Paleoenvironments of the Cañadón Asfalto Formation (type locality), Cañadón Asfalto basin (Jurassic). Patagonia, Chubut province, Argentina. Stable Isotopes, Sedimentology and Paleontology

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Cañadón Asfalto Fm (CA) with Las Chacritas (LCh) and Puesto Almada (PA) members, represents the lacustrine sedimentation during the rift development of the CA basin. The lower member, LCh, is characterized by expansion/contraction cycles, with a shallowing trend and reduction of the waterbody. The lacustrine sedimentation was interrupted by several basaltic flows. In Cerro Cóndor depocenter (CA creek, type locality), the paleolake is defined by extended littoral and marginal facies with palustrine facies which prevailed within the middle and upper part of the sequence. The littoral and marginal facies (expansion stage) are represented by mudstone, microbialites, stromatolites, wackestones and paleosols. The fauna is represented by euestherids and eosestherids conchostracan which well developed shells indicate a stable environment during a period of time. On the other hand, bivalves (Sphaeridae?) suggest a lenthic environment with moderate currents and less than 10 m in depth while cf. *Diplodon* shells evidence poor transport. The lacustrine system received siliciclastic inputs from surface inflows. The palustrine facies (contraction stage) are represented by bioturbated mudstone with benthic fauna and carbon debris, shales, storm levels and evaporites. The long-lasting palustrine environment is characterized by long periods of decrease in freshwater discharge, fluctuating wet lake margins and high organic productivity under reduction conditions that slowed organic matter oxidation. PA Mb represents the restricted stage of the paleolake. The lower section is characterized by shallow water and marginal deposits with pyroclastic inputs. This record suggests a drying trend in the climatic conditions. The conchostracan found are eosestherids, afrograptids and anthronestherids with small shells. This feature could reflect an accommodation to the ephemeral water level with adverse physical and chemical conditions for their development. As ostracods, the monospecific associations in abundant populations are indicative of adverse paleoenvironmental conditions. The marginal littoral environment is represented by mudstones interbedded with palustrine shales. In the upper part of the section, tuffs are dominant and associated with mudstone with mudcracks or with ripples. The small bivalve shells suggest that they were opportunist fauna which development was related with episodes of favorable conditions. Insect larvae (trichopterans) were also found. $\delta^{13}C$ and $\delta^{18}O$ data of the lacustrine carbonates show moderate positive covariance (r= 0.68 LCh Mb) to strong covariance (r=0.89 PA Mb). The two separate covariant trends reflect changes in the basin hydrology between LCh and PA carbonates. The former trend indicates that carbonates precipitated in a waterbody periodically hydrologically closed with sporadic water discharges ($\delta^{18}O$ between -12.1‰ and -17.5‰). Maxima in $\delta^{13}C$ (2.0‰) is associated with productivity (photosynthesis). The latter trend is characteristic for carbonates precipitated under closed lake environmental conditions ($r \geq 0.8$). The higher values in $\delta^{13}C$ (maximum 5.1‰) are associated with atmospheric CO_2 exchange due to extended water residence time while the higher values in $\delta^{18}O$ (maximum -2.1‰) reflect aridity and high evaporation rates in the paleolake. In conclusion, identification of two different covariant trends confirmed the hydrological changes of the basin which have affected the isotopic identity of the water body, in agreement with the sedimentological and paleontological data.

Precipitation of magnesium bearing-sulphates in saline lakes: Influence of sedimentary structures and microbial processes

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The chemical controls on evaporite minerals in saline lakes are known although their surface distribution and the biological control are not completely understood yet. The present study deals with the processes of mineral precipitation in relation to sedimentary structures and microbial mats that occurs in shallow evaporitic lakes located in Toledo, central Spain.

Water measurements and analyses indicate that concentrations of Ca^{2+} (23.65 to 44.71 meq) and SO_4^{2-} (69.06 to 506.48 meq) are typical of continental brines gypsum saturated. The high contribution of other ions in the water results in the ability to precipitate also other minerals, such as Mg^{2+} (41.07 to 729.18 meq), Na^{+} (21.75 to 525.05 meq) and Cl^{-} (11.96 to 707.28 meq). The conductivity was between 0.4 and 7.1 S/m (salinity 2 - 48g/L), and pH between 8 and 10.

The smooth surfaces of the lakes host a veneer of microbial mats showing a green, occasionally purple and a black layer with depth; the latter indicates sulphate reduction processes by bacteria. The mat types and related sedimentary structures change seasonally according to a variety of processes.

During spring and summer, beetles and flies, among others, persistently dig burrows on the microbial mat-covered sediments. When desiccated, the lake floor becomes cracked and vesiculated.
Apart from detrital minerals, a variety of evaporitic minerals are present in the sediments as determined by XRD; optical microscopy, epifluorescence and SEM-ESEM techniques.

Gypsum is the dominant mineral. Lenticular gypsum crystals up to 500µm encrust the surface and also appear as intrasediment precipitates embedded by the microbial mats. Minor tabular celestite crystals commonly replace the gypsum. Magnesium sulphates (hexahydrite, epsomite, pentahydrite and starkeyite) precipitate around the surficial pores in the sediment-air interface. The porosity created by burrowing, cracking and gases released from decaying organic matter, allows fluids to move upward and keeps the upper layers wet. The rising fluids supply the ions required for the precipitation of the magnesium and sodium-rich sulphates. Wetting also favors microbial recolonization of pores. Sodium-magnesium sulphates such as bloedite, (and loweite and konyaite as precursors) enclose the magnesium sulphates previously formed. By further drying of the sediment surface, the sodium sulphates (thenardite and its precursor mirabilite) are formed. Halite and sylvite are the most soluble and remain in solution until the final stages of this sequence of precipitation.

The fluid rising through porosity is caused by capillary evaporation pumping and/or hydraulic pressure. The latter resulted from confinement under the microbial mats forming gas domes and blisters when fluids try to escape to the surface through the vesiculated sediment. The results indicate that mat related structures and microbial metabolisms play an important role in the precipitation of sulphates in shallow saline environments where microbial mats thrive.

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Deep sea sediments in a Mexican polymetallic nodules field

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The presence of elements such as cobalt, nickel, platinum, and REEs in manganese nodules represents one of the most significant components in the ocean basin. Studying the interrelationships between the nodules and the sediments in which they are generated allow the establishment of their distribution and enrichment mechanism in different environments.

In this study we analyze the texture, mineralogy and geochemistry of pelagic sediments associated with polymetallic nodules collected during the oceanographic cruise MIMAR VI. The cruise was organized by Institute of Marine Sciences and Limnology at 13 oceanographic stations around Clarion Island within the Exclusive Economic Zone of the Mexican Pacific. A sediment sample from each oceanographic station was studied for mineralogical and chemical composition. Mineralogical analyses of sediments performed by petrographic microscope and by means of X-ray diffraction, in order to obtain the geochemical data samples, were analyzed for major elements using X-ray Fluorescence and inductively coupled plasma mass spectrometry for trace elements and rare earth elements.

The results showed that the main components of the sediment are authigenic (micronodules), biogenic (radiolarians and diatoms) and terrigenous (pumice, volcanic rock fragments, volcanic glass, quartz and plagioclase). Though mineralogy of sediments associated with manganese nodules is not fully indicative of the genesis of these, the relationships of the major elements (Mn, Fe, Al and Si) and trace elements (Co, Ni, Cu) show a main hydrogenic component of the sediments north of the study area. While in the south, the diagenetic component is more important and is characterized by abundance of Mn, Ni, and Cu. The Si, Al, Ca, Na and K are related to aluminosilicates while Mn, Fe, Ni, Cu and Co is associated with abundance in nodules and micronodules. High ratios Mn / Fe and high concentrations of Ni and Cu contained in the nodules are usually associated with siliceous sediments in the study area's south. The average REE concentration was found to be 941.73 ppm in the nodules and 454.36 ppm in the sediments, the Upper Continental Crust (UCC)-normalized patterns of sediments showed major elements concentration near UCC except for the Mn which has a slightly higher average concentration. This abundance may be attributed to the smectite formation related to diagenetic processes.

The metal content such Ni and Co near Clarion Island is about 1757 ppm and 402 ppm respectively and shale-normalized REE patterns showed positive Ce anomalies related with the well oxigenated area. The metal content could have economic interest for Mexico.

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The Dolomia Principale carbonate platform in the eastern Southern Alps (NE Italy, W Slovenia): the depositional system of its early stages

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The Dolomia Principale (DPR) is one of the best known Upper Triassic stratigraphic units of the Southern Alps. It is related to a wide carbonate platform, outcropping in the Southern Apennines, Dinarids chain, Australpine (Hauptdolomit Fm.) and Hungary. Margin-to-slope facies are known from the Norian, facing both intraplatform basins and open pelagic areas. However, data about the late Carnian start-up stage are limited to northeastern Italy, and little is known of the early depositional system.
The Tuvalian succession was investigated by studying several geological sections along the western Julian Alps. Amulti-disciplinary approach was adopted, involving macro- and micro-facies analysis, sequence-stratigraphy and biostratigraphy (mostly ammonoids and conodonts).
The lower Tuvalian was characterized by low-relief mixed terrigenous/carbonate systems (Tor Fm.), emplaced on an almost flat paleotopography since the late Julian and showing few lateral paleoenvironmental changes in a W-E direction and a transgressive- regressive trend. Mixed systems graded in a widespread high-energy inner ramp environment characterized by dominant carbonate sedimentation (amalgamated grainstone bodies). Diagenetic processes originated a dolomitized lithosome (Portella Fm.) extending over a wide area with uniform thickness (ca. 15- 20 m), and showing only local variation to peritidal settings.
The top of the unit could be considered as a surface on which disparate upper Tuvalian environments were established: while northeastern areas show evidence of pure basinal sedimentation with anoxic episodes (Carnitza Fm). The southwestern sector of the Julian Alps was patterned by shallow marginal marine, mixed terrigenous/carbonate deposits, attributable to low-energy restricted (sometimes evaporitic) environments (Travenanzes Fm. and Monticello Mb-DPR). These features are related to the emplacement of a platform margin belt (DPR) approximately oriented WNW-ESE.
Depositional geometries are partially preserved and the shelf-break profile denotes the evolution of a first stage marked by the margin platform onset followed by increase of the slope angle and deepening of a starved basin. The lower, main aggradational stacking pattern, is followed by an upper strongly progradational stage, dated to the uppermost Tuvalian (*Spinosus* Zone).
Micro-facies analysis of upper slope-to-margin debris occurring in proximal breccia and calcarenite layers reveals a microbial-dominated carbonate factory. Together with microbial crusts, encrusting calcareous sponges, *Tubiphytes* and other *Microproblematica* organisms represent the main components. Moreover, an inner margin, relatively shallower and sheltered, has been described with oncoidal- bioclastic facies and microbialite layers. This area is laterally interdigitating with protected zones in which peritidal sedimentation prevails.
Connection with the innermost area, subjected to southern siliciclastic input and mixed sedimentation (at least for the first aggradational stage), is missed due to Alpine tectonic displacements and elisions.
Margin to slope features strictly recall typical steep slope carbonate platforms of the Mesozoic, with a dominant M-type carbonate factory. However, the whole depositional system of the early stage is quite different, northern carbonate construction was attached to a southern terrigenous coastline and alluvial system. Peritidal carbonate sedimentation was extended to the whole ESA only in the late Carnian.

Basinal inlets in a wide carbonate platform system: a case history from the Late Triassic of northeastern Dolomites (Southern Alps, NE Italy)

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Upper Carnian to Norian successions cropping out in the Dolomites (eastern Southern Alps, ESA) are typically characterized by a thick (locally over to 1000 m) succession of peritidal cycles known as Dolomia Principale (DPR), mainly representing inner facies of one of the widest carbonate platform of the Mesozoic.
Despite the Dolomites represent an area affected by minor tectonic deformation, faulting and displacements increase eastwards, resulting in the complex structural assessment of the S. Stefano di Cadore-Val Bordaglia area. Among several tectonic units, the Mt. Col Unit stands out for its peculiar Upper Triassic stratigraphic framework.
Particularly attention has been paid to a Tuvalian carbonate-terrigenous basinal succession cropping out along the riverbed of the Rio di Mezzodì. Lithofacies are mainly represented by dark marl/pelite and limestone alternations, with irregular coarse to fine calcarenite intercalations. Carbonate grains of finer lithology are frequently represented by fragments of pelagic bivalves and benthic forams, whereas coarser beds commonly contain also gastropods, echinoderms and occasionally cortoids and *Microproblematica*-type fragments. Pyrite crystals and phosphatized shells are frequent, suggesting disoxic conditions on the sea bottom.
The unit overlies a dolomitized interval consisting of bivalve and gastropod-rich packstones to grainstones, with common crustacean fecal pellets, attributable to a carbonate ramp environment (Heiligkreuz Fm.). No specific stratigraphic trend is identifiable in this basinal succession, but its top is always truncated and it is commonly flanked to massive facies of DPR.
Recent and new ammonoid findings allocate the deep water series to the *T. Dilleri*/*Subbullatus* – *A. Spinosus* Zone, allowing good correlation with the Carnitza Fm. which crops out 90 km eastwards (Julian Alps, S. Karawanken).
A georeferenced database containing all geological data available from literature about the Tuvalian substage of the ESA was created. Punctual and areal informations have been interpolated taking account of structural constraints, and a non-palinspastic paleoenvironmental map has been developed for the *T. Subbullatus* Zone. Results show a general SW to NE transition of environmental belts, respectively from subaerial/alluvial plain settings to shallow terrigenous- carbonate lagoons, with a narrow carbonate platform margin elongated in an approximate WNW-ESE direction, facing open pelagic environments northwards.
Considering the polyphase Alpine tectonic displacement of the Mt. Col unit and its presumable northern provenance, the continuous occurrence of a W-E elongated basin could be hypothesized for the Carnic Alps, and likely for a restricted region north to the current Insubric-line position. In the wider paleogeographic scenario of the Tethyan region, a western pelagic inlet connected to the eastern Hallstatt marine domain can be depicted, separating thus the ESA from the Upper Australpine nappes, at least during late Carnian. Moving westwards, away from true open marine areas, water circulation became more and more restricted, justifying disoxic conditions inferred from sediments. Simultaneously, the terrigenous input increased in the same direction, because of the approach to inner sectors, where a direct connection of coastal carbonate-siliciclastic systems to the basin cannot be excluded.
The occurrence of a sea-slice cutting the wide DPR carbonate platform environment cannot be ignored in future paleogeographic reconstruction, even if more work is needed to detect those causes that led to its onset.

Lacustrine Basin Fill in the Center of Africa (DRC): the Jurassic Stanleyville formation

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The Congo basin, located in the Democratic Republic of Congo, is the largest sedimentary basin of Africa. Mesozoic sediments of this intra-cratonic basin outcrop along its eastern edge, south of Kisangani (former Stanleyville). The Stanleyville formation (dated Upper Jurassic) was described in the last century as a lacustrine series resting on a basal thin marine limestone, the "Limefine".

Since this early model was proposed, the depositional environment of the Stanleyville formation and in particular the possible marine incursion has been strongly debated, but without revising the existing core and outcrop samples for the type location near Kisangani that are available at the Royal Museum for Central Africa (MRAC/KMMA, Tervuren, Belgium). In order to refine the former sedimentary descriptions, a series of 9 mining cores drilled in the Kisangani region have been selected for this purpose. The cores were made available during a project with the MRAC/KMMA.

This study focuses on sedimentary structures and facies analysis (that will be detailed in a separate poster presentation). It aims at integrating sedimentary facies in existing lacustrine models and examines the validity of the hypothesis of the presence of Kimmeridgian marine deposits along the Congo River near Kisangani, which lies in the middle of the African continent. The main findings are as follows:

- Eight sedimentary facies are identified, allowing to classify this lake system as a "balanced-fill low-relief margin/shallow basin" according to the lacustrine model proposed by Bohacs et al., in 2000.
- The base of the Stanleyville formation corresponds to fluvial conglomerates which fill an inherited Triassic paleo-topography.
- Above these conglomerates, a typical lacustrine parasequence is observed. It can be divided into 3 system tracts: (1) Transgressive System Tract, which corresponds to flooding of the paleo-topography with formation of a lake system and deposition of littoral to sublittoral sediments, (2) Highstand System Tract, during which the lake reaches its maximum extent (sublittoral to profundal deposits) and (3) Lowstand System Tract when the lake reaches its minimum surface area due to higher evaporation, with littoral, lake shore and lake plain deposits (mudflats, calcareous sandstones and muddy lake plain).
- Unlike what has been proposed, the "Limefine" limestone bed, formerly assigned to a Kimmeridgian marine transgression, appears to be lacustrine limestone. We conclude therefore in the absence of Jurassic marine sediments in the Kisangani region.

Sedimentary Lacustrine Facies from the Stanleyville formation (DRC)

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The Congo basin, located in the Democratic Republic of Congo, is the largest sedimentary basin of Africa. Mesozoic sediments of this intra-cratonic basin outcrop along its eastern edge, south of Kisangani (former Stanleyville). The study of 9 cores (the cores were made available during a project with the MRAC/KMMA) drilled for mining purposes in the Stanleyville formation in the eastern region of the RDC resulted in the identification of the 8 sedimentary facies here presented, and characterizing a typical lacustrine environment. The spatial and temporal evolution of such facies illustrates the lacustrine model proposed by Bohacs et al, in 2000.

The eight identified facies highlighted in the poster are: (1) Fine-Grained Stromatolites, (2) Organic - rich mudstones, (3) Muddy Lake Plain, (4) Greenish Marls, (5) Greenish Calcareous Sandstones, (6) Clean Sandstones, (7) Conglomerates and (8) Flood Deposits.

IODP / ECORD : New opportunities in scientific drilling and subseafloor investigation

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The Science Plan for the International Ocean Discovery Program (IODP): "Illuminating the Earth's Past, Present and Future" is designed to guide multidisciplinary, international collaboration in scientific ocean drilling during the period 2013 to 2023. This Science Plan highlights four main themes, each encompassing a short list of high-priority scientific challenges :

- **"Climate and Ocean Change, Reading the Past and Informing the Future**" targets one of the most pressing questions about the climate, ocean and ice-sheet response to ongoing increase in greenhouse gases.
- **"Biosphere Frontiers"** includes exploration of deep life within the sub-seafloor and the study of ecosystem response to environmental forcing and ocean events.
- **Earth Connections** will concentrate on the links between surface, lithospheric and deep Earth processes.
- **Earth in Motion** addresses dynamic processes that occur on human time scales, including those leading to and resulting from earthquakes, landslides, and tsunamis.

To maximise drilling capability in IODP, three primary platforms will be operated by three independent Platform Providers : the multipurpose drillship *JOIDES Resolution* by the USA, the riser-drilling-capable *Chikyu* by Japan, and Mission-Specific Platforms (MSP) by the European Consortium for Ocean Drilling Research (ECORD).

