data on past weather and climate.

Hainan Island is one of regions most frequently and seriously affected by tropical storms in the Western North Pacific. The most destructive typhoon that directly striking the Hainan Island since 1949 was Marge in September 1973, which brought wind gusts of up to 80 m/s. The landfall of Marge resulted in more than 926 people killed, thousands injured, 126,000 houses destroyed, and 37300 more acres of farmland damaged. Economic losses were estimated to exceed 1 billion RMB. As recently as September 26, 2005, Typhoon Damrey hit Hainan Island to cause widespread damages and casualties, to the extent of at least 21 persons killed and economic losses estimated at 12.1 billion RMB. Faced with expectations of a potentially rapid global climate change, any drastic changes in frequency and intensity of tropical cyclones would be detrimental to coastal communities and ecosystems and socio-economic development because of the rapid increase of economic development in Hainan province and other coastal zones in China. A thorough understanding of how the frequency and intensity of past tropical cyclones changes is essential for predicting future changes and making appropriate management decisions.

In this study, we extend the records of tropical cyclones striking the Hainan Island to reconstruct the history of past tropical cyclones with sedimentary archive of overwash deposits preserved in two micro-tidal lagoons. Several sediment cores were taken from Xincun lagoon and Li'an Lagoon in southeastern Hainan Island. A set of storm-induced deposits were identified by a series of criteria, including detailed core descriptions, loss-on-ignition (LOI) and grain size analysis. These cores were precisely dated by the methods of ^{210}Pb and AMS^{14}C. Dating results suggest that deposition in the lagoon was continuous over the last 300 years with sedimentation rates varying from 4.95 to 12.6 mm/yr. The history of tropical cyclones during the last 300 years has been recovered by typhoon-induced deposits and examined by the corresponding historical documents.

Keywords: paleostorms; typhoon-induced deposits; historical documents; lagoon; Hainan; China

Quantitative provenance analysis of Changjiang River sediments (China)

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We use petrographic, mineralogical, geochemical and geochronological data on modern sandy sediments from all major branches of the Changjiang (Yangtze) River to investigate the relationships among geology and topographic relief of catchment areas, climatic conditions, impact of human activities, and sediment composition. The Changjiang River, the third longest river in the world, drains a variety of different geological units and has a complex source-to-sink sediment-transport system. At present, there are ~50,000 dams built in the Changjiang catchment, among which the Three Gorges Dam, the world's largest power station that became fully operational only recently. In the uppermost reaches in Tibet, sand is litho-quartzose with a moderately poor amphibole-clinopyroxene-epidote heavy-mineral assemblage. Sand becomes feldspatho-quartzo-lithic with abundant metamorphic and sedimentary rock fragments in the Jinshajiang downstream, where moderately rich hornblende-epidote assemblages include minor garnet and clinopyroxene. Sedimentary lithic grains increase further downstream of the Yalongjiang confluence at the expense of quartz and feldspars; the clinopyroxene-dominated moderately rich heavy-mineral suite includes hornblende and epidote. Changjiang sand downstream of the Minjiang confluence is quartzo-lithic, with common volcanic lithics and a variety of metasedimentary grains; heavy-mineral suites include augitic clinopyroxene with subordinate amphibole, garnet and apatite. Quartz and feldspar increase again downstream of the Jialingjiang confluence, and Changjiang sand in the Three Gorges is feldspatho-quartzo-lithic with very rich clinopyroxene-amphibole-epidote suites including garnet and zircon. Only in the lower course, downstream of the Hanjiang confluence, Chiangjiang sand becomes feldspatho-litho-quartzose with moderately rich, amphibole-dominated heavy-mineral suites. In the terminal tract farther downstream, sand composition ranges from feldspatho-litho-quartzose to litho-feldspatho-quartzose with moderately rich, amphibole-dominated heavy-mineral assemblages including epidote, clinopyroxene and garnet. This is the composition of sediments delivered by the Changjiang River to the East China Sea. Based on mineralogical and geochemical data, the complex controls of source-rock lithology and climate-induced weathering on sediment composition in the major tributaries and mainstream can be identified. By using multiple mathematical methods we quantify the relative contributions from each tributary and geological unit to the total bedload budget, and consequently evaluate sediment yield and modern erosion patterns in distinct parts of the drainage basin.

Fine delta facies recognition for monosandbody in large scale overlap channels sand body: PI3 layer in Xing Beiwu area of Daqing Oilfield as an example

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Most oilfields in eastern China belong to delta facies, and the sand body of delta facies channel is an important sedimentary reservoir. The oilfields have entered high water cut and high recovery stage after decades of water injection development. Due to the accuracy of stratigraphic unit it has been difficult to meet the needs of oilfield production, especially inside the deltaic overlapped sand body, in which accuracy must be finely recognised to the level of a monosandbody. However, to identify the fine monosandbody is very difficult in overlapped serious channels sand body. Monosandbody, the sand body both in plan and vertical are continuous, though separated by mudstone or an impermeable interlayer between the upper and lower sand bodies. The reasons that monosandbodies are not connected to each other can be analyzed by parameters such as grain size, separation, matrix content and so on. There are many differences between different monosandbodies, such as the thin mudstone, argillaceous siltstone and argillaceous fine-grained sandstone interlayers. As a result the overlap channels sand body internal heterogeneity is strong, and the performance for the well oil-bearing is non-uniform, and many differences between the water well, which increased the difficulty of remaining oil exploitation in the old oilfield. Taking Xing Beiwu PI3 layer in Daqing oilfield (which is the largest oilfield in China), as an example, it is about 10 meters thick and overlap channels sand body is changeable in plan, overlap and they cut each other in vertical section. The fine delta facies is recognised for monosandbody in large scale overlap channels sand body, in view of the actual problems existed in the development, with the modern sedimentary theory of the depositional time unit division, the relationship study of overlap monosandbody of dense well pattern and the comprehensive utilization of core, logging data and dynamic data. The palaeogeographic environment is restored by the depositional model guide. The key to determine the different monosandbody are vertical installment marks and plane boundary marks of overlap channels sand body. The vertical marks are mud, calcium and physical interlayer. And the plan marks are abandoned channel, interchannel deposition, the “thick, thin, thick” phenomenon caused by overlapped channel lateral, elevation differences, thickness difference, interlayer development position difference and so on. There are 5 low-sinuosity meandering-type monosandbodies identified in PI3 layer in the study area on the basis above. The main distribution direction of the monosandbody is north-west to south-east in plan, which is band shape, 500 to 600 meters wide, 1 to 6 meters thick, and the ratio of width and thickness of monosandbody are also studied. Finally, the divided rationality of monosandbody can be verified by tracer material data and the different factors of different wells and different absorption location. Research of fine monosandbody recognition to oil and gas field exploration and development is of great significance. The study of monosandbody is an important factor for the formation of lithologic reservoirs in the aspect of exploration, and the distribution characteristics affect the design and development plan adjustment, which lay a foundation on the basis of production and find remaining oil better for the old oil fields in the aspect of development.

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Deepwater Gravity-Flow Deposits, Paleogeography and Tectonic Setting of the Late Ordovician in Tarim Basin, West China

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The Upper Ordovician in the Tarim Basin consists of a 3,000 to 5,000 m thick sequence of siliciclastic and calciclastic deep-water gravity-flow deposits. Their depositional architecture and paleogeographic setting are documented in this investigation based on an integrated analysis of seismic, borehole and outcrop data. Eight depositional–geomorphologic elements have been identified in the gravity flow depositional systems: submarine canyon or deeply incised channels, broad and shallow erosional channels, erosional–depositional channel and levee–overbank complexes, frontal splays and lobes, non-channelized sheets and debris flow complexes. Gravity-flow deposits of the Sangtamu and Tierekeawati Formation comprise a regional transgressive-regressive megacycle which can be further classified into 6 sequences bounded by unconformities and their correlative conformities. A series of incised valleys or canyons and erosional–depositional channels are identifiable along the major sequence boundaries which might have been formed as the result of global sea-level falls. The depositional architecture of sequences varies from the upper slope to abyssal basin plain and is generally summarized into 4 major types. Regional change in tectonic setting from a passive continental margin to an active back-arc setting, with formation of the Tazhong and Tabei uplifts caused by compression related to orogeny around the basin during the Late Ordovician, greatly influenced the paleogeographic patterns and distribution of the gravity flow deposits in the basin. The thickest siliciclastic submarine-fan deposits accumulated along southeastern and northeastern deep-water depressions formed by compressive flexural subsidence in the Late Ordovician and they were predominantly sourced from the southeast and the north or northwest. Slide and mass transport deposits and a series of debris flow and turbidite deposits developed along the toes of unstable slopes on the margins of deep-water basins. Turbidite sandstones of channel fill and frontal splay origin and turbidite lobes in the submarine fan systems comprise potential stratigraphic hydrocarbon reservoirs in the basin.

Sedimentary facies and evolution in the Qiantang River incised valley, eastern China

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The sedimentary facies and evolution of the Qiantang River (QR) estuary, and the characteristics and formation of the incised valley sequences and the related shallow biogenic gas reservoir, are described on the basis of analysis of the newly drilled core SE2 and the observation of its correlation with more than 800 boreholes.

The result shows that, since the last glaciation, the Late Quaternary formation of the QR estuary area underwent three stages: (1) deep-cutting stage; (2) rapid-filling stage; and (3) burial stage. From bottom to top, the incised-valley deposits are grouped into five stacked facies: amalgamated channel, floodplain and channel, paleo-estuary, offshore shallow marine and present-day estuary. The fall of global sea level during the last glacial maximum enhanced the fluvial gradient and river cutting, resulting in the formation of the large-scale QR and Taihu incised valleys, with the interfluve being exposed to air on both flanks of the incised valley. Fluvial terraces at thee elevations are present near the present QR estuarine mouth, corresponding to 60–70 m, 90–100 m and 115–125 m burial depths. The valleys were filled rapidly with fluvial sediments during the post-glacial period; with the rise of sea level, the river mouth migrated to landward, and backwater and retrogressive aggradation was enhanced. The QR and Taihu incised valleys are associated with an early filling and transgressive amalgamated channel-infilling sequence formation, and a late filling and transgressive floodplain and channel, paleo-estuary formation. Subsequently, the QR valley was buried under offshore shallow marine and present-day estuary sediments. The thickness of the amalgamated channel-infilling deposits is controlled mainly by base-level rising, backwater, retrogressive aggradation and neotectonism. Further, localized thickening took place where deeper scour pools were present in the incised valley or fluvial terraces were formed during the fall of relative sea level.

During the deposition of the floodplain and channel, paleo-estuary facies, the conditions of sea-level rise, tidal regime, sediment supply and accommodation space were suitable for the development of a tidal ridge system; the sand lenses associated with this facies may represent a tidal ridge system in the incised valley. At the later stage when the present-day estuary were formed, the sedimentary conditions were no longer favourable, resulting in absence of sand ridge deposits. Biogenic gas is stored in the floodplain and channel sand lenses of the incised valleys. The Changjiang River provides the major sediment supply for present-day estuary sediments, and the QR carried sediments constitute only a small portion of the deposits.

