EUG XI

Symposium EVO5

Rapid Changes in Mesozoic Palaeoceanography: Micropalaeontological, Sedimentological and Geochemical Proxies

Convenors

Joerg Mutterlose
Elisabetta Erba
Helmi Weissert

Sunday PM Session

EVO5 : SUpm25 : F5
Calcareous Nannofossils and Milankovitch Cycles in the Lower Jurassic Belemnite Marls (Pliensbachian, UK)

Ben Walsworth-Bell (ben.wbell@unimi.it)[1], **Paul R Bown** (p.bown@ucl.ac.uk)[2] & **Graham P Weedon** (graham.weedon@luton.ac.uk)[3]
[1] Scienza della Terra, Università di Milano, Via Mangiagalli 34, 20133 Milano, Italy
[2] Geological Sciences, University College London, Gower St, London WC1E 6BT, UK
[3] Environment, Geography & Geology, University of Luton, Park Sq, Luton, Beds LU1 3JU, UK

The hemipelagic Belemnite Marls Formation (Dorset, southern UK) accumulated beneath an epicontinental sea during the early Pliensbachian (Early Jurassic). This calcareous mudstone unit is characterised by light and dark marl bedding couplets at the decimetre scale, reflecting primary variations in sedimentation. Previous cyclostratigraphic analysis (Weedon & Jenkyns, 1999) has revealed that these cycles represent orbital-climatic forcing, recording the precession cycle in the Milankovitch spectrum (average period in the Early Jurassic *ca.* 20 ky).

In this study an approximately 6 m interval of the Belemnite Marls was subjected to high-resolution nannofossil distribution analysis. Samples were collected at 3 cm intervals, and quantitative nannofloral data were generated using standard methods. Time-series analysis was applied to these datasets to test for the regular cyclicity diagnostic of orbital-climatic forcing.

Consistently good nannofloral preservation allows assemblage variation to be considered in terms of primary palaeoenvironmental signals. Power spectra generated for a number of the nannofossil time series (e.g.%*Crepidolithus crassus*), together with those for wt%$CaCO_3$ and wt%TOC, contain significant spectral peaks representing a wavelength of 0.38 m. These datasets thus display regular cyclicity at the scale of the bedding couplets. The wt%$CaCO_3$ and wt%TOC time series are significantly coherent (have correlated amplitude variations) at the frequency of the couplet cycles; the phase difference is, within error, indistinguishable from 180°, and thus these parameters vary inversely. The%*C. crassus* and wt%$CaCO_3$ data are also coherent at the frequency of the 0.38 m cycles, but here the phase difference is indistinguishable from 0°; these two parameters are thus in phase (exhibit a positive relationship). The data for most other species (e.g.%*M. elegans*) are coherent, and in phase, with wt%TOC at this frequency (and thus in anti-phase with %*Crepidolithus crassus* and wt%$CaCO_3$).

The distribution of modern nannoplankton is closely related to surface-water fertility (the majority of species are oligotrophic-adapted), and relationships between nannofossil assemblage composition and facies may be considered in these terms. Species-diversity analysis of the Belemnite Marls assemblages suggests that the light (carbonate-rich) marls, which contain low-diversity floras (numerically dominated by *C. crassus*), record intervals of elevated nutrient supply to the photic zone. These sediments may have been deposited during periods of enhanced vertical mixing of the water column. The dark (clay and organic carbon-rich) marls yield high diversity floras; these may represent reduced surface-water fertility, accompanying water-column stratification. It is thus suggested that the rhythmic sedimentation of the Belemnite Marls recorded the influence of precessional climate change on marine circulation. A similar interpretation has been advanced for the Toarcian-Aalenian Fiuminata section (central Italy; Mattioli, 1997).