MSPs may include not only drilling platforms but also sea bed technologies operated from standard R/Vs, long piston coring, and lift boats carrying standard coring or mining-type rigs, as determined by IODP scientific priority and operational efficiency. They are chartered on a specific project basis for drilling in technically challenging conditions, including high latitudes and shallow-water environments.

A major objective for ECORD will be to deliver an average of one MSP expedition a year in the new IODP by adjusting the numbers of low, medium, and high-cost expeditions and creating new opportunities through external co-funding, in-kind contributions, and the close collaboration with other science programmes and initiatives such as the International Continental Drilling Program – ICDP -, the International Marine Past Global Changes Studies – IMAGES - , and the European Multidisciplinary Seafloor Observation – EMSO -. Joint IODP-ICDP "amphibious" proposals that include offshore and onshore boreholes to achieve common scientific goals will combine capabilities of these two programs.

Working towards the establishment of a European Infrastructure to better co-ordinate various European Universities or Institutes that operate and/or develop tools that investigate the sub-seafloor will be amongst ECORD's main goals in the near future. Europe has a leadership position in the development, innovation and potential commercialisation of many cutting-edge technologies regarding sub-seafloor investigations, which require integration, co-ordination and further developments for maximising their use.

Assessing Event Sedimentation in the Cretaceous Bluesky Formation of the Peace River Oil Sands (Alberta, Canada) using the Ichnogenus *Rosselia*

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Introduction. Spectacular examples of well-preserved, stacked *Rosselia* Dahmer, 1937 in bitumen-rich Bluesky Formation core from the Peace River oil sands deposit of west-central Alberta, Canada provided a unique opportunity to measure depositional aspects of these reservoir sediments. Depositional rates and volumes are fundamentally important to process sedimentology, however, assessing these parameters in the rock record is extremely difficult.

Rosselia is a spindle to funnel shaped mud-lined tube interpreted to be the feeding and sediment-stowage burrow of a terebellid polychaete. Stacked *Rosselia* segments are considered to be re-equilibration adjustment structures of a single tracemaker maintaining its connection to the sediment-water interface following high sedimentation. The length and number of stacked re-adjustments can be measured and used as a proxy for assessing the magnitude and frequency of depositional events.

Theory and Methods. A number of wells penetrating the Cretaceous Bluesky Formation have been studied and recovered core was logged as part of a larger project. Two cores containing assemblages of robust, stacked *Rosselia* were selected for further scrutiny.

In order to shed light on modal sedimentation in the Bluesky Formation, the length and number of stacked segments were measured and counted in the core where *Rosselia* occurred. An uninterrupted continuous stack of *Rosselia* segments represents the upward burrowing of one organism over its sedimentologically preserved life, and each segment along the stack reflects one re-adjustment following a depositional event. The height of each segment corresponds to the vertical distance the burrower climbed to re-equilibrate; therefore, it was possible to determine the amount of sediment deposited by measuring the length of each segment. The frequency of depositional events in any one lifetime was determined by counting the number of segments in a stack.

Results. Re-adjustment distances of *Rosselia* in both cores were measured. In response to sedimentation, the average tracemaker re-equilibration response in one core was 3.6 cm and 5.6 cm in the other. This re-positioning suggests that the amount of event deposition averaged 3.6 cm and 5.6 cm, respectively. Extreme adjustments were observed when the cumulative effect of an organism's movements was considered, *i.e.*, a single tracemaker may have been subjected to almost 30 cm of sediment deposition over four separate events in the course of its lifetime. Given that all segmented burrows of a stacked *Rosselia* occur in the biological lifespan--months to perhaps two years--of a single tracemaker, the Bluesky *Rosselia* assemblage in the study area records significant sediment deposition in a relatively short time period.

Conclusions. Depositional rates and volumes are fundamentally important to process sedimentology, however, assessing these parameters in the rock record is extremely difficult. The presence of stacked *Rosselia* in these two cores provided a unique opportunity to study depositional events and environments in the Bluesky Formation. These traces have been used as a 'measuring stick' for determining the magnitude and frequency of sedimentation events. *Rosselia* observed in this work suggest that large volumes of sand were deposited in a relatively quick period of time. This study highlights the use of *Rosselia* as a precision tool for fine-timescale analyses in the rock record.

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Origin and palaeoenvironmental significance of the Berrazales carbonate spring deposit, North of Gran Canaria Island, Spain

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Berrazales carbonate spring deposit, constituted mainly by cascade-like morphologies, is located in the north-west of Gran Canaria Island. This carbonate deposit, classified as travertine from geochemical point of view and as tufa from textural point of view, overlies volcanic lavas (basanite) with around 2700-3100 years old. The deposit is made of four main facies: 1) *Fibrous dense macrocrystalline* facies formed by rapid degassing under high-flow conditions, 2) *framestone* facies consist in coated plant molds formed in moderate water-flows which favoured the presence of biological supports, 3) *micrite/microsparite* facies are primary precipitates in which crystalline aggregates nucleated on organic filaments and/or EPS during slow water-flows, and 4) *banded micrite-coarse crystalline* facies are the result of alternating physical-chemically and biologically induced precipitation in areas of varying flow-velocities.

Biogenic and abiogenic processes played an important role during *fibrous dense macrocrystalline* facies formation. In a first stage, microbial filaments provided a favourable site for calcite nucleation, although slow crystal growth allowed filaments not to be completely entombed. During a second stage, crystallization rate increased (mainly due to rapid CO_2 degassing) and physicochemical precipitation prevailed over biogenic growth. In *micrite/microsparite* facies the degradation of exopolymeric substances (EPS) linked to microbial filaments liberated Ca^{+2}, Mg^{+2} and HCO_3^-, increasing cation concentration in solution and allowing Mg-calcite to precipitate.

The deposit is affected by micritization, dissolution and cementation processes. Micritization is due to abiogenic and biogenic processes. Abiogenic micritization caused by undersatured water inflow affected *fibrous dense macrocrystalline facies*, whereas biogenic micritization occurred when microbial filaments perforated crystals, dissolving and micritizing them.

Isotopic analyses show positive delta^{13}C values (from +2.63 to +4.29 per mil VPDB) and negative delta^{18}O (from -5.65 to -4.48 per mil VPDB) values. Positive delta^{13}C values indicate a thermogene-travertine formed from "deep-sourced" fluids. Spring water temperature was calculated under disequilibrium conditions. Minor variations in delta^{13}C values reflect biological processes due to the lighter carbon isotope consumption during CO_2 removal. Likewise, variations in delta^{18}O values can also reflect effects of evaporation, changes in water temperature, degassing of CO_2 and/or groundwater inflow. Calculations give a temperature range from 20ºC to 35ºC, characteristic of cold to warm spring waters which favoured biogenic activity (microbes and plants).

Berrazales spring deposit unravelled the thermal-volcanic influence in the formation of carbonate spring deposits in volcanic setting and the role of biogenic versus abiogenic processes and their interrelation during and after crystalline growth. The presence of this type of deposits in the Canary Islands is very scarce due to their low preservation potential so their study can be an aid to understanding the main processes and controls involved in the formation of travertines in volcanic settings, and their palaeoenvironmental and palaeohydrological significance.

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Sedimentation and its response to regional tectonics evolution in the Jurassic Yabulai Basin, Northwestern China

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Yabulai Basin is one of the small to medium Meso-Cenozoic faulted basins in Hexi Corridor in NW China. According to the regional tectonic structures and Jurassic sedimentations in northwestern China, the basin group shows a same overprint extension and inversion tectonics environment. Typically, the evolution of Yabulai Basin can be classified into a few distinct tectonic events: firstly, an episode of subsidence in Jijigou and Qingtujing Formation, Early Jurassic; secondly, normal faulting and continuing subsidence in Xinhe Formation, Middle Jurassic; thirdly, a Late Jurassic-Early Cretaceous basin inversion associated with approximately N-S compression; Lastly, shrinkage stage of the basin. The tectonic activities during different tectonic stages have profound influences on accommodation space, tectonic subsidence rate, synsedimentary faulting activity and paleo-structural framework of the basin, which controlled the development of sequence stratigraphy units and sedimentary cycles at various levels, as well as the spatial-temporal distribution and configuration of depositional system tracts in the sequence stratigraphic framework. Cores, logging curves and reflection-seismic lines were used to analysis the sequence stratigraphy, sedimentations and their respond to the basin tectonic evolution.

As a result, seismic interpretations of sequence divide Jurassic into four third order sequences: SQJ_2q, SQJ_2x^1, SQJ_2x^2, SQJ_3s. Seven sedimentary facies associations are identified: the shoreland plain, fan delta, braided delta, turbidite deposits, shallow lakes, half-deep lake and alluvial fan systems. From SQJ_2q to SQJ_2x^2, growing delta dominated sedimentary systems indicate a continue subsidence during the faulted stage. The alluvial fan systems developed in SQJ_3s response to the tectonic inversion of Late Jurassic. The correspondence of sedimentary infill and its response to tectonic movements have been demonstrated in Yabulai Basin. Different sequence stratigraphy and sedimentary infill features in three stages, which correspond to three tectonic processes of Jurassic, generally show the “weak-strong-weak” development features of Yabulai Basin.

Classification of Subaqueous Sedimentary Gravity Flows and Recognition of Their Deposit in Lacustrine Basin with Example of Jiyang Depression, East China

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The classification of subaqueous sedimentary gravity flows and its characteristics is the basis of subaqueous sedimentary gravity flows theory in lacustrine basin. This study focus on the Paleogene subaqueous sedimentary gravity flows deposits in the Jiyang depression in East China, attempts to propose a simple classification of sedimentary gravity flows in lacustrine basin and discusses the recognition mark of their deposit, based on rheological behavior, sediment concentration, flow duration, content of cohesive mud, depositional process interpreted from the features preserved in the deposits. According to their rheological behavior, subaqueous sedimentary gravity flows are divided into debris flows (non-Newtonian flows) and turbidity currents (Newtonian flows). The subdivision of debris flows primarily based on content and function of cohesive mud, with two main classes: mud debris flows with matrix in texture and sandy debris flows with matrix on the composition. The subdivision of turbidity currents primarily based on origin, flow duration and features observed in deposits, with two main classes: surge-like turbidity currents origin of sediment failure with very short duration, quasi-steady hyperpycnal turbidity currents triggered by rivers in flood permits longer flow duration. The deposits of mud debris flows are always freeze en masse with a sequence of thick-bedded massive matrix-supported pebbly mudstone, conglomeratic arenose mudstone and arenaceous mudstone with clasts, sharp upper and basal contacts. The deposits of sandy debris flows, also called sandy debrites, are mainly thick-bedded massive sandstones, which have features as sharp upper and basal contacts, inverse grading, floating mudstone clasts and armored mudstone balls at the middle or top of sandstones bed. The typical features of surge-like turbidity currents deposits are complete or truncated Bouma sequence, normal grading deposits are common with sharp or erosional basal contact and gradational upper contact. Quasi-steady hyperpycnal turbidity currents deposits range from inversely graded units overlain by a normally graded sequence with a sharp or erosional intrasequence contact which reflects the waxing and waning stage of flood. If the erosion is strong enough, the inversely graded units maybe completely eroded and form normally graded sequence. Climbing ripples and horizontal laminae are also common in quasi-steady hyperpycnal turbidity currents deposits.

First mapping of sediment distribution and processes in the Sound of Corcubión (NW of Spain): a multidisciplinary study

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Introduction. The Corcubión Sound is located in the passive Atlantic margin of western Galicia (NW Spain). It is an open, south-oriented embayment with a very strong oceanic influence. The outer limits of the sound are Cape Finisterre and Remedios Point, delimiting an area of approximately 130 km^2, with a mean depth of 30 m and a maximum of 80 m. The entire sound is characterised by the existence of abrupt granite outcrops hindering navigation and generating several islands, the Lobeiras Rocky Isles and others of smaller dimensions. Inside the Sound, two bays and two coves can be recognized. The Ézaro River is the only relevant freshwater input and the ria of Corcubión in the innermost part of the sound is the most protected area.

Methodology. Two seismic surveys were carried out in the area to study the recent sedimentary infill: RIAL-2005 (recording 124 km of seismic profiles) and CECOMER-2013 (127 km). The seismic data were acquired using a "modified Boomer", with a single Boomer source (AAE CSP 300) and a sub-bottom profiler receiver (ORE 3.5 kHz). Two gravity cores were also recovered in the inner part (GC1 and GC2) and sampled to analyse methane, sulphate, TOC, etc.

Results. Seafloor response to high-frequency seismic energy permits the identification of acoustic facies, characterising different echo-character types. Analysing these echo-characters facilitates analysis of the seabed's texture, microtopography and sedimentary processes.
The detailed analysis of sub-bottom profiler records in the Sound permitted us to generate a classification of echo-characters, identifying a total of six different echo-character types. Four echo types (types 1, 2, 5 and 6) were characterised in areas of sediment deposition, while two types (3 and 4) correspond to basement outcrops. A map of acoustic facies was elaborated based on the performed classification. The Sound is clearly dominated by two types of echoes (type 2 and 4) that represent over 70% of the surveyed area. One characteristic echo-character (type 5) is associated with the presence of gas in the underlying sediment. Analyses performed in two cores confirm the presence of methane.
A GIS data base was used to integrate echo-character map, bathymetry and superficial sediment data from nautical charts (IHM, Spanish Navy), coastal geology (IGME, Spain) and wave dynamics from the models of generation of swell waves (Ports of State, Spain).

Conclusions. The integration of data into the GIS allowed us to generate a detailed map of sediment distribution in the Sound of Corcubión, the first performed for the area, as well as a map of sedimentary processes.
The mapping of sediment distribution shows an increase in sediment grain size from the inner to the outer part of the sound, denoting the energy increase due to marine processes (mainly waves). This distribution is modified by the presence of several basement outcrops and by the geomorphology of the area. The Lobeiras islands act as a baffle generating a zone of lower energy behind, where sediment of fine grain size is accumulated and several methane gas fields have been found.
The erosive and high-energy depositional processes are dominant in the external and most exposed part of the sound, where bioclastic gravels appear. However, the ria of Corcubión and the inner part of the sound areas are dominated by low-energy depositional processes.

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What can supercritical-flow bedforms tell us about the internal structure of turbidity currents?

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Although submarine canyons and channels form the main gateway for sediment into the deep sea, the processes involved in this transport are still far from understood. As bathymetric measurements of these submarine canyons and channels increase in resolution, it appears that their thalwegs are not as smooth as is generally presumed. Thalwegs show a hierarchy of bedforms in a manner similar to the familiar ripple/dune/bar hierarchy known from rivers, but in contrast to those bedforms the submarine bedforms show very different geometries and dynamics.

Although recent studies have produced evidence to interpret these submarine bedform hierarchy as a sequence of supercritical-flow bedforms ranging from antidunes to cyclic steps. The dynamics of these bedforms is, however, still far from understood. The main contradiction seem to lay in the fact that, if the bedforms are interpreted as supercritical bedforms, then their flow size should be much smaller (meter scale) than those measured (tens of meter scale). This seems to imply that there might be a thinner and denser supercritical flow at the base of the larger dilute flow. Such dense basal layer could then explain the small size of the bedforms. Additionally, such dense basal layer would be consistent with the transport of heavy monuments through the Monterey Canyon as well as the typical high-density facies we observe in outcrops examples of cyclic steps in submarine channels.

Here we use the high-resolution bathymetry of the bedforms in the Monterey Canyon, as collected by the Monterey Bay Aquarium Research Institute, to single out bedforms trains in different parts of the Monterey Canyon. These bedforms are then classified on the basis of their geometry. Once the bedforms are categorized as either antidunes or cyclic steps we use basic published relations between bedforms geometries and flow properties to deduce rough predictions on the properties of potential dense basal layers.

Application of a grain-size trend model to the southern sector of Rio de Janeiro state coastline, SE Brazil

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The assessment of sediment transport patterns from the spatial variability of statistical parameters - mean (μ), sorting (σ) and asymmetry (Sk) - derived from granulometric data, has been carried out through distinct methods including the so-called grain-size directional trend analysis (STA models). Sediment grain size may become finer (F) or coarser (C), sorting may become better (B) or poorer (P), and the asymmetry may be either positive (+) or negative (-). Up to 14 possible combinations have been identified although only a subset of them are typically employed. There are three main STA models: the McLaren method, STA® (1981, J. Sediment. Petrol, 94, 97-107); the Gao and Collins model (1991, J. Sediment. Petrol.,61, 143-146; 1992, Sedimen. Geol., 80, 47-60); and the Le Roux method (1994, Sedimen. Geol., 94, 97-107). Based mainly on the two latter models, Poizot and Méar developed the software GiSedTrend (2010, Environ. Modell. Softw., 25, 513-525), that was used in this work. The study area lies in southern Rio de Janeiro coast (SE Brazil) and comprises a sector of Sepetiba bay and the bayside coastline of Marambaia, a barrier island that partially isolates it from the open ocean. One-hundred sediment samples, collected in 2013, were preprocessed in the laboratory (sea salt, organic matter and calcium carbonate removal) and then dry-sieved into 13 size fractions (-2Φ to 4Φ). The fine-size fraction (< 4Φ) was wet-sieved and then had its size distribution determined through a laser diffraction granulometer (Malvern^{TM}). Statistical parameters were computed with the software GRADISTAT (Blott & Pye, 2001, Earth Surf. Proc. Land., 26, 1237-1248), and then used to prepare the sediment transport trend maps. The results show that the barrier island bayside coastline is composed mainly of medium sand and, subordinately, by coarse sand, varying between very well and well sorted, whereas the subaqueous sediment samples beyond the 2-m isobath, grade from fine, well-sorted sands to fine, poorly sorted silt. Two distinct sedimentological trends were identified: the first, associated with a ~ 6 km long and narrow spit (Pombeba Point), exhibits converging trend vectors in both sides of this feature. The second, related to the central sector of the study area, shows trend vectors directed from the middle of the bay towards the barrier island (a north to south trend). The application of the software GiSedTrend allowed recognition of four sediment trend combinations that are statistically more significant in the study area: (CB^{-}), (CB^{+}), (FB^{-}) and (FB^{+}). The results of this study suggest interpretations somewhat distinct from those presented by previous studies, which indicated that the two above-mentioned areas are high-energy sectors due to the presence of bedforms and erosional scarps. Our results also verified that the processes involved in the sedimentary dynamics of the study area are highly complex and require further observations in order to be fully understood.