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The Xujiahe Formation sandstone in the Northern Sichuan Basin, China: compositional characteristics and response to tectonic activities

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The Upper Triassic Xujiahe Formation is an important natural gas producer in the Sichuan Basin. Tectonic was a main factor controlling the evolution of the Sichuan Basin during the Late Triassic. The sedimentary record of basin indicates multiple sources and facies changes. The variability in the sources is intimately related to the tectonic activities of the surrounding mountain belts, particularly the Micangshan– Dabashan and Longmenshan tectonic belts on its northern and western margins, respectively. The temporal and spatial variation of the provenance for the Xujiahe Formation is yet to be identified, which has prevented the prediction of the sand distribution regime and strongly limited the progress in oil–gas exploration in this area.

In this paper, the Xujiahe Formation in the Northern Sichuan Basin is examined with respect to the sandstone rock type, debris type, heavy mineral association, and composition of the sandstone in order to characterize the provenance of components in this formation and its response to tectonic activities. Our results indicate that during the Xu-1 stage, the Longmenshan tectonic belt had not risen. The provenance at that time was predominantly the Micangshan Mountain on the northern margin. Prevalent heavy minerals typically presented a zircon, tourmaline, rutile, leucosphenite, garnet, hematite, and spinel association. During the Xu-2 stage, the northern arm of the Longmenshan tectonic belt began to rise and supplied material to the western part of the study area, where the debris mainly consisted of carbonatite. The provenance for the northern and eastern parts of the study area was the Micangshan–Dabashan tectonic belt on the northern margin, where the debris mainly consisted of epimetamorphic and siliceous rocks, including volcanics. At the end of the Xu-3 stage, subject to the Anxianian Movement, the Longmenshan tectonic belt on the western margin underwent thrusting and folding resulting into a mountain belt. Through this process, the Longmenshan Mountain became the main provenance for the study area; the Micangshan–Dabashan tectonic belt became a secondary provenance. During the Xu-4 stage, materials supplied from the Longmenshan Mountain appeared to be, by composition, typically carbonatite gravels, including siliceous rock gravels; volcanic rock gravels were not observed. The parent rocks of all of these gravels originated from the Devonian–Upper Triassic Ma'antang Formation. Materials supplied from the Micangshan–Dabashan, by gravel composition, typically consisted of siliceous rock gravels, including phyllite, siltstone, rhyolite, and carbonatite gravels. The parent rocks of these gravels originated from Sinian–Silurian strata.

The results of this presentation demonstrate the importance of provenance and tectonic in the reconstruction of basin studies.

Keywords: Sandstone composition; Xujiahe Formation; provenance; tectonic activity; northern Sichuan Basin.

Siliciclastic particles dissolution under acid formation water condition with F participation

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A series of important achievements about quartz dissolution in alkaline environments had been produced. However, it is still difficult to determine the characteristics of quartz dissolution through microscope and the HF factor which can also cause such dissolution is neglected all the way.

Taking the strata of Xujiahe Formation in the West Sichuan Basin as an example, this paper had made clear the silicious debris dissolution event in the diagenetic series of clastic rocks and established the theoretical model for recognizing the phenomena of such dissolution by means of macroscopic observation of drilling cores and profiles in the field and testing data.

The diagenetic types in Xujiahe Formation include compaction, cementation, dissolution and metasomatism et al. Dissolution of siliciclastic grains was proved and boundary shapes, remaining part and secondary pores of dissoved grains were recognized.

While the formation water of Xujiahe Formation is $CaCl_2$ type which represents a deep and stagnation condition. The PH value of the formation water is 6 which shows an acid environment. Meanwhile F element with a large changing range was detected in the formation water and had a high content near the structural high part with fracture development. And F element had also been detected in the conclusions of the second and 4^{th} member of Xujiahe Formation. Therefore, the dissolution of siliciclastic particles happened under acid formation water condition with F participation.

During the dissolution process of quartz particles, material exchange and trasformation of other mineral assemblages occurred at the same time, including felspar and rock debris dissolution, siliceous cementation etc. The recognition marks of siliceous dissolution mainly include: geochemistry characteristics, partly dissoved siliceous particles, open contact senm between siliceous grains in tight sandstone and mineral assemblages.

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Characteristics and Controlling Factors on Sequence Stratigraphy of the Lower Miocene Zhujiang Formation at the Pearl River Mouth Basin, South China Sea

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The Pearl River Mouth Basin is an atypical passive margin basin due to the occurrence of a late Mesozoic folded basement and its location on the northern South China Sea. Since the Early Miocene, it was converted from a rifted basin to a down-warped basin and begun to deposit the Zhujiang Formation. Influenced by palaeo-landforms, inherited paleo-uplifts, multiple sediment sources and so on, the sequence architecture of the Zhujiang Formation is different from that of a typical passive margin basin. In this paper, the framework and controlling factors of sequence stratigraphy are studied based on data from various oil fields and the results of ODP Site 1148. The following are our conclusions:

The Zhujiang Formation can be divided into 4 third-order sequences (SQ1 to SQ4) from the bottom upwards. As a typical shelf sequence, characterized by the lack of lowstand system tracts (LST), the SQ1 sequence forms under low subsidence rates and only occurs at the southern depression belt of the Pearl River Mouth Basin. As the subsidence rate of the basin increased dramatically, LST are well developed in the SQ2 and SQ3 sequences that were deposited on the marsh lands between the sedimentary slope breaks of Pearl River Delta and Dongsha Massif. In the later periods of the Zhujiang Formation, subsidence rates reached a maximum with relative sea level being at its highest. Hence, LST and TST deposits disappear during deposition of SQ4.

The controlling factors on the sequence architecture of the Zhujiang Formation varied overtime, which results in both the temporal and spatial complexity of sequence architecture. During the late Oligocene to the early Early Miocene, the main controlling factors on the architecture of SQ1 are the tectonic movements, the inherited paleo-uplift and the palaeo-landform of the faults. The Baiyun tectonic movement forms a regional unconformity that formed a second-order sequence boundary. During this movement, the paleo-shelf break of the Pearl River Mouth Basin migrates from the southern uplift belt to the central uplift belt. Due to magmatic underplating, the Dongsha Massif was rapidly uplifted and eroded strongly. As a consequence, coastal sediments form around the Dongsha Massif in semi-closed marine environments. In paleo-fault depressions, sequence thicknesses in the central parts of the basin are greater than that of the margin. Fault breaks or flexure breaks are well developed around the paleo-basement faults, which influence the distribution of sand bodies at the northern depression belt.

During the middle Early Miocene, tectonic movements were limited. Relative sea-level change and the position of the shelf break and sediment supply were the main controlling factors on the architecture of SQ2 and SQ3. The rate and extent of relative sea-level change will directly impact on the system tract type. It should be noted that relative sea level rises rapidly in this basin, during a period when global sea levels are thought to fall. The shelf break is a boundary between shallow-water deposits and deep-water deposits. Sand-rich delta systems are developed at the northern depression belt and the west of the central uplift belt, and turbidite fan systems are widely developed in the southern depression belt. There are three kinds of sediment supply in this basin, including the Paleo-Pearl River Delta, the Hanjiang Delta and the Dongsha Massif. The Dongsha Massif was submerged and formed carbonate platform at this period.

During the end of early Miocene, SQ4 is mainly controlled by relative sea-level rise that caused retrogradation of the delta systems. Most areas at this time are covered by fine grained shelf deposits.

A Seismic Exploration Example of Structural-lithologic Reservoirs at the Continental Shelf Break Region

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Extensive studies have been done on the exploration of the lithologic reservoir under the simple tectonic background. But exploration technologies and theories about the structural-lithologic reservoir controlled by both complex structure and lithology are not enough. The main challenges we have to face are accuracies on the structural interpretation and the sand body delineation. Taken Lower Miocene Zhujiang Formation of PY Oilfield in the Pearl River Mouth Basin as an example, structural-lithologic reservoirs at the shelf break region are studied comprehensively based on Geology and Geophysics. Pre-stack interference wave suppression, seismic processing of relative preserved reservoir information, high-resolution velocity modeling and sand bodies architecture anatomy are major approaches used in this study.

There are seven main problems for structural-lithologic reservoirs in the study area, including the influence of multiples and gas chimney, long-wave low-frequency velocity variations caused by the dipping formation at the break region, seismic velocity errors caused by variations of sea bottom depth and Quaternary stratum thickness, seismic imaging shadows caused by the high-angle fault, structure mapping with the variable velocity model, interpretations of paleotopography and sedimentary evolution, contact relations and superimposed styles among sand bodies.

The following methods are adopted to solve above problems. Firstly, a new seismic processing procedure driven by VSP data is applied to eliminate the impact of multiples, ghost reflection and gas chimney, and improve the spatial resolution. It is composed of several core technologies, including the compensation for spherical dispersion in time-frequency domain, Radon transform, and the statistical wavelet deconvolution. Secondly, the problems of low-frequency velocity variations are solved by analyzing the zero-offset VSP velocity from various wells. Besides, seismic velocity errors are decreased effectively and structure map accuracies are improved by the spatial variable velocity mapping based on practical interpretation experiences and velocity change laws. Compared with pre-stack time migration (PSTM), this mapping method is more suitable for the shelf break region. The error of structure map is often less than one meter. Thirdly, sedimentary evolutions and spatial distribution laws of sand bodies are analyzed using the attribute slices extracted along reference seismic horizons. Finally, boundaries and contact relations of single sand bodies are recognized, which is guided by the theories of sedimentary architecture, and based on the integration of geological analysis with seismic response analysis and seismic forward modeling constrained by facies.

The drilling results show that seismic exploration errors on structural-lithologic reservoirs of the study area could be controlled within one thousandth using comprehensive research methods mentioned above. The researches can deepen the theory of seismic exploration effectively and reduce the exploration risk of such reservoirs. Therefore, It has significant theoretical and practical meanings.

Applying Multi-scale Data to Semiquantitatively Study on Diagenesis Reservoir Facies—A Case of Upper Triassic Xujiahe Formation in Dayi Structure, Western Sichuan, China

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Diagenetic reservoir facies are the integration of some diagenesis and special reservoir spaces to describe reservoir properties. It is critical for analyzing reservoir evolutionary process and sequence, exploring reservoir formation mechanism and predicting reservoir spatial distribution.

Casting thin sections, scanning electron microscope (SEM), physical analysis and so on are considered as methods to research characteristics and diagenesis types of tight reservoirs of the Upper Triassic Xujiahe formation in Dayi Structure, western Sichuan. On the basis of it, types of diagenesis reservoir facies are divided, logging identification charts of diagenesis reservoir facies are built and the distribution laws of high-quality diagenesis reservoir facies are quantitatively predicted through seismic velocity inversion based on the acoustic curve reconstruction.

The results showed that the main pore space types of tight reservoirs are micropores and microfractures. The average porosity is 2.94%, and the average permeability is $2.025\times10^{-3}\mu m^2$

Diagenesis reservoir facies of tight reservoirs in research area are divided into 4 types, namely, the dissolution pore-micropore-fracture diagenesis reservoir facies with strong fracture (Facies one), the micropore diagenesis reservoir facies with strong compaction (Facies two), the tight diagenesis reservoir facies with strong compaction (Facies three) and the tight diagenesis reservoir facies with strong cementation (Facies four). The curve cross plots of acoustic, density, resistivity and gamma are used to effectively identify different diagenesis reservoir facies.

