Dynamics and facies model of a macrotidal estuary with tidal bores (the Qiantang Estuary, China)

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Recognition of tidal-bore deposits (TBD) in modern and ancient environments has recently attracted significant interest. The macrotidal Qiantang Estuary breeds the world's biggest tidal bores. Hydrodynamics, morphodynamics and sedimentary characteristics of tidal bores and related processes are studied using ADCP and OBS data over a few tidal cycles, time series of field photos and satellite images, and the textural and structural composition of 26 short cores from tidal flats along the north and the south bank.

The results show that the channel morphology is extremely mobile in terms of rapid growth and shifts of intertidal banks over short-term and large spatial scales because channel sediments, dominated by fine sand and coarse silt, are easily resuspended and dispersed by shooting flood flows due to energetic tidal bores, and by strengthening river runoff during rainy seasons. This generally favours sediment dispersal upstream and accumulation along the north bank, and the consequent development of extensive intertidal flats during dry seasons and vice versa during rainy seasons over multi-year periods.

A tidal bore is a hydrodynamic shock as the tidal flow turns to rise, and its passage is very rapid, only lasting a few seconds to a few minutes. High-energy tidal bores have little to do with deposition but are known as a destructive agent to induce significant erosion, sediment suspension and dispersion, and deformation of newly depositional strata. Intense erosion and sediment dispersion are continuous toward and throughout the subsequent rapid flooding period. Most of the suspended sediments fall out immediately after the flow is halted to slow down quickly, and rapid deposition produces massive sandy beds, overlain with parallel laminated sands by the critical flow. Therefore, a general stratigraphical package formed by a series of genetically correlated processes is referred to here as tidal-bore deposition. A typical TBD consists of at least two of the following sedimentary features: (1) erosion surface, (2) massive bedding, (3) graded bedding, (4) parallel lamination, and (5) soft-sediment deformation structures. Tidal-bore deposits differ from other tidal sandy deposits in having coarser sizes and poorer sorting because of their rapid deposition.

Lateral variations in sedimentary facies are obvious in the middle Qiantang Estuary with tidal bores. Four sedimentary facies are identified: (1) tidal-bore deposits in the main channel and on the lower tidal flat, (2) hybrid deposits near the mean low-water neaps, (3) tidal rhythmites (TR) with (incomplete) spring-neap tidal cycles on the middle to upper tidal flats, and (4) annual rhythmites (AR) on the upper tidal flat and marshland.

Along the axis, three facies divisions are obvious and consist of: (1) linear depositional ridges and erosion troughs at the outer estuary, (2) TBDs at the middle estuary, and (3) coarse fluvial deposits at the upper estuary. The tripartite facies model of the Qiantang Estuary is similar to other well-known tide-dominated estuarine facies models, but it is the first to stress tidal-bore deposition in the sedimentary facies using detailed discriminative textural and structural characteristics. The approaches offer the potential to better understand tidal-bore processes and their important role in sediment dispersion and facies formation within modern and ancient macrotidal to hypertidal estuaries.

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Sedimentary patterns of different locations in varied subfacies zones of fluvial-delta system in Songliao Basin, China

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Utilising a large area (10.2 km^2), with a highly dense well pattern (275 wells/km^2), a lot of layers (150 sedimentary time units), logging data from approximately 3000 wells, and initial potential and production performance data, the sedimentary characteristics and patterns of different locations in a fluvial-delta system of a typical target area in Daqing placanticline in the Songliao Basin were analyzed. It is indicated that sandbodies in the fluvial-delta system resemble a big tree, which is divided into three parts, i.e. trunk, branch and leaves. The “trunk” sandbody is large-scale wide band-shaped highly curved channel sandbody, which frequently swings and changes channel in the plan and has serious vertical superposition. The “branch” sandbody is an abundant (83 branches), high density (3.2 branches/km), dominantly small-narrow (90%) subaqueous distributary channel sandbody. The “leaves” sandbody is very thin (no effective thickness and sandstone thickness more than 0.5m) large-sized interchannel sandbody. Based on the depositional setting, sedimentary characteristics and sedimentary facies types of the typical area, nine sedimentary patterns of different locations in varied zones of fluvial-delta system were established. They are: sedimentary pattern of meandering river in the fluvial facies zone, far, transitional, near from lake shoreline in the deltaic distributary plain zone, far, transitional, near offshore from the lake shoreline in the deltaic inner front zone, parallel source direction and fluvial-controlling band-shape sandbody, vertical source direction wave-controlling distant sand bar and scattered lump-shaped sandbody in the deltaic outer front zone. It provides significant geological foundation for the identification of single cause monosandbody, establishment of three-dimensional geological mode and further production of remaining oil.

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Keywords: sedimentary pattern; channel sandbody ； fluvial-delta system; Songliao Basin; Daqing placanticline

Relationship between lithofacies and total organic carbon content in Lower Cambrian organic-rich shales of Lower Yangtze region, China

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The Lower Cambrian marine shales in the Lower Yangzi region, which are deposited in a deeper water passive continental margin basin, are the favorable target for shale gas exploration. The purpose of this study is to identify the different lithofacies of the organic-rich shales from XY1 well and to confirm the relationship between lithofacies and total organic carbon (TOC) content.

Cores from XY1 well were observed from the perspective of lithological character, sedimentary structure and the feature of mineral. Fifty-two thin sections were prepared and analyzed from rock fabric, texture, fossils and mineralogy. Thirty-two samples were served for organic carbon test while fifty-two samples were analyzed for mineralogy by X-ray diffraction (XRD) analysis.

Four general lithofacies are recognized through the analysis of Gamma-ray (GR) log, sedimentary structures, mineral composition and fossils. The characters of different lithofacies can be described as follows: (1) Argillaceous silicalite is rich in quartz (77%) and carbonate mineral (9%), with abnormally high GR value (550 API); (2) Sponge spicule-bearing siliceous shale is the predominant lithofacies in the organic-rich shales, characterized by extensive sponge spicule fossils and pyrite laminations. The lithofacies presents high content of quartz (58%) and clay mineral (21.59%), with average GR value 180 API. (3) Calcareous mudstone is composed dominantly of calcareous and dolomitic mudstones, which develop the massive bedding and faint pyrite laminae. The content of carbonate mineral, clay mineral and quartz are 21%, 25%, 41% respectively. Its average GR value is 130 API. (4) Laminated limestone mainly consists of argillaceous limestone and a few dolomicrite, characterized by dark to light gray laminations. The light-gray laminae are abundant in calcite or dolomite, while the dark-gray laminae are rich in clay organic. Stylolitic structure and slump deformation can be observed. The content of carbonate mineral is relatively high at 71%. It has the lowest average GR value (65 API).

The lithofacies varies not only in petrological and mineralogical properties, but also in TOC content. Through organic carbon test, it is found that the average TOC content of argillaceous silicalite is 11.8%, which is much higher than other lithofacies; TOC content of sponge spicule-bearing siliceous shale ranges from 2.05 to 6.16% and the average is around 3.66%; Average TOC content of calcareous mudstone is 1.95%, with a range of 1.25 to 2.37%; TOC content of laminated limestone is 1.65%.

Through the analysis of sedimentary structures, lithofacies and fossils, it can be inferred that the Lower Cambrian sedimentary facies of XY1 well developes in deep-water slope facies. The argillaceous silicalite and sponge spicule-bearing siliceous shale belong to the basinal facies and the sediment-water interface locates below the Carbonate Compensation Depth (CCD), which is favorable for the preservation of organic matter with anoxic environment. The laminated limestone and calcareous mudstone with relatively low TOC content belong to slope facies and the depositional interface locates near or above the CCD, which is unfavorable for the preservation of organic matter.

The findings of this study suggest that TOC content varies a lot in different lithofacies, which is determined by sedimentary environment.

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The Early Toarcian Oceanic Anoxic Event and its sedimentary record in Switzerland

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In the Jurassic period, the Early Toarcian Oceanic Anoxic Event (T-OAE), about 183 Ma ago, was a global perturbation of paleoclimatic and paleoenvironmental conditions. This episode was associated with a crisis in marine carbonate accumulation, climate warming, an increase in sea level, ocean acidification, enhanced continental weathering, whereas organic-rich sediments are noticeable for example in the Atlantic and in the Tethys. This episode was also associated with a global perturbation of the carbon cycle, which is characterized by a distinctive negative carbon isotope excursion ($\delta^{13}C$) of 3 to 8‰. The cause(s) of this environmental crisis remain(s) still controversial. Nevertheless, the decrease in $\delta^{13}C$ values is commonly interpreted as due to injection of isotopically-light carbon associated with (1) the thermal metamorphism of carbon-rich sediments, (2) formation of the Karoo-Ferrar basaltic province in southern Gondwana, and/or (3) a massive gas hydrate injection. These environmental changes, associated with enhanced greenhouse conditions, are thought to have induced a rise in seawater temperature and oxygen depletion.