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EVO5 : SUpm26 : F5
The Carbonate Signal and Calcareous Nannoplankton Distribution in Jurassic Marl-Limestone Alternations of the Tethyan Realm

Emanuela Mattioli (mattioli@univ-lyon1.fr) & **Bernard Pittet**
UFR Sciences de la Terre, Université Claude Bernard, 43 Bd du 11 Novembre 1918, Villeurbanne Cedex, Lyon, 69622, France

The origin of carbonates in Jurassic pelagic and hemipelagic environments is still under debate. Pelagic carbonate production and imported carbonate mud from shallow platforms both contribute to the carbonate record. In modern and past oceans, calcareous nannoplankton is one of the major pelagic producer and may be recorded in rock-forming proportions. In the Jurassic, the main pelagic organisms to produce a calcareous test are coccolithophorids and *Schizosphaerella* spp. (*incertae sedis*). Various authors have inferred the lithogenetic importance of calcareous nannofossils, in particular of *Schizosphaerella*, since the Early Jurassic (No'l et al., 1994; Claps et al., 1995; Mattioli, 1997). Marl-limestone alternations have been interpreted as resulting from productivity cycles of schizosphaeres and coccolithiphorids (Claps et al., 1995; Mattioli, 1997). In limestone hemicouplets *Schizosphaerella* dominates over coccoliths, while in marls the relative abundance of coccoliths increases. Two interpretations are given: 1) selective diagenesis (Mattioli, 1997), coccoliths being less resistant than *Schizosphaerella*; 2) higher productivity of *Schizosphaerella* in times of carbonate deposition, and of coccoliths in times of clay deposition (No'l et al., 1994; Claps et al., 1995; Mattioli, 1997). However, such productivity cycles contradict the fact that abundances of both coccoliths and *Schizosphaerella* are systematically higher in marls than in limestones, and higher in condensed intervals than in non-condensed ones (Pittet et al., 2000). In order to quantify the pelagic carbonate production in Jurassic marl-limestone alternations, and to understand the palaeoenvironmental factors controlling the carbonate record, numerous sections were studied in Italy, France and Germany. The Early Toarcian and Late Oxfordian were choosen to compare pelagic carbonate production in periods of respectively overall decreased and enhanced carbonate productivity. Our study suggests that nannofossils did not produce the bulk of carbonate mud in the Jurassic, although they contribute to different extent to the pelagic fraction. The contribution of both coccoliths and (mainly) *Schizosphaerella* to the carbonate production is important only in proximity of carbonate platforms, in periods of reduced accumulation rates and/or during clay deposition. The highest estimated carbonate production by nannofossils is lower than 70% of the total carbonate content, but in a Toarcian sample containing only 12wt%$CaCO_3$! The observed marl-limestone alternations therefore result from cyclical export of carbonate mud from shallow platforms basinwards and, only subordinately, by changes in nannoplankton productivity. The variations in carbonate production and exportation are likely controlled by the interplay of short- and long-term climatic and relative sea-level changes.

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EVO5 : SUpm27 : F5
Geochemistry of Mesozoic Organic-Carbon-Rich Sediments from the Norwegian Shelf and Barents Sea

Marcus Lipinski (m.lipinski@icbm.de) & **Hans-Juergen Brumsack**
ICBM, Carl von Ossietzky University, D-26111 Oldenburg, FRG

This study was performed on samples from cores of the "Shallow Drilling Project" (1987-1991) of the IKU, Trondheim (Norway). Sediments of Late Jurassic/Early Cretaceous age from the Norwegian Basin and Western Barents Sea were analysed for their elemental composition. The applied methods include XRF, ICP-MS, UIC-coulomety, and LECO-C-S analysis. Ti/Al ratios of the individual cores are significantly different. Samples from southern Norway and the Barents Sea exhibit lower Ti/Al ratios than those from Mid-Norway. This may indicate different provenance of the terrigenious-detrial matter or a more energetic (shallower) depositional environment at the central location. High Zr values support the latter assumption. Redox sensitive and stable sulfide forming trace metals are significantly enriched in TOC-rich layers (>5% TOC content). This indicates anoxic conditions in the water column and/or close to the sediment surface. Sedimentation rates must have been rather low when seawater serves as the excess metal source. Due to similar depositional conditions the metal enrichment in these boreal black shales seems comparable to those seen in Cenomanian/Turonian black shales. High Zn values in samples from the Barents-Sea may be explained by assuming an additional metal source, most likely hydrothermal. According to the difference in element enrichment the palaeo water depth likely decreased from the south with possibly suboxic bottom water conditions to the central part of the Norwegian Sea with an oxic water column. Shallow water depths or stronger bottom water currents (winnowing?) are indicated by elements that are typically enriched in heavy minerals. Water depth increase again towards the Barents Sea. In sediments of this location the highest metal enrichments are observed owing to anoxic depositional conditions. The paleoceanographic changes may be understood by comparing the variability in Mo/Al ratios in each core. In South-Norway the Mo/Al ratios reflect suboxic to anoxic conditions in this interval. In the central Norwegian Sea Mo/Al ratios are significantly lower owing to less severe oxygen depletion at this location. Most values in the upper core section do not differ significantly from average shale. Highest Mo enrichments are encountered in the Barents-Sea core. Even by not considering the most extreme Mo/Al ratios it becomes evident that anoxic conditions are prevailing at this location. This seems particularly true for the interval from 49.0 to 51.5 m, which was studied at high resolution. In this core section astronomical parameters (Milankovich-cycles) might have had a control on the environment of deposition.