Among 4 types of diagenesis reservoir facies, the dissolution pore-micropore-fracture diagenesis reservoir facies (Facies one) are the high-quality diagenesis reservoir facies, whose porosity between 3% and 8%, and permeability more than $0.5\times10^{-3}\mu m^2$. At the early diagenesis stage A, the intergranular pore space of Facies one began to decrease owing to matrix filling and mechanical compaction. At the early diagenesis stage B, the intergranular pore space of Facies one decreased quickly and lost thirty percent under the influences of intense compaction and local cementation. At the middle diagenesis stage A, the primary intergranular pore almost disappeared. Because soluble components of quartz sandstone were rare, only mudstone matrix and rock debris were dissolved by organic acid. Commonly, intergranular micropores and dissolved pores developed well owing to the conversion of mixed-layers of illite/smectite and the deposition & dissolution of illite. At the middle diagenesis stage B, the recrystallization of mudstone matrix resulted in the occurrence of other intergranular micropores. The late Yanshan movement and Hemalaya movement resulted in the occurrence of tectonic fractures.

The dissolution pore-micropore-fracture diagenesis reservoir facies (Facies one) mainly develop at distributary channel sand bodies of high structure positions and belong to quartz sandstone suffered strong compaction and fracture. The distributions of them are mainly controlled by sedimentary factors.

Relative role of transfer zone in controlling sedimentary architecture: insights from the Fushan Depression, South China Sea

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In sedimentary basins, transfer zone can be defined as a coordinated system of deformational features which has good prospects for hydrocarbon exploration. The Fushan Depression is a half-graben rift sub-basin, located in the southeast of the Beibuwan Basin, South China Sea. Comparative analysis of seismic reflection, palaeogeomorphology, fault activity and sedimentary facies distribution between the western and eastern areas in the Fushan Depression indicates that a transfer zone was developed in the central area, at the intersection of the western and eastern fault systems. Our results documents that the transfer zone had an important controlling effect on the sedimentary architecture by dividing the Fushan Depression into two tectonic systems with different sequence patterns, and causing the formation of the flexure slope belt in the central area. During the high-stand system tract (HST), under the controlling effect of transfer zone, the sand-rich sediments accumulated and distributed along its extensional direction. In contrast, during the low-stand system tract (LST), the transfer zone did not contribute a lot to the low-stand fan distribution in this region which was mainly controlled by the palaeogeomorphology (gradient). It seems that transfer zone allows a new perspective for sequence analysis in continental basins, especially for the interpretation of the formation mechanism of various sequence patterns. In addition, the transfer zone also controlled the hydrocarbon accumulation in the Fushan Depression, suggesting that the exploration targets may be non-uniform.

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Sedimentary characteristics and genetic model of gravity flow deposits in a terrestrial postrift basin — A case study from Yanchang Formation in Ordos Basin

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The Ordos basin is a large-scale Paleozoic and Mesozoic superimposed basin with a multiphase history. Since the Mesozoic the basin was in a postrift stage that reached its peak in Late Triassic, when deltas developed in shallow water and gravity flows developed in deep water.

Sedimentary characteristics and genetic model of Yanchang Formation in the southwest of Ordos Basin were systematically analyzed using cores and logging data. Five types of gravity flows were recognized: slide, slump, sandy debris, muddy debris and turbidites. Impacted by multiple provenances, slope break and paleogeomorphology, gravity flows resulted in sublacustrine fan and slope slump olistolith in slope and central basin.

Sublacustrine fan (inner fan, middle fan and outer fan) developed channels extending from slope break to deep lake and including main channel, distributary channel, channel lateral margin, inter-channel and sheeted turbidite sand. Sublacustrine fan was original from seasonal floods, which carried a large number of shallow water sediments and formed gravity flows when they went into deep water. The gravity flows were rich in sand but poor in mud and formed incised main channels without the effect of aquaplaning. The channels in the slope break were connected with shallow water delta, then they branched off after going into the central lake basin and its sand bodies distributed continuously with a shape of sheets.

Slope slump olistolith are thought to be triggered by volcanic events or earthquakes. It consisted of 4 parts: slide rock, slump rock, debris flow lobe and sheeted turbidite sand. Slope slump olistolith was rich in mud while poor in sand so that the debris flow lobe developed few channels because of the aquaplaning mechanism. Its sand bodies mainly located in the lower slope break and central lake basin, unconnected with those of shallow water delta. The slide rock, slump rock and debris flow distributed discontinuously with a shape of lobe while the turbidite deposits distributed continuously in the front.

The practical exploration indicates that the main channel, distributary channel, sheeted turbidite sand of sublacustrine fan and the debris flow lobe of slope slump olistolith are all favorable exploration targets. Gravity flows make the deep lake rich in sand and mud, resulting in high-quality source rocks and reservoirs distributing widely in the plane and closely vertically. The mudstone and oil shale are not only source rocks but also the direct cap rocks of sand bodies, they formed multiple sets of sandwich-like source-reservoir-caprock assemblage, which improved the reliability of oil and gas exploration in the deep-water lake basin.

The main diagenesis type and its impact on the reservoir of Lower to Middle Ordovician of Yubei, Tarim

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Open platform facies dominate the sediment of Penglaiba and Yingshan Formation of Mid-Low Ordovician in Yubei district, Tarim Basin. The main rock types are sparry calcarenite and dolomite. Dolomite is more developed in the lower Penglaiba Formation than the upper Yingshan Formation. Weak atmospheric corrosion in the limestone can be observed, while most are fully filled with calcite with only a small amount of mold pore and intragranular pore is preserved. So these pores contribute little to the reservoir. Dolomitization contribute to the preservation of mold pore and intragranular pore by preventing the cementation of calcite. Thin section observation and isotope analysis show that dolomite develops during the burial process. The intergranular pore contribute little to the reservoir due to the late stage of strong calcite filling. The main reservoir space of Penglaiba and Yingshan Formation in Yubei district are dissolution caves, which mainly develop within 200m below the top of Yingshan group. Seepage oolitic, collapse breccia, undercurrent caves and other karst phenomenon develop from top to bottom. Most of the caves are half or fully filled with silica and chlorite and the GR values increase in the corresponding position. Brecciated characteristics and C-O isotopes and Sr isotope characteristics are more consistent with the surrounding limestone indicate that the silica is more likely to gather from seawater rather than the hydrothermal source. Karst development may be controlled by local tectonic movement and is limited to a relative small extent. And large-scale karst reservoir cannot be expected.

Geologic-Seismic Models and Prediction of Sands Based on High-frequency Sequence Stratigraphy as Applied to the Late Miocene, BZ Block 34, Huang Hekou Sag, Bohai Bay Basin, China

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The Huanghekou Sag, located in the southeastern Bohai Bay Basin of northern China, provided excellent geological conditions for the formation of subtle hydrocarbon accumulations in this area due to the large-scale shallow water delta system developed in the Neogene. It is key to precisely describe reservoir sandbodies in analyzing geological conditions of the formation of subtle hydrocarbon accumulations; whereas the core issue is to establish relationship between lithology and its associations and attribute (amplitude) in analyzing sandbody reservoir or sedimentary facies. Detailed studies were carried out closely related with establishing this relationship: 1) High frequency sequence analysis is conducted within the third-order sequence framework and sequence is subdivided into parasequence set (fourth-order); 2) Lithology type and its association characteristics are counted and analyzed in details within high frequency sequence framework; 3) Extraction, correlation and optimization of attributes are conducted with high frequency sequence framework; 4) Selecting 3-D areas with relatively dense drilling wells to conduct analysis of relationship between seismic attribute and lithology at drilling well position via statistical methods; 5) The forward synthetic seismic models of 1-D sandbody development are established which indicates vertical associations of sandbody and mudstone, and the relationship between the microfacies they represent and synthetic seismic amplitude; 6) The vertical and horizontal development models and 2-D forward synthetic seismic models of genetic sandbodies are established; synthetic seismic records are correlated with practical seismic profiles to prove the credibility of the spatial development geological models of sandbodies which is the foundation of reasonably describing sandbodies in details.

An example was targeted at sequence SQ1 of the lower member of the Upper Miocene Minghuazhen Formation in BZ34 block of the Huanghekou Sag, Bohai Bay Basin, and totally 10 parasequences were subdivided. Detailed statistics of lithology of each parasequence indicate they were dominated by sandbody and mudstone. Sandstone with larger thickness mainly distributed in PSS1 and PSS10 and other parasequences were dominated by thinner sandstones. Development of sandbody is mainly related with its deposited location within a sequence. Relationship between lithology and its association and amplitude was established as follows: strong amplitude agrees well with thicker sandbodies, weak amplitude represents poor development of sandbodies (with thickness of sandbody less than 2 m), and medium amplitude usually coincides with a large set of mudstone interbedded with medium-thin sandstone, based on statistics of RMS amplitude and lithology of well locations, 1-D forward simulation of 7 types of lithology associations, spatial distribution and forward simulation of 2-D sandbodies.

Keywords: High frequency sequence; RMS amplitude; Geologic-geophysical model; Description of sandboy; Huanghekou Sag

Sedimentary Characteristics and Seismic Geomorphology of Gravity-flow Channels in Rifted Basin: Oligocene Shahejie Formation, Qinan slope, Huanghua Depression of Bohai Bay Basin, China

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In this study, seismic sedimentology was applied to characterize a lacustrine gravity-flow depositional system in the Oligocene Shahejie Formation on the Qinan slope in the Huanghua faulted depression of the Bohai Bay Basin, China. Ninety-degree phasing of seismic traces tied log lithologies (sandstone and shale) to the seismic signal in a relative impedance sense. Sedimentary textures from core descriptions and wireline-log facies analysis were used to convert seismic facies into depositional facies. A stratal slicing created a geologically time-equivalent seismic display that revealed the seismic geomorphologic patterns of the depositional systems, which were then employed to study the plan view pattern and vertical evolution of the depositional systems. This study suggests that there are at least three types of gravity-flow deposits developed in the Oligocene fault-depressed lacustrine basin, including sandy debris flows, slumps and turbidites. Among these, the sandy debris flow is the main and most important depositional type. The C-M plots from core analysis demonstrate that the sample points are distributed along the QR part and are approximately parallel to the base line of C=M. The cumulative granularity probability curve exhibits a circular-arcuate shape, with the suspension content exceeding 30-40% or more. The seismic facies of lacustrine gravity-flow channels can be divided into U-shaped (or V-shaped), saucer-like, worm-like, and spindle-shaped facies according to the shape of the seismic reflections, which are probably related to changes in the fluid energy from strong to weak. The stratal slices demonstrate that during the period when tectonic movement was active and the maximum lake flooding developed, the slope of the lacustrine basin was steep, and the gravity-flow channels that developed along the valley were narrow, straight, and almost parallel to each other. However, at the beginning of lake flooding and in the late period of highstand (HST), the width and sinuosity of the channels increased, and channels became braided downstream, resulting in less erosion of the underlying strata. The integrated gravity-flow depositional systems of the studied area consisted of channel deposits controlled mainly by sandy debrites and the fan-shaped turbidites that developed at the end of the channels, where the topography was open and relatively flat. The source of the gravity-flow sediments was mainly the delta front of the higher area, though some sediments brought from the floods cannot be expelled.