Several studies of the T-OAE have been conducted on sediments in central and northwest Europe but only few data are available concerning the Swiss sedimentary records. This project will focus on Swiss sections in order to evaluate and better constrain the impact of the T-OAE on the depositional environment of the northwest Tethys Ocean. In northern Switzerland (Folded and Tabular Jura Mountains), the Early Toarcian succession accumulated in a slowly subsiding basin between the southwestern Germany basin and the eastern Paris basin. Two sections were studied so far. The lithology of the Rietheim section (canton Aargau) is about 7.6 meters thick and consists of organic-rich mudstone including fossiliferous laminated bituminous marly clays (Kartonschiefer-Fazies). Well-laminated limestone beds (Unterer Stein and Oberer Stein) are present and can be traced over several kilometres and are marker beds. The Gipf section (canton Aargau) consists of fossiliferous clayey marls which grade upward into laminated bituminous marly clays (about 1 meter thick) with intercalated limestone beds. The Unterer Stein bed is clearly distinguishable and shows laminations.

A multidisciplinary approach has been chosen and the tools to be used are based on sedimentological observations (sedimentary condensation, etc.), biostratigraphy, mineralogy (bulk rock composition), facies and microfacies analysis (presence or absence of benthos, oxygenation levels), clay mineralogy composition (climatic conditions), major and trace elements analyses (productivity, redox conditions, etc.), phosphorus (trophic levels, anoxia), carbon isotopes and organic matter content (source of organic matter and preservation).

Microbial mats, microbialites and endoevaporites in High Andean Wetlands: A source of biodiversity and alternative geochemical cycles

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Andean Wetlands are extreme environments where microbial ecosystems develop in association with minerals, either precipitating (e.g., carbonates), or finding shelter (e.g., gypsum, halite). These ecosystems in which microbes associate with minerals (MAM) include biofilms, microbial mats, microbialites and endoevaporites.

Here we present the first report of a wide diversity of MAM ecosystems found in Andean wetlands. They include mats and endoevaporitic systems associated with gypsum and halite (in Tebenquiche), mats, carbonates microbialites and ¨phytomicrobialites¨ (in La Brava), stromatolites (in Socompa) and biofilms associated with gaylussite in Laguna Diamante (inside Volcano Galan). All of these MAM are high productive systems developing under multiple-extreme conditions. Oxygen and sulfide profiles indicated the presence of various metabolisms, but not that of oxygenic photosynthesis, as the main autotrophic process in some of these MAM. Microbial diversity demonstrated to be very different to previously studied MAM ecosystems across the world: MAM in Atacama, Chile, were dominated by Archaea (Crenearcheota and Euryarcheota), Planctomycetes and OP1 group. Cyanobacteria and Proteobacteria were almost absent; therefore suggesting that oxygenic and anoxygenic photosynthesis are not the dominant carbon fixation process. This raises the question how these ecosystems fix carbon and obtain energy? We speculate that the answer lies in alternative carbon fixation pathways described for Creanearchaeota, Plantomycetes and OP1, metagenomic analyses of alternative carbon fixation pathways are presented. In addition, the relationship between arsenic and Archaea: based on arsenite oxidase and arsenate reductase are presented. This is based on metagenomic studies performed red biofilm that flourish associated to gaylussite in the bottom of microbialites in Lake Diamante (Volcano Galan at 4650 m altitude), under extreme conditions such as high arsenic concentration, alkalinity, salinity and UV radiation and low oxygen. These biofilms are composed of Haloarchaea (93%) (16S rRNA shotgun sequencing). Metagenomic analysis indicated a high abundance of arsenite oxidases (Aio) and respiratory arsenate (As(V)) reductases (ArrA) encoded by the Haloarchaea. Phylogenetic analysis revealed a new clade of Aio enzymes in this group of Archaea that gives stronger support to the LUCA hypothesis. A pure culture of an *Halorubrum* strain isolated from the biofilm, showed the presence of Aio and ArrA genes, and enhanced growth in presence of As(III) under both light and dark conditions with an effective oxidation of As(III) to As(V), indicating that Aio enzymes are functional.

Our results are the first to demonstrate that Archaea (e.g., Haloarchae) can benefit from arsenic through As(III) oxidation and give strong support for As(III) as a primary source of energy in early forms of life. Therefore, MAM ecosystems in Andean wetlands could be an analog for early life on Earth. A comprehensive study of these ecosystems, their ecological value and preservation is a challenge we face as scientists and as a society.

Stable isotopes of fluid inclusions: a new method to ground truth climate archives in coral skeletons

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This study is based on the analyses of the stable isotope composition of fluid inclusions with a new geochemical technique of cold-water corals from carbonate mounds at the western margin of Rockall Trough, NE Atlantic Ocean. This technique is on-line delta^{2}H and delta^{18}O analyses of inclusion fluid with a continuous-flow crushing device. The measurement of inclusion fluid in all sampled species supports the presence of an intra- and/or inter-skeletal fluid. On average, the stable isotope composition of the inclusion fluid is higher in ^{18}O and lower in ^{2}H in relation to seawater, indicating that the fluid in cold-water corals is not of seawater composition. The cold-water coral *Lophelia pertusa* shows the largest variation, which is likely due to non-equilibrium fractionation effects inside the coral polyp. This variation can be a kinetic fractionation effect, as both delta^{2}H and delta^{18}O are simultaneously depleted. However, kinetics alone cannot explain why the fluid is enriched in relation to seawater. One argument for the high delta^{18}O values is mixing of seawater with isotopic substances with a high delta^{18}O and a low delta^{2}H during metabolic processes.

Cold-water corals either feed on phytodetritus or zooplankton or a combination of both sources. Stable isotope ratios were determined of phytodetritus collected at 4 m above the bottom with a sediment trap in the proximity of the cold-water corals at the western Rockall Trough margin. Measurements were done on a Thermo Finnigan Delta XP mass spectrometer equipped with a TC-EA pyrolysis furnace. The results from our study fall on a hypothetical mixing line between seawater and average food values and calculations show that the measured fluid has a 38% metabolic and 62% seawater origin. Hence, the results demonstrate that biological fractionation effects cannot be neglected, which is crucial for the use of cold-water coral skeletons as archive for palaeo-temperature reconstruction. More research needs to be done to support these first results.

A first exploration study to determine the stable isotope composition of inclusion fluids of warm-water corals looked very promising, while much less variation observed. If the relationship between warm-water coral fluid delta^{18}O and carbonate delta^{18}O proves to be linear, it might provide a method to estimate non-equilibrium isotopic fractionation effects.

In conclusion, the fluid inclusion method has shown to be a very promising lead so far in understanding the coral skeleton climate archives of cold- and warm-water corals.

Differentiation of the Bathonian-Callovian epicontinental deposits from the Polish Basin - from carbonate ramp to open siliciclastic shelf

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Sedimentation of the Middle Jurassic deposits in the central part of the Polish Basin occurred in a shallow epicontinental sea. During the Bathonian and Callovian times, the sea covered almost the whole area. A wide variety of facies and depositional systems are observed across the basin from east to west.

The easternmost part of the basin (the Lublin Region) sits over part of the East European Platform. A marine transgression entered this area at the Middle to Late Bathonian transition. Sedimentation of reddish-brown crinoidal limestones with mollusks, bryozoans, abundant limonite and ferruginous ooids dominated there. A carbonate ramp depositional system is invoked to explain their origins. The thickness of these limestones is from a few to 50 meters. To the south-east, siliciclastic deposits appear. The lower part of the section consists of deltaic and middle/upper shoreface sandstones. They pass upwards into sandy dolomites with anhydrite nodules and then into dolomites. All of these deposits point to sabkha environments.

In the central part of basin (Kujavian Region of the Mid-Polish Trough), Bathonian and Callovian sediments are fully developed in five transgressive-regressive cycles. Their thickness is from 100 to 300 m. The Lower Bathonian cycle is built of transgressive offshore black shales and a progradational regressive succession of mudstones and heteroliths topped by lower or middle shoreface sandstones. The three Middle and Upper Bathonian cycles begins with transition zone sediments or lower shoreface deposits. The uppermost parts of these cycles are composed of sandstones and limestones representing the upper shoreface, foreshore and lagoon environments. The uppermost Bathonian and Callovian deposits are connected withtransgressive part of the last cycle and are documented by carbonate-siliciclasticshoreface deposits (gaizes, calcareous sandstones and sandy limestones) which pass upwards into spongy limestones of the Upper Jurassic.