EVO5 : SUpm28 : F5
Icehouse-Greenhouse Fluctuations in the Early Cretaceous Induced by Methane Release Events and/or Changes in Oceanic Circulation

Darren Richard Gröcke (d.grocke@gl.rhul.ac.uk)
Department of Geology, Royal Holloway, University of London, Egham Hill, Egham, Surrey TW20 0EX, England

The Earth in the Cretaceous period witnessed one the most dramatic greenhouse periods ever, causing major changes in the ocean and atmosphere. The onset of the Cretaceous greenhouse period has been suggested as mid-Valanginian (Lini et. al., 1992) and earliest Aptian (Larson, 1991), although most earth scientists would favour the latter. A high-resolution isotopic analysis of deep-sea sediments from the R'o Argos have been undertaken to determine environmental changes prior to the onset of global greenhouse conditions in the mid-Cretaceous. The R'o Argos section, SE Spain and subsequent biostratigraphic investigations have revealed a complete and continuous section of Early Cretaceous deep-sea sediments ranging in age from the Early Berriasian to Late Albian (Hoedemaeker & Leereveld, 1995). Preliminary data from the Valanginian at R'o Argos indicate that the isotopic curves are global in their significance.

Comparison of the R'o Argos and Stoll & Schrag (1996) datasets reveal two short-term negative carbon-isotope excursions in the upper Berriasian. Recently, rapid negative carbon-isotope excursions have been attributed to the massive dissociation of methane gas hydrates (Hesselbo et al., 2000). The effect of methane gas hydrate release generally spans a time interval of <150 kyr and since methane is rapidly oxidised to CO_2, this has a major effect on global palaeoatmospheric CO_2 levels and hence palaeotemperatures. Using age estimates in Stoll & Schrag (1996) these negative carbon-isotope excursions approximate to <200 kyr, and certainly within the limits of a methane event. In addition, the negative carbon-isotope excursions generally correspond with a fall in relative sea-level as shown by oxygen-isotope ratios and, thus, a mechanism driving changes in oceanic circulation and subsequent methane dissociation. Post-dating the positive carbon-isotope excursion a gradual decline through the Late Valanginian is recorded, but superimposed on this are rapid negative excursions from R'o Argos. These excursions may also relate to a pulsed release of continental margin methane, produced as a result of decomposition and organic build-up during the mid-Valanginian. Could a

repetitive cycle of methane-release events cause global shifts between and icehouse and greenhouse world until the Early Aptian when the combination of methane and volcanism tripped the Earth into a full blown greenhouse period.

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EVO5 : SUpm29 : F5
Phosphate Accumulation Rates for the Valanginian-Hauterivian: Paleoceanographic Implications

Bas van de Schootbrugge (bas.vandeschootbrugge) & **Karl Föllmi** (karl.foellmi@geol.unine.ch)
Rue Emile Argand 11, 2007 Neuchâtel, Switzerland