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Origin of ordered dolomite in lacustrine, pedogenic and diagenetic continental deposits from Miocene of the Madrid Basin

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In the last decades dolomite has been found in varied contexts including in purely continental and experimental studies have been able to synthesize dolomite and ambient temperature in the presence of microbes that provide suitable surfaces for nucleation of a poorly-ordered, Ca-rich dolomite. Dolomite may form abiotically due to the catalytic effect of carbohydrates resulting from degradation of organic matter. Our paper presents a detailed study of different types of dolomites formed in a well-constrained alkaline and Mg-rich sedimentary/pedogenic/diagenetic environment. The aim of the study is to show that there are high variety of mechanisms (precipitation versus replacement) and controls (biogenic or not) that make the formation of ordered dolomite possible under suitable conditions.

Ordered dolomite occurs in the transition between distal alluvial fans and lake environments of the northern area of the Madrid Basin. Homogeneous smectite-rich mudstones, with traces of analcime, were deposited in the distal areas of alluvial fans. The mudstones contain dolomite and silica laminae interpreted as mineralized root-mats indicating poorly developed paleosoils. Dolostones with prismatic structure constitute the topmost of Stage III dolocretes which also have patches of isotropic silica. Homogeneous lacustrine dolomudstones show some features indicative of subaerial exposure. The overall facies contain a variety of dolomite textures including: microcrystalline dolomite, coarse crystalline mosaics located in root cavities, dolomite dumbbells within root cavities and replacing clays and dolomite spheroids replacing clays, dolomudstones or opal. All dolomite types are ordered and mean $MgCO_3$ content is 51.5 per cent/ mol of $MgCO_3$. The delta^{18}O values range between -3.65 and -5.51per mil VPDB. The delta^{13}C values range between -7.19 and -8.38 per mil PDB, there is not significant differences between the different facies types.

The varied dolomite textures indicate different mechanisms of formation. Dolomicrite formed in alkaline lakes by direct precipitation and replacing clays within the soil. Roots structures were very favourable sites for dolomite formation either on the walls of their cells (dolomite mosaics) or in the rhizosphere. Some dolomite dumbbells nucleate and grow on these dolomite cell walls under high oversaturation conditions, in cases as cement but in other cases replacing clays. Spheroidal dolomite replaced clays and opal under early phreatic diagenesis. The wide distribution of smectites, other Mg-rich clays, silica and analcime indicated that these pedogenic and lacustrine environment were alkaline with pH above 9. Smectites and/or carboxyl groups provided by the degradation of organic matter acted as abiotic catalysts favouring the incorporation of Mg into dolomite and promoting crystallinity. Our study indicates that in these settings the kinetic barriers for dolomite precipitation are overcome by the high pH and rich Mg, but not saline solutions. Under these conditions dolomite formed under biogenic and abiogenic controls and it is not that significant to decipher which one is the prevailing one, as the key control is the highly alkaline Mg-rich environment during sedimentation, pedogenesis and early diagenesis. In short, our paper may open a new insight to understand the dolomite problem as it shows that in relatively well-constrained alkaline environments once the kinetic barriers are overcome a variety of ordered primary dolomite textures may form controlled or not biogenically.

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Late Jurassic to Early Cretaceous evolution of the Arabian Platform in the Central Oman Mountains

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The time period between the Late Jurassic and the Early Cretaceous experienced dramatic changes in terms of plate configuration and paleoceanography. Perturbations of the global carbon cycle have been determined with the help of carbon isotope data available for different locations around the world. Especially the Western Tethys and North Atlantic regions were examined in great detail. Towards the most eastern part of the Tethys and the Pacific, available data is not very dense and additional information is helpful in order to understand how other paleogeographic regions were affected by the above-mentioned changes. The Oman Mountains preserve a Mesozoic succession, which was deposited at this most eastern part of the Tethys realm. It provides new information on impact of climatic and/or environmental changes in a region, which can be described as a window to the Indo-Pacific Ocean.

Stable isotope geochemistry of carbon and oxygen was performed on bulk carbonate samples from sedimentary successions from the Upper Jurassic to Lower Cretaceous formed on the Arabian Platform and outcropping today in the Central Oman Mountains. In addition, calpionellid assemblages were defined on selected samples allowing the definition of some biostratigraphic tie points.

On the Arabian platform, the Upper Jurassic is marked by an erosional sequence and sub aerial exposure, which induced the formation of a karstified surface on top of the grain-supported limestones of the Sahtan Formation. The overlying Rayda Formation shows a fining upward succession from reddish packstones and grainstones to light grey mudstones containing chert nodules. The top of the Rayda Formation is defined with the onset of centimeter bedded marl-limestone alterations of the prograding Salil Formation. The measured $\delta^{13}C$ values show very stable values between 1‰ and 1.5‰ in the lower part of the Rayda Formation before rapidly increasing towards values of ~3‰ at the uppermost part. After this positive excursion, the values decrease and stay at ~2‰ within the lowermost part of the Salil Formation.

The obtained geochemical and biostratigraphic data, together with a detailed description of the facies, allows a reconstruction of the environmental conditions at a paleogeographic position towards the Pacific. Contrary to the stratigraphy found in today's literature, the here-obtained data indicates that the upper part of the Rayda Formation in the Central Oman Mountains is not Berriasian but Valanginian in age. Further the $\delta^{13}C$ values reproduce very nicely the numerous datasets from other locations such as the Southern Alps and the positive excursion found in the uppermost part of the Rayda Formation could be related to the Valanginian Weissert oceanic anoxic event.

Mineralogical and Geochemical Characteristics of Sediment Cores from the Eastern Arctic Ocean during the last 200 ka

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The mineralogy and chemistry of two glaciomarine sediment cores recovered from the Eastern Arctic Ocean during the Arctic Expedition ARK-XX/3 of R/V 'Polarstern' in 2004 were analyzed in this study. Core PS66/321-4SL was recovered from the deep-sea floor east of Yermark Plateau (ca. -2,359m) and core PS66/325-3SL was from the northern continental margin of the Barents Sea (ca. -896m).

There were two main objectives in this study. The first one is to show whether mineralogical variations reflect the paleo-environment or not. The second one is to find the significant elements by XRF core scanner. The bulk mineralogical compositions by XRD were used to correlate with other proxies including chemical compositions. Organic-geochemical proxy data, sulfur, biogenic opal, and sand contents were also compared with the mineralogical and chemical compositions.

Hierarchical cluster analyses based on the correlation coefficient of the mineralogical compositions and some organic-geochemical proxy data were done for about 300 sub-samples. Carbonate, calcite, $\delta^{13}C_{tot}$, gypsum, and dolomite make Ca-rich group. Sand, K-feldspar, and plagioclase show strong positive correlations and make IRD group together with quartz, pyroxene, garnet, magnetite, and aragonite. Mixed layer clay, kaolinite, smectite, Fe-hydroxide, and opal make smectite-kaolinite group. Siderite, halite, TOC, C/N ratio, and sulfur make organic-group. Illite, chlorite, and barite make illite-chlorite group. Ca-rich group, IRD group, and illite-chlorite group might be derived from terrigenous source whereas smectite-kaolinite group and organic-group might be mostly originated from marine source. Graphical presentation of mineralogical compositions versus core depth, together with organic-geochemical proxy data, sulfur, biogenic opal, and sand contents might indicate the paleo-environments.

Mineralogical and chemical compositions from characteristic 50-54 samples selected from the two sediment cores were also analyzed and correlated each other to recognize the major chemical elements which reflect the characteristics of mineralogical compositions and organic-geochemical proxy data. Pd, Hf, and Ag show strong positive correlations and make rare-metal group together with Y, Au, W, and Pt. SrO, Rh, and CaO make Ca-rich group derived from calcite and gypsum and show positive correlation with $\delta^{13}C_{tot}$. Plagioclase, pyrite, k-feldspar, and amphibole constitute sand fractions and make one IRD group. Fe_2O_3, As, Mo, and P_2O_5 make Fe-hydroxide group. MnO make another IRD group together with smectite, pyroxene, magnetite, and aragonite. Te might be derived from diagenetic opal. Nb and Ta might be derived from garnet. Co, Ni, MgO, and Pb have positive correlations. Rb, Cs, Be, and K_2O have also positive correlations. REE and Th have strong positive correlations each other. TiO_2, Sc, Li_2O, Zn, Cr_2O3, V_2O_3, Al_2O_3, Ga, and ZrO_2 have positive correlations. All these elements might be derived from IRD of terrestrial source. Bi, U, and barite belong to one group. FeO might be derived from chlorite and/or siderite.

From those correlations, core analysis by XRF scanning for CaO, MnO, MgO, K_2O, TiO_2, and Al_2O_3 seems to be meaningful in the recognition of the mineralogical variations. CaO designates carbonate sediments, whereas MnO designates the IRD sediments mostly of smectite, pyroxene, magnetite, and aragonite. MgO, K_2O, TiO_2, and Al_2O_3 seem to imply the REE-enriched sediments probably of terrestrial source.

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Thin-bedded mudstone hyperpycnites in a Cretaceous lake (Hwangsan Tuff Formation), SW Korea

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Hyperpycnal flows are rheologically turbulent flows and hence constitute a type of turbidity current. However, they are characterized by long-lived and sustained discharges with fluctuating velocities. The typical resulting deposits are a compound of a basal coarsening-up unit deposited during the waxing period of discharge, followed by a fining-up unit deposited during waning flows. The units are often demarcated by intrasequence erosional surfaces associated with a peak flood. These characteristics depart significantly from classical surging and episodic turbidity flow deposits.

Unlike the sandy turbidite or hyperpycnite, the muddy counterpart is generally poorly documented. It lacks typical sequences indicative of traction processes associated with sandy turbidity flow deposits, although the overall inverse to normal grading patterns in grain size are still evident. The upper successions of the Cretaceous Hwangsan Tuff in southwestern part of Korea are dominantly composed of thin-bedded mudstones that were deposited by various types of turbidity or hyperpycnal flows. This study addresses the characteristics and depositional processes of the lacustrine muddy hyperpycnite.

The Hwangsan Tuff is composed of reworked volcaniclastics up to 300 m thick, deposited in a lake margin, on a delta front to the basin plain. The sequences show a fining-upward grain-size trend with a transition in depositional environments from a marginal delta to the distal, basin plain. The observed retrogradational stacking pattern indicates backstepping of depositional systems. This was probably due to gradual subsidence of the basin relative to sediment supply rate under an extensional tectonic regime.

The upper sequence of the Hwangsan deposits contain peculiar thin-bedded mudstones that is difficult to explain by the characteristics of conventional turbidity currents. Most mudstone beds show overall normal grading and are wavy in form, but internally demonstrate the existence of a depositional break such as an erosional surface and the repetition of rippled units. Thin-bedded mudstone with a pronounced normal grading is interpreted to have been deposited by small, dilute turbidity currents. However, a composite bed of lower massive siltstone overlain by a structureless claystone suggests deposition from slow-moving, high-density flows with high clay content. The hyperpycnal flow deposits in muds are characterized by a thickness change in the horizontal laminae, internal erosion scour, and the recurrence of rippled units, all of which are features indicating deposition from flow fluctuations in long-lived hyperpycnal flows. The low intensity of bioturbation and the presence of abundant plant debris additionally support this hypothesis. In the Hwangsan sequence, the hyperpycnal flows contributed to the building of a mouth bar to a delta front in the lake margin. This implies that the riverine sources in this study area were not located far away, although a 700-km-long distance from the source was reported for modern analogues. In addition, the abundant occurrence of hyperpycnites and the thickness of the mudstone succession among all the deposits suggest a high-stand lake level and an arid climate at the time of deposition.

Late Quaternary stratigraphy and evolution of Korean tidal flats: implications for glacial-last interglacial sedimentation

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Quaternary sediments in coastal regions contain signals of sedimentation/erosion histories as well as sea-level and climate change. The west coast of the Korean Peninsula is an indented ria-type coast with broad tidal flats. Sediments in this region are highly sensitive to sea-level fluctuations as a result of Quaternary glacial-interglacial cycles. This study presents a high-resolution sedimentological/geochemical study of five boreholes recovered from Korean tidal flats.

Together with the chronology of ^{14}C AMS and OSL dates, sedimentological and geochemical data suggest that the Korean tidal flat deposits are composed of four sedimentary units: 1) Saalian basal fluvial gravel/paleosol, 2) Eemian tidal mud, 3) Weichselian gravel lag/paleosol, and 4) Holocene tidal deposits, in ascending order. The Holocene tidal deposits are grouped into two sequences, separated by weathered/oxidized paleosol and gravel layers. Stratigraphically, the sequence in each core starts with fluvial deposits followed by tidal deposits. The lowermost fluvial/paleosol deposits are interpreted to have formed during a sea-level lowstand prior to coastal inundation during the Eemian Stage. The transition from the gravel beds to the overlying tidal deposits represents a trangressive erosion surface, implying an abrupt change from fluvial to tidal deposition. Towards the Weichselian glacial period, the fall in sea level must have resulted in the erosion of considerable portions of the Eemian tidal succession, thereby eliminating any MIS5 deposits. Erosion/nondeposition continued up to the MIS3 Weichselian glaciation when the sea-level lowstand prior to the postglacial transgression was once again dominated by fluvial deposits. With the onset of the postglacial transgression toward the Holocene, tidal processes in the coastal region resulted in the modern tidal sequence.

This study provides a clear link between nearshore sedimentation and glacial-last interglacial climate-driven sea-level changes, and also serves regional stratigraphic correlations and the applicability of the Asian monsoon climate model to the Yellow Sea.

Towards a chemically assisted appraisal of detrital modes and mineralogical distributions in Eocene series from the south central Pyrenees (Tremp basin)

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Eocene sections of the South Central Pyrenees record well exposed siliciclastic sequences encompassing continental to deep-sea accumulations in a foreland basin. Assessing primary mineralogical distributions in such a system requires facing the burial-related problem of mineralogical reworking together with the difficulty of directly assessing detrital modes for various grain-size classes from the sands to the muds. We report here preliminary results from two Eocene sections in the Tremp basin (Isabena and Campo sections), that pave the way towards a chemically-assisted strategy for the quantification of detrital modes.

Systematic bulk rock geochemical analysis of correlated sequences is used to screen the intersample variability as a function of age, sedimentological facies and average grain size, and to select for detailed petrographic and DRX studies the most extreme compositions, i.e. the envelope of the compositional cloud. As usual, the latter is largely shaped by grain-size variations, so the challenge turns to filter out this environmental bias to get access to provenance-related signals and the original characteristics of detrital grain populations.

Preliminary results from the sections under study suggest that compositional variability may be interpreted based on the principle of settling/hydraulic equivalences as a means to soften particle size related environmental biases (Garzanti et al. 2009). Of particular interest in this respect are the strong covariations of Zr/Al and Si/Al, Ti/Al, V/Al, Cr/Al that correlate with both the nature and the petrographic diversity of siliciclastic lithoclasts as compared with framework grains (Q F) in sands, and the sustained increase in Mg/Al ratios in finer grained sand fractions that correlate with the well-known relative enrichment in dolostones as compared with the other less dense Q F L grains. Sediment sources range from basement-dominated (high K calk-alcaline plutonic series from the Pyrenean axial zone with their medium grade metamorphic envelope) to thrust-dominated sources (Mesozoic carbonates and low grade sandstones, possibly with some Palaeocene contributions). The relative abundance of these two types of sources varies in time and space as a function of catchment positions and is illustrated in the geochemical/petrographic record.

Garzanti E., Ando S. & Vezzoli G. (2009). Grain-size dependence of sediment composition and environmental bias in provenance studies. *Earth & Planetary Science Letters* 277, 422-432.

Orbital forcing as a driving force behind the Weissert Episode (Valanginian, Early Cretaceous): new insights from detrital and nutrients influxes into the Vocontian Basin

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The Valanginian stage is characterized by a positive carbon isotope excursion (CIE, 1.5‰), the so-called « Weissert Event ». This event coincides with a widespread crisis of carbonate producing biota associated with important platform drowning events. The formation of the Parana-Etendeka large igneous province (LIP) (ca. 134 Ma) has been widely assumed to be responsible for an increase of CO_2, triggering long-term greenhouse conditions, increased weathering and elevated nutrient transfer rates from continents to oceans. However, many aspects of this model have recently been questioned. Climate is the fundamental parameter of the model proposed in the previous studies as it is linked to both geodynamic and stratigraphic events. However, despite the ongoing importance of the debate on Valanginian climate variations, there are relatively few studies that detail high-resolution climatic changes during the positive C-isotope shift.

The aim of the study is to assess the changes in terrigeneous and nutrient influxes into the Vocontian Basin associated to fluctuations in weathering processes. The multiproxy approach used herein is focused on high-resolution mineralogical (clay assemblages) and geochemical (major elements, $CaCO_3$ and phosphorus contents) analyses performed on the marl-limestone alternations of the Upper Berriasian–Valanginian Orpierre section (SE France). This section consists of a continuously deposited sedimentary succession, which is well calibrated by biostratigraphy and cyclostratigraphy.

At Orpierre, it appears that mineralogical and geochemical trends reflect a primary signal driven by palaeoenvironmental changes. Based upon a previous cyclostratigraphic study, performed at Orpierre, terrigenous, nutrient and clay influxes are calculated for the first time during the Valanginian.

The fluctuations of the terrigenous, phosphorus and clay influxes reflect changes in terrigenous input and nutrient levels linked to changes in the weathering regime in the source areas. At Orpierre it appears that during the Valanginian time interval, the weathering pattern resulted mainly from climate variations. Three major climate episodes have been highlighted: (i) near the Late Berriasian–Valanginian boundary : the Berriasian–Valanginian Episode (BVE) with a duration of ~576 kyr ; (ii) near the Early–Late Valanginian transition that includes the positive carbon isotope excursion : the Weissert episode (WE) with a duration of ~653 kyr ; and (iii) in the Late Valanginian : the Late Valanginian–Hauterivian Episode (VHE) with a duration of ~516 kyr. These episodes are marked by higher terrigenous and nutrient influxes related to enhanced humid conditions. Over the full record, they closely follow the variations in the insolation induced by Earth orbital parameters. Particularly, maxima eccentricity are recorded when wetter conditions and higher terrigenous inputs are recorded in the Vocontian Basin. The orbital forcing is probably the driving force behind the palaeoenvironmental changes that prevailed along the northwestern margin during the Berriasian–Valanginian interval.

The Urgonian olistolites of the Aravis Range (Haute-Savoie, France). Evidence of the progradation of the Urgonian platform in Late Hauterivian times in the Northern Subalpine Mountain Ranges

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In the Savoyard area of the Northern Subalpine Mountain Ranges, particularly in the Aravis Range, olistolites with Urgonian facies are embedded in hemipelagic facies with ammonites, echinoids and large benthic foraminifers (orbitolinids) of Late Hauterivian age. These olistolites document the collapse of the edge of a pre-existing carbonate platform. They are referred to the lowstand systems tracts of sequences Ha6 and Ha7 of Clavel et al. (2007). This peculiar setting results from the coeval progradation of the Urgonian Platform.

The succession from bottom to top consists of:

1. A cherty limestone formation (Kieselkalk) with *Toxaster retusus*, the top of which is ascribed to the Upper Hauterivian (Ligatus Zone *p.p.*): transgressive systems tract and highstand systems tract of sequence Ha5.