At the boundary between the Middle and the Upper Jurassic in both areas (eastern and central parts of Polish basin) a condensed bed from a few to several tens of centimeters in thickness, called the “nodular bed,” occurs. It spans a number of ammonite zones of the Middle and Upper Callovian.

In the western part of the Polish Basin, deep water Bathonian and Callovian calcareous or non-calcareous claystones and mudstones with ammonites, pyrite, pyritized flora and marly-sideritic concretions dominate. These deposits correlate laterally with offshore and transition zone sediments of an epicontinental sea that intercalate with chloritic sandstones with abundant bivalve fauna and often with ferruginous ooids. These features indicate sedimentation in a shoreface environment. Thickness of the Bathonian-Callovian deposits ranges here from 100 to 200 m. In this part of the basin, a condensed bed at the boundary between the Callovian and Oxfordian is not observed. The Middle and Upper Callovian is represented by tens of meters of offshore – transition zone claystones and mudstones; in the most northern part shoreface sandstones also occur. The overlying Upper Jurassic beds are also developed in siliciclastic facies.

Genetic mechanism analysis of deep tight reservoirs based on multi-factor coupling — a case study from Bashijiqike Formation of Kelasu tectonic zone in Kuqa Depression, Tarim Basin

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The Kuqa Depression is a Mesozoic and Cenozoic foreland basin developed on a Proterozoic and Paleozoic basement, which is located in the northern Tarim Basin. Under the effect of Himalayan orogeny, a series of thrust faults formed in the mountain front with resulting fold structures. Kelasu tectonic zone is in the northern Kuqa Depression, whose main gas-bearing reservoir is the Cretaceous Bashijiqike Formation that comprised fan delta front and braided delta front deposition.

The Bashijiqike Formation of Kelasu tectonic zone in Kuqa Depression developed the tight reservoir whose average porosity was lower than 10% and permeability was lower than $0.1\times10^{-3}\mu m^2$. Based on the analytical data including thin sections, property tests, CT scans, rate-controlled mercury penetration techniques, temperature tests of the fluid inclusion, the property evolution of reservoir during the whole geological history was inverted quantitatively under the control of “diagenetic evolutionary sequence - pore structure”. Combined with the stratigraphic burial history and the hydrocarbon accumulation history, the genetic mechanism of the tight reservoir in Bashijiqike Formation was studied.

The result shows that the origin of tight reservoir is controlled by multiple geological factors including deposition, diagenesis, tectogenesis, burial history, gypsum-salt effect and hydrocarbon infill. The burial history of Bashijiqike formation can be divided into three stages consisting of early slowly shallow burial, middle rapid deep burial and late varied adjustment stage.

Taking Keshen area as an example, during early burial period (130Ma-23Ma) the burial rate was low with 21m/Ma for burial depth < 2200m. The reservoir experienced mechanical compaction. During the middle burial period (23Ma-1.64Ma) the burial rate was about 210m/Ma for burial depth ranging from 2200m to 6700m. Deep compaction and cementation occurred during this period. Carbonate cements were partly dissolved by acidic water generated from hydrocarbon filling, which produced intergranular secondary pores. Under the ground of thrust-napple tectonic movement, rapid uplift and subsequently rapid burial of Bashijiqike Formation during the late burial period (1.64Ma-), the stress release was fast, leading to development of fracture which improved the physical property of deep buried reservoir. The gypsum-salt layers whose thickness were between several hundred metres and two thousand metres overlain on the Bashijiqike Formation, absorbed tectonic stress, reduced the pressure of overlying formation and preserved the pore space of underlying formation due to the suspended lift of plastic strata. After quantitative inversion of porosity, the initial porosity of Bashijiqike Formation was 34.5%. With a present burial depth of 7000m, compaction and cementation were the main causes of porosity loss. The secondary porosity gained by dissolution of feldspar particles and carbonate cements contributed with 1.4% to porosity increase. Controlled by the various geological factors above, the present porosity of Bashijiqike Formation was 3-5%, forming deep-buried effective reservoirs.

Reservoir diagenesis modeling and quantification evaluation from the deep strata in the Kuche Foreland Basin

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In this study, using an independently developed diagenetic physical modeling system, we conducted a series of geologic process-constrained experiments to simulate sandstone diagenesis and porosity evolution of the Cretaceous reservoirs in the Kuche Foreland Basin. These experiments simulated early, long-term, shallow burial and subsequent rapid, deep burial, reproducing the process of rapid vertical compaction of deep reservoirs during the unique burial mode of the foreland basin.

The diagenetic modeling system used here consists of six reaction furnaces and a computer-controlled assembly. All reaction furnaces are equipped with metal kettles to hold laboratory samples. Mineral percentages in the simulated sandstone samples were proportioned to correspond with detrital components in actual Bashijiqike sandstones, which include coarse, medium, and fine sand grains. The sample in each reaction kettle included mudstone and sandstone in two parts: a 14-cm-thick layer of sandstone in the upper part of the sampling tube and a 4-cm-thick mudstone in the lower part. The formation water in the Cretaceous sediments of the Kuche foreland basin is mainly of calcium chloride type, so a calcium chloride solution of 2 wt.% as well as acetum of 1 wt.% was added to the experimental fluid.

Reservoir sandstone samples were observed and characterized using an polarizing microscope. (1) During simulations of shallow burial depths of 1000 m and 3000 m, point contacts between clastic particles are dominant in medium- and fine-grained sandstones, and most primary intergranular pores are preserved. (2) At simulated burial depths of 3000 m and 5000 m, point contacts still dominate between clastic particles in medium- and fine-grained sandstones. (3) At simulated burial depths of 5000 m and 7000 m, point to line contacts between clastic particles are replaced by line contacts only due to intense compaction. (4) At simulated burial depths of 7000 m and 9000 m, line contacts dominate between clastic particles, with minor particle cracks and underdeveloped dissolution also present. Intergranular pores are mainly residual primary intergranular pores.

The analysis of deep-reservoir diagenetic evolution and the quantitative assessment of pore types, density, sizes, and throat sizes field the following findings. (1) The evolution of deep-reservoir porosity in a foreland basin can be divided into four stages: (i) long-term, shallow burial; (ii) a transition from shallow burial to rapid, deep burial; (iii) early, rapid, deep burial; and (iv) late, rapid, deep burial. Of these, the third stage is crucial to the improvement of deep-reservoir porosity and permeability, and thus to the formation of favorable reservoirs. (2) Clastic grain breakage and diagenetic fissures originating from rapid, deep burial and dissolution are responsible for the occurrence of favorable deep reservoirs. (3) Reservoir pores and pore throats show a significant increase at a burial depth of 5000-7000 m, and are characteristics of the most favorable reservoirs within this depth interval.

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On the Early Triassic "Great Bank of Guizhou" in Guizhou Province, South China

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The "Great Bank of Guizhou" was termed for the isolated carbonate platform that grew in the Luodian area of southern Guizhou Province, South China during latest Permian to Middle Triassic. Re-examination of the Triassic carbonate successions in the southern Guizhou Province allows reconstruction of the latest Permian to Middle Triassic paleogeographical configuration of the southern Guizhou areas. We also found that (1) the isolated Luodian Carbonate Platform grew in the Nanpanjiang basin during the Early Triassic; (2) there were not banks, penebanks and embryonic banks in Luodian and adjacent areas because grainstone is < 10% within the Lower Triassic Luolou and Ziyuan Formations, and thus the "Great Bank of Guizhou" is not recommended.

Spatial characterization of turbidite deposits under the influence of autogenic controls: a 3D physical modelling approach

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Autogenic and allogenic controls are an important parameter for the spatio-temporal evolution of submarine fans. 3D physical simulations of turbidity currents with accurate autogenic controls were carried out. Two series of 10 similar experiments with high-density turbidity currents (HDTC) and low-density turbidity currents (LDTC) were run keeping all others input parameters (discharge, volumetric concentration, type and grain size of sediment) constant. A new statistical approach based on the analysis of variance is used to characterize the geometry of the deposits ((a) symmetry, L/W aspect ratio, morphodynamic evolution) in terms of their deterministic or random nature. Results indicate that local autogenic processes may change the flow evolution, the transport capacity) and deposits of submarine fans. The morphodynamic evolution generated by HDTC showed complex stages of filling and stacking, caused by two types of autogenic channelling of the flow governed by autogenic controls. Type I is characterized by flows channelized due to the elevation of the levees without avulsions and efficient sediment transport with well-developed terminal lobes; and Type II: flow channelling with avulsions, less efficient sediment transport, and with terminal lobes less well developed. Nevertheless, deposits show a random behaviour with respect to the length/width ratio, the evolution of the depocentre of sediment bodies and distinct morphological elements such as elongate central deposits, fringes and distal lobes. In contrast, LDTC morphodynamics are simple without self-confining processes or distinct elements. All geometric elements show a deterministic nature. The experiments show evidence that high rates of sediment supply decisively influence the evolution and morphodynamics of sedimentation. High concentrations induce heterogeneous deposition with strong compensational stacking.