Keywords: Seismic-Geomorphology, Seismic-Sedimentology, Lacustrine Gravity-flow Channels, Es1 Formation, Qinan slope

Sequence Stratigraphic Framework: Upper Triassic Yanchang Formation, Ordos Basin, North China

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The Ordos Basin, located on the western part of the North China Platform, is one of the most petroliferous basins in China. Most of the oil production in Ordos Basin occurs from the Upper Triassic Yanchang Formation. An approach was adopted here that applies the principles and techniques of sequence stratigraphy to establish a sequence stratigraphic framework for the Yanchang Formation, and describe the sedimentary characteristics of the 3rd-order sequences. Using outcrop, core, well logs and seismic data, seven 3rd-order sequence boundaries and four 2nd-order sequence boundaries were identified. The sedimentary sequences and lithological cycles were recognized by studying natural gamma curves using the method of band-pass filtering, and six distinct lithologic cycles were determined in the Yanchang Formation. The identification of sequence boundaries and the determination of lithological cycles were integrated, allowing the Yanchang Formation to be divided into three 2nd-order sequences, and the three 2nd-order sequences to be subdivided into six 3rd-order sequences. During deposition of the Yanchang Formation, the Ordos Basin was a cratonic basin where laterally uniform sequences are separated by regional unconformities. These observations imply deposition in a relative stable depositional environment. Changes in the nature of deposition systems are affected by changes in the nature of tectonic zones in the basin. Alluvial fan deposits are located on the West Marginal Thrust Zone. Fluvial deposits are located on the northeast and southwest of the basin, adjacent to an active source of clastic sediment. Lacustrine deposits are located on the sag zone near the western part of the basin. Fan-delta systems are located on the West Marginal Thrust Zone and the South Marginal Zone. Meandering river delta deposits are located on the northeastern part of the basin. Braided river delta deposits are located on the southwestern part of the basin. The general absence of slope break zones, suggest that the thickness of sandstone bodies in lowstand systems tracts is not great. These sequences of the Yangchang Formation have the characteristics of multiprovenance (Northeast and Southwest) and multicycle (six cycles) deposits. Based on sedimentary facies, we also established a deposition architecture model for this formation in the Ordos Basin.

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Reservoir bed characteristics and favorable reservoir bed prediction of tight sandstone within coal measure strata: A case study from the Lower Jurassic reservoir bed in Kuqa Depression, Tarim Basin, China

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Based on the study on reservoir bed characteristics and porosity evolution of the sandstone within the Lower Jurassic coal-measure strata in the Eastern Kuqa Depression, Tarim Basin, the reservoir bed in the study area is compacted under the influence of acidic aqueous media that was generated from coal measure strata during the early phase of diagenesis. The development of favorable reservoir bed is comprehensively controlled by sedimentation, diagenesis and tectonism: the effect on physical property of reservoir bed is more from compaction than cementation; coarser sandstone possesses stronger compaction resistance and is more vulnerable to dissolution; better developed fractures result in stronger dissolution ability of sandstone. Therefore, the coarse sandstone that occurs in braided channel facies and the strongly dissolved strata with well developed fractures are predicted to be the favorable reservoir beds in the study area.

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Oil accumulation related to migration of source kitchens in the Lukeqin Structural Belt, Turpan-Hami Basin, China

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The Lukeqin structural belt is the main heavy oil accumulation zone in the Turpan-Hami Basin. The recent discovery of light oil in the Triassic indicates that there may be multiple source kitchens contributing to the oil accumulation. Oil geochemical analysis and oil-source correlation show that the oil in deep and shallow reservoirs of the Lukeqin Oilfield presents different physical and saturated hydrocarbon mass spectrum characteristics. The Triassic heavy oil is derived from northern Upper Permian lacustrine source rocks, and the light oil in the Yudong-9 Well from northwestern Lower Jurassic coal-measure source rocks. The timing of oil charging was determined by K/Ar isotope dating, reservoir fluid inclusion analysis and the evolution history of different source rocks. In summary, the accumulation process consists of two stages. From the end of the Triassic to the early Jurassic, the northern Permian source kitchen generated a considerable amount of oil, which was finally degraded to heavy oil, which migrated to the south and then accumulated. The northwestern Jurassic coal-measure source kitchen began to generate oil at the end of the Cretaceous, while the northern source kitchen could only generate a little hydrocarbon. The heavy oil and the light oil have different source rock locations, migration directions and accumulation times. The migration of hydrocarbon source kitchens affected the present-day distribution of heavy oil and light oil reservoirs.

“Flood causes” braided river delta depositional model of the Upper Paleozoic in Ordos Basin

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Ordos basin is the second largest basin in China. Its total area is 25×10^4 km^2. There is rich gas resource and broad exploration field in Ordos basin. Vertically, there are several gas bearing stratum. Horizontally, gas bearing area is large. In 1989, Jingbian gas field was found. Jingbian gas field is the first gas field with proven resource of 100 billion cubic meters located in weathering crust of lower Paleozoic. After that, several giant gas fields were found, such as Wushenqi, Yulin, Shenmu, Zizhou and Sulige gas field. Total proven gas resource is $3.54\times10^{12}m^3$. Gas exploration of upper Paleozoic mainly focused in Shanxi-He8 formation of middle- northern Yishan slope. Shanxi-He8 formations are main gas bearing strata. Lithology of Shan1 and He8 is sandstone and mudstone. And lithology of Shan2 is sandstone and mudstone interlayered with coal. Sandstone of Shan1-He8 formations is widespread in basin. Thickness and width of single sand body is 10～40m and 10～30km. These sand bodies are superimposed vertically and interconnected horizontally. Previous studies showed multiple interpretations for genesis of these sand bodies. Mainstream view maintained that genesis and widespread distribution of these sand bodies were results of braided river – delta sedimentation and frequent rework of river. While some researchers held that sand bodies of He8 formation were beach bars. In a word, previous researchers tried to explain widespread distribution of Shan1-He8 sand bodies. But, these models could not explain widespread distribution in whole basin. Especially, previous studies could not explain the existence of middle-coarse sandstone and pebbly sandstone in several wells in southern part of basin. In this paper, the author discussed the sedimentary system and distribution evolution model of Shan1-He8 formations based on outcrop and core description, modern geological investigation and water flood simulation experiment. Through analysis of palaeogeography and detailed description of cores, the author proposed that widespread distribution of coarse sandstone of Shan1-He8 formations is similar to "Flood causes" braided river delta sedimentation. The author validated "Flood causes" braided river delta sedimentation model by water flood simulation experiment. The experiment indicated that gentle landscape, repeated advance and retreat of water, strong hydrodynamic power and sufficient sediment supply are main controlling factors of widespread distribution of sand bodies. In relatively dry climate conditions, transportation of multiple-phases floods could lead to long distance extension of coarse sand. This resulted in horizontally widespread and vertically overlaying braided river delta sand bodies. The author drew distribution maps of sedimentary facies and sand bodies. These maps is helpful to find favorable exploration targets.

Key words: Floods cause，Braided river delta，The relay carrying，Upper Paleozoic，Ordos basin

Two different types of eyeball-shaped limestone from Mid-Permian of Sichuan Basin, Southwest China

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During the Mid-Permian, the Mid-Upper Yangtze region was covered by carbonate rocks, which have been identified as regional marine source rocks in the Paleozoic. One kind of special structure of these carbonate rocks is named eyeball-shaped limestone, composed of the "eyeball" and "eyelids" component. It is widely distributed in the lower section of Qixia Formation and the mid-lower part of Maokou Qixia Formation, Middle Permian. "Eyeball" is lighter in color, enriched in bioclastic, such as algae, brachiopods, foraminifera. In contrast, "eyelids" are darker in color, dominated by mudstone. They are rich in ostracods and experienced intensive chemical compaction, resulting in the oriented arrangement of the ostracod shells.

Previous studies hypothesized that associated variations in eyeball and eyelids component were related to the development of upwelling, which could influence the paleo-oxygenation facies of the shallow shelf. Here we present two different types of eyeball-shaped limestone of Maokou Formation from Huayingshan and Dapuzi sections, Chongqing. Eyeball-shaped limestone of Huayingshan section show typical characteristics mentioned above. In addition, eyelids" are organic - rich. Eyeball-shaped limestone of Dapuzi section show the similar outcrop characteristics with that of Huayingshan section. However, when we observe "eyeball" and "eyelids" under the microscope, they both contain abundant fossil algae, dominated by dasycladacean algae, which usually live in shallow normal tropical water. Calcareous algae are well preserved in "eyeball", but they are pressed elliptical shape, and oriented parallel to bedding planes in "eyelids".

Our results suggest that the genesis of eyeball-shaped limestone is more complex than expected. The "eyeball" and "eyelids" are not necessarily formed in different depositional environments. Fragile skeletons such as calcareous algae are well preserved in "eyeball", indicating that cementation took place during the early diagenesis with little diagenetic compaction. They were broken due to compaction of the unlithified "eyelids", indicated by a large number of dissolution seams.

We proposed that the upwelling cannot attribute to all the eyeball-shaped limestone in the Mid-Permian of Sichuan Basin. On the contrary, the environment deposited the "eyeball" and "eyelids" may be not so different, and early diagenesis seems to play a primary role in the development of this special structural. Furthermore, our finding in Huayingshan section indicates the dissolution of calcareous algae is not the main source of cement for carbonate sediments in the aragonite sea.

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Tectonics, stratigraphy and Mesozoic hydrocarbon potential in the Levant Deep Marine Basin, Eastern Mediterranean

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The Syrian Arc (SA) is series of anticlines and synclines extending from central Syria, Jordan, Palestine and Sinai forming an S-shaped fold belt in the tectonically complex region of the Eastern Mediterranean (EM, here we refer to Levant Deep Marine Basin to the west and Pleshet Basin to the east). The recent large gas discoveries since 2009 are located within late tertiary deep-water of EM with total recoverable reserves of over 30 Tcf, attracting the attention of many researchers to this region. A proven gas reservoir in the Lower Miocene Tamar sands with over two thousand meters thickness is sealed by the Messinian Salt, trapped in 'Syrian Arc (SA)' type folds. Folding of the entire SA fold system was initiated in the late Turonian, causing an E-W trend with abrupt thickness changes of Mesozoic-Cenozoic formations and folding asymmetrically on the Western Bank of Syrian Arc (WBSA) which affected three stages (Pre-Jurassic, Late Mesozoic-Early Cenozoic and Late Eocene-Oligocene) in the region.