2. A lower lithostrome with Urgonian olistolites with *Toxaster retusus*, *Valserina primitiva*, *Palaeodictyoconus beckerae*, *Montseciella glanensis*, and *Clypeina paucicalcarea*, *i.e.*, an assemblage corresponding to the Upper Hauterivian (upper part of the Ligatus Zone - lower part of the Balearis Zone): Lowstand systems tract of sequence Ha6.

3. A lower hemipelagic unit with *Pseudothurmannia* cf. *pseudomalbosi*, *P.* cf. *angulicostata*, P. *stanislasi*, *Toxaster retusus*, *Valserina primitiva*, *V. broennimanni* (forme primitive), *Palaeodictyoconus beckerae*, *Montseciella glanensis*, and *Paracoskinolina* cf. *sunniladensis*, *i.e.*, an assemblage corresponding to the Upper Hauterivian (upper part of the Balearis Zone - lower part of the Ohmi Zone): transgressive systems tract and highstand systems tract of sequence Ha6;

4. An upper lithostrome with Urgonian olistolites with *Valserina primitiva*, *Paleodictyoconus cuvillieri*, and *Montseciella glanensis*, i.e., an assemblage corresponding to the Upper Hauterivian (medial part of the Ohmi Zone): lowstand systems tract of sequence Ha7;

5. An upper hemipelagic unit with *Paraspiticeras* gr. *percevali*, *Emericiceras* gr. *emerici*, *Torcapella* cf. *fabrei*, T. *suessiformis*, *Raspailiceras* sp., and *Toxaster seynensis*, *i.e.*, an assemblage corresponding to the transition of the Upper Hauterivian (upper part of the Ohmi Zone) to the lowermost Barremian (lower part of the Hugii Zone): transgressive systems tract and highstand systems tract of sequence Ha7;

6. The 'Urgonian cliff', the base of which is lowermost Barremian (lower part of the Hugii Zone): lowstand systems tract of sequence Ba1.

Lake Pavin paleolimnology and sedimentary records of regional Natural Hazards over the last 7,000 years (French Massif Central)

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In order to understand past interactions between human societies, climate and natural environments, lacustrine archives are widely studied around the world. Among them, volcanic lakes can also provide information about natural hazards specific to volcanic areas such as limnic eruption. In Western Europe, Lake Pavin (France) is a meromictic maar formed ca. 7,000 years ago. This lake is almost circular with an area of 44 ha and has a maximum depth of 92 meters with anoxic waters below 60 meters depth. Recent studies on the water column confirm the presence of methane and carbon dioxide in these anoxic waters.

In this study, we focused on sedimentary deposits using geophysical mapping techniques (multibeam bathymetry and high-resolution seismic reflection) and sediment cores retrieved both in shallow water environments and within anoxic waters in the deep central basin. Multi-proxies analyses were carried out on sediments including X-Ray fluorescence, spectrophotometry and organic geochemistry by Rock-Eval pyrolysis. Radiocarbon dating has been performed both on leaves debris and bulk sediment.

Results report gas-rich sediments mainly consisting of diatoms, deposited in three sedimentary environments: a littoral area, a plateau clipped by a landslide scar in the north part of the lake and a flat central basin surrounded by steep slopes. A 14 m long core retrieved in the central basin is mainly composed of two in-situ diatomite units separated by a massive unit resulting from an instantaneous deposit dated ca. AD 1300 and originating from the slide scar identified at the edge of the plateau. Evolution in diatom and pollen assemblages, but also in mineral and organic content reflects changes in the trophic status of the lake from its origin to the present day, with a progressive transition from a young lacustrine system fed by allochtonous material to an organic maar with strong algal supplies. On the plateau, acoustic mapping and sedimentary analyses indicates a slump deposit dated around AD 600 that may have been caused by a crater outburst and followed by a water-level drop in the lake and a catastrophic flood in the valley. These two major events in AD 1300 and AD 600 were associated with waves that have been identified through erosive sand and leaves layers on the littoral. A major lake-level drop is also confirmed by changes in sedimentary organic matter composition after AD 600.

Finally, this study provides new elements about trophic status evolution of maars and brings information about regional Natural Hazards through the late Holocene in the French Massif Central.

Moroccan phosphate deposits: An example of transgressive tracts influenced by storms

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The exploitable phosphates of Morocco are of Maastrichtian to Eocene age. They consist of transgressive successions overlaying a Paleozoic basement and reflect four types of phosphate particles: phosphate grains, fossiliferous or bioclastic particles, composite grains or reworked sediments and coprolites. Phosphate grains represent the dominant fraction (up to 80 wt%) with particle sizes ranging between 0.04 mm and 2 mm. There is no dominance of any type of grain in the succession. However, dominance can be observed at the scale of depositional sequences and stratigraphic stages. The P_2O_5 and CO_2 contents allow exploration of the spatial evolution of the deposits. The application of sequence stratigraphy to the sedimentary successions allows us to determine their depositional sequences, evolution and the geometry of the sedimentary successions. The sedimentary successions reflect recurring sediment dynamics during periods of maximum opening and deepening. Opening periods represent transgressive phases, which allow phosphate sedimentation to develop under the marked influence of basin hydrodynamics. Closing periods are marked by deposition of fine carbonate and clay sediments. The depositional sequences are globally characterized by irregular extension and in particular by the nodular character of phosphates at the end of each sequence. Correlations of these sequences reveal a substratum of irregular sedimentation influenced the lateral variations, as shown by the number of genetic sequences recorded. The geochemistry, especially the high content of trace elements (Zn and Sr), indicates a slow sedimentation with low rate of accumulation. High P_2O_5 contents can be explained by the influence of storm waves and ocean circulation patterns.

This canvas can be justified by the grain-size, aspect and form of phosphate particles as well as by the sedimentary structures observed in the sequence.

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The Middle-Late Triassic Event Sediments in Ordos Basin: Indicators for Episode of the Indosinian Movement

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Episode of Indosinian Orogenies at the end of the Middle Triassic was marked by an unconformity between the Middle Triassic and Late Triassic sequences in the eastern part of North China Plate, but it is difficult to recognize in this unconformity in the western part of North China (Ordos Basin) due to the successive sedimentation of Triassic stratum.

Based on the drilling cores of the Yanchang Fm., this study fosuses on the characteristics, frequency, scale and time sequences of these event sediments such as sublacustrine fan, seismites, tuff and kerogenous shale. The results indicate that these sequences are present predominantly at the initial stage of Chang-7 section of the Yanchang Fm, whose deposition coincides with the time episode of the Indosinian movement. This is an important dodumentation of Indosinian movement in Ordos Basin. It further implies that the boundary between the Middle Triassic and Upper Triassic may be roughly equivalent to that between Chang-7 section and Chang-8 section. The planar distribution of the event deposits is characterized by weakening trend from southwest to northeast of the basin, suggesting that these events responsed to Indosinian Qinling orogeny. The genetic relations of these event sediments and Dickinson triangular diagram reveal that the Indosinian-Qinling collisional orogenic process led to the unprecedented changes of Ordos basin and the genetic dynamic resulted mainly from the collisional suture between the Yangtze plate and the North China plate during the closure of the Paleo-Tethys.

Keywords: Indosinian orogenies, Event sediments, Yanchan formation, Middle-Late Triassic, Ordos basin

Lithofacies of Deepwater Fine-Grained Depositional System and Its Significance for Shale Gas and Oil Exploration in Lacustrine Basin: An Insight from Qingshankou Formation, Qijia-Gulong Depression, Songliao Basin, Northeast China

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In order to clarity the types of lithofacies in deepwater area of continental lacustrine basin and its affection towards shale gas/oil exploration, fine core observation, well logging analysis, interpretation of high resolution 3D seismic data, determination of whole core macerals and field emission scanning electron microscope pore research have been carry out in the deepwater area of Qingshankou Formation in Qijia-Gulong Depression, Songliao Basin. The results show that, six lithofacies can be identified in deepwater fine-grained depositional system, including oil shale, deepwater mud, bottom current rework sand (BCRS), shelly beach, turbidite, and mass transport deposits (MTD). Based on maceral analysis of 36 samples in deep water area of Qingshankou Fm in the study area, the occurrence of organic matter was divided into three types, which were enriched along the layer, disperse and enriched along layer-reworked. Hydrocarbon accumulation types of shale oil/gas were divided into three types on the basis of former study and division, which were matrix-dominated type, interlayer-dominated type and pore-dominated type. Good correlation has been found between lithofacies and the occurrence of organic matter, reservoir space types, and hydrocarbon accumulation types. Reservoir space types of oil shale and deepwater mud are dominated by organic matter pores, intergranular pores between clay minerals, intergranular pores between authigenic pyrite, and microfractures, which belonged to matrix-dominated hydrocarbon accumulation; shelly beach, bottom current rework sand (BCRS), and turbidite lithofacies were interlayer-dominated hydrocarbon accumulation, which were the favorable targets of shale gas and oil exploration; while mass transport deposits (MTD) were pore-dominated hydrocarbon accumulation with well developed primary pores and secondary dissolved pores.

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Structurally-controlled dolomitization of the Cambrian to Lower Ordovician carbonates at Quruqtagh area, northeastern flank of Tarim Basin, NW China

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Dolomites extensively occur in the Lower Cambrian to Lower Ordovician carbonates at Quruqtag area, northeastern flank of Tarim Basin. Enormously thick (≤ 1 km) hemi-pelagic to pelagic carbonates (mainly dark grey banded and lenticular limestones) were deposited from the Early Cambrian to Early Ordovician. The dolomitized rocks generally occur as irregular or anastomozed light-coloured (beige) dolomite bodies along fracture/fault networks which crosscut the stratified limestone beds. Based on detailed field investigations and petrographic examinations on the structurally-controlled dolomites, three types of matrix dolomite (fine crystalline planar-e float, fine to coarse crystalline planar-s (e) and fine to coarse crystalline nonplanar-a dolomites) and one type of cement dolomite (non-planar saddle dolomite) are further distinguished. Two episodes of vein-filling calcites postdate the cement dolomites.

The occurrence of floating dolomite rhombs commonly along stylolites in limestones suggests that they were formed in the remnant Cambrian-Ordovician seawater preserved in the precursor limestones, and were closely associated with burial pressure dissolution through which minor Mg ions were released from the host; this is supported by the similar C, O and Sr isotope values to those of host limestones. The preferential distribution of the rest matrix and cement dolomites along the fracture/fault networks suggests structural controls on the dolomitization, along which hydrothermal fluids at depths were readily channeled and migrated upwards. With the fracture/fault networks, dolomite replacement of fractured limestones and subsequent precipitation of dolomite cements in cavities preferentially took place there when Mg concentration reached saturation with respect to dolomite as a result of increasing entrainment of Mg ions in the upward-migrating hydrothermal fluids in the context of enhanced water-rock interactions. However, the large overlaps of O and C isotope values between dolomites (matrix and cement) and host limestones suggest somewhat fluid heritance from the remnant connate seawaters within formations. On the other hand, the more radiogenic ^{87}Sr isotope compositions and higher homogenization temperature of the saddle dolomite cements suggest stronger fluid-rock interaction with elevated temperatures in which case the more Mg ions were likely released from the argillaceous limestone host and/or more deeply-seated siliciclastic rocks during fluid migration. Regional geological evolution suggests that hydrothermal dolomitizaiton was favoured within the end-Carboniferous to Early Permian. During this interval, although the study area was located within an overall transpressional tectonic regime due to oblique collision of the Middle Tianshan arc to northeast onto the Tarim Basin, the secondary transtensional faults and/or fractures could have provided relatively favorable fluid conduit systems along which hydrothermal dolomitizing fluids were readily channeled from depths, leading to extensive dolomitization upon limestones there, thereby forming irregular networked dolomitized bodies enclosed within the limestone host. However, with the progressive tectonic uplift during the Late Hercynian orogeny, consecutive downward charges of meteoric fluids finally resulted in termination of the dolomitization and shift to calcitization.

New U-Pb zircon chronology of the Ediacaran-Cambrian boundary strata in South China

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During Ediacaran-Cambrian (E-C) transition, remarkable biological, oceanic and geochemical and tectonic changes occurred simultaneously; the most remarkable was the disappearance of Ediacaran fauna at the end of Neoproterozoic and subsequent explosive radiation of skeletonized animals from the Early Cambrian (namely "Cambrian explosion"), which was exemplified well by the Chengjiang Biota in SW China. Therefore, exact radiometric dating for the E-C boundary is fundamental to explore and understand the early geological evolution, particularly the co-evolution of early life and earth surface processes in a more refined time stratigraphic framework.

In the pre-trilobite Lower Cambrian strata of platform successions, small shelly fossils (SSFs) are widely used as the correlation tool, in the absence of trace fossils Phycodes (or Treptichnus) pedum occurring at the base of Cambrian at the stratotype section in Newfoundland. The E-C boundary in South China was initially proposed as the first appearance of the SSFs named as Marker A, and lately as the marked increase in SSF diversity named as marker B in the shallow-water succession at the traditional section of Meishucun, eastern Yunnan, SW China. Some researchers, however, favored the co-appearance of SSF Anabarites trisulcatus and Protohertzina anabarica as the indicator to mark the boundary, which commonly lie above Marker A. Therefore, the placement of the E-C boundary has been highly debated due to the absence of precise radiometric ages, facies-dependent occurrences of fossil assemblages and possible presence of depositional hiatus in shallow-water strata. In deeper slope and basin successions, in absence of SSFs of shallow-water origination in general, the occurrence of basal phosphoritic bands/nodules and subsequent appearance of sponge spicules in the thick Niutitang (or equivalents) black shales that overlies the Liuchapo or Dengying Formations, was traditionally taken as the base or near the base of Cambrian. Without additional constraints, the stratigraphic correlation between shallow-water platform and slope-basin strata is highly illusive and uncertain.

Here we present two sets of new high-resolution SIMS U-Pb zircon ages of four samples from the tuffaceous beds preserved in the boundary successions (Dengying, Liuchapo and Niutitang formations) off carbonate platforms in western Hunan and eastern Guizhou, South China, to constrain the E-C boundary and coeval geological evolution. One set of two concordant U-Pb ages of 542.1±5 Ma near the base of Liuchapo Formation deposited in marginal zone-foreslope at Ganziping, western Hunan, and 542.6±3.7 Ma in the mid-upper part of Liuchapo cherts of basinal setting at Bahuang, eastern Guizhou, for the first time, provide the direct age constraint on the E-C boundary in South China, and further affirm the diachroneity of Liuchapo Formation deposited in different depositional settings. The age-anchored negative carbon isotope excursion at this horizon further confirms the E-C boundary placement coincident with the global biogeochemical anomaly. Another set of two U-Pb ages of 524.2±5.1 and 522.3±3.7 Ma at the base of Niutitang Formation at two localities, eastern Guizhou indicates that this widespread formation was deposited about 20 Ma later than the onset of Cambrian. All these data refine the geochronology of lowermost Cambrian in South China and correlation with equivalents elsewhere.

Is the Cretaceous Aeolian Sandstones of Xinjiang Basin in Jiangxi Province the Sedimentary Response of the Eastern China Plateau?

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The Cretaceous was a period of great prosperity for the continental red faulted basins in South China. The Cretaceous red beds are widespread in Jiangxi province, which are mainly composed of brick- and purplish-red conglomerates, sandstones, making up of important foundation of the Danxia landform, such as the well-known Longhu Mountain World Geopark. The red beds have been traditionally described as fluvial fan and river sediments by most previous studies, but the aeolian sandstones were ignored.

However, many sets of large-scale high angle tabular and wedge-shaped cross-bedding fine-grained sandstones of the Upper Cretaceous Tangbian Formation are well exposed in Guixi, Yiyang and Hengfeng areas of Xinjiang basin, northeastern Jiangxi. The cross-beddings have 1.5 to 6.0 m- thick cosets and 2 to 4 cm- thick sets with the dip angle of 18° to 42° and somewhat converges dowornward. Grains of more than 2 mm and erosive surfaces were not found at outcrops. Both the compositional and fabric maturity of the sandstones are relatively high. The content of quartz is very high, and the cement is mainly calcite. Detrial composition statistics and Dickinson plotting show that the sediments were mainly derived from the craton interior of the continental block provenances, which imply intensive weathering and long distance transportation. Based on the major element geochemistry, the tectonic setting of the provenance area was deduced as passive continental margin. From the SEM images, most quartz grains from the large-scale cross-bedding sandstones are characterised by very good roundness, and there are aboundant typical textures, including dish pits, crescent-shaped pits and SiO_2 pellicle on the surfaces of the quartz grains, which are all the typical identification marks of aeolian sedimentary environment.

Because of the above macro- and micro-scopic sedimentary evidence, the large-scale cross-bedding sandstones of the Upper Cretaceous Tangbian Formation in Xinjiang basin should be interpreted as the product of aeolian instead of fluvial fan or river environment, which maybe the sedimentary response of the Eastern China Plateau during the Late Mesozoic. The Plateau with a height of more than 4000m was assumed to block off warm and wet air current from the eastern Pacific, leading to the arid and hot semi-desert and saline sedimentary environments under a tropic-subtropical paleoclimate condition. Therefore, the investigation on the aeolian sandstones of Xinjiang basin could provide important clues for the Cretaceous paleoclimate and paleoenvironment in Southeastern China and add new content to the Longhu Mountain World Geopark as well. Moreover, the aeolian sandstones need to be paid more attention for the research of the Cretaceous depositional systems in Southeastern China.

Key Words: Aeolian Sandstone; Cretaceous; Paleoclimate; Xinjiang Basin; Eastern China Plateau

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The role of lake-level fluctuation in generating depositional trends in continental rift basins: a case study of Dongying Formation, Nanpu Sag, Bohai Bay Basin

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Conventional sequence stratigraphy, developed for passive-margin basins, suggests that allogenic controls determine the generation of the sequence architectures. Through a case study of Nanpu Sag of the Bohai Bay Basin (a typical continental down-faulted depression), we demonstrate that in continental rift basins, lake-level fluctuation, represent one of the main allogenic controls but may not determine the depositional trend in the same way as eustasy on passive margins.