Anatomy of falling-stage deltas in the Turonian Ferron Sandstone of the western Henry Mountains Syncline, Utah: growth faults, slope failures, and mass transport complexes

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Recent work on the Upper Cretaceous (Turonian) Ferron Sandstone in the western Henry Mountains Syncline of south-central Utah has established its environment of deposition as a series of modest-sized (5-20 km wide), probably asymmetric, mixed-influence deltas ("Ferron Notom Delta": FND) that dispersed sediment eastward from the rising, Sevier orogenic hinterland into the Western Cordilleran Foreland Basin. Analysis of sandstone body stacking patterns in a 67 km-long, depositional strike-parallel (north-south) transect indicates that the growth of successive deltas was strongly forced by synsedimentary growth of a long wavelength (~100 km, 50 m amplitude) fold structure. Herein, I document two discrete areas within this transect which provide superb three-dimensional exposure, in order to determine the details of stratal stacking patterns in the depositional dip direction, and thereby to assess the stratigraphic context of the FND. In the two study areas, dip transects expose facies representing from river mouth bar to distal delta front environments over distances of 2-4 km. Key stratal packages are clinothems that offlap, downlap, and describe descending regressive trajectories with respective to basal and top datums. They are thus interpreted as the product of relative sea-level fall. The vertical extent of clinoforms suggests that deltas prograded into <30 m of water. Furthermore, these deltaic successions preserve abundant evidence of delta front slope failure, growth faulting, and incision and filling of deep (<15 m), slope gullies. Gully fills are composed of chaotic intraformational breccia and/or massive sandstone, and constitute linear, "shoestring" sand bodies in the distal portions of individual paleodelta systems. They are interpreted to have been cut and filled during the late falling stage and lowstand of sea-level cycles. The north-south distribution of the stratal style described above seems to be focused on the flanks of the growth anticline, and so the numerous falling-stage systems tracts preserved within the FND likely owe their origin to synsedimentary structural growth, and the unstable fluid pressure regime that this growth imposed on the sea floor and shallow subsurface. The ancient deltas of the FND are small and yet because of this, entire delta systems can be examined in this well-exposed field area. The scaling relationships established here likely apply to larger deltas in the rock record.

New insights into far-field response to the onset of late Paleozoic glaciation: data from the upper Mississippian succession of East Fife, Scotland

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Several recent studies of Carboniferous stratigraphy worldwide converge upon a late Mississippian (Visean, Asbian, basal Chesterian, c. 333-332 Ma) age for the earliest large-scale, relative fluctuations of sea-level attributed to growth of Gondwanan ice centers and the onset of the late Paleozoic Ice Age (LPIA). In this study, we document a well-exposed, c. 500 m thick succession of Asbian-Brigantian age in eastern Scotland. We suggest that a major upward change in the dominant facies assemblages from coastal fluvial and estuarine, to marine and deltaic, signals a change in the frequency and magnitude of relative sea-level fluctuations. We attribute this change to the onset of large-magnitude glacio-eustatic sea-level excursions in the latest Asbian. The section of interest spans the upper part of the Strathclyde Group (Asbian-Brigantian) and the overlying Lower Limestone Formation (Brigantian), and is continuously exposed in intertidal platforms between the villages of Pittenweem and St Monans on the Fife coast. The succession can be divided broadly into three facies assemblages with minor overlapping elements. The first assemblage comprises erosionally-based, cross-bedded sandstones (coastal fluvial channel belt deposits) and thinly interbedded sandstones and mudrocks with thin coals and carbonaceous shales (coastal floodplain and mire deposits). The second facies assemblage consists of heterolithic sandstone-mudrock intervals in many cases organized into coarsening-upward cycles a few meters thick and thin carbonaceous intervals (estuarine channels, flats and basins). The third assemblage contains some of the facies noted above, but in addition preserves thick monotonous mudrock intervals, bioclastic limestones (both offshore marine shelf deposits), and thicker (<30 m) coarsening-upward intervals (delta front). The interval as a whole preserves a complex interstratification of the three facies assemblages, with an overall upward shift from dominantly fluvial to dominantly marine/deltaic facies. The Brigantian Lower Limestone Formation, which forms the uppermost 100 m of this succession, preserves exclusively the marine/deltaic facies assemblage. This assemblage denotes a regime in which large-magnitude sea-level fluctuations were common, in contrast to the lower parts of the succession where such fluctuations are not recorded. The change in regime occurs within an interval corresponding to the latest Asbian, suggesting that growth of Gondwanan ice sheets was first felt at this time in the far-field paleotropical realm of eastern Scotland. This interpretation is consistent with a variety of recently-published estimates of LPIA onset, and somewhat earlier than the onset interpreted from near-field stratigraphic records of eastern Australia, suggesting that the initial growth of ice centers in Gondwana was not synchronized.

Quaternary evolution of the Mayaguana Bank (SE Bahamas) from skeletal to non-skeletal carbonates. How old is the Lucayan Limestone?

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A transition from skeletal to non-skeletal carbonates was first documented from cores drilled on Great Bahama Bank (NW Bahamas) during the 1980's. Dated, by various methods, from the Late Pliocene, around 2.8 to 3.2 Ma, this shift led to the definition of two lithostratigraphic units, respectively known as the Pre-Lucayan and the Lucayan Limestone. Investigations of shallow drill-cores from Mayaguana Island suggest that this shift in carbonate production occurred more recently in the geologic record of this platform.

The Lucayan Limestone consists of patchily-cemented peloidal-oolitic limestone containing lenses of skeletal grainstone and coralgal boundstone. This unit is restricted to the platform interior, thus excluding marginal reefs and coral-bearing limestones. The Lucayan Limestone contains numerous discontinuity horizons, up to 1 per 2 m of core. The Pre-Lucayan Limestone consists of well-lithified, randomly dolomitized, skeletal packstone to wackestone, in which cm-sized coral fragments are common. Discontinuity horizons are less abundant, approximately 1 per 5 m of core.

The Mayaguana Bank (SE Bahamas) is a small carbonate platform (57 x 12 km) capped by a low-relief island. The bank lies 50 km to the north of the east-west trending Cauto-Nipe strike-slip fault, and nearly 300 km to the north of the North Caribbean Plate Boundary Zone. The stratigraphic record of the island spans the Early Miocene to the Present and consists of peritidal carbonates.

Fifteen ca. 30 m-long drill cores have been recovered from Mayaguana Island with a mean recovery of 71.1%. A total of 458 thin sections have been manufactured, and 400 of these have been examined with a petrographic microscope. Seventeen whole-rock samples have been prepared and sent for Sr-isotope dating.

The Lucayan Limestone is between 1 m and 6.5 m thick in the studied cores, from the coastline towards the platform interior, and contains up to 5 discontinuity horizons. The base of this formation is reached between 2 m above sea-level and 5 m below sea-level. The lower boundary corresponds to a sharp limit or an erosive surface atop a lithified limestone or dolostone. A lateral facies change is observed between the platform margin and the platform interior. The former is characterized by oolitic-peloidal sand with minor skeletal components, whereas that latter shows peloidal packstone containing few mollusc fragments. By superposition, the age of the Lucayan Limestone is inferred to span the Middle and the Late Pleistocene. The underlying, well-lithified, Pre-Lucayan Limestone consists of bioclastic grainstone-packstone and coralgal floatstone, which are rich in encrusting organisms. This formation ranges from the Late Miocene to the Early Pleistocene according to Sr-isotope dating. Discontinuity horizons are less common, on average 1 per 5 m of core.

The Lucayan Limestones vary greatly in thickness throughout the Bahamas, from 43 m on the Great Bahama Bank to 1 m on Mayaguana. This could be related to differential subsidence between the banks, or to regional folding centred on the Great Bahama Bank leading to higher sinking rates for this platform. The transition from skeletal to non-skeletal sediments has tentatively been linked to the closure of the Central American Seaway, around 3.6 Ma, which triggered the Northern Hemisphere Glaciations around 3.2 Ma. The younger age of this shift recorded on the Mayaguana platform shows that this hypothesis needs some refinements, or that the age of the Lucayan Limestone on the Great Bahama Bank should be revised.

