An Application of Radio Frequency IDentification (RFID) Technique to Field Investigation of Gravel Movement on a Sand-Gravel Mixed Beach

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On gravel beaches, measuring the displacement of individual grains by waves is essential in order to understand sediment transport processes and beach morphology. We present a result of laboratory and field application of Radio Frequency IDentification (RFID) technique. RFID technique makes it possible to detect and trace individual passive integrated transponders (PIT) inserted in the gravels even in the field for a long time, ideally more than several years. In the laboratory test, PIT tags could be detected and identified by using a search antenna of 70 cm length and 25 cm width even when the tracers were buried under ground as deep as 60 cm. A field test was conducted on a sand-gravel mixed beach near the mouth of the Sakawa River in Japan. 190 PIT tags inserted in color-painted gravels were released on the foreshore and traced for one month. The traceability of the RFID technique was roughly four times more efficient than the visual search of color-painted gravels. The trajectory of gravels show a strong relationship with the temporal change of the run-up wave heights which are estimated from offshore waves and tides by Saville's composite slope method. During the tracing period, there were some high run-up wave events. In these events, gravels tend to accumulate on foreshore. On the contrary, foreshore tended to be regressive and sand component of foreshore sediments were more dominant in moderate wave conditions. The result is not consistent with a general understanding of beach morphology of uniform sediments. It implies the existence of mixed effects of sands and gravels. Based on the quantitative analysis of Sunamura's C-value which is a non-dimensional value related to beach morphology, we conclude that effective sediment components controlling beach morphology change due to sediment segregation by waves.

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Basin-filling stratigraphic analysis of basin succession trend and tectonic evolution processes: examples of East Asian rift and forearc basins

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Basin-filling stratigraphy can be defined as “the study of basin-filling sediments from the standpoints of succession trends and three-dimensional development patterns of depositional systems with consideration of their controlling factors.” This paper attempted the basin-filling stratigraphic analysis for selected East Asian rift and forearc basins to delineate variations of basin filling succession patterns and their controlling factors. As the results, the characteristic succession patterns were recognized both for rift and forearc basins, and they showed strong relationships with the basin mass balance between basin accommodation and sedimentation related to background tectonic conditions.

The basin-filling succession patterns in the East Asian rift basins can be categorized into four basic types: simple transgression case, transgression to late regression case, transgression to early regression case and aggradation case. It is interpreted that basin-order mass balance between the sediment accumulation and characteristic subsidence patterns of rift basins, which show rapid subsidence followed by exponential decrease, creates the specific basin filling succession trends through syn-rift to post rift phases. In case the subsidence rate through syn-rift to post rift phases is much larger than the sedimentation rate, the simple transgression case with a continuous underfilled trend may occur. Pure passive margin basins can correspond to this case. If the sedimentation catches up with the decreasing subsidence, the transgression to late regression case occurs. The aggradational case with fluvio-deltaic sediments is caused by a unique situation that the subsidence rate and sedimentation rate are totally balanced or the sedimentation continuously exceeds. This type of rift basins characteristically occur offshore China, Vietnam, Thailand and Malaysia, where tremendous amounts of clastics are supplied from the monsoon Himalaya region.

The forearc basin-filling succession patterns and constituent depositional systems are strongly influenced by the morphological type variation of forearc basins defined by Dickinson (1995). The marine sloped to submerged ridge type is mainly filled with deep marine turbidites or shales. The terraced to shelved, overfilled type commonly shows a transgressive to regressive pattern consisting of turbidite, slope, shelf to shallow marine systems in response to the increase of clastic supply from the adjacent volcanic arc. The benched type, which has an emergent trench slope break ridge, characteristically shows a regressive succession from marine to fluvial systems, or thick aggradation of bay to coal-bearing fluvial systems. If the forearc setting maintained for a geologically long time, it is estimated that the morphological forearc basin types can be transferred from the submarine sloped, submerged ridge type to the shelved, benched types, as the trench slope break ridge tends to develop along with the accretional prism development due to plate subduction. This kind of forearc basin style change can be traced in the forearc zone along the Northeast Japan arc.

It is concluded that the basin-filling stratigraphic analysis provides important information on the tectonic basin history and petroleum geological conditions.

Glacio-eustasy and formation of sequence boundary since 1.8 Ma based on the core analyses of IODP Expedition 317, Site U1352B on upper slope in offshore New Zealand

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Introduction and methods

Siliciclastic sequence boundaries were originally considered to form at the inflection point of the eustatic fall (Posamentier et al., 1988). Later, Plint and Nummedal (2000) suggested that sequence boundaries form at the lowest position of relative sea level. Such uncertainty is problematic because precise ages are needed for sequence boundaries to allow correlation with the positions of both relative sea-level and eustasy. IODP Expedition 317 drilled three sites on the continental shelf (84-122 m water depth) and one site on the upper slope (344 m water depth) in the Canterbury Basin on the eastern margin of the South Island of New Zealand. We analyzed cores from slope Site U1352. We studied the core samples with following procedure. 1) We described sedimentary facies around predicted depth of the seismic sequence boundaries and detected discontinuities in the core. 2) We took samples every 20 cm from below and above ~7 m of the discontinuities. 3) We picked the benthic foraminifera, *Nonionella flemingi* from the samples and measured oxygen isotope ratios. 4) We measured stable isotope of organic carbon and Total Organic Carbon (TOC) from the same samples.

Results and discussions

Seven major faices discontinuities in the core correspond to Pleistocene sequence boundaries interpreted on the well-imaged seismic profiles. The correlation between these discontinuities and oxygen isotope ratios shows that seven high-frequency sequence boundaries since 1.8 Ma formed during the lowstand to early rising stages of the glacio-eustatic cycle, in contrast with the original concept, for longer period (third-order) sequences, of sequence boundary formation at the falling inflection point. Stable carbon isotope ratios derived from marine organic matters and TOC fluctuation synchronize with oxygen isotope and stable carbon isotope records derived from benthic foraminifers.

Proposal for co-ordinated international efforts to study active turbidity current systems and their deposits at key test sites

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Turbidity currents, and other types of submarine sediment density flow, arguably redistribute more sediment across the surface of the Earth than any other flow process. It is now over 60 years since the seminal publication of Kuenen and Migliorini (1950) in which they made the link between sequences of graded bedding and turbidity currents. The deposits of submarine sediment density flows have been described in numerous locations worldwide, and this might lead to the view that these flows are well understood. However, it is sobering to note quite how few direct measurements we have from these submarine flows in action. Sediment concentration is the critical parameter controlling such flows, yet it has never been measured directly for flows that reach and build submarine fans. How then do we know what type of flow to model in flume tanks, or which assumptions to use to formulate numerical simulations or analytical models?