During deposition of Dongying Formation (50~25Ma), three estuaries developed successively due to the segmentation of its northern boundary fault, the Xinanzhuang Fault. During this period, the depositional trend (progradation, retrogradation, aggradadtion) was different along the Xinanzhuang Fault. In these estuary areas, a progradational or aggradational trends are evident, whilst retrogradation is shown in non-estuary areas. A comparison of the estuary areas in well-log data and 3-D seismic data also reveals sedimentological differences between them. During deposition of the Dong 3 formation, downcutting is evident in the estuaries of the Gaonan area. During deposition of the Dong2 and Dong1 formations, similar downcutting is limited. In the estuaries of the Laoyemiao and Beipu regions, no downcutting is evident. These phenomena indicate that sediment flux in Gaonan region was higher than in the other two. During Dong3 times, the depositional trend of the Gaonan area shows progradation and aggradation but in both Laoyemiao and Beipu areas, even though progradation parasequence sets can be identified, the depositional trend is retrogradational as a whole. Our study emphasizes the conclusion that the lake-level does not solely control the depositional trend, and its fluctuation is influenced by the flux of sediment through the estuaries because even during periods of lake level rise, progradation is evident due to the occurrence of a high sediment flux. Outside of these regions, retrogradation is evident in non-estuary areas. Different levels of progradation and/or down cutting reflect changes in sediment flux and can determine the location of the main estuary regions of elevated sediment flux.

Mass Transport and Its Petroleum Geological Significances in Deep Water Deposits of Lacustrine Basin — A Case Study of Deep Water Deposits in Ordos Basin

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Mass transport system was developed extensively in marine deep water deposits, and it plays an important role in controlling the distribution of oil and gas, This view has caused worldwide concern in the study of marine deep water deposits in recent years. The paper studies Yanchang formation in Ordos Basin through using many outcrops, rock cores and assaying data. The research indicates that mass transport system was also developed extensively in the deepwater area in large-scale depressed lacustrine basin, and we can briefly recognize it with geologic and seismic methods. This study further shows that the deep water deposits of Yanchang formation is divided into three kinds of sediment gravity flows which are slump, sandy debris flow and classic turbidite, as well as traction underflow. Slump and sandy debris flow belong to mass transport but classic turbidite and traction underflow belong to fluid transport, the two types of gravity flows have essential distinction in the rheological features. For the sand body to form in this area, many scholars enormously exaggerate the size of fluid transport(especially turbidity effects), in fact, mass transport is the main reason. Sandy debris flow is the most important mechanism to form the thick oil sand in the deep water deposits of Yanchang formation.

Keywords: mass transport; sandy debris flow; sediment gravity flows; petroleum geological significances; Yanchang formation; Ordos Basin

Accumulation mechanism of shallow marine gravity flow deposits - large efficient reservoir bodies of the Huangliu Formation in the Yinggehai Basin, South China Sea

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Large efficient reservoir-shallow marine gravity flow deposits of the member 1 of Huangliu Formation in the central Dongfang area of the Yinggehai Basin, South China Sea, is enigmatic in preserved sedimentary features and interpreted depositional mechanism. Paleontological study of these gravity flow deposits indicates that the paleo water depth was 40-110 m (shallow shelf). The gravity flow features include convolute deformation beddings and contemporaneous deformation structures. The vertical series are mainly Bouma sequence A and AB, lacking Bouma CDE. The gravity flow deposits show the characters of deposition from multiple events (superposition of 3 large turbidite events and combination of vertical series), and developed continuously though vertical evolutions. The comprehensive genetic mechanism of the large gravity flow deposits that formed in shallow marine environments incudes: (1) continuous sediment supply, (2) large-scale regression during the depositional period, (3) episodic dynamic and differential subsidence of the shelf. The continental shelf experienced several rapid subsidence increments, which made the sediments that are from same source be transferred to different directions and form various systems on the slope break. (4) Coupling and response relationship between these three factors. The gravity flow deposits that developed on the shallow marine shelf are the combined results of sediment supply from Lanjiang provenance, tectonic activities of the slope break in the central part of basin, and relative fall in sea-level.

This study focuses on the macroscopic and microcosmic features, accumulation control factors, and particular mechanism of the shallow marine gravity flow deposits based on the research methods and techniques of tectonic-sequence stratigraphy, sedimentology, and geophysics exploration. Research Contents include the sedimentations, architectures, and distributions of the shallow marine gravity flow deposits. The plane scale of the turbidite system changed as it migrated laterally through time. Therefore, intensive study of the genetic mechanism of these large scale shallow marine gravity flow deposits as well as its vertical evolution show important theoretical value and practical significance for the theoretical research of large gravity flow deposits in shallow marine environment, and also provide reference for the frontier exploration of oil and gas.

The main conclusions include: (1) The maximum thickness of gas bearing sandstones that was exposed in drilling log is about 87 m, which presents large scale, sustainable developed, and multi-periods characters of the shallow marine gravity flow deposits that stacked and distributed within 2000 km^2 areas. (2) The shelf paleogeomorphology experienced dynamic changes controlled by the episodic tectonic subsidence, which made the paleo-shelf steep (3-5°dip angle) and unstable. (3) After long distance transport on the shelf, the tractive currents evolved into gravity flows due to the dynamic subsidence of the shelf, which produced deposits of both fluid flow and gravity flow types. (4) The transit process from fluid flows to shallow marine gravity flows make the deposits well sorted with good physical property and compositional maturity, which provides essential conditions for efficient reservoirs.

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Cenozoic tectono-sedimentary analysis of the Bohaiwan basin, eastern China

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As the typical rifting basin developed in Cenozoic Era in eastern China, the Bohaiwan basin consists of four uplifts and seven depressions. There were also many normal faults and extensional strike-slip structures in these depressions. On the basis of the seismic and drilling data, the palaeogene chrono-stratigraphic sequence framework is established. Accordingly, by the analysis of sequence thickness and fault activities, the palaeogene tectonic evolutionary process is divided into two rifting episodes. Rifting episode 1 or the initial rifting period (Ek~Es_4, 65~42Ma): Ek~Es4 formations mainly distributed around the basin, but hardly developed in the central part of the basin. Rifting episode 2 or strong rifting period (Es_3~Ed, 42~24.6Ma): Es_3 formation spread all over the basin at much higher deposition rate. And the sedimentation center moved to the central part of the basin during Es_2~Ed period.

Under the control of complex multiphase tectonic evolution, the type of sedimentary facies and the distribution of sedimentary systems showed an obvious regularity. During the period of Ek~Es_4, the basin-controlling faults started to develop and mainly dominated the alluvial fan and fluvial depositional systems. Therefore, the lithology was mainly made up of sandy conglomerate, purplish gray mudstone, gypsum-mudstone, salt-rock, sandstone, a few limestone and dolomite. Up to Es_3, the tectonic activities became stronger, and the deep and half-deep lacustrine and lacustrine delta sediments developed. Correspondingly, the lithology consisted of deep gray mudstone, thin layer sandstone and oil shale. During the period of Es_2~ Es_1, the tectonic activities were significantly weakened. The shore shallow lacustrine and delta facies developed in the basin, while the lithology included coarse clastic rocks interbedded with red and lacustrine pale grey mudstone, bioclastic limestone and dolomite. Since the time of early-middle Ed, the deposit center of the basin moved to the present Bohai Sea where the lacustrine and delta sedimentary systems were controlled by strong tectonic activities and the lithology mainly contained gray or dark gray mudstone and delta sandstone. However, the current land part of the basin came into the shrinking period and developed fluvial sedimentary systems, where the lithology was characterized by the red and green mudstone interbedded with sandstones reflecting the floodplain swamps facies. Until later Ed, the basin experienced a short-rising and erosion process on the effect of a slight EW compressive stress.

The characteristics of the sedimentary evolution in this basin are closely related to the subduction of the Pacific Plate under the Eurasian Plate. Due to the direction-changing of the Pacific Plate subduction from NNW to NWW during Es_3 (42Ma), the Tan-Lu fault in eastern China also experienced relevant changing from sinistral rotated compressive shearing activity to dextral transtensional activity, which formed the dynamic background for the episodic rifting activity in Bohaiwan basin. In addition, the dextral strike-slip and pull-apart activities between the Tan-Lu fault and Lan-Liao fault had become the key factors that caused the subsidence center migrating to the central part of the basin since Es_3.

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Orbitally forced sea level changes in the Cemanian of the Tethyan Himalaya

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Although data suggest elevated temperatures and high sea level in Cenomanian, rapid sea level changes possibly caused by polar ice growth and melting events were discussed (e.g. Gale et al., 2002). We investigated the Cenomanian marine strata of the Tethyan Himalaya tectonic zone. The bio- and C-isotopic stratigraphies of the upper Cretaceous sediments within the studied area were initially established by Li et al. in 2006 and Wendler et al. in 2009. We undertook new studies of the planktonic foraminifers as well as detailed sedimentary logging and sequence stratigraphic analysis. The C-isotopic events additionally correlate well with the ones in the European reference curve.

The strata are mainly composed of marl and marly limestone couplets and thin bedded limestones. Based on stratal geometry, the lithology assemblages, microfacies, physical and chemical proxies of sea level changes (CaCO3 content and magnetic susceptibility), the succession was subdivided into twelve forth order sequences. Two sequence boundaries of third order sequences within the succession were identified as well.

The carbonate content and magnetic susceptibility values were measured at a resolution of ~20 cm. The carbonate of marine sediments is mainly originated from skeletons of marine fauna, while the magnetic susceptibility is related to the content of terrigeneous input which dilutes the autogenic minerals in the sediment. They were used as proxies to characterize the effects of marine and terrigeneous fluxes on the sediments in hemipelagic and pelagic basins. Spectral analysis of these proxies reveals peaks at ~0.57 m, 0.71 m, 1.34m, 2m and ~5.7 m. The ratios of these frequences match well with Late Cretaceous orbital parameters. We therfore relate them to the eccentricity and obliquity forcing.

Based on lithology assemblage, microfacies, $\%CaCO_3$ and magnetic susceptibility, the relative sea level curve were estimated. Our work indicates that the sedimentary and carbonate cycles are mainly controlled by global sea level changes and occur in concert with changes in the Earth's orbital parameters. Two significant fast falling events in the Cenomanian were identified, which correspond with the global sea level curves established in other continents. The effects of subsidence, sediment loading and thermal expansion in the study area can hardly lead to the abrupt and significant sea level falls. The only mechanism for the two falling events is the growth and melting of polar glaciers.

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The collection and analysis of high-resolution sedimentary process data at Dagu river mouth of Jiaozhou Bay, China

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1. Introduction

The study of sedimentary process from small river systems has become a focus in recent years. When extreme events (such as flood events induced by typhoons) occur, river flux increases rapidly and can have great impact on sedimentary environments of river mouth and coastal zones. The Dagu River is a typical small mountain river in the north of China. It is 179.9 km in length and originates in Fushan moutain in Zhaoyuan of Shandong province. The drainage area is 6131.3 km^2 and the gradient of the slope decreases gradually downward. Dagu River is the largest river flowing into Jiaozhou Bay and supplies over 85% of the fresh water to Jiaozhou Bay. In this research, the high-resolution sedimentary process data at Dagu river mouth has been recorded and analyzed.

2. Data and methods

A platform with autonomous instruments was developed to investigate synchronized waves, currents, water level, seabed changes and water turbidity at the Dagu river mouth from Sept 24 to Oct 4, 2012. The related data has been seized and recorded effectively during the strong wind weather process.

40 surficial sediment samples were collected within 2 cm below the sediment surface in cross-shore sections of the coastal zones on Oct 2, 2012. The positions of sampling sites were determined with GPS. All the samples were treated by the following procedure: (1) 2g dry sample of sediment, 15ml distilled water and 5ml H_2O_2 (30%) were mixed and slightly heated, then left for 24 hours and organic matter removed. (2) 1-2 drops of $(NaPO_3)_6$ solution were added as dispersant and the mixture was placed in an ultrasonic bath to agitate and disperse for 2 hours. A Malvern2000 was used for measuring the grain size distribution of the sediments. According to their gravel+sand/silt/clay ratios, the sediments were classified following the classification of Shepard (1954). The sediment parameters were calculated according to the methods of Folk and Ford (1957). The sediment transportation tendency was based on the method of Gao and Collins.

3. Results and conclusion

(1) We observed an obvious increase of SSC during a strong wind weather event. SSC was positively correlated with wave height and the duration of increased wave action. Increases in SSC were not constant but appeared to be correlated with peaks in wave height. The highest SSC was also associated with the peak of an ebb tide.

(2) The seabed has showed rapid erosion with high SSC during the strong wind weather. However, when the strong wind weather ended, the SSC decreased sharply and seabed also showed rapid deposition.

(3) According to the grain size data, the surface sediment of seabed showed a Southeast transporting tendency, which suggests that the sediment in the study area mainly sourced from Dagu river.

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IGCP 630: Permian-Triassic climatic and environmental extremes and biotic response: A launch

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Many marine ecosystems are under threat at the present day. The geological record provides numerous analogues of environmental upheavals and major biocrises, the most disruptive of which occurred during the Permian-Triassic (P-Tr) transition at ~252 million years ago. Many of the factors that contributed to the P-Tr biocrisis, e.g., increased atmospheric CO_2 concentrations, rapid global warming, and oceanic anoxia are also observed in the present-day or are anticipated to develop in the near future. The P-Tr transition may thus record a natural experiment in global-scale ecosystem collapse that, if properly deciphered, could provide important insights into possible responses of modern marine ecosystems to present-day climate and environmental change. This project addresses themes related to current global concerns and issues including the response of the biosphere to global warming, sustenance of global biodiversity, and maintaining the habitability of planet Earth.

After completing successfully the IGCP 572: P-Tr ecosystems (2008-2013), a group of geoscientists, including Zhong-Qiang Chen (China), Thomas J. Algeo (USA), Margret L. Fraiser (USA), Steve Kershaw (UK), Jinnan Tong (China), Sylvie Crasquin (France), Michael J. Benton (UK), Guang R. Shi (Australia), Charles M. Henderson (Canada), Arnie Winguth (USA), Paul B. Wignall (UK), Kunio Kaiho (Japan), Ghulam Bhat (India), and Yuri D. Zakharov (Russia), are co-leading a new IUGS-sponsored International Geosciences Program project (IGCP 630) working on the P-Tr climatic and environmental extreme events (2014-2018). More than 130 researchers from 27 countries participated in IGCP 630.

The new IGCP project aims to investigate the climatic and environmental extremes and ecosystem's response during the P-Tr mass extinction and its aftermath through analyses of the rock and fossil records from around the world. Through detailed studies of latest Permian to Early Triassic biostratigraphy, palaeontology, palaeoecology, sedimentology, geochemistry, and biogeochemistry, IGCP 630 will attempt to document global ecosystem's collapse and rebuilding in seas and on land, formulate the mechanism biotic response to climatic and environmental extremes; to reconstruct the global P-Tr oceanic and climatic conditions and probe mutual effect; and to correlate all of this data in a global stratigraphic framework. Ultimately, IGCP 630 will (1) reveal climatic and environmental extremes at a global scale and their impacts on ecosystems in seas and on land, (2) elucidate the factors controlling biotic recovery in various habitats and climate zones, (3) determine the similarities and differences in the responses of different marine groups to biotic crisis, and (4) assess the effect factors slowing the restoration of devastated ecosystems.

These goals will be achieved primarily by collaborative fieldwork in >10 different countries over five years and related laboratory work in over 20 different countries. The results of our project will advance scientific understanding of the interactions between the biosphere and geosphere and lead to a better understanding of ancient defaunation events. As a result, IGCP 630 will provide a friendly platform for participants to communicate their own research results and also bring together global experts, and research facilities to solve a truly global-scale problem.

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Detailed Internal Architecture of a Braided River Delta in Modern Lake Daihai, North China, Determined from Trenches, Cross Section, and Ground-Penetrating Radar

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Detailed geological information from trenches and cross section are integrated here with ground-penetrating radar (GPR) for analysis of modern deposits analog in braided river delta reservoir. Twenty eight trenches were d igged with a depth of 1.5~2.0m and sedimentary logging are recorded in the field. A representative cross section of 1.2km long and 1.8m high incised by Bantanzi braided river where pebbly braided channels and sandy mouth bar can be identificated obviously. Better still, the cross setion is continuous from delta plain to front, so it is a resource for geoscientists interested in the architecture and sedimentology of braided river delta, such as dimensions and continuity of facies associations, and the transformation from channels in plain to mouth bar in front. In addition, five lines of two-dimensional GPR surveys were made with a length of 0.9~1.7km and a depth of 1.8m. To facilitate comparison of geologic features in the depth domain and radar reflectors in the time domain, the radar data are depth migrated. The GPR interpretation is carried out mainly on migrated 500 MHz data with a vertical resolution of about 0.1 m.

Based on dissection of the trenches, cross section and GPR, four architectural elements are identified and described. Internally, braided channels in delta plain consist of trough cross-bedded gravels, and mouth bar in delta front consists of wave ripples fine sands. The same sedimentary architectural elements and associated bounding surfaces are distinguished in the GPR data by making use of principles developed in seismic stratigraphic analysis. Measures of the spatial continuity and variation of the bounding surfaces are obtained by the Bantanzi cross section and GPR for each architectural element. According to interpretation of the section and GPR, the interspaces between trenches are estimated, and a lithologic fence diagram has been built to exactly cognize the deltaic complex.

This work also confirms that different types of hydrocarbon reservoirs require different correlation techniques. In delta plain, channels concave eroded fine sediments and existed in isolation, or superposed with other channels. In delta front, mouth bar prograded gradually and formed foreset bed. Therefore, two correlation models are built which lithostratigraphic model is suitable for channels in delta plain, and chronostratigraphic model is much suitable for mouth bar in delta front.

Cyclic patterns of the Valdorria carbonate platform-top deposits (Carboniferous, Northern Spain)

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Carbonate platforms exhibiting cyclic patterns are widely known in the rock record. The controlling factors of cycles include intrinsic and externally imposed processes such as eustasy and tectonic . As during the Pleistocene, glacio-eustatic sea-level fluctuations during the Late Paleozoic ice age with Gondwana ice sheet waxing and waning triggered cyclothems in several basins around the world.

The Valdorria carbonate platform, dated of Bashkirian, exhibits such cyclic deposits. The platform is particularly well preserved and tilted at nearly 90°, allowing to constrain its overall 2D geometry and stratal patterns. The aggrading phase reaches up to 240 m in thickness and extends on more than 4 km, prograding eastwards. Cyclic units are flat westwards and gently dip eastwards, at a maximum angle of 18°. Fusulinids gave an age belonging to the Asatauian Horizon (late Bashkirian), which lasted for 1.6 My. Nine major continuous cycles (C1 to C9, respectively) have been defined in the platform-top strata of the eastern margin. Cycles extend over a 2 km long area and can be delineated through nine well-developed sub-aerial exposure surfaces (S1 to S9, respectively), which can be traced on the outcrop and mapped in detailed.

Internally, seven cycles (C1 and C3 to C8) out of nine show lateral and vertical variations of facies, with a shoaling upwards predominant trend. These seven cycles have only minor, 1-2 centimeter-thick dissolution features on their top, likely implying short emersion intervals. On the contrary, cycle 2, mainly consisting of Donezella-rich boundstones, lacks vertical variation, but exhibits karst and dissolution features as deep as 1 m. Cycle 9 exhibits a well-developed 3 m thick calcrete bed at top, along with extensive karstification basinwards affecting deeper outer platform deposits. These features imply a more significant sea-level fall and long-lasting emersions.