Phosphorus (P) is an essential nutrient and is intimately linked to the carbon cycle, because it controls productivity and therefore export of carbon. Phosphorus is primarily delivered to the ocean through continental weathering and erosion. During the early Cretaceous the link between the carbon and phosphorus cycles has been shown by the contemporaneous occurrence of phosphatic horizons representing drowning events and positive carbon isotope excursions (Valanginian and Aptian). Detailed investigation of a number (6) of Hauterivian sections along the former northern margin of the Tethys for their Phosphate Accumulation Rates (PAR) combined with other data from the literature allows for the construction of a phosphate accumulation curve that is based on 475 data points. This work largely confirms earlier work by Föllmi (1995). From the Valanginian to Barremian PAR show a maximum during the early Hauterivian (Radiatus-Nodosoplicatum zones), with a gradual increase during the Valanginian and a rapid decrease during the late Hauterivian and minimal values during the Barremian. High PAR correlate with high carbonate accumulation rates during the early Hauterivian. Slowdown of PAR during the late Hauterivian correlates with lowered carbonate accumulation rates. This is also reflected by the carbon isotope record for the Hauterivian, with decreasing carbon isotope values during the early Hauterivian and increasing values during the late Hauterivian. Based on oxygen isotope records for the Tethys the early Hauterivian shows relatively cool water temperatures, which is interpreted as the result of cold water influx from the Boreal realm during a general transgressive phase (van de Schootbrugge et al., 2000). The coincidence of high PAR, mesotrophic carbonate producing biota (crinoids, bryzoans, sponges) and cool water temperatures might point to increased upwelling along the northern margin of the Tethys. The reason that this did not lead to increased C_{org} burial and further drowning might be that carbon cycling was pushed in a higher energy mode from the Valanginian into the Hauterivian. On the whole the Hauterivian probably represented a stable mode of greenhouse climate, with high atmospheric pCO_2 and high run-off and detrital influx (P, alkalinity and terrestrial OM) and during which the ocean became buffered favouring carbonate carbon burial under mesotrophic conditions.

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EVO5 : SUpm30 : F5
Calcareous Nannofossils: Palaeoecological Proxies for Deciphering Environmental Changes in the Cretaceous

Jörg Mutterlose (joerg.mutterlose@ruhr-uni-bochum.de)[1] & **Elisabetta Erba** (elisabetta.erba@unimi.it)[2]
[1] Institut für Geologie, Mineralogie und Geophysik, Ruhr-Universität Bochum, 44801 Bochum, Germany
[2] Dipartimento di Scienze della Terra, Università di Milano, 20133 Milano, Italy

Calcareous nannofossils have been one of the most important groups of primary producers in the marine food chain since the Jurassic. They represent one of the key groups for better understanding the marine ecosystem and are thus ideal proxies for deciphering palaeoecological and palaeooceanographic changes. Secondly their skeletons, which are made up of $CaCO_3$, form a substantial part of extant and fossil pelagic carbonates, whereby this group is an important CO_2 sink. In recent years the palaeoecological affinities of various Cretaceous nannofossils have been studied and used for palaeoceanographic interpretations. We try to summarize the current stand of art of this planktonic group with respect to its use for palaeoecological reconstructions.

Palaeobiogeography and temperature: For specific intervals of the Cretaceous bipolar distribution patterns have been described. These distinctive latitudinal gradients of certain species, impoverished at low latitudes and abundant at high latitudes, possibly reflect latitudinal differences in temperature. Palaeoclimatically, this implies the existence of climatic belts throughout parts of the Early Cretaceous (Early Valanginian, Hauterivian), resulting from considerable temperature gradients from north to south. These Early Cretaceous biogeographic patterns are very similar to the record in modern oceans.

Nutrients: Though calcareous nannoplankton are rather oligotrophic with respect to other phytoplankton, certain nannofossil taxa seem to be controlled by nutrification events. These allow for the reconstruction of upwelling areas and zones of higher productivity. The nannoconid group has been interpreted as peculiar of the lower photic zone and controlled by fluctuations of the nutriclyne depth. Consequently, changes in abundance of nannoconids and other coccoliths have been used to recontruct the fertility of surface waters.

Evolution: The Cretaceous is punctuated by nannofossil evolutionary events, radiations, extictions and turnovers. In the mid-Cretaceous a distinctive radiation of calcareous nannofossils is associated with major changes of other planktonic organisms (diatoms, silicoflagellates, planktonic foraminifera) and the onset of a new oceanographic regime, perhaps marking the transition from the Mesozoic into the modern ocean.