It is proposed here that international efforts are needed for an initiative to monitor active turbidity currents at a series of 'test sites' where flows occur frequently. The flows evolve significantly, such that source to sink data are needed. We also need to directly monitor flows in different settings with variable triggering factors and flow path morphologies because their character can vary significantly. Such work should integrate numerical and physical modelling with the collection of field observations in order to understand the significance of field observations. Such an international initiative also needs to include coring of deposits to link flow processes to deposit character, because in most global locations flow behaviour must be inferred from deposits alone. Collection of seismic datasets is also crucial for understanding the larger-scale evolution and resulting architecture of these systems, and to link with studies of subsurface reservoirs. Test site datasets should thus include a wide range of data types, not just from direct flow monitoring.

This 'test site' initiative may be timely and feasible, due to recent technological advances in monitoring sensors, moorings and autonomous data recovery. This will be illustrated here by seminal field datasets recent collected by colleagues from the Squamish River Delta, Monterey Canyon, Congo Canyon and offshore SE Taiwan. This talk will conclude with some suggestions for appropriate test sites and collaborative approaches to future data collection.

Acknowledgements: This overview is based on a seminal body of recent flow monitoring work by international colleagues including John Hughes Clarke, Maria Azpiroz, Matthieu Cartigny, Michael Clare, Cortis Cooper, Stephanie Girardclos, Philip Hill, Gwynn Lintern, James Liu, Andrew Lin, Dan Parsons, Charlie Paull, Cooper Stacey, Esther Sumner, and Jingping Xu, amongst others.

How do you test rigorously whether (and in which locations) turbidites provide a valuable long term record of major earthquakes?

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Turbidites triggered by slope failure resulting from major earthquakes have the potential to produce a valuable record of past earthquakes. However, to apply turbidite paleoseismology it is necessary to be able to recognize turbidites caused by earthquakes, and distinguish them from turbidites caused by other triggers. It is also necessary to understand whether some major earthquakes fail to generate distinctive turbidites, such that the turbidite record of major earthquakes is incomplete. If this is the case, it is important to determine which submarine settings and earthquake types tend to produce more or less complete records.

Major earthquakes have definitely triggered large volume submarine failures (e.g. Grand Banks in 1929), but large volume failures might be triggered in other ways. Turbidite volume alone is not a particularly reliable way of inferring paleo-earthquake triggering. The most reliable criteria is that the turbidite results from widespread slope failure, associated with the widespread ground shaking that characterises major earthquakes. Widespread slope failure can be inferred in two ways; from synchronous emplacement of turbidites in adjacent basins and from confluence tests. Demonstrating synchronous turbidite emplacement in adjacent basins can be difficult because it needs precise age control, and careful assessment of potential uncertainties in turbidite ages. The confluence test infers that earthquake shaking affects the headwaters of both tributaries of a submarine confluence, which are too widely spaced for them to be affected by a single storm. If the same number of turbidites is seen in both the incoming and outgoing tributaries, an earthquake trigger is inferred. However, the number of turbidites in a core can also depend upon the height above the channel floor, as demonstrated by ancient submarine channel outcrops. The internal character of a turbidite cannot be used with confidence to infer that it resulted from earthquake-triggered slope failure. It is highly unlikely that temporal variations in earthquake shaking are recorded as characteristic variations in grain size within turbidites. The rate at which sediment is released from a slope failure is unlikely to correspond exactly to the history of ground accelerations.

Coring near the epicentre of the 2004 (M_W 9.1) and 2005 (M_W 8.7) Sumatran earthquakes suggests that they did not produce widespread turbidites within intraslope basins (Sumner et al. 2013). Indeed, five of the six cores from these basins lacked any turbidites in the last 100 to 150 years, despite the well documented occurrence of multiple large magnitude ($M_W > 7$) earthquakes nearby. Mapping of the seafloor in this area found few large slope failures. Comparison of bathymetric surveys completed before and after the Mw 8.8 earthquake offshore Chile in 2010 also found no slope failures extending for > ~ 1 km (Völker et al., 2011). These studies included some of the largest magnitude earthquakes in recent times. Therefore, it is not at all clear that all major earthquakes generate widespread slope failure and extensive turbidites. It is possible that earthquakes can rather cause consolidation and strengthening of slopes in some settings. Further work is needed in locations where it is known a major earthquake has occurred, to understand which locations provide the most complete turbidite record of major earthquakes.

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Fluvial responses to sea-level changes during and around the Younger Dryas in incised-valley fills of the Tokyo Lowland, central Japan

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The geometry of a river channel crossing a coastal lowland changes in relation to sea-level changes, but the response of the channel to different rates of sea-level change is not well understood. This study examined the response of channel geometry to changes in the rate of sea-level rise during and around the Younger Dryas (12.9–11.5 cal kyr BP [ka]) in latest Pleistocene to Holocene incised-valley fills under the Tokyo Lowland, central Japan. The fills, which consist mainly of sediments from the Tone River, are 70 m thick along the coast. They unconformably overlie middle to late Pleistocene (Shimosa Group) deposits and consist of braided river, meandering river, estuary, and delta systems, in ascending order. The meandering river system was deposited during 13.9–9.3 ka. The depositional age at –50 m relative to the Tokyo Peil datum (T.P.) is 11.4–11.2 ka. At –50 m T.P., the meandering river system changes from a channel sand-dominated facies to a floodplain mud-dominated facies, the channel movement changes from lateral to vertical, and the river gradient changes from 0.33/1000 to 0.07/1000. During the Younger Dryas, sea level rose at 4 mm/yr and sediment accumulated at almost the same rate, resulting in a laterally migrating meandering river system and the deposition of lateral channel sands. Before and after the Younger Dryas, sea level rose at 20 mm/yr and sediments accumulated more slowly, at 10 mm/yr, resulting in a retrograding system, gentle river gradients, and fine-sediment deposition in a vertically aggrading system in which isolated channel sand belts were deposited in floodplain mud. The results suggest that the threshold rate of sea-level rise, at which the channel movement of the Tone River system changed from lateral to vertical, was 4–7 mm/yr.