The cyclicity was most likely driven by glacio-eustatic factors superimposed on intrinsic processes, in particular subsidence at the local or regional scale. The occurrence of small-scale minor cycles within major cycles supports an orbital control.

Karst features of the Valdorria platform are of further interest because they are comparable with those assumed for coeval (Serpukhovian to Bashkirian) platforms yielding important hydrocarbon reservoirs, e.g., Karachaganak, Kashagan and Tengiz fields.

Distribution and Controls of Carbonate Reservoirs in Middle Permian, Sichuan Basin, China

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Qixia-Maokou Formation was the first industrial gas production area in Sichuan Basin. The discovered gas reservoirs are mainly located in south part of the basin. Tight rock and poor physical property are the main restraining factors for the extending of gas exploration in this layer. This article, using micro and macro analysis methods, studies the controls and distribution of valid reservoirs in details, which are very important for the extending of exploration in this layer.

Reservoir controls: Data based on14518 samples from 100 wells show the physical property in Qixia-Maokou Formation is generally poor except some local area with relatively good physical property. Dolomitization and corrosion play an important role for forming valid reservoirs. Dolomitization can improve physical property of reservoirs: the average porosity of dolomite is 2.1 %, the maximum of it is 16%, while that of the limestone is only1.08%. Corrosion is the most important control for improving physical property of reservoirs of carbonate. The discovered reservoirs in south part of Sichuan Basin belong to fault-cavern or fault-cave type with low porosity and permeability.

Distribution of dolomite reservoirs: Based on outcrop investigation and stratigraphy correlation, weakly dolomization carbonates, such as calcareous dolomite and dolomitic limestone, distributed in large area and have poor physical property of reservoirs, which is not better than limestone. Saccharoidal dolostone, dolomite content is larger than 90%, is good reservoir, whose original lithology is limestone of high-energy shoal facies. The most of them are distributed in the margin of platform of western basin, while a few of them distributed in the inner platform within Longnvsi and Guangan region. The thickness of dolomite reservoirs changes rapidly in lateral. The thickest of dolostone within middle Permian is found at Zhougongshan-Hanwangchang area in southwest of the basin, where the thickness of it is thicker than 100m. The strata pinched out northward to Daxingchang and eastward to Sansuchang. Dolostone of the second member of Qixia-Maokou Formation in northwest Sichuan Basin is mainly formed in Kuangshanliang-Tianjingshan area.

Distribution of karst reservoirs: Based on 21 profile stratigraphy correlations, Middle Permian was eroded in different degrees in Sichuan Basin, which indicate that the basin was uplifted during Dongwu Period after the sedimentation of the strata. The residue thickness figures compiled based on data of 1200 wells confirm that 3 paleo-uplifts was developed, located in Luzhou, Kaijang, and Mianyang. Moxi-Gaoshiti area of Central basin, located on the karst slop between Luzhou and Kaijiang paleo-uplift, which is similar to accumulation status of Jingbian gas field in Ordos Basin, is favorable for the forming large kart gas reservoirs. So that, Moxi-Gaoshiti area is favorable exploration plays for Middle Permian gas reservoirs.

Methane and carbon dioxide fluxes at the sediment-water interface in organic-rich reservoirs, Federal State of Micronesia

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Introduction: Mangrove swamps, wetlands of the tropics and subtropics, are important ecological environments and sensitive ecosystems that link between terrestrial and marine environments. The magnitude and pathways of the annual flux of organic matters and carbon through many of the world's ecosystems is unclear including mangrove forests [1]. Some estimates suggest that the tropics are net source and temperate ecosystems are large sink for carbon dioxide and organic carbon [2]. This is particularly true for coastal ecosystems in the tropical ocean, such as mangroves, coral reefs and estuaries. However, delivered large amount of organic matters from terrestrial input, marine organisms and tree itself are settled in mangrove forests. Therefore, dissolved oxygen is depleted to decompose the organic matter and bottom conditions are changed to anoxic or suboxic environments. Methane and carbon dioxide, produced from anoxic sediments, are released into the atmosphere which results in a global warming [3]. In this study, we present data on the rate of oxygen consumption, hydrocarbon gas concentration and diffusive fluxes of methane, carbon dioxide and decomposed substances at the sediment-water interface in anoxic environments of mangrove swamps and oxic sandy sediments.
Methods**:** Five sediment cores were recovered from mangrove forest (4 sites) and coral-based sandy sediment (1 site) in Federated States of Micronesia (FSM) during 2013. In each site, one sediment core was prepared for porewater extraction and sediment organic carbon analysis, the other one was incubated for oxygen consumption rate and released gas detection. Porewater was extracted in the laboratory after obtaining the push cores by using modified Rhizon samplers which vacuum produced syringe at interval in the range of 3 cm. To determine the total oxygen uptake from the sediment, cores were incubated at in situ conditions.
Results**:** The organic contents are recorded in mangrove swamps and sandy sediment as 10.5-34.3 mg g^{-1}, 0.3-1.1 mg g^{-1}, respectively. In the incubation chamber, the oxygen consumption rate is larger in organic-rich mangrove sediments (7.6 ± 0.3 to 13 ± 0.6 mmol O_2 m^{-2} d^{-1}) than in the sandy sediment (2.3 ± 0.2 mmol O_2 m^{-2} d^{-1}). The diffusive flux of methane and carbon dioxide from sediments to the overlying water are 0.5-10 μmol CH_4 m^{-2} d^{-1}, 32.4 - 82.1 mmol CO_2 m^{-2} d^{-1}, respectively.
Conclusions**:** Mangrove swamps as a sink of organic matters transform the large amounts of carbon delivered from terrestrial and marine ecosystem. As a consequence of anoxic- or suboxic degradation of carbon in the sediment and the water column, carbon dioxide and methane are emitted into the atmosphere.

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Preliminary report of a multidisciplinary stratigraphic research on the upper Paleozoic strata near Ny-Alesund, Broggerhalvoya, Spitsbergen

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In spite of harsh polar environment, upper Paleozoic strata of Spitsbergen have been considerably studied for more than a century because not only of their superb exposure on the vegetation-free arctic terrain but also of their well-preserved primary structures and abundant fossil occurrences. Special interest has been given to environmental changes during the late Paleozoic which finally led to the biggest mass extinction in the end Permian. However, the upper Paleozoic stratigraphic framework has been made mainly based on outcrop sections in the Isfjorden area and many other regions have been limitedly investigated. The time-equivalent sections in the Broggerhalvoya is placed within the West Spitsbergen Fold-and-Thrust Belt and numerous stacking by nappes hampers straightforward understanding of the strata and distracts stratigraphers' concern. This collectively resulted in the upper Paleozoic strata of the region remained as poorly understood.

The upper Paleozoic strata of the Broggerhalvoya is represented by the Gipsdalen Group (upper Carboniferous to lower Permian) which is further divided into the Broggertinden, Scheteligfjellet, Wordiekammen, and Gipshuken formations in ascending order. The Kapp Starostin Formation of the Tempelfjorden Group (middle to late? Permian) overlies the Gipsdalen Group and marks the top of the Paleozoic in the area.

A new trial for the refinement of litho- and bio-stratigraphy of the upper Paleozoic strata in the Broggerhalvoya has been made by a group of sedimentologists and paleontologists with special interests in detrital zircon ages, carbonate microfacies, and marine sessile benthic faunas. A total of 300 m of the exposed sections have been measured in detail (1:50 scale) with recording occurrences of fossil faunas. The preliminary results confirm the transitional boundaries between clastic Broggertinden and carbonate Scheteligfjellet formations. Transition from the Scheteligfjellet Formation to the Morebreen Member of the Wordiekammen Formation, which is characterized by appearance of chert nodules in the gray limestone and dolomite, is also gradual. The boundary between the Morebreen and the overlying Tyrrellfjellet members also seems to be gradual. In the upper part of Tyrrellfjellet member a transition from bedded dolomite to carbonate breccia were recognized but it is not certain if it indicates the boundary between the Wordiekammen and Gipshuken formations. The Gipshuken Formation was not investigated yet. In addition, a detailed sedimentary measurement with fossil collecting was carried out for the Kapp Starostin Formation in the region. Fossiliferous silicious limestone and glauconitic sandstone with intercalated shale are recognized in the lower part of the Stollnuten section. However, the Voringer Member, which is known as the lowest unit of the formation and commonly documented from all other regions in Spitsbergen, is evidently absent in the section. The overlying units are represented by thick succession of dark colored chert beds.

Other than the detailed measurements of the sections and the routine rock samples, invertebrate macrofossils and bulk samples for microfossils are intensively collected from the Schetelligfjellet and the Kapp Starostin formations for biostratigraphic analysis and further studies on ecological and environmental changes in the Boreal realm through the late Paleozoic. Most of the sandstone units are sampled for detrital zircon geochronology aiming resolving changes in sedimentary provenance and refining depositional age. Tabular coral-multithecapora-bryozoan bioherms are discovered in the Morebreen Member and the samples are prepared for the detailed researches. Continuing this preliminary survey, Korea Polar Research Institute has started another 3-year project for the multidisciplinary stratigraphic researches on the Broggerhalvoya area.

Sedimentological Controls on Prospective Conventional and Unconventional Resource Plays: Case Studies from the Devonian of the Western Canada Sedimentary Basin

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Conventional petroleum exploration in the Western Canada Sedimentary Basin is considered by many to be at a mature stage. Along the eastern margin of the basin, however, there is still considerable potential for new conventional and unconventional resource plays as only limited deep-well information is available. In Manitoba, out of the 6729 vertical wells drilled (as of April 2014), only 146 wells intersect Middle Devonian strata. Oil shows have been documented in almost all Devonian formations but no economic discoveries have been made in these formations to date. We have investigated the sedimentology and organic petrology of the Middle Devonian Winnipegosis Formation and the Upper Devonian Duperow Formation in Manitoba with the goal of understanding the sedimentological controls on their reservoir and source rock potential and stimulating exploration of deep targets in the region. Detailed core examination, carbonate and organic petrography, geochemistry and Rock-Eval pyrolysis were done for this project.

The Winnipegosis Formation consists of fossiliferous dolostones and minor limestones, up to ~100 m thick, which are divided into a lower member of ramp facies and an upper member of rimmed shelf-to-basin facies with isolated reefs. Potential exists for conventional reef and platform plays in dolomitized facies which have up to 35% intercrystalline and vuggy porosity. Bituminous laminites in ramp and platform strata are up to 70 cm thick and have total organic carbon (TOC) values of up to 52%, suggesting potential for a resource play with local sourcing. These bituminous laminites are interpreted to be the product of elevated phytoplankton productivity and are best developed in stratigraphic intervals associated with the transition from ramp to platform/basin and from open to restricted basin.

The Duperow Formation in Manitoba is a 122–195 m-thick succession of fossiliferous limestones, dolostones and evaporites interpreted to represent deposition in the arid interior of a rimmed shelf. The Wymark Member is recognized as the main reservoir unit in the Duperow Formation but live-oil staining is observed throughout the formation. Reservoir intervals of porous subtidal and intertidal facies, up to 14 m thick, are capped by tight evaporite lithofacies, up to 3.5 m thick. Facies-controlled dolomitization, attributed to sabkha evaporative pumping and seepage reflux, appears to be the primary control on porosity development, with dissolution as a secondary influence. Massive dolostone and dolomitic microbial bindstone have up to 25% intercrystalline and vuggy porosity and up to 210 mD permeability. Porosity reduction is due to synsedimentary marine cements of radial-fibrous and radiaxial-fibrous calcites and burial cements of nonferroan blocky calcite, anhydrite and gypsum, which variably occlude interparticle and intercrystalline pores and vugs.

In conclusion, the sedimentology and organic petrology of the Winnipegosis and Duperow formations along the eastern margin of the Western Canada Sedimentary Basin reveal potential for new conventional and resource plays.

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High-resolution $\delta^{13}C$ and $\delta^{18}O$ chemostratigrapy of carbonates from the Miocene Ries Crater lake margin (Hainsfarth Quarry, S Germany): Environmental versus diagenetic control

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The isotopic composition ($\delta^{13}C$ and $\delta^{18}O$) of carbonates is routinely used as palaeoclimatic proxy from modern and recent lakes. Ancient lakes, however, were seldom investigated for their primary carbon and oxygen isotope composition. This is due to some extent to the diagenetic overprint of primary environmental signatures in carbonates with time and, perhaps, also to the difficulty to identify seasonal mechanisms in ancient lacustrine systems. Miocene Carbonates of the Ries Crater Lake (Southern Germany) have formerly been analysed for C and O isotope geochemistry on drilling cores taken on the southern basinal and slope areas. Combined to other geochemical, petrographic and palynological proxies, these previous studies showed a chemical evolution of a closed lake system from a freshwater stage towards a hypersaline one. In this study we present the first geochemical analyses of the proximal/shoreline facies of the Ries Lake system cropping out at the Hainsfarth Quarry. These carbonates certainly represent a portion amongst the youngest and latest infillings of the lake system. These deposits are located at the northern margin of the lake and are principally characterized by a succession of ostracodal/gastropodal packstones/grainstones, algal (*cladophora*) boundstone as bioherms and nodules, and palustrine facies. A high-resolution chemostratigraphic analysis (one sample every 5 to 25 cm) has been undertaken on bulk and micritic carbonate intervals with the aim of identifying environmental change in the lake system. In order to clarify the "pristine" nature of the geochemical signatures observed in our dataset, these data will be complemented by analyses of the $\delta^{13}C$ and $\delta^{18}O$ of preserved ostracode shells, SEM analyses and cathodoluminescence microscopy. The $\delta^{13}C$ values of the bulk and micritic carbonates range from -7.4 to +4.0‰ (mean = 0.3‰) and the oxygen isotopic composition shows a very similar pattern with $\delta^{18}O$ values varying from -7.7 to +3.9‰ (mean = -0.4‰). The correlation of both carbon and oxygen isotopic values is positive and almost perfectly linear ($R^2 = 0.95$). This trend is in agreement with the previous interpretation of the lake as a closed saline system. The fluctuating trend of the isotopic profiles suggests? seasonal environmental changes from a saline lake towards what are interpreted as freshwater conditions. Care must be taken, however, when interpreting these results since such negative carbon and oxygen isotope ratios may also reflect a freshwater/meteoric diagenesis of carbonates that were previously formed under saline conditions. The studied carbonates, being located at the lake margin, were indeed likely sensitive to changes in lake levels and potentially experienced several emersion phases and therefore meteoric alteration.

Early Cretaceous tectonic rejuvenation of an Early Jurassic margin at Mt. Cosce (Narni Ridge, Central Apennines, Italy)

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Evidence for an extensional phase in the Early Cretaceous was detected in the western sector of Central Apennines during a geological mapping project (1:10,000 scale) in the Narni Ridge, at Mt Cosce (~100km N of Rome). A pelagic succession of the Umbria-Marche-Sabina type overlies shallow-water carbonates (Calcare Massiccio Fm., Hettangian). Jurassic sedimentation was controlled by the local architecture of the W-Tethyan rift, which dismembered the vast Calcare Massiccio platform. While tectonic subsidence forced the drowning of hangingwall-block carbonate factories around the Hettangian/Sinemurian boundary, followed by deeper marine sedimentation, benthic carbonate production survived on horsts until the early Pliensbachian, when they became sites of condensed pelagic deposition. From the Pliensbachian to Early Cretaceous, basin-fill deposits onlapped and eventually buried the inactive marginal escarpments of structural highs.

A Jurassic structural high corresponds to Mt. Cosce. While its top and condensed succession are not exposed due to orogenic deformation and modern erosion, its margins are locally preserved, marked by the angular unconformity with basinal units and the diagenetic modification (silicification) of the C. Massiccio. One arresting feature at Mt. Cosce is a sedimentary breccia (Mt. Cosce Breccia), forming sparse to laterally continuous outcrops, which rests unconformably on the horst-block C. Massiccio. The polygenic breccia is chaotic, and displays: I) heterometric clasts made of rocks not younger than the Early Cretaceous, set in a greenish matrix; II) white pebbly mudstones, with radiolarian- and calpionellid-rich (Maiolica Fm.) elements. The lithoclasts were clearly fed locally, and represent formations from the C. Massiccio to the Jurassic basinal succession, as well as various Jurassic condensed facies. The youngest age detected within clasts, the absence of calpionellids and the occurrence of *Hedbergella* sp. in the matrix, suggest an Hauterivian-Barremian age for the breccia. The unconformity and breccia indicate in our interpretation an episode of reactivation of an Early Jurassic fault, and exhumation of a paleoescarpment tract that had been buried by the lower part of the Maiolica Fm. (with calpionellids). A purely gravitative cause must be ruled out based on the geometries and composition of the breccia: several clasts represent pre-Cretaceous units, like Middle/Late Jurassic radiolarian cherts. Their presence can only be explained by inferring that they found themselves topographically uplifted with respect to the Cretaceous basin. In our interpretation the clasts were fed from the exhumed vestiges of the Middle/Late Jurassic onlap wedge, including the peritidal substrate and the former epi-escarpment deposits (condensed facies), as a product of escarpment rejuvenation, erosion, and displacement along an Early Cretaceous fault. A non-tectonic interpretation would imply deep (100's of m) erosion down to the Jurassic part of the basin-fill sequence along submarine canyons, for which no evidence whatsoever exists in the area. While the breccia now occupies the eastern slopes of Mt. Cosce, undoing the Neogene thrusting-related deformation (Mt. Cosce is part of the hangingwall anticline of the Narni Thrust) indicates it must in fact document a former W-facing margin as the Mesozoic paleoescarpment was rotated due to folding. Last, Quaternary extensional faults further dissected the folded and thrusted rocks embedding the Jurassic rift.

Sedimentology and palynofacies of the Triassic Gokdere-type pelagic succession in western Taurides (Southern Turkey): implications for palaeogeographic reconstruction

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The presented results take part of a research project carried out in the frame of the 3-year Darius-Programme focused on the areas fringing southern Eurasia, in the Middle East and western Central Asia. The project aimed to reconstruct the stratigraphic architecture and palaeogeographic evolution of the central Taurides during the Late Triassic–Early Jurassic, a critical time interval lying between the closure of the Palaeo-Tethys Ocean and the onset of the Cimmerian deformation. The data collected during the 3-year project come from sections pertaining to different tectono-stratigraphic units belonging to the Antalya Nappes (southern Taurides), from both the Çataltepe (CN) and the Alakirçay (AN) Nappes. The first one, largely cropping out in the west of the Antalya gulf, was deposited on a Triassic shelf evolving to a Jurassic-Cretaceous slope and basin deposits. The Alakircay Nappe differs from the other Antalya Nappes for the presence of a continuous Middle-Upper Triassic to Cretaceous pelagic sequence, sometime associated to basic volcanics (rift deposits) at its lower part. Our data come from the Yaylakuzdere section (AN) cropping out in the western Taurides, west of the Antalya Gulf. In this region, the Antalya Nappes are exposed as imbricated tectonic slices between the Mediterranean Sea and Beydagları. In the Yaylakuzdere section, the Middle to Upper Triassic pelagic succession includes the Karadere-type spilitic pillow basalts and part of the Gokdere-type pelagic sediments. The Upper Triassic volcano-sedimentary succession differs from the other investigated successions of the same Nappe in displaying peculiar sedimentary and organic matter facies marked by the presence of organic rich shales dominated by amorphous organic matter, marine phytoplankton (acritarchs) and relatively high TOC values. The sedimentary succession consists of muddy limestones, marls and black shales intercalated to calciturbidites. The mixed carbonate-siliciclastic calciturbidites contain carbonate debris associated with large amount of quartz (mostly of sedimentary provenance) and minor micas.