Paleogeographic reconstructions show that shallow-marine carbonate shelf developed within the passive margin from the Middle Jurassic to the middle Cretaceous, followed by Tethyan transgression and pelagic and fluvial sedimentation from the late Cretaceous and late Tertiary, respectively. A stratigraphic summary of the WBSA from published seismic profiles show lithostratigraphic successions and depositional sequences from the Mesozoic times. All these successions include various source and reservoir rocks that were deposited in the proximal and distal parts of the EM. Hydrocarbon accumulations of the four main reservoirs are known in the EM: 1) oil-prone Middle-Upper Jurassic shallow-marine carbonates and 2) Lower Cretaceous shore-line sandstones, mainly in the Pleshet Basin; 3) gas-prone Upper Oligocene to Early Miocene Tamar turbidite sandstones and 4) lower Pliocene turbidites, below and above the Messinian evaporites, respectively, mainly in the Levant Deep Marine Basin and offshore Pleshet Basin. Oil source is organic-rich Barnea limestone in Middle Jurassic and Ghareb shale in Upper Cretaceous. The vertical oil migrations accumulate at the crest of the anticlines corresponding to the SA, according to published seismic profiles. We pronounce potential for hydrocarbon accumulations in the Mesozoic sediments in the Levant Deep Marine Basin.

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Carbon and Strontium isotope-stratigraphy research of the Carboniferous in Guizhou Province, Upper Yangzi region

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The Carboniferous is an important part of the Late Paleozoic, and there were many geological and biological events documented, e.g. three ice episodes, sea- level changes, and the end Serpukhovian extinction event, etc. The $\delta^{13}C$ as a sensitive proxy of biological and environmental cycles can be used for high-resolution chemostratigraphical as well as biostratigraphical correlation in a short interval within a certain region; while, the $^{87}Sr/^{86}Sr$ is considered as having a stable trend and can be used as a global definition of the long interval of 2-50 Ma, which are sensitive proxies of the eustatic change and mantle-crust activities and benefit to the research of biological and environmental co-evolution.

Nashui section is about 48 km southwest from Luodian City in Guizhou Province. A continuous sequence of Carboniferous deposits is well exposed along the east limb of a brachyanticline, and mainly consists of thin bedded cherty wackestone, carbonate turbidites and debris-flow deposits. 93 samples were collected for the measurement of $\delta^{13}C$ ratios, and 50 micrites were selected for the analysis of $^{87}Sr/^{86}Sr$. According to the data of carbon and strontium isotopes, $\delta^{13}C$ and $^{87}Sr/^{86}Sr$ dating curves can be established and analyzed.

Based on the different trends of carbon and strontium isotopes, the curves can be divided into five parts: (1) Middle and late Visean, $^{87}Sr/^{86}Sr$ and $\delta^{13}C$ curves have the same trend of decline. Because it was developing at a time of the first ice age of the Carboniferous, many lands were covered with glaciers, and some biomass declined, it caused $^{87}Sr/^{86}Sr$ and $\delta^{13}C$ ratios to fall; (2) End Visean, $^{87}Sr/^{86}Sr$ fall steadily, and the lowest value of the Carboniferous appeared, which is caused by the sea-level rise. But the $\delta^{13}C$ curve has an opposite trend, and the negative shift caused by the increasing biomass, because it is a glacial time interval, so the transgression and warm climate make the biomass rise; (3) It represents the curves from the Serpukhovian to early Bashkirian. In this stage, $^{87}Sr/^{86}Sr$ and $\delta^{13}C$ curves have a positive trend. However, the second ice age of the Carboniferous was developing in this interval. Then, $^{87}Sr/^{86}Sr$ and $\delta^{13}C$ curves should be falling. The reason is that the second ice age isn't in their top peak, there is also a strong continental weathering, and coal is deposited globally, so $^{87}Sr/^{86}Sr$ and $\delta^{13}C$ curves have a positive excursion; (4) the curves from early Bashkirian to middle Kasimovian. They have opposite trends, $^{87}Sr/^{86}Sr$ ratios rise first and then decline, but $\delta^{13}C$ curve has a negative shift first and then a positive excursion. And it is caused by the glacial episode in the early stage, and after this, came the interglacial stage, the sea level rose; (5) End Carboniferous stage, $^{87}Sr/^{86}Sr$ and $\delta^{13}C$ ratios are depleting continuously, it might be caused by the formation of Pangea continent.

Keywords: Carboniferous glaciers; Carbon isotopic stratigraphy; Strontium isotopic stratigraphy; The Upper Yangzi region

Permian Mantle-Sourced Magmatic and Hydrothermal Exhalites, Santanghu Basin, NW China

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A suite of new sedimentary rocks are discovered in Permian Lucaogou Fm. in Santanghu rift basin, Xinjiang, NW China, formed by Late Carboniferous intracontinental rifting. They are mm-laminated and 200 m thick and composed mainly of grains from a magmatic source and deposited in a starved profundal lake. They are named as magmatic and hydrothermal exhalites. Samples from cores and Yuejinggou outcrop were studied using transmitted and reflective-light, CL, and SEM microscopy, microprobe and XRD analyses. Element composition and Sr-Nd, inorganic C and O isotopic compositions were analyzed to interpret the origin of minerals and diagenetic fluids.

Three groups are identified. Group I is magmatic-hydrothermal exhalites, composed of grains characteristic of magmatic or hydrothermal-smoker rocks. They were transported by explosive, effusive, or exhalative flows from subsurface and deposited directly on the lake floor. The first of three types is explosive exhalites of alkaline feldspars and fragments of carbonatite, pyroxenite, analcime phonolite, and intermediate-felsic and alkaline tuffs. The second is effusive exhalites of mainly carbonatite fragments. The third is hydrothermal exhalites of dolomite, ankerite, quartz, and pyrite, characteristic of black and white smokers. Group II are mixed sedimentary-exhalative rocks. The first of three types is composed of mixed plutonic fragments and carbonized grains, including carbonaceous alkaline and alkaline feldspar-dolomite rocks. The second is collapsing breccias, formed by in-situ or secondary deposition of fragments of collapsed smoker chimneys and pillars. The third is hydrothermal microbialite formed by thermophilic and toxin-loving microbes, including pyritized and apatitized microbialites and microbial dolostone. Group III is phreatomagmatic breccias, formed by brecciation of consolidated or semi-consolidated country rocks.

An example is beforsite explosive exhalite, containing beforsite fragments of serpentinized dolomite phenocrysts and irregular dolomite and serpentine groundmass. Six samples have a low Si (SiO_2 < 34%), high Na and K (K_2O+Na_2O < 4%), and high Mg, Ca, and Fe ($CaO+FeO+Fe_2O_3+MgO$ = 33-39%) content. The Si and Mg content is higher and Ca lower than that of typical beforsites. The content of Ce, Zr, Ti, and P is characteristic of carbonatite, whereas that of Sr, Ba, Nb and REE is of alkaline rocks. The crystallization of high-T carbonatite magma was affected by metasomatism by a reducing fluid as indicated by enrichment of LREE and large lithophile elements Rb, Ba, Th, K, and Sr, depletion of HREE, P, and high field-strength elements Nb, Ti, and Zr, high concentration of LREE, and a negative Eu isotope. The other example is microcrystalline dolomitic hydrothermal exhalite, which occurs as laminae 0.5-3 mm thick and was produced by a white smoker. The $^{87}Sr/^{86}Sr$ ratio of 10 whole-rock samples is 0.70457-0.706194, average 0.705360. It is lower than 0.7067-0.7085 for Permian marine carbonate rocks and lower than the average 0.720 for crustal sialic rocks, but similar to the average 0.70350 for mantle-sourced rocks, suggesting a mantle source.

Frequent mantle magmatic and hydrothermal activities caused explosive and effusive magmatic and exhalative hydrothermal processes in the basin. Group I formed during episodes of small active volcanism. Magma evolved to form peralkaline carbonatite and alkaline tuff initially and intermediate-felsic rocks at the end. The results show a special type of sedimentary rocks and shed light on processes of plate amalgamation and origin of tight oil in Lucaogou Fm. in northern Xinjiang during late Paleozoic.

The Guadiana incised-valley system: preliminary results from the LASEA 2013 cruise

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The LASEA 2013 cruise was executed in August 2013 in the northern margin of the Gulf of Cádiz, with the main goal of collecting data from the Guadiana River-influenced shelf, in order to: (1) study changes affecting the entire drainage basin, supposedly recorded in the shallow-marine record; (2) correlate shelf unit sequences with the upper slope sedimentary record, composed dominantly of contourite deposits in specific stretches of the margin. As thus, the shelf record should provide the crucial link from the catchment to the deep-sea domains. As a first approach, attention is paid to the most obvious sedimentary manifestation of the influence of the river on the shelf domain, represented by the Guadiana incised-valley system. Previous studies in the area identified several incised-valley features, but data coverage was not sufficient to capture their spatial variability and complexity.

The database comprises both geophysical and sedimentological records. Geophysical data include multibeam bathymetry, TOPAS profiles and single-channel Sparker seismic profiles. Sedimentological data include sediment cores collected with gravity- and vibro-corer devices. These data were complemented with previous seismic profiles collected with both Sparker and Geopulse seismic sources, and with previous sediment cores, mainly collected by vibration method.

Several incised-valley features are recognized at shallow waters (20-30 m), the most significant of them is identified at less than 20 m water depth, extending seaward up to more than 45 m water depth. The incised valley is at least 1.5 km wide in the most proximal (recognized) section, decreasing seawards in width. The internal architecture of the valley exhibits the intercalation of laterally prograding sediment bodies and high-amplitude, subparallel configurations laterally related to valley margin prograding wedges.

The internal facies architecture suggests a transition from relatively high-energy fluvial to proximal estuarine environment to a lower-energy estuarine depositional environment. In addition, the main incised-valley system is located east of the present-day estuarine system linked to the Guadiana River. Thus, the study of the valley extension into the shelf is expected to provide clues for the recent reorganization of the entire fluvial system, during the course of the postglacial sea-level rise and ensuing sea-level stabilization.

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The Coniacian–Campanian Latium–Abruzzi carbonate platform, an example of a facies mosaic

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This study describes facies mosaics from a rudist dominated carbonate platform from the Coniacian–Campanian interval that widely crops out in the Central and Southern Apennines, Italy. The Upper Cretaceous succession has been analyzed in order to propose a depositional model to identify the building blocks and to analyze their vertical evolution and response to sea-level changes. The focus is on the western sector of the Latium–Abruzzi platform, where complex, gradual lateral and vertical facies changes are recorded.

The studied succession is assigned to the ‘‘*Accordiella conica* & *Rotorbinella scarsellai* Biozone’’. According to the stratigraphic distribution of the same taxa recognized in the southern Campanian Cretaceous limestones of Appennine platform, and the finding of a bio-horizon bearing *Keramosphaerina tergestina* associated with *Murgella lata* and *Scandonea samnitica*, the fossil content suggests a stratigraphic interval not older than Coniacian-Campanian.

Three lithofacies associations (LF-A, LF-B, LF-C) characterize the analyzed succession. The first lithofacies association (LF-A) is represented by rudist pillarstone and rudist rudstone/floatstone passing laterally into wackestone/packstone showing HCS. LF-A developed in the low to moderate energy environments of the inner shelf. The second lithofacies association (LF-B) is dominated by cross-bedded grainstone representing the reworking of bioclastic grains (rudist fragments) derived from the areas of the shelf colonized by rudist biostrome. The mobilization of sediment took place in response to storm or wave currents that promoted the development of migrating lime-sand shoals passed into submarine dunes in an open-shelf setting. The last lithofacies association (LF-C) represents the most proximal environments, between upper intertidal and restricted lagoon environments. The lithofacies is represented by mudstone to wackestone and laminated bindstone. Laminoid fenestrae and microbial layers are common.