Millennium-scale infilling of a tide-dominated bay: Spatial and quantitative reconstruction of Holocene sediments of the Tokyo Lowland, central Japan

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The infilling patterns of tide-dominated bays, which comprise estuaries and deltas, have been modelled on the basis of limited cross sections. This study used 18 sediment cores, 467 radiocarbon dates, and 6100 borehole logs to map in detail the sequence stratigraphy and paleogeography of the Tokyo Lowland. It then reconstructed the millennium-scale infilling process of a tide-dominated bay in the Nakagawa Valley, in the northern part of the Tokyo Lowland, that formed as an incised valley during the Last Glacial Maximum. The incised-valley fill unconformably overlies middle to late Pleistocene deposits and consists of 16 sedimentary facies, which are divided in ascending order into braided river, meandering river, estuary, spit, and delta systems. In a sequence-stratigraphic interpretation, the basal unconformity is regarded as a sequence boundary, the boundary between the braided river and meandering river systems (>14.0 cal kyr BP [ka]) is regarded as a transgressive surface, and the boundary between the estuary and delta systems (8.0–6.9 ka) is regarded as a maximum flooding surface. At 5 ka, the Tone River shifted its course to the Nakagawa Valley and filled up the bay with deltaic deposits. Before 5 ka, the tide-dominated bay in the Nakagawa Valley was filled instead by suspended particles derived from outside the bay. Tidal currents supplied the bay with fine sediment that accreted laterally from the margin to the axis as tidal flat and bay sediments during transgression and regression phases, respectively. Tidal currents prohibited sediment deposition along the axis of the bay. The regressive bay sediments show fining-upward lithological sequences distinct from the coarsening-upward sequences of the deltaic sediments after 5 ka. Such lateral accretion of particles derived from outside of the bay is documented in other tide-dominated coastal environments and is probably a common feature in this setting.

Can microbialites represent a harsh environment? The evidence from the Permian-Triassic boundary section, northwestern Sichuan Basin, south China

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Microbialites, a prominent feature of the aftermath of end-Permian mass extinction, has long been interpreted to result from upwelling bringing anoxic or lower dysoxic bottom water onto the shallow platform. As a result, microbialites are also regarded as the response to lowered oxygen condition and enhanced bicarbonate saturation of seawater which could led to end-Permian extinction and delay of Triassic recovery. However, examination of the Permian-Triassic boundary section (Yudongzi) in northwestern Sichuan Basin of south China has produced a variety of sedimentologic and biotic evidence that point to where the microbialite deposited may be oxygenated and favorable for grazers.

We systematically collected samples for geochemistry and petrography at a resolution of ~0.5 m for precise stratigraphic measurement. Every sample was cut into two, one was made into large (5 × 7.5cm) and small (2.8 × 4.6cm) thin sections prepared for opticalmicroscope analysis of the microstructurs and trends in size of shell benthos within the microbialite. The other was powdered for total organic carbon and total sulfur abundance analysis with CS230 Carbon/Sulfur analyzer to assess the redox conditon where the microbialite formed.

We observed a rapid wavering increase in size of shelly benthos (especially bivalves and brachiopods but except for ostracodes) within the microbialite that always stably deposited near normal waves base according to sedimentology analysis, suggesting an obvious improvement of benthonic ecosystem and environment. At the same time, geochemistry investigations reveal microbialites have low organic carbonate and total sulfur abundance (the samples from Yudongzi contain an average of 0.07 wt% organic carbon and 0.29 wt% total sulfur), indicating environment may be not anoxic or dysoxic when the microbialite deposited.

Based on those evidences and analyses above we consider that there may be a rapid recovery in the oxygenated shallow settings and Triassic microbialites should not be thought of a result of harsh environment.

Key words: microbialites, Permian-Triassic boundary, Triassic recovery, Sichuan basin

The Dead Sea subsurface biosphere: Identifying specific microbial assemblages and their metabolic potential in an extreme environment

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Following the discovery of living microbes in deep marine sediments, there has been an increasing interest in understanding their role in the formation of authigenic minerals and/or early diagenesis in continental settings. The Dead Sea Deep Drilling Project (DSDDP) is an international research initiative aiming to reconstruct the paleoenvironmental and paleoseismic history of the Dead Sea Basin (DSB) in the Levantine region. The quality of this sedimentary record, encompassing around 200 ka of glacial and interglacial cycles, together with the hypersaline nature of the sediments allow us identifying an extremophilic biomass and further investigate their role in the formation of authigenic minerals. This was accomplished for the first time in these sediments combining an on-site and ulterior sampling strategy to minimize contamination sources.
By using an array of cutting edge microbiological methods including 16S rRNA gene and metagenomic sequencing we have determined archaeal and bacterial communities, and defined “microbial facies”. In halite-gypsum rich sediments, deposited under holomictic conditions, *Halobacteriaceae* members seem to dominate relying on the anaerobic degradation of organic matter at very slow rates. Their “salt-in” osmotic adaptation allows them to subsist down to 200 m in the sedimentary column whereas bacterial communities are hardly recoverable. Conversely, aragonitic sediments deposited under meromictic conditions host bacterial members, seemingly well adapted to the chemical conditions of the Dead Sea. Members of the KB1 Candidate Division, defined in the Deep Hypersaline Anoxic Lake of the Red Sea (Eder et al., 1999), make a major part of the 16S rRNA library. They are involved in a collaborative trophic chain relying on the degradation of osmotic solutes allegedly accumulating in the diluted epilimnion of the lake during periods of heavy rainfall. Members of the MSBL1 Candidate Division, which dominates the aragonite archaeal 16S rRNA gene sequence library, use the methylated amins resulting from this degradation to perform methanogenesis (Yakimov et al., 2013). This process seems to occur only in such sediments and is expected to leave little chance for other microbes to develop and further rely on the remnant of this activity. Overall, aragonitic sediments did not yield analyzable DNA below 2 m in the core.
Little information on the activity of these microbes is still available. However, the identification of specific mineral precipitates such as euhedral pyrite or other iron sulfides, native sulfur concretions and EPS relicts associated with aragonite and gypsum are indicative of active carbon and sulfur cycles in both the water column and the sediments of the Dead Sea. Together with metagenomic information, their presence also suggest the occurrence and completion of various metabolic pathways previously undetected under the dominant hypersaline conditions existing in the Dead Sea (e.g. sulfate reduction and sulfur-oxidation) underlining the potential influence of microbes during sedimentation and early diagenesis. Hence, paleoenvironmental reconstructions based on sedimentary cores should take into account the potential disruption of geochemical proxies, and routinely undergo geomicrobiological investigations as recommended by recent IODP/ICDP policy.

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Explosive to effusive volcanism on submarine settings of the Santos Basin (Brazil): the role of magma–sediment–water interaction

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The subaqueous variety is the most abundant form of volcanic eruptions on Earth. Despite this abundance, their lack of accessibility and outcroppings makes this a troublesome field of study. One issue currently being debated is the ability of subaqueous basaltic eruptions to occur explosively at seafloor depths. To investigate this topic further, the present work focuses on ancient volcanic cones of Santonian age and found in the northern Santos Basin. In order to constrain the volcanic products and cone morphology, a conjunction of rock analyses and 3D seismic interpretations was carried out.

In this region, volcanic cones can be seismically identified and categorized into three morphologic types: (1) chaotic seismic facies with a V-shape, which is related to the pipe, (2) sloped and divergent seismic facies that occur outside the V-shape circle, which appears to be a maar, and (3) fairly continuous, often high-amplitude, sloped seismic facies that override the other seismic facies and form the volcanic cone itself. These volcanic cones are stratigraphically correlated to the mudstones and arenites from the Jureia formation.