Distinguishing storm and seismogenic turbidites in lacustrine records: examples from South Island, New Zealand

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Precisely dated lacustrine sediments from lakes adjacent to active plate boundaries have the potential to yield records of the frequency and magnitude of landscape perturbations. However, distinguishing earthquakes from other perturbations such as floods and non-seismically generated mass wasting remain challenging impediments to the development of lacustrine paleoseismology. In addition conventional approaches to palaeoseismology using lakes with negligible fluvial sediment input overlook the potential of using the volume of sediment delivered to lakes from landscape responses to earthquakes as a way of reconstructing shaking intensity. In this study we have used lakes located along the strike of the Alpine fault in the South Island of New Zealand to develop a precisely dated chronology that records seismic shaking from episodic rupture of the fault and high magnitude storm events. Storm deposits can be distinguished from seismic shaking deposits on the basis of the layer sequence, thickness, frequency and the regional extent of perturbations. Earthquake deposits consists of 150 to 200mm thick turbidites that are interpreted as coseismic mass wasting deposits formed by the collapse of lake margin and delta sediments during seismic shaking. These deposits lack soft sediment deformation and liquefaction structures because the lakes are adjacent to the Alpine fault and experience catastrophic collapse of subaqueous slopes during earthquakes. The seismic origin of these deposits is independently verified by Bayesian age modeling of numerous radiocarbon dates to correlate event stratigraphy along strike and with known ruptures on the Alpine Fault. The seismic deposits are overlain by stacks of 2 to 100mm thick hyperpycnites that represent landscape responses to seismic shaking. These deposits are generated by sediment liberated by seismic shaking and transported to the lakes during floods within ~50 years of the earthquakes. These deposits are overlain by alternating organic-rich and inorganic silt beds that record relatively long periods between major earthquakes (c 200yrs) when the landscape is in a quiescent state interrupted by episodic delivery of sediment from precipitation-driven landsliding and flooding. We conclude that distinguishing flood and seismic deposits depends on building a robust and independently testable depositional model that couples landscape responses to perturbations with lacustrine processes.

The Early Cretaceous climate conundrum

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Early Cretaceous life and the environment were strongly influenced by the accelerated break up of Pangea, which was associated with the formation of a multitude of rift basins, intensified spreading, and important volcanic activity on land and in the sea. These processes likely interacted with greenhouse conditions, and Early Cretaceous climate oscillated between "normal" greenhouse, predominantly arid conditions, and intensified greenhouse, predominantly humid conditions. Arid conditions were important during the latest Jurassic and early Berriasian, the late Barremian, and partly also during the late Aptian. Humid conditions were particularly intense and widespread during shorter episodes of environmental change (EECs) - the Valanginian Weissert, the latest Hauterivian Faraoni, the latest Barremian to earliest Aptian Taxy, the early Aptian Selli, the early late Aptian Fallot and the late Aptian to early Albian Paquier Episodes. Arid conditions were associated with evaporation, low biogeochemical weathering rates, low nutrient fluxes, and partly stratified oceans, leading to oxygen depletion and enhanced preservation of laminated, organic-rich mud (LOM). Humid conditions enabled elevated biogeochemical weathering rates and nutrient fluxes, important runof and the buildup of freshwater lids in proximal basins, intensified oceanic and atmospheric circulation, widespread upwelling and phosphogenesis, important primary productivity and enhanced preservation of LOM in expanded oxygen-minimum zones. The transition of arid to humid climates may have been associated with the net transfer of water to the continent due to the infill of dried-out groundwater reservoirs in internally drained inland basins. This resulted in shorter-term sea-level fall, which was followed by sea-level rise. These sea-level changes and the influx of freshwater into the ocean may have influenced oxygen-isotope signatures. These changes mimicked changes towards cooler conditions, and part of the Early Cretaceous climate conundrum, related to two schools of thought – one advocating the presence of transient cooler and even glacial conditions and the other in favor of warm and more equable climate conditions – may be resolved by this interpretation.

Studying the geochemistry of *Platygyra sinensis* coral as a temperature proxy in the Persian Gulf

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Introduction. The instrumental records of the sea surface temperature (SST) rarely exceed a few decades. This makes proxy recorders of environmental conditions such as corals, valuable candidates as a proxy for temperature in tropical and subtropical regions. It is well-known that the ratio of strontium to calcium (Sr/Ca) in coral skeletal varies inversely with SST. Various studies, typically in the Pacific, have reconstructed SST values using coral Sr/Ca ratio and oxygen isotopes. However, such studies are very limited in the Persian Gulf. In this work, we attempt to develop a climate archive for the Persian Gulf region using Sr/Ca and oxygen isotopes in *Platygyra sinensis*, a widespread coral in the Persian Gulf, within a 35-year calibration window.

Summary of Methods. A coral head of *Platygyra sinensis* with a diameter of 72 cm and a height of about 58 cm was collected from the Persian Gulf close to the Hengam Island in water depth of 10 m. The sample slab of 10-mm thickness was cut from the head parallel to the axis of maximum coral growth and X-rayed to identify annual growth rate bands. The powder samples of coral skeleton were milled out of the coral along the continuous polyp tracts at each step increment of 1 mm. About 80µg of the powdered sample was used for oxygen and carbon isotopic measurements using a Delta Plus mass spectrometer coupled to an automatic Kiel III-carbonate device at the laboratory in Rosenstiel School of Marine and Atmospheric Science (RSMAS), University of Miami (USA). Measurements of Sr/Ca ratios were carried out using a Vista-Pro Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES) housed at the laboratory of RSMAS.

Results As there has been no calibration study for *Platygyra sinensis*, in order to reconstruct SST values, we used the previously reported equation established between the Sr/Ca ratio in the skeleton of the *Montastraea annularis* and SST in south Florida:

$Sr/Ca = 9.994(\pm0.042) - 0.0377(\pm0.0029)[SST(n = 95; r2 = 0.62)]$

Other equations developed by other scientists were also examined for comparison. The results showed a strong seasonal temperature signal which ranged from 13 to 36 °C. The results were compared with the values derived from the Comprehensive Ocean-Atmosphere Data Set (COADS). Although the SST values reconstructed from coral sample had lower mean values than that derived from COADS, a significant correlation is observed between them. The oxygen isotope variations in coral skeletons are primarily controlled by the temperature-induced fractionation and seawater oxygen isotope values. The seawater oxygen isotope itself is a function of seawater salinity (SSS). Having the Sr/Ca-based temperature and the coral oxygen isotopes values, the SSS values can be estimated using the following equations:

$SST(°C) = 5.18 - 4.523(\delta^{18}O_{coral} - \delta^{18}O_{water})$

$SSS(ppt) = (\delta^{18}O_{water}+19)/0.54$

The SSS values obtained from these equations ranged from 30.0 to 39.5 ppt with an average of 34.6 ppt.

Conclusion. In general, our results suggested that the massive coral *Platygyra sinensis* could be used to develop proxies of SST and SSS variability in the eastern Persian Gulf region.

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Microbial controls on the distribution of micro-porosity within travertine facies

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Travertine hot-spring depositional systems precipitate $CaCO_3$ at rates which are orders-of-magnitude higher than any other carbonate factories. Additionally, travertine hot spring systems witness high rates and large magnitudes of physical and chemical gradient (e.g., temperature, pH and CO_2 degassing) along their downstream flow pathways, resulting in distinct travertine fabrics. These crystallization rates and high gradients in physico-chemical conditions over short distances combine to make individual travertines disproportionately deposited at very different length scales. Recent investigations confirm the important role of microbes within the observed travertine fabrics and evidence the distinctive microbial communities in the observed in downstream facies (vent, apron and channel, pond, proximal slope and distal slope facies).

As a result of those high rates of carbonate precipitation and high environmental gradients over small spatial scales, the primary micro-porosity encountered in the different travertine fabrics is directly influenced by both abiotic (surface tension, temperature, degassing) and biotic (microbial influence) factors. Secondary early and late diagenetic processes may additionally influence the primary micro-porous networks.

This study especially aims to quantify the role of microbes in producing specific primary textures, and thereby porosity and permeability networks at micro-scale. The microcrystalline architecture of complex carbonate build-ups has traditionally hampered comprehensive interpretations of their porosity and permeability evolution. A critical spatial dimension in these deposits is the 1 µm average diameter of the microbial cells that serve to mediate $CaCO_3$ crystal precipitation via metabolic and physiological mechanisms. However, newly developed visualization techniques are now revolutionising our ability to accurately reconstruct the depositional and diagenetic histories of these microporous fabrics at the nanometer to centimeter scale. This includes integrated applications of transmitted-light microscopy, confocal laser imaging, scanning electron microscopy and X-ray computer tomography. Results yield 3D visualization and parameterization of the travertine crystalline fabric, pore geometry and connectivity, and stratigraphy across previously inaccessible spatial and temporal scales.