A correlation panel of five measured stratigraphic sections shows that the recognized LF laterally pass into one another over a few hundred meters, forming a facies mosaic. The recognized facies are arranged into shallowing-upward cycles characterized by silt- and mud-rich facies at the top of each cycle. However, due to the complexity of the carbonate system, these cycles were only recognized through the correlation of stratigraphic sections and were less evident by analyzing the single stratigraphic sections.

Finally five major intervals were recognized, each of them dominated by one or two facies associations. With the exception of the basal part of interval I, which is composed of intensely dolomitized limestone, intervals II and III record an increase in hydrodynamic energy suggesting more open conditions. Successively, the dominance in mud-supported textures in interval IV, suggests more restricted conditions that culminated in emergence. A new episode of open-marine conditions is marked by the occurrence of LF-A and LF-B in interval V.

This outcrop investigation evidences how the application of facies mosaic concept supports the role of the autocyclic factors in the generation of shallowing-upward cycles and attenuating the allocyclic forcing in a rudist dominated platform.

Pockmarks in Lake Neuchâtel: studying the sedimentological and geochemical characteristics of three crater-shaped lake floor depressions

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In the marine environment where pockmarks have been studied in great detail, it has been found that they are often the surface expression of focussed fluid flow. In lakes however, fewer studies of pockmarks are available and this paradigm stands yet to be more thoroughly verified for lacustrine settings. Here, we present a detailed sedimentological and geochemical study of three pockmarks, discovered as crater-shaped lake floor depressions during a multibeam bathymetric survey of Lake Neuchâtel (Western Switzerland) in 2012. Seismic data (3.5 kHz resolution) across the pockmarks show distinct seismic reflections intercalated within the background sedimentation. These signals have been interpreted as overflow deposits, documenting phases of active fluid flow and sediment mobilization from inside the pockmarks, causing sediment to be spilled over the rims and deposited on the outside of the craters.

Our study aims at providing a detailed characterisation of the pockmarks based on their morphologic expression, sedimentological archives and geochemical fingerprints in order to understand the relationships between the overflow events and their triggers in the past and potentially today. The morphologic expressions have been studied by multibeam bathymetry and reflection seismic data, as well as lake floor video inspection with a remotely operated vehicle (ROV) provided by the lake police. In Kullenberg type long piston cores and gravity short cores adjacent to the pockmarks the sedimentary composition of the overflow material as well as the repeated occurrence of pockmark activity can be studied. The presence and isotopic signal of fluids (methane and/or water) possibly escaping through the pockmarks have also been investigated. Therefore, headspace methane of sedimentary pore fluid samples from inside the pockmarks have been analysed by gas chromatography and mass spectrometry.

The pockmark named Chez-le-Bart (diameter ≈ 160 m, depth ≈ 10 m), is partially filled with poorly consolidated mud. Compared to the overflow material in the sediment cores, this mud shows clear similarities in terms of the total carbon (≈ 5.5 %C) and quartz grain contents (based on coulometer measurements and smear slide analyses respectively). A second pockmark – Treytel (diameter ≈ 100 m, depth ≈ 4 m) – encompasses two smaller sub-craters partly overprinting each other. A third pockmark – La Lance (diameter ≈ 95 m, depth ≈ 13 m) – seems to be associated with a tectonic fault zone and the evidence of sediment expulsion is less clear. Pore fluid measurements indicate that methane concentrations in the surface sediments (max. 90 cm depth) at all three pockmarks are low (< 6.0 µmol CH_4/ml sediment). All isotopic values of $\delta^{13}C_{CH4}$ average around 78.5 +/- 2.9 ‰ PDB indicating a microbial origin of the methane.

From the sediment found within Chez-le-Bart and Treytel it is hypothesised that actively outflowing fluid prevents this material from properly consolidating. The low methane concentrations associated with the pockmarks indicate that groundwater rather than methane is responsible for the expression of activity at the craters. However, geochemical and sedimentological investigations are still ongoing in order to decipher the role and history of activity of these three pockmarks for Lake Neuchâtel.

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Stable isotopes of tufa in temperate karstic regions: reliable palaeoenvironmental proxies or erratic records?

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The objective of the study was to evaluate the relevance of sub-recent tufa barriers in groundwater-fed rivers in temperate humid karst regions as (palaeo)environmental indicators. The main question investigated was, how do recent tufa formations in the Krka River reflect the hydrochemical and environmental conditions.

16 barrage tufa barriers formed in the Krka River (SE Slovenia) in a 14 km long section (between 7 and 21 km downstream the spring) were analysed for their elemental, mineral and stable isotopic (C, O) composition, and compared to the recent hydrogeochemical and climatic parameters. It was hypothesized that in spite of complex hydrological situation, the elemental and isotopic proxies in tufa would reflect general environmental conditions in the catchment area.

The lithology of the catchment area reflects in the major solute composition of the river water, dominated by large input of HCO_3^-, Ca^{2+} and Mg^{2+} originating from carbonate dissolution. The most conspicuous characteristics of the river water chemistry was its high Mg/Ca ratio (0.35 – 0.66), showing a high degree of dolomite relative to calcite dissolution. The overall carbon mass- and isotope balance of the river showed that approximately equal fractions of total dissolved inorganic carbon is of geogenic (aquifer dissolution) and biogenic origin, mostly washed out of the soil zone. The river water was up to 10 times supersaturated with respect to calcite throughout the year. Nevertheless, the tufa deposition is localized to rapids and cascades. The abiotic carbonate precipitation rate was calculated from measured hydrochemical parameters and the temperature, where the DBL (Diffusive Boundary Layer) model for a H_2O-CO_2-$CaCO_3$ system supersaturated with respect to calcite was applied. Assuming the DBL thickness of 100 μm and thickness of water layer above the precipitation surface of 10 cm, the calculated precipitation rate was between 1.32 and 1.38 mm yr^{-1}, which yields the barrier growth rate of up to 1 cm per year; this is in good agreement with observations in the field. Chemical and mineralogical compositions of individual barriers were very variable, with calcite fractions between 75 and 98 %, and dolomite content up to 20 %. The Mg/Ca ratio of calcite precipitated from the river at ambient conditions should vary between 0.026 and 0.033, whereas the measured values were between 0.025 and 0.120 due to the Mg contributed by dolomite and non-carbonate detritus. Because of inhomogeneous distribution of Mg-bearing minerals in the texture of tufa, the elemental ratio cannot be used as an indicator of environmental conditions, apart from the mechanical weathering and erosion of dolomite in the watershed. While the dolomitic detritus can easily be identified through its chemical composition, this is not the case for the detritic calcite originating from limestone weathering, but both of them strongly affect the C and O isotopic composition of tufa, increasing its $\delta^{13}C$ and $\delta^{18}O$ values by up to 4 ‰. Of all analysed barriers, only a few represented “pure” tufa, where the C and O isotopic compositions, as well as Mg/Ca ratios reflected well the ambient conditions of precipitation, which was much more intense in the summer months than during the rest of the year.

The results showed that both elemental and isotopic records of tufa precipitated from the same river may be subject to large spatial variability, in particular where dolomite is abundant in the watershed and weathering and erosion may contribute considerable proportion of detritic fraction.

The sedimentological context of a complete whale skeleton hosted within a Holocene sabkha sequence

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This study employs sedimentary sections hosting a cetacean skeleton as a new data source to constrain the timing of, and characterise the sedimentary sequence associated with, the Holocene sea level maximum in the Persian Gulf.

During the Last Glacial Maximum (LGM) eustatic sea level lay 120 – 130 m lower than today exposing the floor of the Gulf to aeolian processes. With the end of the LGM, sea levels increased with marine waters reaching the Strait of Hormuz and entering the Gulf by 12.5 ka. Eustatic sea level reached present levels by approximately 7 ka and has since declined due to the effect of hydro-isostasy, yet, the timing and elevation of the Holocene highstand varies spatially and temporally.

The study site lies at the termination of a dredged channel excavated through the Abu Dhabi coastal sabkha sequence. During 2006 a cetacean mandible was exposed in the channel wall, subsequent excavation revealed a largely-intact skeleton of a baleen whale of the genus *Megaptera*. The sedimentary sequence, within which the cetacean skeleton is hosted, records the termination of the Holocene reflooding of the Gulf.

The lowermost facies comprises a siliciclastic horizon interpreted to represent a transgressive unit formed as the underlying quartz-rich aeolian dunes were flooded, eroded and admixed into the transgressive carbonates. An overlying microbial mat horizon is inferred to have been deposited in ponds associated with the flooding of the antecedent dune topography during slowing transgression followed by a stillstand. The hardground that immediately overlies the microbial mats is interpreted to have developed in the lower intertidal to subtidal zone during renewed, and rapid, transgression. As the lower portions of the cetacean jaws and skull are locally embedded within the upper part of the hardground, the cetacean must have been emplaced into the intertidal zone prior to complete lithification. The stratigraphic sequence overlying the hardground, and containing the cetacean skeleton, exhibits a fining-upward trend consistent with a reduction in energy regimes due to deepening of the palaeoenvironment during continued transgression.

This sequence differs significantly from the sedimentary sequence described previously from the Abu Dhabi sabkha and associated with a progradational geometry. Of particular significance is the lack of a microbial mat horizon at the contact between the carbonate-dominated intertidal sediments and the overlying supratidal evaporite-dominated units. Microbial mats demark the uppermost intertidal zone and, during progradation, are easily preserved on entering the supratidal environment. Their absence from the Mussafah Channel section is consistent with a rapid fall in sea level in the form of a forced regression.

The timing of emplacement of the whale has been constrained through radiocarbon dating of skeletal allochems associated with the skeleton. The calibrated ages are internally consistent with the oldest date (6887-6567 cal BP) being recorded from the hardground. A date of 5304-4957 cal BP was recorded from a barnacle that is believed to have been attached to the whale's skin during life and, thus, dates its emplacement into the intertidal setting. The sediments surrounding the skeleton are dated to (5285-4922 cal BP); this is inferred to represent the latest stage of transgression. It is inferred that the Holocene highstand terminated at approximately 5,000 BP.

Millennial fluctuations of sediment loads within the Rhone turbiditic system (Gulf of Lions, western Mediterranean)

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Turbiditic systems are active when they are fed by sediments transported from the shelf to the basin floor. However the sediment transfer depends upon the connexion between sediment source and the turbiditic system. This source-to-sink linkage is mainly controlled by climate and sea level changes.

The Rhone Turbiditic System (RTS) is the largest sediment body in the western Mediterranean. It results mainly from the accumulation of sediments supplied by the Rhone River. Presently, the head of the Petit Rhone Canyon is situated at about 70 km from the river mouth; in contrast, direct connection existed during the Last Glacial Maximum (LGM). Temporal fluctuations linked to sea-level changes, together with climate changes in the watershed have had a major impact on the amount and lithology of sediment delivered to the basin floor, as well as on sedimentary processed controlling the architecture of the turbiditic system.