These seismic facies were correlated back to well penetrations in the area, and the rock samples are: (1) massive volcanic breccia and lapillistone, with sediments and juvenile fragments, termed peperites, which have common ameboidal shapes or curvi-planar surfaces, (2) volcanic lapillistone and breccia with the same petrographic properties as the prior breccia, but which were poorly sampled, and, (3) submarine basaltic lava flows, presumably pillow lavas, and hyaloclastites. Some basaltic lava flows are highly vesicular that supports, in this case, a shallow submarine environment.

Based on the correlation between the volcanic cone morphology (evaluated by 3D seismic analysis) and rock samples, one can interpret that the initial eruptive process develops explosively. This explosivity, however, is not related to the exsolution of volatiles from the magma – as in subaerial eruptions, but rather is produced through the heating of interstitial water in the sediments by basaltic magma. Thus, it is a product of a phreatomagmatic eruption, which explains the chaotic seismic facies with a V-shape as the result of interfingering relationships of lava and sediments after the explosion. This eruption generates the maar and pipe morphologies.

It is deduced that, during its ascent to the surface, magma encounters the connate water present in the sediment pore space. This water is rapidly heated to steam and expands dramatically. When the steam pressure exceeds that supported by the rock´s cohesion, a phreatomagmatic eruption takes place. Subsequently, the continuously rising magma exceeds locally the amount of sediment. After this point, begins the formation phase of the volcanic cone, which is constructed by an effusive eruption with lava flows and hyaloclastites deposits.
At the final stage of volcanism, the amount of lava decreases and the interaction with abundant water generates rapid quenching and cooling – forming predominantly hyaloclastites. This suggests that the variation in the ratio of magma, sediment, and water is responsible for the observed volcanic morphologies and related products.

Dolomitization of the Upper Permian Changxing Formation in Yuanba gas field, NE Sichuan Basin, China

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The reef-shoal dolomite is the main reservoir of Upper Permian Changxing Formation in Yuanba gas field, NE Sichuan Province, Southern China. Dolomites vertically distribute in the upper member of Changxing Formation and laterally among reef cap, inter-reef shoal and back reef shoal facies. Different types of dolomites have similar ratios of $^{87}Sr/^{86}Sr$ (range from 0.7071 to 0.7075) which are consistent with those of dolomitic reef limestone, indicating dolomitizing fluids mainly came from synchronous seawater. Dolomitization occurred in a shallow burial low-temperature environment judged from the dolomitizing fluids temperature (40°-55°C) which is calculated from dolomite-water fractionation equation.

Even in an open-flow environment, different properties of dolomitizing fluids emerge because of the palaeogeomorphology and sea level fluctuation. (1) Relict bioclast medium-coarse crystalline reef cap dolomite has obviously negative $\delta^{18}O$, high Fe, Mn and slow crystal formation characteristics, suggesting the mixture of meteoric water and seawater involved in the reef cap dolomitization. (2) Microcrystal dolomite of inter-reef shoal has high $\delta^{18}O$, significantly high Fe, Mn, Sr and low order degree. It is closely related to the evaporated brines, though data may indicate a complex source of dolomitizing fluids. (3) Finely- medium crystalline dolomite of back reef (or shoal) owns a very low Fe, Mn value and high content of $MgCO_3$, together with the rapid crystal formation, all of which demonstrate the normal water dolomitization features.

Key words：Yuanba; Changxing Formation; Geochemistry; Reef-shoal Facies; Shallow Burial Dolomitization

Lateral accretions in low efficiency turbidites associated with a structurally-induced topography (Oligocene Molare Unit, Tertiary Piedmont basin, north-western Italy)

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Lateral accretions associated to meandering channels are one of the most common features of fluvial systems and channel–levee complexes characterizing slope systems in divergent margins. Nevertheless, the occurrence of this type of structure does not always imply the occurrence of a meander. This is the case of well-preserved lateral accretions characterizing sand-rich turbidites of the Molare Unit cropping out in the Mioglia area, located in the western part of the Tertiary Piedmont Basin, a large polyhistoric episutural basin that has many similarities with ponded basins in slope settings.

The Rupelian Molare Unit in the study area features a basal interval consisting of alluvial fans, which pass upward into transgressive fan deltas of northern provenance infilling structural depressions produced by normal faults, while the upper part consists of a predominantly mudstone succession recording an abrupt deepening of the basin due to tectonic inversion. Within these mudstone facies, lenticular coarse-grained and poorly-sorted sandstones (1-5m thick and 100-300m wide) characterized by well-developed lateral accretions can be found. The scour marks at the base of these sandstone units indicate paleocurrents directed toward the N, i.e. perfectly perpendicular to the laterally accreting surfaces (all dipping toward WSW), and exactly in the opposite direction of the underlying fan delta deposits. A detailed facies analysis shows that these sandstone bodies are produced by a lateral juxtaposition of sharp based normally graded beds in which a facies variation perpendicular to the paleocurrent can be observed. A facies tract in a cross-current direction shows that pebbly conglomerate and pebbly very coarse sandstones (F3, F2 in Mutti's scheme) grade over very short distances toward WSW into massive, crudely graded, poorly-sorted coarse-grained sandstones (F5) and poorly-developed, crude laminated medium- to fine-grained sandstones (F8-F9). The coarse-grained facies (F3, F2) are always concentrated toward ENE forming basal erosive surfaces dipping toward WSW, i.e. as lateral accretions.

These sandstone bodies, moreover, are encased between two structural highs associated to two reverse faults that reactivate pre-existing normal faults, i.e. the Mioglia flexure NNW-SSE oriented and located to the SW and the Garbarini fault characterized by the same orientation but located 5km to the NE. The high-resolution physical stratigraphy and facies analysis show the synsedimentary activity of these two reverse faults highlighted especially by evident stratigraphic pinchings of the upper Molare stratigraphic succession toward NE, i.e. against the Garbarini fault where laterally-accreted sandstone units are characterized by evident onlap relationships, testifying that this structure operated as a morphologic threshold for turbidity currents.

In conclusion, these evidences show that poorly-sorted sandstones with well-developed laterally-accreting surfaces are deposited by very-low efficient dense flows generated by resedimentation processes affecting the underlying fan delta deposits uplifted along the Mioglia flexure. The rapid deceleration of these southerly derived and longitudinally segregated flows against the bounding slope to the N, related to the Garbarini fault, produces the lateral accretions through the deposition of the coarse-grained flow front to form F3 and F2 facies, and the consequent overtaking and lateral deflection of the body and tail of the flow, which deposit laterally juxtaposed F5 and poorly-developed F8-F9 facies. This work also shows that deflection processes in highly confined basins can produce lateral accretions equal to those commonly reported in divergent margins.

Measured rates of sedimentation: what exactly are we estimating?