These new visualization approaches have been applied in two specific case studies in two distinctive travertine systems. The first case study focuses on terrestrial hot-spring travertine deposits in the Denizli Basin of Turkey (700-900 ka) and the second case study on the travertine fabrics in Yellowstone National Park (0-31 ka at Mammoth Hot Springs, WY, and Gardiner, MT, US). Results provided crucial information on the role of microbial presence and activity in producing specific primary textures and carbonate cements. This will serve as the contextual framework for tracking the interaction between the microbial entombment, metabolism and pore network evolution, providing input parameters for pore network simulations.

4D-DIAGENESIS@MOUND: Understanding the temporal and spatial variability of early diagenesis in carbonate mounds

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Cold-water coral carbonate mounds are important, yet often underestimated, carbonate factories in mid- to deeper slope environments. Frontier research during the last decades in such systems led to a better understanding of carbonate systems thriving in colder and mostly deeper realms. Recent to Sub-recent (Plio-Pleistocene to Holocene) carbonate mounds localized on the European continental margins cannot be any longer neglected in the study of carbonate systems. They clearly play a major role in the dynamics of mixed siliciclastic-carbonate continental slopes.

The primary (palaeo)-environmental architecture of such carbonate mounds, composed of cold-water corals embedded in hemipelagic matrix sediments, is well-characterized. However, despite proven evidences of aragonite dissolution and the precipitation of secondary solid mineral phases overprinting the primary environmental record, the spatial and temporal variability of early diagenetic and biogeochemical processes shaping the final nature and petrophysical character of mounds is until now not yet fully understood. Understanding the functioning of a carbonate mound as biogeochemical reactor, triggering early diagenetic processes in space and through time is necessary (vital) for the reliable prediction of potential late diagenetic processes and the better understanding of ancient mud mound systems. Approaching the fossil carbonate mound record, through a profound study of recent carbonate bodies is innovative and will help to better understand processes observed in the fossil mound world.

The 4D-DIAGENESIS@MOUND project aims to decipher the temporal and spatial variability of (microbial-mediated) diagenesis in carbonate mounds influenced by a shallow sulphate-methane transition zone (SMTZ). In first instance the spatial variation has been further deciphered through the detailed study of gravity cores taken on two carbonate mounds on Pen Duick Escarpment in the Gulf of Cadiz (pore water analysis, solid phase geochemistry, petrographical microscopy). Additional core sections on the top of carbonate mounds in the Melilla Mound Field in the Alboran Sea have been targeted for the further quantification of diagenetic imprints (especially coral dissolution and authigenic microbial-induced carbonate precipitation). The cores were recovered within the framework of the EuroFLEETS campaign 'The Mediterranean-Atlantic Gateway Code: The Late Pleistocene Carbonate Mound Record' aboard the R/V Marion Dufresne.

During a second phase of the project, carbonate mound sediments will be brought within a bioreactor to monitor dissolution and precipitation of mineral phases through time under constrained lab-conditions. Special attention will be paid to the development of an in-house bioreactor simulating the environment wherein carbonate mound systems thrive, as well as to the 3D visualization of the diagenetic phases within mound sediments by means of multi-scaled nanotomography.

Rare earth element geochemistry of the Early Devonian Kess Kess carbonate mounds (Eastern Anti-Atlas, Morocco)

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Rare earth element (REE) analysis has the potential to elucidate the oxidation state (using the Ce anomaly) of Early Devonian oceans when the Kess Kess developed and to test claims for a supposed hydrothermal input into the sea water (using the Eu anomaly). Detailed petrological and geochemical analyses were carried out on Early Devonian Kess Kess mound limestones of the Seheb el Rhassel Group exposed in the Hamar Laghdad Ridge (Tafilalt platform, Eastern Anti–Atlas, Morocco) in order to evaluate marine *vs* hydrothermal processes for the origin of these mounds. The Kess Kess mounds have been the centre of a long-time debate and were recently interpreted as hydrothermally derived. The upper part of the Kess Kess formation (formally Seheb el Rhassel Group) is characterized by mound and inter-mound facies, both consisting of fossiliferous limestones with variable amounts of skeletal debris and carbonate cements. Warm fluid circulation affected these limestone during the Early Devonian resulting in the formation of a hydrothermal plumbing system preserved in the mound and inter-mound facies (cavities, veins and dykes). Fluids seepage may have been responsible of the formation of vent systems in the upper part of the group.

Shale-normalized REE patterns for limestones display pronounced LREE depletion compared to MREE (average Pr_{SN}/Dy_{SN}=0.46) and HREE (average Pr_{SN}/Yb_{SN}=0.55). The REE+Y patterns of most limestones are characterized by a high Y/Ho ratio (up to 87), positive La anomaly and distinct but variable negative Ce anomaly. Most of the samples show negative to slightly positive Ce-anomaly, whereas samples from trilobite rudstone and vein fills show a pronounced positive Ce anomaly. Samples from vein fills and layered micrite display a positive Eu anomaly of 1.5 consistent with precipitation from relatively high temperature hydrothermal fluids. Samples of ironstone and quartz-bearing rocks were collected from vent systems in the upper part of the Seheb el Rhassel Group. Ironstone shows a seawater REE pattern, whereas quartz reveals strong depletion in total REE content and a positive Eu anomaly.

By using partition coefficients derived from modern natural proxies and experimental values we calculated hypothetical Early Devonian seawater REE (EDS-REE) patterns. EDS-REE patterns were calculated using samples with typical marine REE patterns (e.g. inter-mound facies) and samples with a weak marine signature (e.g. fossiliferous limestones). Ce anomalies in the EDS-REE pattern vary systematically with the facies, which may imply mixing of Early Devonian seawater with other fluids.

In order to test if studied limestones and their variable facies distribution, reflect variable redox conditions typical of seep/vent environments, our data set was compared with data from other carbonate mounds and reefs (e.g. Canning Basin).

Although most samples show REE patterns consistent with open ocean seawater, Ce concentration recorded changes in redox conditions consistent with variation of depositional facies. In particular, the data revealed that those facies affected by circulation of mixed fluids, that were part of the plumbing system, show a positive Ce anomaly, low ΣREE content and Eu anomaly greater than 1 probably due to hydrothermal input into seawater.

Initial geochemistry data of the Lake Ohrid (Macedonia, Albania) "DEEP" site sediment record: The ICDP SCOPSCO drilling project

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Ancient lakes, with sediment records spanning >1 million years, are very rare. The UNESCO World Heritage site of Lake Ohrid in the Balkan region is thought to be the oldest lake in continuous existence in Europe and, with 212 endemic species described to date, is a hotspot of evolution. An international group of scientists working on a project entitled 'Scientific Collaboration on Past Speciation Conditions in Lake Ohrid (SCOPSCO)' realized a deep drilling campaign of Lake Ohrid in spring 2013. Based on several coring seismic campaigns between 2004 and 2011, Lake Ohrid became the target of an ICDP deep drilling campaign, with specific research aims: (i) obtain precise information about the age and origin of the lake, (ii) unravel the lake's seismotectonic history, (iii) obtain a continuous record of Quaternary volcanic activity and climate change, and (iv) investigate the influence of major geological/environmental events on evolution and the generation of extraordinary endemic biodiversity. Drilling was carried out by DOSECC (Salt Lake City, USA) using the DLDS (Deep Lake Drilling System) with a hydraulic piston corer for surface sediments and rotation drilling for harder, deeper sediments.

Overall, about 2,100 m of sediment were recovered from 4 drill sites. At the "DEEP" site in the center of the lake, seismic data indicated a maximum sediment fill of ca. 700 m, of which the uppermost 569 m sediment were recovered. Initial data from core catcher samples and on-site susceptibility measurements indicate that the sediment sequence covers more than 1.2 million years and provides a continuous archive of environmental and climatological variability in the area. Currently, core opening, core description, XRF and MSCL –scanning, core correlation, sub-sampling, and biogeochemical analyses (TOC, TIC, TS, TN) of the sediment cores from the "DEEP" site is conducted at the University of Cologne. High-resolution geochemical data obtained from XRF-scanning and biogeochemical data (16 cm resolution) imply that the sediments from the "DEEP" site are highly sensitive to climate and environmental variations in the Balkan area over the last glacial-interglacial cycles. Interglacial periods are characterized by high Ca counts and high TIC and TOC contents, likely associated with high contents of calcite and organic matter in the sediments. Previous studies have shown that the calcite contents in sediments from Lake Ohrid are predominantly triggered by precipitation of endogenic calcite resulting from enhanced photosynthesis and higher temperatures. Moreover, high Ca counts mostly correspond to low K counts indicating reduced clastic input and a denser vegetation cover in the catchment. In contrast, high K and low Ca counts characterize glacial periods, indicating reduced precipitation of endognic calcite and enhanced deposition of clastic material. The variations in Ca and K counts mainly represent climatic variations on a glacial-interglacial timescale. Inorganic geochemistry data shall also be used to improve the age control of the "DEEP" site sequence. First findings of macroscopic tephra horizons allow a preliminary age control on the sediment succession, and peaks in K, Sr, Zr, and magnetic susceptibility might indicate the occurrence of cryptotephra layers in the sediment sequence.