Turbiditic environments are generally considered as inappropriate for bio-stratigraphic and chrono-stratigraphic reconstructions. However, we developed here a method for identifying hemipelagic beds within turbidites, based on the amount of reworked foraminifera. The isotopic signature of these hemipelagic beds is compared to a reference core and allows to establish a robust chronology of two cores situated within the RTS canyon and upper valley. Based on this chronological framework, it was possible to determine the temporal and spatial variability of the sedimentary record and to better understand the control of internal and external forcing.

The results of our study allow to conclude that: 1) the pelagic material sampled between turbiditic beds has preserved paleoceanographic changes; 2) the morphology of the RTS controls the amount of confinement of the turbidity currents and results in various arrangements of lithofacies; 3) Hyperpycnal turbidites are recognized for the first time in the RTS; they correspond to the period of connexion between the Rhone river and the Petit-Rhone canyon head during the LGM. 4) the disconnection is marked by a decrease in the number and thickness of turbidites around 19 ka cal BP.

The presence of hyperpycnites, despite the large size of the Rhone, testifies for the huge amount of sediment delivery to the deep-sea between 20 and 19 ka, in phase with glacier retreat in the Alps.

Fauna associated to rhodoliths beds megahabitats from Vitória-Trindade Ridge, Espírito Santo, Brazil

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The Vitoria Trindade Ridge (VTR; 20°S–21°S, 29–38° W) comprises a west-east chain of nine seamounts extending to 1,150 km distant from Espírito Santo State slope, with depths ranging from 10 to 100 meters (average depth near to 60 m) and includes two islands Trindade and Martin Vaz at its eastern end. Surveys using Side Scan Sonar (SSS) and Remote Operating Vehicle (ROV) were conducted on four main seamounts (Jaseur, Davis, Vitória and Almirante Saldanha) and revealed an large extension of rhodoliths beds megahabitas in the mesophotic zone (over 30 m depths). Rhodoliths are constituted by crustose coralline algae with laminar growth that form calcium carbonate nodules. The rhodoliths recover the bottom surface constituting a hard substrate that can support a high diversity of benthic organisms. We analyzed the benthic fauna associated to rhodolith beds, most of that contributing to the rhodoliths structure construction once they also present calcium carbonate skeleton. Thirty rhodolith units were collected from each sample site by technical dive on depths ranging from 30 to 72 meters. The nodules were preserved in 10% formaldehyde solution, measured on their diameter axes and their volumes were registered. The epifauna of each nodule was registered and then they were fragmented for accessing the criptofauna. The organisms were analyzed using stereomicroscopy and sorted on high taxonomic categories (Phyla). Their occurrences were registered and the most important taxa compounding the rhodoliths associated fauna were Foraminiferea, Annelida, Mollusca, Bryozoa, Arthropoda (Crustacea), Echinoderamata and Porifera. We found two main patterns of taxonomic groups characterizing the epifauna and the criptofauna, respectively, occurring in all depths sampled. Although some groups were registered on epifauna and criptofauna, they occurred in lower number in one than in another. The higher number of occurrence in epifauna was registered for Foraminiferea (64%), followed by Bryozoa (10%) and Annelida (Polychaeta – 9%). Other groups were also observed in epifauna: Arthropoda (Crustacea - 7%), Mollusca (5%) and Porifera (3%). For the criptofauna, Annelida (Polychaeta) accounted for 50% of all registered occurrences, followed by Mollusca (Bivalvia -19%) and Echinoderamata (Ophiuroidea - 18%), Sipuncula and Foraminiferea contributed with 6% and 4%, respectively. These are the first report on biota composition from mesophotic zone rhodoliths beds from Vitória-Trindade Ridge. This megahabitat was first identified using the acoustic seafloor mapping technics. Knowledge about rhodoliths beds communities structures could evidence sedimentary process, besides contributing themselves for the sediment carbonate composition. This study brought up essential information about habitats geomorphology and functionality as subsides for planning protected areas on such a peculiar environment.

Bleached Sandstone and Ferrous Carbonate Cements are the Footprints of Ancient CO_2 Reservoirs

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In the "Grand Staircase" north of Grand Canyon (USA), the upper Navajo Sandstone (Jurassic) crops out as the 75 km-long White Cliffs. The lower Navajo comprises the Vermillion Cliffs. Some geologists argue: 1) that the upper Navajo was originally red and was bleached by the accumulation of huge volumes of buoyant hydrocarbons; and 2) that bleaching of overlying rocks was the source of iron in the abundant iron-oxide concretions of the lower Navajo. These researchers go on to interpret the concretions as primary precipitates that formed where iron-bearing, reducing fluids mixed with oxidizing water. Our work indicates that the iron-oxide concretions are secondary, and formed via microbial oxidation of siderite ($FeCO_3$) concretions. Rather than calling on two waters that mix, we argue that siderite and accompanying ferroan calcite precipitated in reducing water beneath bleached sandstone, and that later, as the Colorado Plateau was uplifted and oxidizing waters invaded the Navajo, siderite was altered to iron oxide. In contrast, ferroan calcite did not dissolve. Near-zero $\delta^{13}C$ values from this calcite indicate minimal contribution from reduced carbon sources. Our reinterpretation of original mineralogy of concretions avoids the problem of how oxidizing water could have penetrated the lower Navajo while reducing fluids were bleaching the upper Navajo. We also answer the question of why iron was transported downward. When CO_2 dissolves in water, it increases that water's density. Researchers interested in the fate of supercritical CO_2 injected into vertically confined aquifers have shown that dissolution of CO_2 into formation water causes gravity-driven, convective transport systems to develop. In the study area, CO_2 (likely sourced by Oligocene intrusions) and small quantities of methane migrated upward to the contact between the Navajo and overlying, impermeable rocks of the Jurassic Carmel Formation. Bleaching of the upper Navajo and downward transport of iron required two processes: 1) Sparse methane stripped the iron-oxide coatings from the sand grains, putting Fe^{2+} into solution; and 2) Dissolution of abundant CO_2 added mass to the reducing water and caused down-dip and down-section transport of Fe^{2+}, $FeHCO_3^-$. HCO_3^-. Growth of ferrous carbonate cements took place in reducing waters in and beneath the bleached zone, far from sources of oxidizing water. As the Colorado Plateau was uplifted, the Navajo on structural highs was breached, and oxidizing water invaded the formation. Iron-oxidizing microbes facilitated alteration of siderite, forming dense rinds cemented by iron oxide on the perimeters of precursor concretions. Ferroan calcite was preserved because its dissolution consumes rather than generates acid. Some iron-oxide concretions have central core zones with abundant rhombic iron-oxide pseudomorphs after siderite-- rather than diffusing to the microbes on the inner surface of the surrounding rind, the iron comprising the pseudomorphs was oxidized in situ. We propose that the change from rind thickening to core-stone oxidation (within an individual concretion) records drainage of the Navajo aquifer and the fall of the water table to a position below the oxidizing concretion. At Zion National Park, basalt dated at 1.02 Ma fills a paleovalley that was cut into concretion-bearing Navajo Sandstone. Rinded concretions with core stones lie just below the likely position of the water table at one million years ago, suggesting that they entered the vadose zone shortly after this time. Our work shows that bleached sandstone and underlying, iron-rich concretions delineate CO_2 reservoirs, and that these concretions can record aquifer drainage and the emergence of the host rocks into the unsaturated zone.

Depositional Model for Geothermal Spring Carbonates

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Geothermal spring carbonates form generally in hot spring setting. Proximal parts of this setting favor deposition of travertine rocks. Travertines are well studied in active and fossilized hot spring settings where waters are too hot and environments too harsh to allow vegetation to growth. Because water temperature rapidly decreases downstream and in isolated environments, plants colonize distal parts of geothermal springs forming tufa deposits.

Studies have been performed in the Rapolano region (Italy), Denizli Basin (Turkey) and Mammoth Hot Springs (USA). Field observations and measurements have led to lithofacies classification and three-dimensional cartography. Lithofacies are well constrained by their distribution and morphologies. Different morpho-depositional systems and environments are recognized in the three studied areas. Newly acquired data has been compiled with environmental classifications of active (Fouke, 2001) and fossilized (Guo & Riding, 1998, 1999) springs to present a depositional model for fan-&-wedge mounds formed in geothermal spring settings.

The model presents lithofacies and environmental distributions. Their lateral evolution is discussed according to the distance from the spring vent and from the primary path flow. Typical travertine lithofacies, e.g. dense laminated sparstones and porous laminated framestones (crystalline crusts, shrubs, etc…) form the more proximal deposits while typical tufa lithofacies, e.g., phytoclastic limestone and phytoherms, form distal deposits. Travertine lithofacies are also distributed according to spatial variations in spring water flow. Higher hydrodynamic conditions in the primary path flow, where spring waters are focused, lead to dense laminated sparstones. Secondary path flows are characterized by changes in hydrodynamic conditions as running and sluggish waters alternate. These conditions generally induce terrace formation.

References

Fouke, B.W. (2001) Depositional facies and aqueous-solid geochemistry of travertine-depositing hot springs (Angel Terrace, Mammoth Hot Springs, Yellowstone National Park, USA) - Reply. *Journal of Sedimentary Research*, 71, 497-500.

Guo, L. and Riding, R. (1998) Hot-spring travertine facies and sequences, Late Pleistocene, Rapolano Terme, Italy. *Sedimentology*, 45, 163-180.

Guo, L. and Riding, R. (1999) Rapid facies changes in Holocene fissure ridge hot spring travertines, Rapolano Terme, Italy. *Sedimentology*, 46, 1145-1158.

Architecture of Geothermal Spring Carbonates : example of Coexistence between Tufa and Travertine in Denizli Basin (Turkey)

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The studied deposit of Obruktepe (Basin Denizli, Turkey) is a Quaternary deposit which forms an elongated mound and corresponds to carbonates deposited in geothermal spring setting. The 3-Dimensional architecture of the deposit provides information about development of carbonates in geothermal spring settings and evolution of environments. In fact, detailed determination of lithofacies allows to distinguish five morpho-depositional systems: (1) vent system, (2) smooth slope system, (3) travertine terrace, (4) tufa barrage and (5) flood system.

Depositional processes such as encrusting, trapping or settling have been identified according to integration of data acquired at different scales: from lithofacies observation (optical microscopy, cathodoluminescence and SEM) to geobodies observation (stratigraphic section and linedrawing) as well as stable isotope analysis.
The mean values of $\delta^{13}C$ and $\delta^{18}O$, respectively 4.9 ‰ and -8.74 ‰ PDB confirm the deep circulation of groundwater. However, the arrangement of environments strengthens the lateral continuum between travertine deposits and those of tufa in this geothermal system. As a result a depositional model is presented in which the deposit of carbonates are related to changes in spring water flow. This model allows us to discuss the factors that control the deposition of spring carbonate related to faults.