EVO5 : SUpm33 : F5
Interregional Correlation of Aptian OAE (Selli) Deposits between Slovak Western Carpathians and Swiss Pre Alps

Otilia Lintnerova (lintnerova@fns.uniba.sk)[1], **Jozef Michalik** (geolmich@savba.savba.sk)[2], **Andre Strasser** (andreas.strasser@unifr.ch)[3] & **Lucas Wissler** (lukas@erdw.ethz.ch)[4]
[1] Comenius University, Dept.of Mineral Deposits Geology, Bratislava, Slovakia
[2] Slovak Academy of Sci., Geological Institute, Bratislava, Slovakia
[3] Universite de Fribourg, Institut de Geologie, Fribourg, Switzerland
[4] ETH Zurich, Geological Institute, Zurich, Switzerland

During Early Aptian Selli Event, Tethyan pelagic limestone sequence has been interrupted by world-wide correlable bituminous shale intercalation. This global oceanic anoxic event (1a OAE) is recorded by the Konhora Fm in the Rochovica section of the West Carpathian Pieniny Klippen Belt (Lintnerová 1999, Michalik et al 1999, Lintnerová et al., 2000). A combination of high resolution $\delta^{13}C$-, bio- and sequence stratigraphy, TOC, kerogene type, vitrinite reflectance allow precise correlation of this sequence with its equivalents in Romandes Prealpes (Roter Sattel section; Strasser et al., in print) situated originally on the same northern margin of Penninic Oceanic Branch. High resolution $\delta^{13}C$ record of that time use to be divided into eight segments (see Menegatti et al., 1998): the "Selli" level is denoted by both the first and second step-like δ13C shifts (from 1.4 to 3.3 and from 3.3 to 3.9 ‰, respectively) in the Globigerinelloides blowi- and at the base of Leupoldina cabri zones. Biostratigraphy and TOC distribution indicate that both anoxia formation and organic matter (OM) storage were controlled by overproduction. The $\delta^{13}C$ change better correlates with terrestrial / marine OM ratio and with sea-level fluctuations than with TOC. Terrestrial / marine ratio corresponds both with HI, Ro (maceral types) and with relative index of OM weathering. The Rock Eval analyses (Tmax 434-438°C) and clay mineral composition indicate slight diagenetic alteration of black shale (Lintnerová et al., 2000). The high variation of δ^{18} O values in the lower part of black shale was documented and put in the question simple dependance between temperature and resulting $\delta^{18}O$ values. On the other hand, there is no correlation between $\delta^{18}O$, TOC and $\delta^{13}C$. These aspects stress close similarities in the Aptian sedimentary record of both the Carpathian Rochovica- and Pre-Alpine Rotel Sattel section. It is interesting, that also diagenetic alteration of both these profiles, one thousand kilometers apart each of other, is comparable.

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EVO5 : SUpm34 : F5
The Impact of Rising Atmospheric pCO_2 on Early Aptian Carbonate Platforms

Lukas Wissler (lukas.wissler@erdw.ethz.ch), **Hanspeter Funk** (hanspeter.funk@erdw.ethz.ch) & **Helmut Weissert** (helmut.weissert@erdw.ethz.ch)
Geological Institute, ETHZ, 8092 Zuerich, Switzerland

In this study we focus on the role of rising pCO_2 during the Early Aptian carbonate platform drowning. We studied a Late Barremian to Early Aptian carbonate platform on the Helvetic shelf. Three sections along a N-S transect from proximal to distal shelf environments were investigated. A highly resolved correlation of the shelf sediments with pelagic successions is based on carbon isotope stratigraphy combined with biostratigraphy and a detailed sedimentological analysis. The drowning of the Helvetic carbonate platform coincides with the nannoconid crisis and with a pronounced negative peak in the carbon isotope record (C. litterarius zone) and falls within a time of enhanced volcanic activity. We interpret the negative peak to reflect a CO_2 pulse due to imbalances in the organic carbon subcycle (Methane release). Elevated atmospheric pCO_2 reduced the marine calcium carbonate oversaturation factor **Ω** and resulted in decreased cacification potential of planctic and benthic organisms. Platforms growing in places with additional environmental stress like cool temperatures or relatively high nutrient content, both typical for the Helvetiv shelf, drowned while platforms in protected environments were able to survive despite globally lowered calcium carbonat oversaturation. We consider the Early Aptian platform crisis in the Helvetiv Alps as an example to show how recent carbonate platforms may react to the currently rising CO_2 pressure: reef growth will be weakened and platforms in stressed environments will be affected by drowning.