Compositional variation of rhodoliths: Examples from the South Atlantic Ocean, Brazil

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Rhodoliths are free-living nodular calcareous structures composed mostly (>50%) of crustose coralline algae (CCA) and a variety of endofauna. Rhodolith banks are common in the oceans occurring from tropical waters to polar regions and from intertidal zone to the limit of the photic zone. Rhodolith banks occur in Brazil between 3° and 25°S and present the longest continuous rhodolith bank in the world, located in the Abrolhos Shelf. Herein, the objective is to present and discuss the variation in rhodolith composition along the eastern Brazilian shelf, considering distinct oceanographic settings, shelf morphology and sediment supply. The rhodoliths were collected through diving at different water depths: Central Abrolhos shelf (Ab) (shallow waters: 20 to 30m deep waters and 55 to 76m); and Southern Espírito Santo shelf (ES) (shallow: 32m and deep: 50m). The average diameter was measured from the largest, smallest and intermediate axes. The calcium carbonate content (%$CaCO^3$) was obtained by using hydrochloric acid. The estimated voids spaces volume was performed using computed X-ray tomography. The samples were classified if massive or laminar internal arrangement. The Ab rhodoliths showed average diameters of 8cm for shallow and 10.1cm for deep areas. The internal structure was classified as massive. The %$CaCO^3$ was 98.6±0.3% for deep and 94.2±0.2% for shallow areas. The biotic composition, the CCA with laminar growth *Peyssonnelia*, *Lithoporella* and *Mesophyllum*, and foraminifers as *Amphistegina* were identified. The associated fauna was composed by the ichnofossils *Gastrochaenolites*, *Entobia*, and *Trypanites*. Bryozoans, corals, bivalve shells, serpulids tubes, foraminifers and sponges were also observed forming structures. The ES rhodoliths were the smallest, with mean diameter of 4.7cm for shallow and 8.6cm for deep areas. These rhodoliths showed laminar structure, with %$CaCO^3$ of 95.3±0.6% for shallow region and 92.3±3.1% for deep ones. Despite of the similar levels of %$CaCO^3$ between the sampled areas, the occurrence of voids spaces frequent in the ES samples led them to present a smaller volume of $CaCO^3$ comparing to Ab rhodoliths. The biotic components of ES samples were mainly CCA with laminar growth, *Spongites*, *Peyssonnelia* and *Lithophyllum* besides bryozoans, occurred in the deep region, whereas in the shallow depths, *Mesophyllum*, *Lithothamnium* and *Lithophyllum* were registered. For the fauna, in the deep area, bryozoans were the most abundant component in addition to serpulids tubes, foraminifera, bivalve shells and coral fragments. For the shallow area, corals were the most abundant organisms, followed by bryozoans, gastropod shells, bivalves and balanids. On both areas it was observed a decrease in the abundance of fauna while increasing the depth. Similar situation have been mentioned for the vitality of rhodolith, which could lead to a difficulty of its use by benthic organisms. Comparing samples from the shallow to deep regions between the study areas, it was observed that species richness did not showed significant variation, however, the abundance of organisms differed considerably. The massive structure of Ab rhodoliths seems to be a limiting factor for the association of endobionts. Thus, the rhodoliths from Abrolhos and Espírito Santo showed structural differences that were associated with the characteristics such as shelf geomorphology and sediment supply, quite distinct between them. The environmental characteristics are marked in the rhodoliths structure and if analyzed with precaution in fossil rhodoliths could be used as paleoenvironments proxies.

Patterns of nearshore temperature and meltwater input along a high-latitude margin during the prolonged demise of Gondwanan glaciation

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Palaeoenvironmental reconstructions from across the globe indicate that the climatic and oceanographic changes that accompanied the Permian transition from deep icehouse to greenhouse conditions were uneven and asynchronous. Because of a paucity of well-constrained data, environmental changes in Gondwana remain poorly understood relative to tropical Pangaea. In this regard, the Permian System of eastern Australia provides a unique record of the response to this transition along a high-latitude, open marine shelf. Not only was glaciation protracted here relative to other regions of Gondwana, but the record also spans high temperate to polar palaeolatitudes, providing an opportunity to examine environmental changes along a latitudinal transect. We use Mg/Ca ratios and oxygen isotope compositions of well-preserved brachiopods and calcitic bivalves to assess the evolution of meridional temperature gradients and glacial meltwater contributions during the Permian acme and demise of the late Palaeozoic ice age. Geochemical proxy data are considered within the context of the shallow marine deposits that contain the analyzed fossils. The stratigraphy records glacial activity along the entire north-south extent of the margin, with glacial severity generally increasing to the south. Glaciation was not continuous, but rather focused into four discrete, glacial epochs (P1-P4), each several million years in length, which spanned Asselian through Capitanian time. These were separated by warmer 'nonglacial' intervals of similar duration. Glacials P1 and P2 were the most intense, and coincide with evidence for the development of widespread ice sheets across many areas of Gondwana, whereas glacials P3 and P4 were less intense and likely of alpine scale. Geochemical proxy records correspond to climatic changes indicated by sedimentological data. Results indicate that the meridional temperature gradient along the margin decreased as glacial conditions became less-severe, from c. 0.6°C/°latitude to c. 0.4°C/°latitude. These gradients are not diagnostic of the overall ocean temperature gradient, but rather highlight the amplified effects of global warming at high latitudes. Oxygen isotope records show considerable variability, not only between glacial and nonglacial epochs, but also along the length of the palaeolatitudinal transect. When integrated with Mg/Ca-derived palaeotemperatures, it is evident that glaciers contributed substantial amounts of ^{18}O-depleted meltwater to coastal shelves. Meltwater inputs were relatively high and variable during the early part of the record (P1-P2), especially in the southern portion of the transect, and gradually decreased as glacial influence waned. This $\delta^{18}O$ variability reveals the importance of considering local effects—in this case meltwater input—in the interpretation of oxygen isotopic data from ancient fossil materials.

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Control of depositional process and response on the architecture of Upper Cretaceous mudrocks: Insights from outcrops and cores: Texas, USA

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The prolific Eagle Ford Formation exploited in South Texas as an unconventional shale reservoir crops out as the Boquillas Formation in Val Verde County, West Texas. Though commonly referred to as shale because of their fine grain size, these formations comprise cyclically interbedded pelagic organic-matter-rich, globigerinid wackestones and organic-matter poor, planktonic skeletal grainstones. Volcanic ash beds commonly co-occur with the grainstone deposits. The Eagle Ford/Boquillas was deposited on a drowned shelf during the Cenomanian – Turonian, in dysaerobic/anaerobic water conditions as a second order stratigraphic sequence. This study focuses on the middle member of the Boquillas, interpreted to be the analogue of the best producing facies in subsurface.The alternating of the two main lithologies, though interspersed with ash beds, gives to the Eagle Ford an apparent cyclicity. The key question is: can this cyclicity be used for correlations? Literature review shows two opposing hypotheses regarding the accumulation of the grainstone beds: deposition above storm wave base by storms or below storm wave base by reworking by bottom currents.

Sedimentological observations were made on 5 main outcrops, representing 1.4 km combined length of exposure. Large hand samples were slabbed for visual analysis and classical petrography was made on thin sections. This data set was supplemented with LIDAR panorama and GigaPan high-resolution photomosaics of on the most laterally extensive of the outcrops from this study (10 to 12 meters high and 400 meters long).

Globigerinid wackestones consist of laminae of tests and fragments of planktonic foraminifera, inoceramids prisms, calcispheres, and rare radiolarians, in a calcareous mud matrix of coccospheres, coccoliths, , organic matter, and clay minerals. These deposits display planar bedding, very low angle laminations, abundant reactivation surfaces, scouring and filling but lack bioturbation. Larger scale, undulating erosive surfaces are also present and generally extend over several to tens of meters cutting through firm or hard grounds. Planktonic skeletal grainstone deposits are characterized by silt to sand size pelagic bioclastic material (planktonic foraminifera, calcispheres, peloids, some saccoccomid articles and possibly inoceramid fragments),very minor clay minerals. The only mud sized sediment is encountered in the peloids. The geometry of the planktonic skeletal grainstone deposits is variable, with laterally continuous beds and laterally discontinuous isolated deposits on a same stratigraphic horizon. Both beds and lenses have sharp bases with rare evidences of erosion. Sedimentary features include: low angle cross stratification, trough cross stratification, sigmoidal foresets, low angle foresets, low-angle tangential bottom foresets, steep foresets, planar bedding, sub-horizontal lamination and reactivation surfaces. Large current ripples have been observed at the top of the beds. Some lenses display barchanoid morphology with steep foresets. Both the globigerinid wackestones and the planktonic skeletal grainstone beds and lenses were deposited below storm wave base under the influence of bottom currents. The abundance of the coarse planktonic skeletal material derived from higher trophic level predators is a function of the reproduction of primary producers which is driven by the input of iron from the volcanic ash beds.