Sediment-petrological study and reservoir characterization of travertine carbonates at Rapolano Terme, Italy

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The travertine quarry La Chiusa in Rapolano Terme (Italy) has been the subject of several petrographical and geochemical studies (Chafetz & Folk, 1984; Guo & Riding, 1998) and has now been studied in the light of the increased interest in reservoir characteristics of microbial continental carbonates. Located in the back-arc of the Apenninic subduction, the western part of central Italy is characterized by extensional tectonics and high geothermal gradients. The combination of active thermal groundwater circulation, limestone subterranean reservoirs and permeable fault systems results in hot spring settings and deposition of carbonates. Both fossil and active deposits occur in the vicinity of extensional faults bordering the Siena back-arc basin.

Detailed fieldwork revealed the 3D architecture of the continental carbonate deposits (with dimensions of a couple of hundreds of meters). Four boreholes have been drilled through the deposits. The core material and the quarry faces were correlated in order to identify depositional units, and studied with petrographical and petrophysical methods. The correlations and the petrological studies reveal 6 depositional environments which are organized from upstream to downstream: (i) travertine mound environment, (ii) travertine depression environment, (iii) alluvial plain environment, (iv) tufa mound environment, (v) tufa depression environment and (vi) paleosol. The organization of the depositional environments provides evidence that the deposits at La Chiusa have been created by a multiple spring system. The different environments form geographically restricted areas characterized by typical morphologies and depositional processes under different physical, chemical and biological conditions and influences. The result is a distinctive distribution of different primary pore networks controlled by the position of the springs and the direction of the path flows, as well as by the previous topography. The pore connections between the different environments are not obvious, but some main erosional surfaces and fractures amplify the primary pore networks and form good drainage systems.

The data presented here concern a specific geothermal system but may explain geometries and lithofacies distributions in particular in poorly exposed systems or in well cores. The present work will be used as a model to investigate the spatial distribution of porosity and permeability in atypical buried carbonate reservoirs such as the Cretaceous microbial carbonate bodies recently discovered in the Atlantic Ocean.

References

Chafetz, H.S. & Folk, R.L. (1984) Travertines: depositional morphology and the bacterially constructed constituents. *J. Sedim. Petrol.* 54, 289-316.

Guo, L. & Riding, R. (1998) Hot-spring travertine facies and sequences, Late Pleistocene, Rapolano Terme, Italy. *Sedimentology* 45, p. 163-180.

Sand injection associated to channel margin instability on the Upper Miocene turbidites of the Inner Kwanza basin (Angola)

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The Kwanza Basin is divided into an eastward raised part in the inland domain, the Inner Cuanza basin, and a westward shelf to the deep marine domain, the Outer Cuanza basin. During the Cenozoic period, the eastern part of the basin (now the Inner Cuanza basin) was submitted to an overall uplift that led to the continentalization of the domain and present-day sub-continuous outcrop along the coastal cliffs. In particular, Miocene to Early Pliocene turbiditic canyons, incised on the shelf and lower slope, have been evidenced on the 50 to 80 meter high coastal cliffs of the central domain from Cabo do Sao Braz to Barra do Cuanza (Cauxeiro, 2013).

This work focus more specifically on the careful description and interpretation of peculiar post-depositional sand bodies cross-cutting Upper Miocene turbidite channel margin deposits at the Sangano beach, 70 km south Luanda. On this area, successive channel-levee systems show both a clear compensation pattern and a partial entrenchment into previous clayey levee deposits. Channels are one to several hundred meters wide and 30 to 50 meters thick in their axial part. They display both an overall fining upward sequence and an axial facies partitioning from mass-transported deposits in the central part to cross-bedded coarse sand and parallel laminated to rippled fine sand in the channel margins. Depending of the area, the contact between the channel and the levee deposits is sharp and steeply inclined or transitional. The coexistence of these two patterns would be consistent with highly meandering channel processes with both preferential erosion on the external part and inner levee building in the internal part of a meander loop.

The sand injection network was specifically found in the channel-inner levee transition of the southern flank of a 150 meters wide channel. This transitional facies onlap a main erosional surface developed on an older external levee deposit. It is mainly composed of one decimeter to one meter thick medium to fine parallel laminated sand layers sandwiched with greenish gray pelites that indicate the alternation of high velocity plane bed transportation and suspension settling at the channel margin. The inner-levee deposits are partly tilted towards the channel axis demonstrating the progressive parallelization along the inclined erosional surface during differential loading. Close to the erosional surface several sandy layers show a duplex system by channel-ward sliding over a major decollement plane at the base of the bed. In this way, some beds are thickened by antiformal stack during a forward breaking slide sequence. These antiformal structures are topped by multiple staggered fine to medium well sorted sand injections, following and crosscutting successively the bedding plane with a stair-step (bayonet-like) pattern.

This architecture is interpreted as a syn-sedimentary gravity driven slide sequence through the unconsolidated inner levee deposits during a main turbiditic event, with partial erosion of previous axial deposits. The instantaneous pressure gradient associate to both the decollement and the anticlinal stack, approaches the lithostatic pressure and led to lateral dewatering with partial fluidization and injection of the sand through the sandwiched pile above the antiformal stack. This syn-depositional injectite process must be taken into account for evaluating reservoir potential of inner levee deposits.

Trace fossil evidence for targeted elasmobranch predation on thalassinidean shrimp

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Both terrestrial and marine invertebrate organisms often leave a record of their activities in the sediment in the form of trace fossils, at least during certain stages of their ontogeny. In contrast, trace fossils of the activities of vertebrate organisms are scarce, although some terrestrial trace fossils have provided exclusive insights into the social behavior of their producers. In the marine realm, trace fossils produced by vertebrates are relatively rare, difficult to identify, and problematic to interpret. However, in certain settings, observations on serendipitously preserved and exposed trace fossils can shed light on the predatory behavior of marine vertebrates.

In Miocene outer shelf to nearshore sandstones of the Taliao Formation in NE Taiwan, large numbers of bowl-shaped trace fossils can be observed. Morphology and size range (diameter typically 10-30 cm, average depth around 10 cm) of these trace fossils agree well with feeding traces of modern stingrays, and the trace fossil *Piscichnus waitemata,* which has been attributed to bottom feeding rays. Stingrays direct a jet of water from their mouths to excavate a bowl-shaped pit in order to expose their prey. In the material filling the excavated bowl, broken pieces of two other common trace fossils, *Ophiomorpha* and *Schaubcylindrichnus,* are often found, and in a number of cases, vertical shafts of *Ophiomorpha* surrounded by dispersed pieces of wall material have been observed. In contrast, surrounding sediment rarely contains this kind of broken pieces of wall material. These observations clearly indicate that stingrays specifically targeted the producers of the trace fossils: thalassinoid crustaceans and worms, respectively. The targeted predation of these relatively deep burrowers furthermore suggests that the rays used their electroreceptive organs to locate the prey, as such direct targeting of buried prey only based on olfactory senses have been shown to be ineffective in experiments with extant myliobatifom rays.

Evidence from the central Arctic Ocean for a late Quaternary outburst flooding event

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On glacial time scales, the climate system is controlled by gradual processes such as e.g. variations in orbital parameters governing the distribution of solar radiation between the hemispheres and different latitudes. However, under certain conditions rapid processes in key regions can cause dramatic shifts in the system. A prime example is the repeated drainage of the pro-glacial Lake Agassiz, which is believed to have played a role in the onset of the Younger Dryas cold spell.

Many cores from the Eurasian Basin of the Arctic Ocean contain a conspicuous gray layer, layer rich in ice rafted debris, with a sharp lower boundary and a lithology that is distinctly different from over- and underlying sediment. This layer is essentially missing in the Amerasian Basin. X-ray images made from several cores indicate that this widespread layer was deposited extremely rapidly over large parts of the Eurasian basin. Isotopic, sediment geochemistry, and clay mineral studies performed on a set of cores ties the gray layer to the Siberian hinterland west of the Putorana Plateau, and tentative dating associates the layer with the transition period from Marine Isotope Stages 4 to 3, 60-50.000 years ago. For this time interval, spatial reconstructions of the Eurasian ice sheet based on geomorphological data indicate the presence of huge ice dammed lakes at its south-eastern margin. This paleoceangraphic evidence thus support the hypothesis that sudden drainage of huge ice dammed lakes bordering the Eurasian ice sheet occurred at least once before the Lake Agassiz drainage events on the North American continent.

Quantitative lithofacies palaeogeography of the Permian in the Middle and Upper Yangtze Region, China

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Quantitative lithofacies palaeogeography is developed on the foundation of traditional palaeogeography, the core of that is the quantitative palaeogeographic map. Quantity means that on the palaeogeographic map, the division and identification of each palaeogeographic unit are supported by the quantitative data and quantitative fundamental maps.

The methodology of quantitative lithofacies palaeogeography is the single factor analysis and multifactor comprehensive mapping method which was initiated by Professor Feng Zengzhao.

The Permian is widely developed and well exposed in the Middle and Upper Yangtze Region. Based on detailed investigation and study, the Permian in the study area can be divided into the Middle Permian Qixia Stage and Maokou Stage, the Upper Permian Wujiaping stage and Changxing stage, while the distribution of the Lower Permian is very limited.

The Permian in the study area is composed of carbonate rocks, clastic rocks, siliceous rocks, pyroclastic rocks, volcanic rocks and coal, with carbonate rocks being dominant.

Based on the petrological and paleoecological study, according to the specific methodology above, 8 single factors were chosen including thickness (m), content (%) of marine rocks, content (%) of shallow water carbonate rocks, content (%) of biograins with limemud, content (%) of biograins with sparry calcite cement, distribution of reefs, content (%) of deep water sedimentary rocks and content (%) of thin-bedded siliceous rocks, and 4 quantitative palaeogeographic maps of the Middle Permian Qixia Age and Maokou Age, the Late Permian Wujiaping Age and Changxing Age in the study area were composed.

The results show that the framework of lithofacies palaeogeography of each age of the Permian in the study area is very clear, and can be generalized as follows: seas alternated with lands, platforms alternated with basins, there were banks and reefs on platforms, and there were slopes between platforms and basins. Meanwhile, the lithofacies palaeogeography of each age has its characteristics.

The lithofacies palaeogeography of the Qixia Age was a carbonate platform. And there were many banks on the platform.

The lithofacies palaeogeography of the Maokou Age is similar to that of the Qixia Age. Major difference between them is that slope and basin developed in the northeastern study area.

The lithofacies palaeogeography of the Wujiaping Age is very similar to that of Changxing Age, the distribution of palaeogeographic units appear in the following forms from west to east: eroded area, fluvial plain, clastic platform, carbonate platform, slope and basin, and banks and reefs were developed on the carbonate platform. The major differences between the 2 ages were: the area of clastic platform of the Changxing Age decreased, while that of carbonate platform and basins increased; and over 50 reefs developed on the carbonate platform.

An overall view of the evolution of lithofacies palaeogeography of each age of the Permian in the study area was characterized with succession, development and development stage.

Succession is mainly reflects in the prominent similarity between the lithofacies palaeogeography of the Qixia Age and Maokou Age and between the Wujiaping Age and Changxing Age.

Development is reflected in the fact that although the lithofacies palaeogeography shows obvious succession between the Qixia Age and Maokou Age and between the Wujiaping Age and Changxing Age, there is also change and development, and the change in some aspect is great.

Development stage is reflected in the great difference between the lithofacies palaeogeography of the Middle Permian and Late Permian.