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Sedimentation rate is a time-dependent regionalized variable. It is positive where deposition is occurring, negative where erosion is occurring, and zero where there is stasis. Geologists obtain sedimentation rate data by measuring values of thickness change in unit time over known time intervals. This measurement is generally carried out at point sites, for instance in one-dimensional stratigraphic successions; then values for the same sedimentation system (or for the same type of system) are grouped together, usually by averaging. There now exist large sets of data obtained in this way, almost exclusively for systems that are principally depositional. This present work looks at some fundamental theoretical issues involved in the use of sedimentation rate data, issues that seem not yet to have been addressed.

Sedimentation systems are formed of sources and sinks; these are linked together by transport paths. Sources are sites at which there is erosion and transport simultaneously; sinks are sites at which there is deposition and transport simultaneously. The average sedimentation rate in a closed sedimentation system is necessarily zero whenever the total amount of sediment in active transport is constant. Average sedimentation rates that are non-zero therefore indicate either (a) that the system being studied is not closed, or (b) that the amount of sediment in active transport is not constant. From this it follows that an average sedimentation rate that is non-zero should be treated as either (a) an estimate of the extent to which the system in question is open, i.e., an estimate of the flux at the system's boundaries, or (b) an indication that the system is statistically non-stationary over the measurement time interval used. It makes little sense to measure sedimentation rate for systems that are accepted *a priori* as being both closed and statistically stationary in time – for the result then must always be zero.

Spatial and temporal autocorrelation is intrinsic in all sedimentation systems. However, it is generally ignored when sedimentation rates are measured and their values interpreted. The existence of this autocorrelation means that measurements of sedimentation rate made at different sites and times cannot justifiably be averaged arithmetically, even for the simplest of systems. Values of average sedimentation rate calculated by arithmetic averaging should always be treated with caution. They are not reliable estimates of the flux at a system's boundaries, nor are they reliable indicators of a system's stationarity or non-stationarity.

This spatial and temporal autocorrelation is not a purely statistical phenomenon. It is an inevitable consequence of the lateral transport of sediment, and therefore is to be found even in fully deterministic sedimentation systems. Lateral transport sets bounds on what is possible at a site at any time: (a) deposition can occur at a site that potentially is a sink only if sediment is transported into that site, and (b) erosion can occur at a site that potentially is a source only if sediment is transported away from that site. The sediment availability on the lithic surface is therefore one of the fundamental controls of the spatial pattern of deposition, erosion and stasis. This pattern evolves predictably in time – assuming that the environmental conditions remain the same at the sites in question – and the succession of sedimentation states at a site is therefore always to some extent predictable. An appreciation of the importance of spatial and temporal autocorrelation in sedimentation systems allows a better interpretation of sedimentation rate data. It also points to the need to measure the autocorrelation of sedimentation rates in present-day systems.

Advanced computed tomography analyses of cold-water coral mound cores: new insights into mound formation processes

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Cold-water coral (CWC) ecosystems constitute important carbonate factories along all ocean margins, where they form locally large 3-dimensional structures called CWC mounds. CWC mound formation depends on (i) suitable environmental conditions for CWC settlement and growth, and (ii) the interplay between coral framework and sediment. Concerning the latter aspect, sediment supply is suggested to be the dominant control. Thereby, reduced sediment input and intense currents are thought to increase food supply and prevent burial, while increased sediment supply favours burial. Recently, the baffling capacity of the CWC framework was identified as additional factor.

CT analyses have become a common tool in geological research during the last two decades. Within CWC research, CT is predominantly used for visualisation purposes, for example, the visualisation of corals in gravity cores and diagenetic as well as bioerosional features in corals. First quantitative appraisals presented a slice-to-slice quantification of CWCs using threshold segmentation or a density-based technique. The herein presented approach presents a 3-dimensional macrofossil clast segmentation combined with a macrofossil clast size (including standard grain size parameters, such as mean, mode, skewness and kurtosis) and orientation analysis. First results suggest that the stacking pattern of the preserved macrofossil clast depends on the CWC mound aggradation rate. Large macrofossil clast sizes with variable clast orientations (usually steeper than 60°) are interpreted as preserved original CWC framework and prevail in core sections with high aggradation. Slightly reduced macrofossil clast sizes and sub-horizontal macrofossil clast orientations are interpreted as preserved CWC rubble and occur in core intervals with reduced accumulation rates. Highly reduced macrofossil clast sizes with sub-horizontal orientation occur below unconformities and within condensed intervals. Consequently, the performed macrofossil clast size and orientation analyses provide important information for improving our understanding of CWC preservation within CWC mounds and can be used to evaluate mound aggradation. Furthermore, these analyses allow one also to optimise sampling strategies for cost-intensive dating.

Aggradation and carbonate accumulation of Norwegian cold-water coral reefs

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Cold-water coral (CWC) ecosystems present common carbonate factories along the Atlantic continental margins, where they can form large three-dimensional reef structures. There is increasing knowledge of their ecology, molecular genetics, environmental controls and threats available. However, information on their carbonate production and carbonate accumulation is still very limited, even though this information is essential for their evaluation as carbonate factories and carbonate sinks.

The aim of the presented study is to provide high-resolution reef aggradation and carbonate accumulation rates for Norwegian CWC reefs from various settings (sounds, inner shelf, continental margin), including a new approach on the evaluation of the preservation status of CWC deposits by quantitative computed tomography analysis. The observed aggradation rates exhibit the highest documented rates from CWC reefs so far with a maximal aggradation rate of nearly 1,500 cm kyr^{-1} (15 mm yr^{-1}), which is close to the annual growth rate of the reef-forming coral *Lophelia pertusa* (up to 17 mm yr^{-1}). Reef aggradation within the studied cores was restricted to the Early and Late Holocene. Available datings of Norwegian CWCs support this age pattern for other fjords while on the Norwegian shelf CWC ages are also reported from the early Middle Holocene. The obtained mean carbonate accumulation rates of up to 103 g cm^{-2} kyr^{-1} (short-term maximum: 2114 g cm^{-2} kyr^{-1}) exceed previous estimates of CWC reefs by a factor of 2-3 and by almost one order of magnitude to adjacent sedimentary environments (shelf, slope, deep sea). Only fjord basins locally exhibit carbonate accumulation rates in the range of the CWC reefs. Furthermore, CWC reefs are in the range of carbonate accumulation rates of tropical reef environments. The obtained results clearly suggest the importance of CWC reefs as local, maybe regional or even global, carbonate sinks.