EVO5 : SUpm35 : F5
Extreme Isotopic Variation in the Early Cretaceous: An Assessment of Possible Methane Release or Volcanic Influences

Gregory Price (g.price@plymouth.ac.uk)
Department of Geological Sciences, The University of Plymouth, Drake Circus, Plymouth, UK

Stable isotopic measurements have been made on coccolithic-rich sediments of early Cretaceous age from two DSDP/ODP sites. The degree of alteration of the sediments has been assessed through the application of chemical analyses and scanning electron microscopy. The isotopic data reveal similarities to published data from other Cretaceous successions and hence identify isotopic variation on a global scale. The lightest oxygen isotope values are observed in the lowest parts of the site and are most likely to be associated with the incorporation of relatively isotopically negative diagenetic carbonate. Carbon isotopes from this early Cretaceous interval reveal two notable positive excursions during the Lower Aptian to Lower Albian and are considered to be correlatable with the oceanic anoxic events 1A and 1B. The data also reveals, immediately prior to the OAE 1A positive excursion, a large negative carbon isotope excursion. Such a trend could be accounted for by an extremely voluminous rapid release of methane from gas hydrate. The oxygen isotope data also reveals that water temperature possibly increased during this brief time interval. However, as the geochemical data show large enrichments of both Mn and Fe across this horizon, it is postulated that both the metal enrichments and negative carbon isotope trend could also be influenced by volcanic activity. Volcaniclastic sediments are present within the studied interval. Furthermore, ocean fertilisation resulting from volcanic fall out, rising global temperatures and increased atmospheric carbon dioxide concentrations

may have triggered blooms of marine phytoplankton, as evidenced by peaks of Ba. It is also possible that enhanced organic-matter production and burial in the oceans following the negative carbon isotope excursion may well have sequestered carbon dioxide through increased productivity and enhanced biological pumping leading to a reduction in palaeotemperatures.

EVO5 : SUpm36 : F5
Island-Arc Carbonates of Guerrero Terranes (Cretaceous) in Mexico, Pacific Coast: Preliminary Data

Julien Beltramo (julien.beltramo@ujf-grenoble.fr)[1], **Juventino Martinez-Reyes** (jmr@servidor.unam.mx)[2], **Annie Arnaud-Vanneau** (annie.arnaud@ujf-grenoble.fr)[1], **Karl Föllmi** (karl.follmi@geol.unine.ch)[3] & **Thierry Adatte** (thierry.adatte@geol.unine.ch)[3]
[1] Université J.Fourier - OSUG, Laboratoire de Géodynamique des Chanes Alpines (UMR 5025), Maison des Géosciences, B.P. 53, 38041 Grenoble Cedex France
[2] Unidad de Ciencias de la Tierra, Campus UNAM, Juriquilla, Qro, Mexico
[3] Institut de Géologie de l'Université de Neuchâtel, Rue Emile-Argand, 11, Case Postal 2, CH-2007 Neuchâtel, Switzerland

Shallow-water carbonates of island-arc origin that are preserved in Aptian-Albian terranes of the West Pacific coast of Mexico exhibit a distinctive set of sedimentologic and paleontologic features with a particular preservation of primary porosity. The present work is focused on island arc outcrops located along the Pacific coast in three regions: Northern part of Baja California, Jalisco and Michoacán.

During volcanic activity, island arc carbonates formed in adjacent, conical or subconical islands that have risen into the photic zone resulting from a complex series of events involving submarine volcanism and production of volcanogenic sediments. Reefal environments grow on different volcanic substrates - ashes or lavas - during periods of reduced volcanic input. They are represented by fringing coral reefs in situ, with well-preserved rudists shells (mostly Caprinids) and gastropods (Nerinea). Some reefal sediments are characterized by a strong porosity and an unusual preservation of shell materials (e.g., preservation of original colours in shells from the Punta China outcrop, B.C.)(Allison, 1955). The fast expansion of these Cretaceous reefs was coupled with ongoing pyroclastic influx and consequently frequently interrupted by burial of volcanoclastic detritus or lava flows.