The Gokdere-type pelagic succession contains well preserved palynological assemblages composed of in situ Triassic and recycled Palaeozoic palynomorphs. Reworked palynological assemblages of Gondwanan affinity, shows close similarities with Devonian-Permian microflora already documented in the SE Turkey, in Saudi Arabia and in Oman. The in situ palynomorphs confirm a late Carnian-Norian age for this unit, as previously documented in the literature. The colour index of the recycled Palaeozoic sporomorphs indicate a thermal alteration index (TAI) of approximately 2.7-3 corresponding to a temperature not more than 120° for this type of OM. Facies and organic facies indicate an epicontinental basin as depositional environment, strongly controlled by relative sea level fluctuations. During the progressive steps of sea level rise the basin depocenter lowered beneath the mixed layer surface favouring the accumulation and preservation of amorphous organic matter under anoxic-low dysoxic conditions and the black-shale sedimentation. At the time of sea level fall the increased area of exposed land and older rocks led to an increase in the total debris content (both organic and minerals) transported by turbidity currents into the adjacent basin. The increased oxygenation caused pronounced organic matter degradation as it settled through the water column. The relatively good preservation degree and TAI data of recycled sporomorphs and the presence of quartz of sedimentary provenance indicate unmetamorphosed Palaeozoic sandstones and shales as source area. According to the present knowledge of the regional geology, the Palaeozoic reworked debris could have originated in the Sultandagi Region, at the northern part of the Anamas-Akseki Autochthonous and in the Antalya Nappes (Tauride High).

Diagenetic overprint on the primary record in varved coccolith limestones, Lower Oligocene, Outer Carpathians

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Oligocene coccolith limestones, known as the Tylawa Limestones, dated at nannoplankton zone NP 23, laid down in the landlocked basin of Parathetys, are composed of alternating the sub- millimetre couplets of light and dark laminae. The laminae resemble varves, but their sequences could not be correlated laterally for distances greater than ca. 20 km, while similar laminae in a younger Jasło Limestone (dated at nannoplankton zone NP 24) are correlatable over hundreds of kilometers. This raised doubts about the varve (annual) nature of laminae in the Tylawa Limestones.

The ultrastructure of laminae in the Tylawa Limestones from the Polish part of the Carpathians was studied using various techniques in optical and electron microscopes. The light laminae consist of coccolith debris packed in fecal pellets and irregular aggregates. The skeletal material of coccolithophores is well preserved, often as complete coccospheres. Diagenetic alteration in the light laminae consists mainly calcium carbonate cementation and destructive effects of diagenesis are limited to scarce traces of dissolution and mechanical breakage. The thinner, dark laminae are composed mainly of fine siliciclastic grains and organic matter. They include numerous characteristic voids and dissolution surfaces. The size and shape of the voids indicates that they originated by dissolution of pennate diatom frustules. The voids are largely compressed and partly filled with host sediment. The dark laminae, are interpreted as record of seasonal blooms of diatoms. The siliceous skeletons, originally abundant, were selectively eliminated by dissolution during diagenesis.

Alternation of laminae laid down during blooms of coccolithophores (summer) and diatoms (spring) proves that laminae in the Tylawa Limestones are true varves. Selective dissolution and reduction in thickness of the dark laminae disturbed lamination to such extent that lateral continuity of distinctive patterns of the light and dark laminae cannot be correlated over large distances, but the laminae may still be used for approximate time calibration of the sedimentary record.

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The Ballık travertine system: a seismic scale travertine

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In 2006 the Lula oil field was discovered, with Pre-Salt continental carbonates acting as reservoir rocks. Similar reservoir discoveries, in front of the east coast of South America as well as west of Africa, resulted in an increased interest in these continental carbonates. Several of the observed core fabrics are widely recognized in travertines. Furthermore, seismic data reveal domal progradational-aggradational carbonate build-ups and in the Namibe Basin (Angola) fracture fed moundlike morphologies are linked to fissure ridge and “dam and cascade” travertines. From an exploration point of view the distribution and extension of different geobodies and their petrophysical properties need to be delineated. However sedimentological observations in discovered reservoirs are limited to core scale and should therefore be extrapolated to a larger context. Hence the necessity for travertine analogue studies worldwide.

A sedimentpetrological investigation was executed on travertines of the Ballık area (Denizli Basin, Turkey). A 3D depositional model was constructed in combination with an extensive sedimentological description from fabric to geobody scale. The petrophysical properties are determined with helium porosimetry and nitrogen permeability measurements, mercury injection capillary pressure, water saturation, nuclear magnetic resonance, acoustic velocity and computed tomography.

The large-scale depositional travertine system can best be compared to a mound or fissure ridge, with the spring(s) controlled by tectonic activity within the Denizli Basin. The travertine build-up can be split up into two main systems. The first system, represented by the sub-horizontal and biostromal reed travertines, was formed in a shallow sub-aquatic environment. The second travertine system, mainly represented by the sloping facies, formed in a thin water film in a sub-aerial setting. A general progradation of the system is observable due to the occurrence of the stacked sloping travertines, resulting in sigmoidal clinoforms with downlap terminations.

The question could be raised how these travertines would look on a seismic line. They would appear with an external mound morphology, associated to normal faults in an extensional setting. Contacts with other lithologies will be easily recognisable due to their different acoustic impedance. The external morphology of the mound will thus result in strong reflectors. Inside the mound, the biggest acoustic impedance will be caused by differences in porosity and pore types. The lithofacies distribution will thus dominate the internal structure. Particularly waterfall travertines (with primary caves), when present, should be observable. They would result in a progradational pseudo-seismic line in an angle to the contacts of the sloping with the sub-horizontal facies. The size, morphology, and extensional tectonic setting are in good agreement with the aggradational-progradational carbonate build-ups reported for the Pre-Salt play of the South Atlantic.

The presented lithofacies geobody model in combination with petrophysical and acoustic data can thus possibly form the basis for a reservoir analogue and synthetic seismic modeling of the Pre-Salt carbonates and other domal travertine reservoirs worldwide.

Upscaling in complex carbonate reservoirs: a (geo)statistical approach

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Heterogeneity is a general characteristic of carbonate reservoir rocks, and relates to their geological history: sedimentary origin, burial history and diagenetic processes. These processes have an influence on the complexity of the porosity network. Especially in travertine rocks the size and shape of the pores result in a very complex porosity network. Hence, a critical decision has to be made at which scale petrophysical measurements should be taken in order to be representative and statistically stationary. This study aims to quantify the representativeness of porosity types at different scales in complex carbonate reservoirs. The concept of the Representative Elementary Volume (REV), i.e. the smallest value that can be taken as a representation for the entire sample area/volume that does not respond to small changes in volume or location, was introduced by Bear in 1972.
CT datasets provide a large amount of 3D data, which allow to investigate the influence on the REV of both pore shapes and resolution of the dataset. In this case study two approaches to calculate the REV are proposed and compared.
The first method consists of defining the fluctuation of the porosity parameter, using the chi-square criterion. The chi-square parameter measures how much a single tested subsample deviates from the mean value of all realizations. If this deviation remains small enough for decreasing sample sizes, the REV is reached. The second method uses the relationship between the REV and geostatistical interpretations. A volume V_i falls within the REV domain if $Y(x,V_i)$ can be treated as a stationary random function for any x in the domain. This approach provides additional information about the shape of the REV.
The REV's of travertine samples, calculated using both methods are similar and vary between 1 and 45cm^3 based on 10cm diameter cores (300 x 300 x 500µm resolution). The large variation in volume can be explained by facies type of the examined samples. The horizontal laminated travertine facies (small pores and a homogeneous distribution of porosity) typically has a small REV, while a waterfall travertine facies (large pores and a heterogeneous distribution of porosity) has the largest REV. The REV's calculated based on 2.5cm diameter plugs ((12µm)^3 resolution) vary between 3 and 20mm^3, again depending on the facies type of the sample. These results confirm the existence of different REV's when a nested structure of scales is used.
This observation leads to the necessity to establish a link between different datasets, which have different resolutions. This can be achieved by using a workflow derived from multiple point geostatistical studies. This technique combines the strengths of pixel-based and object-based techniques. The shape of the pores is reproduced, while retaining the flexibility of a pixel-based method. Scans of the 2.5cm diameter plugs are used as a training image while data from 10cm diameter cores are used for conditioning. The quality of the simulated datasets is determined by comparing pore shape distributions and the simulated permeability value of a corresponding part of both the original dataset and the simulated dataset. The simulated samples provide further information about the size of the REV over the studied scale range and bridge the gap between 10cm and 2.5cm diameter samples.
This study illustrates that the size of the REV is dependent of the lithology of the analyzed rocks. Only by calculating the REV at different scales, reservoir properties in complex carbonate rocks can be evaluated correctly.

Are landslide-turbidite recurrence intervals random and what are the implications of a common distribution for triggers, regional controls and climatic influence?

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Due to their potential volume and speed, submarine landslides can generate destructive tsunamis that cause fatalities, or damage expensive seafloor structures. Understanding their timing is therefore important for future hazard assessments; however, dating large numbers of landslides close to their origin is logistically difficult. Previous landslide studies are typically limited to fewer than ten observations. To address this we analyse long-term (0.15-19.45 Myr) turbidite records from several deep-sea basins which are interpreted to be the distal deposits of large, disintegrative landslides. Our records include sufficient number of turbidites (N=125-1571) for robust statistical analysis which allows us to look at long-term controls on event timing and test for relationships with possible triggering mechanisms such as earthquakes, sea level, climate change and volcanic activity. We present case studies from five modern and ancient systems based on detailed analysis of outcrops and sediment cores.

Basin plains that feature multiple sediment input points (Zumaia, Marnoso-arenacea, Balearic and Madeira Abyssal Plains) closely approximate a Poisson distribution for turbidite recurrence intervals. A Poisson distribution indicates a lack of memory in the system and a constant probability of event recurrence through time. This suggests that temporally-ordered controls such as sea level and climate change are not a strong dominant control. We validate this conclusion using proportional hazard and generalised linear modelling which show no statistical significance between sea level change and recurrence rate. It is possible that overprinting of multiple input sources creates this apparent random distribution; however, for sites where it is possible to differentiate flows by source, we also see a Poisson distribution. A case study for Canary Island-sourced flows provides insight into possible triggers for volcanic island collapse, showing a lack of direct sea-level control.

The Iberian Abyssal Plain represents a more open slope-fed basin plain setting, with only one main input source. Turbidite recurrence intervals closely fit a log-normal distribution over a period of almost 20.0 Myr, as well as for subsets of the data over shorter (0.5 to 3.9 Myr) timescales. We demonstrate that while the mean recurrence changes over time (as shown by a Gaussian finite mixture model), the form of the distribution does not. This may indicate that the nature of sediment input and/or triggers were similar, but that their tempo was modified by tectonic or climate effects. We present a model explaining how Poisson and log-normal distributions might be generated for turbidite recurrence based on basin morphology and in response to different triggering mechanisms.

While Poisson and log-normal models explain the predominance (>95%) of turbidite recurrence frequency, a few anomalously long recurrence intervals infrequently punctuate our records. These are periods of unexpected quiescence for landslide and turbidity current activity. The overarching distributions diagnose background characteristic recurrence; however, such short-term perturbations in recurrence may be explained by major climatic and/or tectonic events.

Our novel approach to landslide-turbidite recurrence frequency provides unusually detailed and long-term records. Detailed quantitative, statistical analyses of turbidite records provides key data for future hazard assessments, landslide-climate studies and also for understanding the geological tempo of large volume, sediment delivery to the deep sea.

Extreme global warming and submarine landslide activity – cause and effect at the Initial Eocene Thermal Maximum and implications for the future

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A set of previous studies suggest that submarine landslides and associated turbidity currents may become more likely due to future extreme global warming. Determining whether global warming increases likelihood assists in assessment of landslide-triggered tsunami hazards and risk posed to seafloor structures. It has also been proposed that release of methane from gas hydrate within marine sediment, due to landslides or other processes, could be a major control on atmospheric methane abundance. The validity of this "clathrate gun hypothesis" is contentious. Methane emissions from wetlands may exceed those from gas hydrates hosted in marine sediments, as suggested by isotopic analysis of methane within ice core records.

Turbidite records (N=285 to 421) at two deep-water sites show prolonged hiatuses in turbidity current activity during the Initial Eocene Thermal Maximum (IETM) at ~55 Ma. The IETM represents the warmest period on Earth during the Cenozoic, featuring, at its peak, a dramatic 6-8^{o}C warming of global deep waters over a period of approximately 10 kyr. This is marked by a major carbon isotopic excursion in marine records. Understanding changes in the frequency of landslides and turbidity currents in response to the IETM may help to predict future changes in landslide and turbidity current frequency as climate warms. Here we consider whether the results from two locations provide evidence that landslide-turbidity current activity increased during the IETM, and whether landslides may have helped to drive climate change through methane emissions. This has not previously been investigated using continuous turbidite records across well dated climatic excursions.

It is likely that our records mainly represent large and fast moving disintegrative submarine landslides. Statistical analysis of long term (>2.3 Myr) records indicates that the IETM corresponds to a reduction in turbidity current and landslide activity, and was followed by a period of significantly reduced turbidity current and landslide activity. Our results have important implications for future landslide-triggered tsunami predictions, and assessment for subsea structures that may be vulnerable to turbidity current impacts. Finally, we do not identify an increase in landslide activity prior to the IETM. A global review of other IETM sites appears to also support this conclusion. We therefore suggest that globally widespread, landslide-triggered dissociation of hydrate may not be a likely cause for the negative carbon isotopic excursion during the IETM.

Late Hauterivian and Barremian progradation of the Urgonian platforms surrounding the Vocontian Basin (France), illustrated by NNE-SSW and WSW-ENE transects

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A number of Urgonian sections from the Jura, Chartreuse, Vercors and Vivarais regions are known from geological literature, and were re-sampled in recent years. These sections are tentatively correlated within a sequence stratigraphic framework. Although some agreement can rather easily be reached regarding the identification of transgressive surfaces or maximum flooding surfaces, there have always been arguments regarding the position of the sequence boundaries. In shallow-water settings the TS and the SB merge together but, in deeper settings, we tentatively identify the best candidates for the SB where there are apparently significant downward shifts of facies.

This sequence stratigraphic model is biostratigraphically-constrained, with the primary markers being ammonites. They are found mostly in the hemipelagic facies below and above the Urgonian facies but there are also a few ammonitic records associated to flooding episodes within in the Urgonian facies themselves. These primary markers, particularly those associated to flooding episodes, provide sufficient evidence to show that Urgonian (Rudistid) limestones are at least as old as the Late Hauterivian, commonly of Early Barremian age and are not restricted to the Late Barremian-Bedoulian times as stated by some people. It should be noted that the Barremian–Bedoulian transition marks a general change in facies trends, which predates the end of Urgonian platforms in many localities.

The secondary biostratigraphic markers are benthic foraminifers and calcareous algae that primarily lived in shallow-water environments but were commonly redeposited in deeper-water environments within calcareous turbidites. As recently documented in L'Estellon section (Drôme, France; relabeled the "Rosetta Stone" of the Urgonian stratigraphy) the first and last occurrences of the above mentioned microfossils within these turbidites can eventually be calibrated directly with the ammonite zones. These secondary markers allow us to check, better constrain and refine the earlier stratigraphic framework, particularly in those sections where ammonites are lacking.

The keys to the understanding of the Urgonian platforms are to be found at the platform edges or in the coeval basins, not in their interiors. The "progradational" model for Urgonian platforms has been successfully tested over the last two decades and it can easily be exported to many other places of the Mediterranean realm, including France (Provence, Corbières, the Pyrenees), Spain, Portugal and even to the Middle East.

Well data analysis in the view of reconstructing channel morphology and sandbody geometry in fluvial meandering systems

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Process-based models dedicated to meandering systems, such as FLUMY[a], although producing realistic sand-bodies geometries, require parameters, not directly accessible from the rock record, in particular from well data: channel geometry, floodplain slope, sand ratio, flood intensity and return period, avulsion period.

We developed a method that combines the distribution of the sand crossing and hydraulic relationship to infer most of these parameters. Sandy deposits in fluvial successions correspond to different unitary or amalgamated sedimentary bodies: crevasse splay, sandplug or point bar. The point bar height (eg channel maximum depth at the meander bend) can be easily related to the channel mean bankfull depth (eg in straight reaches) from hydrological studies on modern systems. From well data, the characteristic point bar height is identified based on the slope breaks observed on the co-variogram built from the sand crossings. Then, the fluvial hydraulic parameters from channel to drainage area are obtained from specific relationship relating these parameters to the point bar height for different climatic settings and various ranges of drainage area.

Large sand-crossings reflect the amalgamation of several deposits more likely to be point bar during periods dominated by lateral sweeping of the floodplain by the meanders in a low aggradation context. Estimation of the sand body extension is based on the assumption that for given surface and sand proportion, the number of stacked sand bodies (e.g. mainly point bars deposits) show a good correlation with sand body lateral dimension. A heuristic formula is proposed based on a simplified description of a unitary point bar deposit.

Identification of these geometric elements constitutes a breakthrough for the process-based modelling as it enables informing the major key elements of a simulation: discharge, avulsion period....

[a] FLUMY: processed-based and stochastic modeling of meandering systems.

Estimation of rock uplift from fluvial incision. Example from Seine river system during the middle-upper Pleistocene

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The rate of fluvial incision, based on elevation and chronostratigraphic pattern of stepped terraces, is commonly interpreted as the rate of rock uplift, assuming that terrace formation is a transient step in the long-term process of formation of a graded stream profile. In the following, we discuss the contribution of the absolute sea-level elevation to the incision rate in region characterized by low tectonic forcing.

A new fluvial terrace chronostratigraphy of the Aube and Yonne Rivers correlated to the Seine river terrace system is supported by terrace long profiles, new ESR ages and published ages. It is at first sight similar to the European terrace framework.