The tectono-sedimentary evolution of Pliocene lignite deposits in Kangal- Neogene Basin, Central Turkey

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The Kangal Neogene Basin is an intra-cratonic basin, located south of Sivas (Central Turkey), was filled with continental sedimentary sequence, and contains important coal deposits with approximately 500 million short tons lignite reserves. This basin is surrounded by the sedimentary and ophiolithic Pre-Neogene basement rocks and it contains several lignite deposits, particularly Etyemez and Kalburçayırı sites. The aim of this study is to investigate fault structures which are related with the quality of the lignite deposits and to understand tectono-sedimentary evolution of the Etyemez area located the southern part of the Sivas-Kangal (central Turkey). For this reason, beside detailed sedimentological studies, 25 new boreholes have been drilled to define both the thickness and the quality variation in a lateral direction, and to determine the underground structure and amount of reserves of the coal deposits in the Kangal Basin.

According to all coal analysis, the Etyemez coal is characterized as low calorific value and high moisture content. The calorific value of the coal obviously increases in a lateral direction depends on the thickness of the overburden sediments in the study area. Thus, the syn-sedimentary growth faults have controlled the spreading, thickness and quality distribution of the Etyemez coals in the Kangal Basin. NE-trending normal fault systems have developed in marginal parts of the basin and influenced the thickness and distribution of the coal bearing Neogene sediments.

The depositional environment of the Kangal Neogene Basin is determined fluvial and lacustrine environment. The Pliocene sediments in the Kangal intermontane basin consist of two main sedimentary facies. These are in ascending order from bottom to top; (1) fluvial facies (claystone-mudstone unit), (2) lacustrine facies (limestone unit). The deposits of the fluvial facies consist mainly of claystone, mudstone, coaly mudstone and rippled sandstones, with well-sorted channel fill conglomerate intercalations. Locally, coalified plant detritus and fresh-water gastropod -bearing mudstone interbeds also occurred in the fluvial sequence. On the other hand, the thick coal seams and related coaly mudstones mainly formed within the uppermost part of the fluvial sequence.

Sedimentological evidences and fossil content of the lignite seams (The fresh-water gastropods *Limnea* sp., *Planorbis* sp.) and related mudstone and claystone constituents indicate that the coal deposits were formed within the fresh-water lacustrine environment composed of flood-plain and mud-plain swamps in the intermontane basin during the Pliocene period. Hence, the lacustrine limestones act as a form of indicator unit for the coal fields.

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Clastic photozoan-rich prograding wedge of the Pietra di Finale Fm (Ligurian Alps, Italy)

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This work focuses on the Miocene mixed carbonate-siliciclastic deposits of the Pietra di Finale Formation, where the carbonate portion consists of bioclasts constituted mainly by photozoan elements such as *Halimeda* segments and *Porites* fragments. The Pietra di Finale Fm outcrops along the Ligurian coast in the Finale Ligure area and unconformably overlies on the Ligurian Alps substrate. Six logged sections were measured and microfacies analysis complemented the stratigraphic and sedimentological analyses. Four main facies have been recognised. The first facies is a crudely bedded skeletal conglomerate with low angle cross lamination. Pebbles mostly derived from Alpine dolomite and metamorphic substrate, whereas the skeletal faction is represented by balanids, echinoids and bivalves. This facies could be interpreted as deposited in a nearshore/shoreface environment. The second facies is a crudely to well stratified balanid-rich rudstone to floatstone with abundant *Halimeda* in a sandstone matrix deposited in a shoreface setting. This facies passes basinward into the *Halimeda* floatstone to rudstone facies rich in *Porites* fragments with a prograding depositional geometries and interpreted to be deposited in the offshore-transition zone. The fourth facies is represented by a bivalve-rich floatstone in a hybrid sandstone matrix with subhorizontal beds representing deposition in the offshore zone. In this example is shown how *Halimeda* can flourishes also with conspicuous terrigenous input tolerating high nutrient conditions. Typically Mediterranean Lower to Middle Miocene carbonate platforms are dominated by seagrass environments in the euphotic zone and coralline algae in the oligophotic zone promoting the development of carbonate ramp depositional profile. In this case study we investigate the role of regional vs global conditions that might promote this *Halimeda*-dominated carbonate production that have respectively substituted the seagrass carbonate factory in the euphotic zone, less tolerant to the high nutrient conditions, and the red algal production in the oligophotic zone. Another peculiarity of this mixed example is represent by the clastic contribute of corals in spite of buildup. In such way the photozaon clastic factory has also controlled the depositional profile that resulting in a prograding wedge-shaped morphology with an important nearshore siliciclastic supply produced by erosional processes of the more proximal terrigenous facies and limited carbonate sedimentation just in the deeper part of euphotic and oligophotic zone with the deposition of more distal carbonate facies.

Evolution of the No. 2 Fault zone and its Influence on Sedimentary and Structural Evolution of Central Depression in Qiongdongnan Basin, South China Sea

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The No. 2 Fault zone, located in the central region of Qiongdongnan Basin (QDNB), is one of the most important fault zones in the northern margin of South China Sea. It separated the Northern Uplift and Central Depression, and controlled the sediment deposition and structure evolution in the Central Depression. Based on regional geological data, seismic data, drilling data and logging data, a detailed tectostratigraphic interpretation on the 2D multichannel seismic data and 3D seismic data newly acquired was carried out. By using quantitative analysis of fault and back-stripping technique, a new perspective of the geometry and kinematics features of the No. 2 Fault zone has been came up, as well as its influence on sedimentary and structural evolution of the Central Depression has been discussed. The result shows that the QDNB was formed in a setting of NW-trending extensional stress field in the Late Eocene. During this time, the No. 2 Fault was initiated with a characteristic of distributed discontinuous and segmentation activity. As a result, the small NE-trending grabens and half-grabens were appeared. In the Oligocene, with the seafloor spreading of the South China Sea, the direction of the regional tectonic stress field changed from NW to SN, and the previous small discontinuous faults started to propagated, connected and merged. Different from previous studies, our model suggests the No. 2 Fault zone was not a single fault, but a left-stepping, en-echelon fault system consisted of Ledong-Lingshui arcuate fault zone and Songnan-Baodao arcuate fault zone. In the seismic profiles, the No. 2 Fault presented listric shape and extending downward to the Moho discontinuity. So the main No. 2 Fault is a large scale detachment fault. In the Changchang sag, east of QDNB, the terminal of the No. 2 Fault were a series of minor echelon faults and their dip toward the opposite direction of the normal faults in the south of Changchang sag. Therefore, under the control of the No. 2 Fault zone, the basin structure in the Central Depression had changed from grabens in the west to half-grabens in the east. During the Middle Miocene, the activity of No. 2 fault declined rapidly, and it had little or no influence on the sediments filling. After that, the concealed activities of the No. 2 fault still has contributes on the development of aggradational continental slope system in the central and eastern QDNB.