With the cessation of volcanic activity, volcanoes first underwent relatively high rates of subsidence. They were progressively submerged into the photic zone, this leading to favourable conditions for widespread carbonate production. Island arc limestones generally consist of thick platform sequences with well-developed lagoonal deposits. Lagoonal facies are characterized by rudists and Miliolids. The carbonate deposit ends in the uppermost part of the Albian with an emersion surface often marked by karstification. These kinds of carbonate platform reached a remarkable thickness and were affected by sea-level changes and/or tectonic uplifts.

These outcrops allow us to establish in detail the evolution of two types of carbonate platforms: ·Platform which developed during volcanic activity, where installation, development and extinction of shallow marine communities were constrained by effects of volcanic inputs and various types of volcanic substrates. ·Platforms which developed during thermal subsidence of extinct volcanoes.

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EVO5 : SUpm37 : F5
Biotic Response to the Upper Aptian $\delta^{13}C$ Excursion in the Central Atlantic Ocean (DSDP 545) and Western Tethys (Vocontian Basin)

Jens Herrle (j.o.herrle@uni-tuebingen.de) & **Christoph Hemleben**
Institut und Museum fuer Geologie und Palaeontologie, Universität Tuebingen, Sigwartstr. 10, 72076, Germany

A high resolution study has been performed on samples from the Vocontian Basin (SE France) and the Mazagan Plateau (NW Africa) to focuses on the distribution of calcareous nannoplankton and carbon isotopes of the Aptian to Lower Albian time slice. A pronounced shift in the $\delta^{13}C$ signal of bulk sediment to heavier values in the Upper Aptian has been proposed by various authors. Our data from the Central Atlantic and Western Tethys show an excursion toward heavier values of up to 1.5 ‰, lasting for about 3 million years. The initial $\delta^{13}C$ shift occurs at the boundary of the *Hedbergella trocoidea* /*Ticinella bejouaensis* foraminifera zones at about 114 Ma and is characterized by a nannoconid-crisis. The excursion terminates at the Aptian/Albian boundary. The $\delta^{13}C$ excursion occurs coincidently with a fertility rise within the surface water indicated by increasing numbers of radiolarians concurrent to a cooling event in the Late Aptian to Early Albian. This cooling, characterized by increasing numbers of boreal nannoplankton species in the Western Tethys, occurs with a time lag of approximately 1 Ma with respect to the begin of the $\delta^{13}C$ excursion. Our data indicate a shift from an enhanced $CaCO_3$-productivity system (represented by calcareous nannoplankton) before the $\delta^{13}C$ excursion to an enhanced SiO_2-productivity system (represented by radiolarians) within the $\delta^{13}C$ excursion. The general feature of the Upper Aptian $\delta^{13}C$ excursion may be comparable with the Miocene "Monterey excursion". However, we suggest that the $\delta^{13}C$ excursion was not only caused by rapid extraction of organic carbon from the open-ocean. We rather propose that the observed change within the productivity system may be related to a change in the ocean carbonate chemistry.

EVO5 : SUpm38 : F5
Planktonic Foraminiferal Distribution Cyclic Patterns; Proxy from the Upper Aptian Piobbico Core, Central Italy

Isabella Premoli Silva (isabella.premoli@unimi.it) & **Paola Sala**
Università degli Studi di Milano, Dipartimento di Scienze della Terra, Via Mangiagalli 34, Milano, Italy

It is well known that planktonic foraminifera display a marked increase in number of species, and in the overall abundance and size of specimens after the early Aptian Oceanic Anoxic Event 1a (OAE1a). This increase was accompanied by the progressive appearance of more ornamented morphotypes with respect to the older assemblages preceding or coeval with OAE1a. This trend was interrupted by a major extinction event spanning the Aptian/Albian boundary and, according to recent deep-sea findings, apparently related to the OAE1b. In order to clarify distribution patterns through the upper Aptian, planktonic foraminifera of the Piobbico Core (Umbria-Marche Basin, central Italy) were re-investigated. The acetate peels from 42 to 72 m of the Piobbico Core were photographed with a digital camera and the abundance of planktonic foraminifera was re-estimated at 1-mm spacing on the obtained pictures. The constructed abundance curve is more detailed than the previous curve plotted in Tornaghi et al. (1989) but they are consistent. The series analysis shows that the distribution of planktonic foraminifera displays frequencies within the Milankovitch bands correlatable with the short eccentricity, the highest power in the spectra, and the obliquity in some intervals, whereas precession signals are rarely visible probably as a consequence of selective diagenesis. The power spectra of the obliquity are stronger in the intervals characterized by more abundant larger-sized planktonic foraminifera in association with the *Nannoconus truittii*acme. As nannoconids apparently proliferate when the nutricline was located in the lower photic zone (Erba, 1994), we can suggest that large-sized planktonic foraminifera evolved at the onset of at least a weak stratification of the upper water column. The presence of a proto-thermocline was only temporary as it was disrupted at the close of the Aptian as suggested by the extinction of all more specialized planktonic taxa.