Over the past Million years, the incision rate of these streams has been non-uniform. Coherent incision patterns have been obtained from the upper reaches of the Aube, Yonne and Seine (Montereau) and the lower reach of the Seine (Paris, Rouen). Three periods are identified: before 0.8 Ma, the stepped terraces present low differences in altitude corresponding to incision rates estimated to 20-30 m/My; between 0.8 and 0.4 Ma, a fivefold increase of the incision rate is observed (100 m/My); then from 0.4 Ma and onwards, the incision rate decreased more notably along the lower reach of Seine river (20m/Ma) than along the upper reaches of the Seine River and its tributaries (60m/My).

The change in incision rate between the first and second period is classically attributed to the development of the 100 ka climatic cycles, a periodic climatic change from glacial to temperate conditions that controlled the sediment flux and water discharge driving the erosion processes and the terrace genesis. Major incision occurred during the climatic change from warm and humid conditions to cold and dry ones. The large sediment yield during the cold period resulted in the deposit and reworking of a coarse alluvial layer over a large floodplain. Another incision, of limited amplitude, is also observed during the transition from glacial to interglacial period.

The increase in incision rate during the second period although driven by climate recorded the response of the fluvial system to a eustatic fall that affected the low sea level (around -120m) as well as the high sea level (elevation some 40m below the high sea level of periods 1 and 3). Thus during period 2, the river incision had probably been effective during the high sea level periods, reworking the cold period alluvial layer. A change in tectonic uplift might have produced similar responses of the fluvial system. However, this hypothesis is not considered as the long term incision rates are uniform on rivers of the Paris Basin that are not influenced by base level changes (Meuse, Moselle).

Based on our data, the non uniform rate of incision of the Seine river system during the last million years is attributed to changes in climatic and eustatic conditions rather than changes in tectonics uplift. Rates of rock uplift are to be estimated during periods characterized by sea level fluctuations in-between stable minima and maxima to avoid bias in the estimation.

Use of outcrop analogue-based tools for predicting large-scale architecture of fluvial reservoirs and aquifers

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Outcrop analogues are routinely employed as a means for achieving geological realism in static models of fluvial hydrocarbon reservoirs and aquifers, whereby outcrop-derived experience is transferred to the subsurface through tools applicable in stochastic modelling and well correlation practice. Well correlation of fluvial sandstones can be guided by reference to 'correlability' models, which quantify the likelihood of correlation of channel bodies across equally spaced wells, based on analogue sandstone width distributions. Sequential indicator simulations of the distribution of permeable deposits can be conditioned by indicator variograms that can be parameterized based on geological knowledge using existing empirical relationships. This study demonstrates the application of a technique to test the value and limitations of these tools, and to assess the impact of analogue choice in workflows involving their use.

Outcrop panels that capture large-scale sedimentary heterogeneity present in extensively exposed fluvial successions provide ideal tests of the proposed predictive tools, which are here used to model outcrop architecture following a typical subsurface workflow. As a test for benchmarking correlability models and analogue-informed indicator variogram models, an architectural panel of a large photo-interpreted outcrop of the continental interval of the Cretaceous Blackhawk Formation (Wasatch Plateau, Utah, USA) has been employed. Vertical logs, intended to represent 'dummy' wells, have been constructed across the panel, and the intervening architecture has been predicted by correlability models and sequential indicator simulations, informed by outcrop analogue data drawn from an architectural database (FAKTS).

FAKTS output was used to compile correlability models and indicator variogram models for the cross-gradient horizontal direction for channel and floodplain deposits, on the basis of data from: (i) a range of analogues that partially match with the Blackhawk Formation in terms of system classification (accumulation under the influence of humid to subhumid climates in foreland basins), and (ii) empirical relationships relating depositional-element width statistics (mean, standard deviation) to net-to-gross.

The forecasting methods are assessed by quantifying the mismatch between predicted inter-well architecture and outcrop observations. Results highlight the value of correlability models as a way to check for the geological realism of correlation panels, and show the need for sampling of a statistically significant number of bodies for the method to be most valuable. The relationship between the FAKTS-based correlability models and the correlability of the sampled outcrop is consistent with the choice of analogues displaying slightly optimistic or pessimistic sandstone-width distributions, and supports the use of alternative analogues as a way to account for uncertainty in analogue choice.

Correspondingly, geostatistical simulations conditioned on indicator variogram models based on the same analogues display degrees of approximation of the models to the outcrop that reflect the goodness-of-fit of analogue channel-complex descriptive statistics, if model-outcrop similarity is considered in terms of size distribution of connected components. Yet, a consistent overestimation of vertical and horizontal connectivity functions for channel deposits is indicative of algorithm limitations.

As the proposed analysis effectively demonstrates value and problems connected with the use of analogue-based tools, further work of this type will result in the provision of best-practice guidelines for improving the way analogues are used in subsurface modelling scenarios.

A peak-over-threshold extreme precipitation lake record since AD 1374 in NE Iberian Peninsula

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Lake Montcortès is a small (0.14 km^2 surface area), 30 m deep, karstic lake located in the eastern Pre-Pyrenees (NE Spain). The permanent anoxic hypolimnetic conditions in this lake have favored the preservation of finely annually laminated sediments in central-distal areas of the lake basin for the last three millennia. A robust age model has been established through varve counting on petrographic thin sections combined with radiocarbon and ^{210}Pb dating. The good correlation of the varve counting with the ^{14}C AMS dates underlines the annual nature of the lamination.

Three main types of detrital microfacies have been distinguished in the varves: i) non-continuous detrital layers; ii) continuous detrital layers; iii) matrix-supported layers. In addition, two types of turbidite layers have been identified. Transport mechanisms have been proposed for those deposits including slope reworking processes as well as interflow and underflow events. Annual number of detrital layers interbedded within this varve record was compared against instrumental records of extreme daily rainfalls (available since 1917) providing minimum rainfall thresholds and return periods associated to the identified types of clastic microfacies. Non-continuous detrital layers are deposited during rainfall events higher than 80 mm (> 2 years in average recurrence interval) while graded detrital layers and turbidites were associated with even higher amplitude rainfall events (> 90mm and > 4 years recurrence interval).

The frequency distribution of extreme hydro-meteorological events during the last centuries is not stationary and its pattern coincides with historical floods from the nearby Segre River. Higher heavy rainfall frequency occurred during AD 1347-1400 and AD 1844-1894, while less rainfall events happened at AD 1441-1508, 1547-1592, 1656-1712, 1765-1822 and 1917-2012. Variations in extreme rainfall frequencies prior to the 20th century show a positive correlation with solar activity, suggesting solar induced-changes in atmospheric circulation patterns. The 20th century stands out as the longest interval of low number of extreme rainfall events within the studied period and contradicts foreseen regional trends of increasing frequency of extreme rainfalls under warmer climate scenarios.

Sedimentary processes, transport mechanisms and triggers of debris flows in subaquatic canyons in the Rhone delta (Lake Geneva, Switzerland, France)

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Deep-water marine channels are highly dynamic environments due to the erosive power of sediment-laden currents. These underflows reshape the morphology of the subaquatic conduits during episodic events such as large floods, major earthquakes and/or landslides. Gravity flows, which can be associated with scarp failures in proximal levees or major floods, can be transported thousands of kilometres to distal areas of canyons. Nevertheless, the evolution of these underflows is still poorly understood because of their complex rheology, their large spatial scale and the difficult monitoring of these energetic events. For this reason, Lake Geneva´s sub-aquatic canyon in the Rhone Delta, with its smaller size, well-known boundary conditions and detailed bathymetric data, makes an excellent analogue to understand these types of hydro-sedimentary processes that usually occur in deep-water channels in the marine realm.

A multidisciplinary research strategy including innovative coring via MIR submersibles, in situ geotechnical tests, geophysical and sedimentological analyses, as well as acquisition of repeated multibeam bathymetric data sets, were applied to understand the triggering processes, transport mechanisms and deposition features of gravity flows throughout the active canyon of the Rhone Delta. The difference between two bathymetric surveys in 1986 and 2000 revealed an inversion in the topography of the distal active canyon, as the former distal channel was transformed into a mound-like structure. A 12 m-thick layer was deposited in the canyon. Sediment cores from this deposit were retrieved in 2002 and 2011 via the “F.-A. Forel” and Russian MIR submersibles, respectively. These cores contained a homogeneous, sandy material. Its sediment texture, grain-size, high density and shear strength, and low water content suggest that it corresponds to a debris-flow deposit that possibly took place after the initiation of a mass movement due to a scarp failure in proximal areas of the canyon. In addition, in situ geotechnical tests on the modern canyon floor have shown a soft top layer above a stiffer substratum. This soft layer, which increases in thickness towards distal areas, may act as a basal surface for hydroplaning, and might have allowed the debrite to be transported ~9 km away from the source of the scarp failure. This study highlights how large mass movements in proximal sites influence the morphology of distal areas by damming the channel and, eventually, forming new conduits, as revealed by multibeam bathymetries acquired in AD 2012 in this subaquatic canyon.

Use of garnets in determining provenance of sandstones at Alagoas stage, Campos Basin – Rio de Janeiro

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Sandstones record a wide variety of source areas, thus the provenance studies focus on the analysis of this type of rock. It is considered to be an excellent resource for the study of basins, indispensable for identifying sediment distribution routes, and also fundamental for the recognition of the potential sectors of occurrence of hydrocarbon reservoirs. Garnets, among all heavy minerals, are considered ideal for these studies due to several characteristics: they suffer little variation in density which reduces the effect of hydraulic selection; maintains certain stability during weathering, transport and diagenesis, and even have a compositional variation that allows detailed information about the rock types of source rocks. To conduct this study, samples from offshore boreholes of Alagoas Stage, at the Campos Basin, were processed. The Alagoas Stage, Aptian age, corresponds to a transitional sequence and is usually placed in the package of rocks between the so-called "pre-Alagoas unconformity" and the top of the evaporitic package. Analyses of the chemical composition of garnets were made on 35 samples through 13 boreholes. The results were plotted in two distinct triangular diagrams represented by vertices: P, ALS, GAU and PGAU (P: pyrope; ALS: almandine + spessartine; GAU: grossular + andradite + uvarovita and PGAU: pyrope + grossular + andradite + uvarovita). These diagrams discriminate five compositional fields: (A), (B), (C), (D) and (E) corresponding to eight groups of source rocks that carry garnets. The analysis of partial data indicates the predominant presence of three main compositional groups of garnets. A preliminary interpretation suggests that populations are mostly from high-grade lands (granulites and gneisses - field A), low to medium grade metapelites (field B), and a minority of amphibolites and mafic gneisses (field C). Garnets set in field B are the majority, and may alternatively indicate source lithologies of granitic pegmatite type or granitic type S. They have low levels of PGAU and high values of spessartine. Compositional analyzes allowed the identification of significant changes in provenance, especially in three particular wells. One of the aspects observed in some samples is the appearance of garnets rich in calcium derived from metamorphic limestones. These garnets are grossularias with low levels of andradite. Another important change is the appearance of garnets from granitic rocks: pegmatites and granitoids. Such garnets are fairly representative in several boreholes in the study. Finally, the participation of garnets with characteristics of amphibolite / mafic gneisses is minimal. Therefore, the significant population of garnets plots in ternary diagrams fields indicates that 55% of the samples have granite derivation, confirming the origin of these sands.

Sand dunes – an important source of atmospheric dust and loess in deserts

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Sources of both fine (<10 μm) and coarse (20-80 μm) dust grains have been debated for decades. Fine dust plays multiple roles in mediating physical and biogeochemical exchanges among the atmosphere, land and ocean, and thus is an active component of the global climate. Coarse dust sequences (loess) archives Quaternary climate changes. Thus, to better estimate past, current, and future impacts of dust on the climate and the environment, and to better reconstruct climatic information from loess sequences, we address the questions regarding sources of dust and the mechanisms that generate dust grains. We present our recent findings on the sources of both atmospheric dust and loess in Africa and Arabia. We conclude: (1) Sand seas are an important source for desert loess; all examined loess regions are located downwind of adjacent sand seas, present mineralogical similarity, and their activity is coeval with the sand dunes. (2) Multiple sources of current atmospheric dust exist in the Sahara, but ~30% of the examined dust storms originated from active sand dunes (and additional ~20% from leptosols and calcisols, each, ~15% from arenosols). Moreover, the wind erodibility of sand dunes is the highest of all examined geomorphic units and soil types. Since only limited silt and clay grains are stored in the active dunes, we postulate that the fine and coarse dust grains were/are generated through active eolian abrasion of sand grains in the dunes. Past laboratory and field experiments showed that abrasion of natural sand grains generate finer grains by either: (1) spalling, chipping or breakage of grains, forming silt-size quartz grains, and (2) removal of grain surface coatings composed mainly of clay minerals. Our results explain the concurrent loess accumulation and increased dustiness during the last glacial period, when sand dunes covered large portion of the Sahara, and their activity has been more common than during the Holocene. This study has the potential to improve regional scale dust-transport models that aim to assess future effects of dust on the climate.

Integrated geological, geophysical and numerical modeling studies applied to the understanding of Amazon River Mouth Basin evolution

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This work focuses on the evolution of the stratigraphic record in the central and northwestern shelf and slope areas of the Amazon River Mouth Basin, since the Late Miocene, when the basin saw a shift from predominantly carbonate to siliciclastic sedimentation. The investigation is based on analysis of 2D multichannel seismic sections and chronostratigraphic data from exploratory wells, followed by numerical stratigraphic modelling performed with the software DIONISOS®.

A biochronostratigraphic analysis indicated an age of between 9.5 and 8.3Ma for the definitive cessation of the carbonate sedimentation on the shelf. This is somewhat more recent than has been reported. By this time the Amazon shelf had also been incised by a canyon that allowed the direct influx of sediment to the basin floor, thus confirming that the paleo-Amazon fan was already initiated by this time. During a prolonged lowstand, Messinian third-order sequences are preserved only in the incised-valley fills of the canyon with no equivalent strata on the shelf. Third and fourth-order sequences, younger than Messinian, are preserved when an early Pliocene sea-level rise overtopped the shelf.

Sequences younger than 3.8 Ma often show a fourth-order cyclicity with an average duration of 400 kyr (larger scale eccentricity cycles), especially in areas of high sedimentation rates. This analysis of the seismic and chronostratigraphic database allowed the recognition and proposition of an age model for five sedimentary sequences developed in the study area between the Late Miocene and Recent: S1 (9,5-5,6 Ma); S2 (5,6-3,8 Ma); S3 (3,8-2,4 Ma); S4 (2,4-1,8 Ma) and S5 (1,8-0,0 Ma). In turn, the numerical stratigraphic modelling represented an important analytical tool, allowing the quantification of the main parameters that conditioned the deposition of the sequences, such as: the sedimentary input, and the regional and local subsidence rates induced by gravity tectonic structures (normal and reverse faults). These digital models allowed the definition of probable basin scenarios that developed during the evolution of the Late Miocene-Recent stratigraphic succession. These scenarios include three stages:

1. The central-north region of the Amazon River Mouth Basin evolved under comparatively lower rates of sedimentary input and subsidence between 9.5 and 3.7 Ma (sequences S1 and S2), after the cessation of the carbonate sedimentation on the continental shelf. Concurrent with this was the deposition of carbonate sediments eroded from the shelf into the deep basin.;
2. After this stage, between 3.8 and 2.4 Ma (sequence S3), the dominant prograding basin architecture was achieved by enhanced subsidence rates, with huge volumes of sediments also being carried into the basin. These parameters would be responsible for both the progradation and aggradation of the shelf sedimentary systems as seen through the entire study area;
3. During the Quaternary, between 2,4 Ma and the Recent (sequences S4 and S5), the rates of subsidence and sedimentation kept increasing, which allowed the construction of large sedimentary wedges characterized by even stronger progradation of shelf sedimentary systems, as well as aggradational units. The Quaternary sequence shows the greatest thickness at the current shelf break and upper slope, indicating that the major depocenters previously described in the same region were actually formed during the Quaternary.

Microbially-colonized sediments in a wind-driven hydrodynamic coastal system

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Special attention has been given in recent years to the study of microbial mats in modern environments, in relation to the processes involved in the formation and deformation of sedimentary structures. These modern studies aid in the recognition of analogous structures in fossil records with the consequent inference in paleoenvironment research. However, the reconnaissance of the physical processes behind fossil mat structures still remains a challenge, since a number of physical processes such as those dominated by currents and wind may produce similar signatures in rocks.

This research documents the wind action over structures and provides a basis for their identification in sediment profiles. The study area (Paso Seco, Argentina; 40°33′S; 62°14′W) comprises a blind tidal channel choked by a sandbar forming a wide sedimentary platform (~2.5 × 0.3 km) with the presence of small saline ponds (S = 60.5, pH = 8.8). With a maximum tidal amplitude of 0.27 m (measured at spring tide with a HOBO water level logger), tidal range is negligible. The closed basin, a *sabkha*-type evaporitic environment, is comprised mainly by siliciclastic sediments colonized by microbial mats. Although the area has a semi-arid climate (precipitation < 400 mm $year^{-1}$) with strong local NNE winds (average maximum velocity 40 km h^{-1}), the underlying sediments obtain moisture from precipitation and the ascending capillary movement of sub-surface water, stimulated by evaporation. Three types of mat structures, typical of evaporitic environments, were recognized in relation to their proximity to water. Type I structures, found along the shoreline of the tidal channel, are similar to those found in estuarine environments, such as desiccation cracks with upward curved edges, characterized by spring-tide flooding. Type II structures include cauliflower-like nodules encrusted with salt and knotty structures, which are typically colonized by cyanobacteria. Type III structures, located farthest from the tidal channel on a platform that gets inundated only by precipitation, exhibit the formation of mat-tears, flipped-over mats and wrinkles; and more resistant structures such as folds and roll-ups (with several involutions). Large portions of mats are detached from the underlying substrate, and strong winds sweep them starting along pre-existing desiccation cracks, thus forming these structures due to their flexible behavior. The axes of folds and crumples are perpendicular to the prevailing wind direction. A striking feature of these thick (>5 mm) mats is a highly coherent structure produced by interwoven filaments of the cyanobacterium *Microcoleus chthonoplastes*, giving it a remarkable leathery appearance. Pennate diatoms (e.g. *Navicula phyllepta*, *Gyrosigma spencerii*, *Cylindrotheca closterium*) appear in smaller proportions. Consortia of EPS-producing prokaryotes are found on the top layer of the mat. The EPS and the microbial architecture of interwoven trichomes provide high cohesiveness and elasticity, conditions necessary for a torn mat to exhibit flexible deformation under wind-shear stress. Core sections show biolaminites up to 3 cm-thick, which reflect aeolian conditions with the presence of rounded medium-sand grains (0.25 to 0.5 mm).

This research contributes novel evidence of wind-related mat deformation structures, which can be interpreted as signatures in geological records, provided microbial mats enhance the preservation of these structures.