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Are dendrolite and thrombolite macrofabrics always primary? Examples from the Cambrian of Shandong, China

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Dendrolite (dendritic) and thrombolite (clotted) microbial carbonate macrofabrics are well developed throughout the Cambrian (Series 3) Zhangxia Fm (~500 Ma) near Jinan, Shandong, China. In outcrop and hand specimens these fabrics are conspicuous as mm-cm dark grey to brown masses, variously shrub-like, curved, elongate or rounded, in lighter-colored, typically yellow to reddish, matrix. In thin-section the dendrolites are composed of the calcimicrobe *Tarthinia*, with thick diffuse micritic walls surrounding poorly defined spar-filled chambers. These are associated with partly altered wackestone and with bioclastic packstone matrix containing recrystallized trilobites, ostracodes, and sponge spicules. In contrast, the fabrics that macroscopically resemble thrombolites appear in thin-section to be composed of wackestone surrounded by microspar and spar which we infer to be altered wackestone and other, unidentified, matrix.

Comparisons of macrofabric and microfabric show that micritic fabrics (*Tarthinia* and wackestone) are dark in both thin-section and hand-specimen, whereas the recrystallized and/or dolomitized areas that were originally wackestone and packstone are light colored in both thin-section and hand-specimen. The alteration of the wackestone and bioclastic packstone affects the macrofabric in two distinct ways. First, the dark fabric dominated by *Tarthinia* is augmented by adjacent patches of dark unaltered allomicrite. Second, the pale matrix, which emphasizes the darker macrofabric, is enhanced by alteration. As a result, the darker component of the fabric is heterogeneous in origin, comprising both microbial carbonate and matrix, and the surrounding lighter component only represents part of the matrix.

Bright fluorescence in the microbial carbonate (*Tarthinia*) and allomicrite suggests the presence of organic carbon, whereas the packstone and the altered fabrics show lower signals. We propose that the presence of organic carbon protected both the microbial carbonate and the allomicrite from alteration by hindering diagenetic fluid flow, whereas the organic carbon-poor grainy fabrics (packstone, recrystallized shells) were less protected and therefore prone to alteration. We envisage the following stages of fabric development:

(i) Erect shrubby growths of *Tarthinia* were synsedimentarily surrounded by allochthonous micrite and bioclasts that formed interstitial wackestone and packstone matrix.

(ii) Burial diagenesis preferentially affected the wackestone and packstone fabrics, partly overprinting them with aggradational spar and replacive dolomite but also leaving some areas, particularly of wackestone, unaltered.

As a result, areas that appear dark in hand-specimen and thin section include both *Tarthinia* and unaltered wackestone, and areas that appear light are altered areas of wackestone and packstone.

These results show that the dendritic and clotted macrofabric consists of *Tarthinia* and/or allomicrite. Consequently, the dark apparently dendrolite and thrombolite fabrics are not always entirely microbial, but represent calcimicrobes (in this case *Tarthinia*) augmented by unaltered allochthonous wackestone-packstone matrix. In contrast, the light matrix is enhanced by recrystallization/replacement but nonetheless only represents part of the matrix. In these examples, augmentation of the dendrolite macrofabric appears relatively minor and the dark fabric does generally reflect the distribution of the calcimicrobes. Conversely, the thrombolite-like fabric appears to be largely a product of alteration. We conclude that some thrombolite-like macrofabrics may not only be substantially enhanced and/or modified by alteration, but could be virtually entirely products of diagenesis.

Sedimentary dynamic and associated morphologies of the northern slope of Little Bahamas Bank (LBB): a re-evaluation of the carbonate base of slope apron model

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The northern slope of Little Bahama Bank (LBB) has been considered as a typical modern example of a base of slope apron, in opposition to the classic submarine fan model, essentially because of the lack of a clear architectural organisation, e.g., the development of channelised geometries, levees and depositional lobes. However, thanks to the new set of data collected during the recent Carambar cruise (Nov. 2010), several types of architectural elements have been identified and induce a re-evaluation of previous models.

An integrated approach is proposed, from a multi-scale geophysical dataset (multibeam echosounder, 3.5 kHz/Chirp profiles and 2D multichannel seismic lines) and gravity cores. It allows to distinguish three main parts along the slope, according to the slope degree, facies pattern and architectural element distribution. (1) The platform margin is associated with a steep slope until 400 m water depth, and is characterised both by bypass and depositional processes, the latter leading to the development of a thick sediment wedge. (2) The upper-middle slope is mainly composed of periplatform ooze with a downslope decrease of submarine cementation. This part is incised by 18 canyons associated with wedge-shaped and/or aggrading terraces bordering their talwegs. These complex canyon morphologies appear to be controlled by the interplay between internal slope slides, regressive erosion, diagenetic cementation and turbidity current activity. (3) The end of canyons, at 950 m water depth, marks the beginning of the lower slope where canyon mouths open to several shallow distributary furrows. These shallow furrows are filled by very fine-grained carbonate sand and stop on the distal lower slope in partially confined depositional areas, at about 1150 m water depth. In addition, the lower slope is also characterised by erosional structures oriented in a NW direction, highlighting the Antilles Current action that reworks sediments in the eastern part and deposits fine-grained sediments in the western part, hence contributing to the contourite LBB Drift growth.

This study shows that the base of slope apron model is too restrictive to describe the northern slope of LBB. Indeed the sedimentary dynamic and associated morphologies occurring on this slope are not limited to a platform-parallel apron of debris fed by coarse gravity deposits originating from internal slope erosion, but are the results of the combined action of off-bank transport, turbidity currents and bottom currents. These processes induce a sorting of particles and the onset of distinct deep-water architectural elements that are specific to Bahamian carbonate slopes.

Ash beds in Upper Ordovician shales from the northern Holy Cross Mountains: stratigraphic significance and depositional processes

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The Upper Ordovician sedimentary record in the northern Holy Cross Mountains (HCM) consists of mudrock succession, up to 180 thick (Trela, 2007). Its lower portion is dominated by dark/black shales of the Jeleniów Formation spanning the Sandbian to lower Katian stratigraphic interval. In the Jeleniów PIG 1 well these shales are interrupted by K-bentonites ranging largely in thickness from 0,5 to 10 cm. The thickest ash layer, up to 40 cm thick, occurs within the Sandbian *multidens* graptolite zone and it is accompanied by multiple stacked K-bentonite beds. This ash horizon seems to be coeval to the Kinnekulle K-bentonite in Baltoscandia recording multiple volcanic eruption (Bergstrom et al., 1995).