Boquillas cyclicity is a function of alternating periods of lower primary productivity with lower sediment accumulation rates (globigerinid wackestones), and shorter periods of high primary productivity and higher accumulation rates (planktonic skeletal grainstones). Organic matter content is a function of the bioclastic sedimentary dilution. The discontinuous character of the planktonic skeletal grainstone beds and lenses makes wide scale correlation using these impossible.

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Deep water depositional dynamics of the Atokan (Middle Carboniferous) 13 Fingers Formation, Anadarko Basin, Texas Panhandle, USA

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The Atokan (Uppermost Bashkirian – Lower Moscovian) 13 Fingers Formation of the Anadarko Basin owes its name to the distinctive wireline-log signature it displays across most of the basin This succession displays more than a dozen alternating highs and lows of similar thickness on the gamma, neutron density, resistivity, and spontaneous potential curves. Previous studies have interpreted the 13 Fingers Formation to be a third-order sequence. The climatic regime at the time of deposition was Icehouse, with high amplitude, low frequency sea-level variations. Due to its very high organic carbon content, this formation has recently triggered increasing interest in hydrocarbon unconventional exploration, which, so far, has proved to be challenging.

This study focuses on the depositional dynamics of the 13 Fingers Formation based on sedimentological descriptions of slabbed core, and petrographic analyses of thin-sections. Major and trace element composition was investigated using a handheld X-ray fluorescence scanner and a gamma-ray spectrometer.

During the early Pennsylvanian, the studied core was located offshore, on the northwestern slope of the Anadarko Basin. Four main lithologies are observed on the core that can be divided in 5 different sedimentary facies based upon their depositional dynamics. Fine-grained sandstones are interpreted to be prodelta deposits including proximal delta front turbidites, prograding prodelta fine-grained sands and prodelta. Sapropelic layers reach up to 64% TOC (alginate). Geochemical data and sedimentology indicate marine deposition. Two types of carbonate deposits are encountered. Their heterozoan faunal association indicates mesotrophic level. Some beds are dolomitized and have moderate TOC (<2%). Calcilutites show evidence of deposition as mass flows of different degrees of viscosity (from high viscosity to turbulent) originating from shallower parts of the basin. Calcisiltite beds are interpreted to be contourites, formed from shallow-water-derived carbonate material deposited by mass flows and redeposited by bottom currents. The organic-matter-rich mudrocks exhibit high levels of TOC (5-15%) and represent pelagic sediment that accumulated below storm-wave base and was then reworked under the influence of bottom currents in a dysoxic to anoxic environment.

The typical wireline-log signature of the 13 Fingers Formation is related to the rhythmical alternation of contrasting lithologies. Control of these lithological variations can be linked to a simple eustasy related model, possibly explaining the wide spread character of the wireline log signature. Fine-grained sandstone intervals correspond to lowstand system tracts. The sapropelic layers represent maximum flooding deposits when detrital input was minimal. Both types of carbonate beds are associated with increased highstand carbonate production updip. TOC-rich mudrocks consist of pelagic fine grained material that accumulated under the influence of bottom currents. Their high organic matter content suggests deposition as transgressive system tracts when detrital input was minimal.

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Sedimentary rock colour and palaeoclimate: An example from a Late Triassic lake succession in East Greenland

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A key element in lacustrine sedimentology is to test and develop new climate proxies. Geochemical or geophysical analysis is often used to provide a variety of climate signatures. Processing of samples required can be very time consuming and requires expensive equipment. However, colour measurements of ancient lacustrine sediments constitute a relatively cheap, efficient and simple approach to interpret past climate change. Modern studies use the CIE Lab colour system when describing sedimentary rock colour. The CIE Lab colour system is a three dimensional colour sphere with the xyz-axis defining the three variables: Lightness, green/red and blue/yellow values.

In this study we examined a succession of Late Triassic lacustrine deposits in East Greenland. The lake basin was situated at about 40° N at the margin of the dry interior of Pangaea. The sediments varied from red mudstones to light grey dolomitic limestones and showed a clear cyclicity in the field. In order to test if this cyclicity could be related to orbital control we investigated rock colour variation in two overlapping sections with a total thickness of 77 m. Samples, which were taken every 33 cm, were oven dried and crushed to fine-grained silt before the colour was determined on a CM-5 Spectofotometer from Konica Minolta. In addition to rock colour we also examined lithology (every 2 cm), magnetic susceptiblity (every 33 cm), and gamma ray variation (every 33 cm). Frequency analysis of the proxies was carried out using PAST. Variations in lightness as well as in green/red and blue/yellow values show significant peaks (cycles) with thicknesses of 0.95, 1.6, and 5.5 m. These peaks match well those defined by variations in lithology, magnetic susceptibility, and gamma ray. The ratios between these cycles (1 : 1.8 : 5.8) suggest that the 0.95 m cycle records the 20.000 year precession cycles, the 1.6 m cycle the 36.000 year obliquity cycle and the 5.5 m cycle the 100.000 year eccentricity cycles. In addition a 19.0 m cycle is identified in some of the proxies and probably records the long eccentricity cycle of 413.000 years. The interpretation of orbital-scale cyclicity is supported by magnetostratigraphical data. The orbital cycles apparently controlled precipitation in the area, lake dynamics and colour of the formed sediments. It is inferred that the red mudstones formed during an arid climate in ephemeral lakes and that part of the sediment is of aeolian origin (loess). The lightest sediments (dolomitic limestones) most likely represent a humid climate and formed in perennial lakes. A clear long-term trend towards lighter colours is seen in the succession and is interpreted to represent a gradual change towards more humid conditions. It is speculated that the lake basin initially lay within the reach of monsoonal rain, but that the basin due to slow continental drift towards the north gradually became influenced of a climate controlled by the westerlies.

The mechanism of formation of bioclastic shoals at shelf-edges of the Mishrif Formation (Cenomanian) in the Halfaya area, Southern Iraq

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The Cenomanian Mishrif Formation extends over most parts of the Arabian Basin including Southern Iraq. The formation is approximately 400 m thick in the Halfaya area. The main facies of the formation represent open-platform and shelf-edge depositional settings.

This paper focuses on the mechanism of formation of the shoals at the shelf-edges of the MB2-MC1 layers of the Mishrif Formation. The lithologies of the MB2-MC1 layers were studied using core and microfacies analysis and are mainly composed of grainstones and packstones, together with minor wackstones and mudstones. A wide range of bioclasts were identified, including rudists, bivalves, bryozoans, benthic foraminifera, echinoderms and green alga. Based on the characteristic of the lithologies and bioclastic types, we propose five facies for the MB2-MC1 layers.

(A) Rudist debris grainstone; Rudist debris were derived mainly from rudist banks/reefs along the shelf margin to the east of the southern Mesopotamian Basin; (B) Mollusc-fragment grainstone; (C) Bioclastic packstone/wackestone; (D) Skeletal sand grainstone; (E) Peloidal grainstone. The shoals are here divided into four types, these being rudist debris shoals, mollusc-fragment shoals, bioclastic shoals and peloidal shoals, respectively. The vertical profile of lithology indicates that there were three times of shoal growing, with more than 100m thick.

We define two main mechanisms for the formation of shoals in the Mishrif Formation of the Halfaya area. The first mechanism was shoal formation as a result of rudist banks/reefs eroded, at the windward side of shelf-edges. This resulted in the exposure of the shoal, with carbonaceous mudstone deposited at the crest of the shoal. This process produced the rudist debris and mollusc-fragment shoals (facies A&B). The second mechanism for shoal formation was by shallowing of the subtidal zone at the leeward side of shelf-edges. This resulted in bioclastic shoals (facies C&D) containing significant proportions of benthic foraminifera and green alga indicative of an open marine facies. Facies E was deposited at the shelf-edge during early regression. The presence of hummocky cross bedding implies that this setting may have been influenced by storms.

The highest porosities and permeabilities occur in the shelf-edge facies A and B. This is consistent with similar observations made elsewhere in the Middle East.