Various thickness and irregular distribution of K-bentonites in the Jeleniów Formation seem to be reflection of fluctuating volcanic activity, however, the sedimentary features of the background dark shales suggest that physical and biogenic factors contributed significantly into preservation of ash beds. The sedimentary structures reported in these shales include sub-millimetric horizontal lamination and fine lenticular to wavy-crinkly fabrics as well as discrete bioturbational mottling confined to the individual laminae. The Jeleniów Formation was deposited in the dysoxic/anoxic bottom waters with intermittent oxic periods (Trela, 2007; Zhang et al., 2011). The oxygen deficient sedimentary conditions are considered to be a favourable setting for preservation of ash layers because of decreased activity of borrowing organisms (see Ver Staeten, 2004). However, the light-coloured discrete trace fossils of small *Chondrites* emplaced on the dark mudrock indicate that biogenic processes might have modified the sedimentary record of ash layers in the Jeleniów PIG 1 well. The closely spaced Sandbian/Katian K-bentonite beds appear to reflect their complex history including rapid burial of primary volcanic ash by the background muddy sediment preventing them from physical and biological reworking and mixing (see Ver Staeten, 2004).

Considering the paleogeographic location of Baltica during the Sandbian–early Katian time Torsvik and Rehnström (2003) argued that distribution of huge pyroclastic material over Baltica was driven by westerlies of Southern Hemisphere. They pointed out that the prime source of massive ash falls over this palaeocontinent was volcanism associated with the alkaline magmatic event in Avalonia. Likewise, the Baltoscandian K-bentonites the Sandbian-early Katian ash beds in the northern HCM appear to be accumulated from pyroclastic material delivered by westerlies from the Avalonian volcanoes.

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Permian-Triassic alluvial-floodplain red beds, calcretes and rhizoliths from the Holy Cross Mountains, Poland

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The uppermost Permian in the NW part of the Holy Cross Mountains is represented by distal alluvial-floodplain facies with various type of calcrete horizons and rizoliths deposited in a semi-arid climate. This succession belongs to PZt cyclothem dated by miospores of *Lueckisporites virkkiae* Bc Zone and Siodła Formation overlain by red mudstones/sandstones of the Jaworzna Formation yielding spore-pollen assemblage of *Lundbladispora obsoleta – Protohaploxypinus pantii* Zone (Fijałkowska, 1992, 1994) as well as conchostracan carapaces of *Falsisca postera* and *F.* cf. *verchojanica* (Ptaszyński and Niedźwiedzki, 2004).
The distal alluvial fan facies consist of red mudstones with subordinate thick conglomerate and sandstone beds representing the PZt cyclothem. The mudstones are predominantly massive, however in places they show horizontal lamination and alternation with heterolithic thinly bedded sandstones and mudstones. In some horizons red massive mudstones contain scattered carbonate nodules showing sharp boundaries or intercalations of rare thin indurated calcrete beds. The sedimentary facies of the PZt cyclothem reveal features of sediments deposited in shallow ephemeral lakes as well as accumulated from unconfined sheetfloods. The thicker conglomerate and sandstone intercalations infill palaeochannels cutting into the background mudstones. Numerous calcrete horizons within the PZt succession suggest the lower sediment accumulation rate or even non-deposition periods favoring development of continental carbonates.
The Siodła Formation is made up of massive reddish to mottled greenish/red mudstones with numerous root structures, traces of sediment brecciation and more or less oval carbonate nodules. The inventory of root-related structures includes rhizoliths and rhizoconcretions as well as calcite tubules. The rhizoliths length is up to several centimeter scale, while the diameter varies between a few millimeters to a few centimeters. The infill of root moulds consists of massive and red calacareous mudstone, distinctly darker in comparison to the host mudstone sediment. The mottled red mudstones of the Siodła Formation were deposited in ephemeral lakes on floodplain and had lost their primary structure due to rooting and other pedogenic processes related to breaks between episodic sedimentation.
The Jaworzna Formation consists of thin- to medium-bedded red sandstones and mudstones with shale partings. The sandstone beds reveal small-scale cross bedding, horizontal lamination and desiccation cracks. The Jaworzna Formation is interpreted as the sheetflood deposits (Szulczewski, 1995) or even fan delta succession prograding into standing water bodies.

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Dedolomitisation in a microbially-dominated carbonate system: Zechstein, NW Europe

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Dedolomitisation is the process of calcite replacement of dolomite (calcitisation) and it is a process which has affected many dolomite rocks. In many cases dedolomitisation has been related to the effects of meteoric diagenesis on dolomite, soon after deposition or much later on uplift and subaerial exposure. However, it is now clear that calcitisation of dolomite can take place during shallow burial (i.e. pre-compaction, depths less than several 10s of m) as well as during deeper burial (after compaction). In addition, in settings where dedolomitisation is common, as in the Upper Permian (Zechstein) carbonate-evaporite succession of NW Europe, limestones previously interpreted as dedolomites may on closer inspection actually be primary limestones. The recognition of dedolomites is based on macrostructures seen at outcrop and in core and microtextures seen petrographically, all indicating calcite replacement of dolomite, and geochemistry, especially stable isotopes and Sr content. In the Zechstein outcrops of NE England, and the subsurface of Germany-Poland, dedolomites are widely developed, often in carbonate strata in close proximity to anhydrite facies or their dissolution residues and collapse breccias. In some cases the dedolomites have conspicuous structures, including small (cm) to large (0.5 m) concretions of radiating, spherulitic fibrous calcite and concentric banding, and bizarre pseudocoralline, honeycomb fabrics of rods and bundles. Some concretions are clearly pre-compaction, being fractured and having sutured contacts. Other dedolomites are uniform replacement mosaics of coarse calcite crystals with relicts of fossils and lamination. CL, however, suggests the former presence of anhydrite, probably as a replacement of the dolomite before calcitisation. Dedolomitisation does seem to be facies controlled, apart from the proximity to anhydrite beds: fine-grained sediments tend to be calcitised more easily than coarser facies, such as grainstones, especially with the more destructive fibrous calcite type, and organic-rich facies tend to be more easily replaced too. Zechstein dedolomites were the result of the passage of Ca^{2+}-rich fluids through the dolomitic sediments and the source of these fluids could have been 1) meteoric influx, i.e. near-surface early, eo-, or late/uplift-related, telo- genesis, or 2) related to gypsum-dehydration to anhydrite during moderate to deep burial, or 3) related to anhydrite-gypsum dissolution during uplift. One further mechanism (4) could have involved the activities of sulphate-reducing bacteria during burial, causing the release of Ca^{2+} from gypsum-anhydrite. The association of framboidal pyrite with calcitised dolomite would be consistent with this. Biomarkers extracted from Zechstein Z2C dedolomite show that the bacterial contribution (2-methylhopane index = 10.2-12.4%) to the total organic content is in general higher than in Z2C dolomite and limestone facies (2-7%, rarely up to 12%), with deposition taking place under oxic/suboxic conditions (homohopane index = 0.08-0.2). However, the sterane/hopane ratio (0.08-0.13) in the dedolomites indicates a significant contribution from algae compared to dolomite and limestone facies. Dedolomitisation generally has a deleterious effect on reservoir quality, reducing porosity and permeability. Hence an understanding of dedolomitisation and its controls, as well as predicting its distribution and geometry, are a worthwhile pursuit.