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Sunday PO Session

EVO5 : SUpo01 : PO
Recent Anoxic Kyllaren Laminae: A Modern Analogue to Jurassic (Toarcian) Black Shale Formation?

Matthias Paetzel (matthias.paetzel@hisf.no)[1], **Rune Moldeklev**[1], **Hallgjerd H. Ravnås**[1], **Ragna Stakland**[1], **Astrid M. E. Willis**[1], **Jørn Øversveen**[1], **Hans Schrader** (hans.schrader@geol.uib.no)[2] & **Jaap S. Sinninghe Damste** (damste@nioz.nl)[3]
[1] HSF-College, The Faculty of Science, P.O.Box 133, N-6851 Sogndal, Norway
[2] University of Bergen, Department of Geology, Allégaten 41, N-5007 Bergen, Norway
[3] Netherlands Institute for Sea Research, Department of Marine Biogeochemistry and Toxicology, P.O. Box 59, 1790 AB Den Burg, The Netherlands

Marine anoxic laminated sediments are supposed to be the original material to form black shales. The sedimentary record of processes related to recent anoxic lamina formation might thus be used to reveal processes that lead to ancient lamina formation. For this purpose sequences of mm-scale laminated anoxic sediments are analyzed on a lamina-by-lamina resolution in four gravity core from the 29 m deep Kyllaren fjord, Western Norway. The cores are taken at 5, 10 and 13 m water depth. X-ray imaging allows core-to core correlation and a detailed description of structure and texture of the sediments. Based on x-ray analysis time synchronous sequences of basin-wide change are defined including marked dark and light lamination. Smear-slide analysis is used to reveal minute information on the composition of each lamina, suggesting processes of their formation. Minerogenic grainsize does not show any clear pattern in regard to the dark/light lamination, varying from sand: 0-20%, silt: 60-90% and clay 5-30%. The diatom composition indicated that 50% of the dark laminae are dominated by marine planktonic diatoms, while 50% of the light laminae are dominated by marine benthic diatoms without a distinct pattern. The most obvious difference is observed in the organic versus minerogenic matter ratio revealing increasing minerogenic matter percentages within the light laminae and increasing organic matter percentages within dark lamina sediments. These preliminary results suggest productivity dependent formation of the Kyllaren laminae. The sedimentary composition of the Kyllaren laminae is tried to be compared with the composition of black shale laminae of the Jurassic (Toarcian) Jet Rocks, East England, using the same analysis technique. These laminae are earlier suggested to be deposited on a similar seasonal productivity basis.

EVO5 : SUpo02 : PO
Organic Matter Preservation and Palaeoenvironmental Implications for Lower Cretaceous Marine Sapropels from Norway and Barents Sea Shelf

Uwe Langrock (ulangrock@awi-bremerhaven.de) & **Ruediger Stein** (rstein@awi-bremerhaven.de)
Alfred-Wegener-Institut für Polar und Meeresforschung, Columbusstrasse, Bremerhaven, 27568, Germany

The Jurassic-Cretaceous boundary period is marked by a distinctive change of pa-laeogeography and sea-level on a global scale. Low North Atlantic spreading rates initiated a sea-level low-stand forming large (at least partly) restricted epicontinental marine environments during Kimmeridgian through Valanginian times. The Arctic Ocean was open to the Atlantic only via a narrow sea-way between Greenland and Norway which was over 1500 km long and up to 300 km wide. The studied area (Norwegian Shelf, Barents Sea) was, in general, characterised by a low hinterland relief and organic carbon-rich argillaceous sedimentation into shallow marine environments. Four IKU drilling cores (13/1-U2, 6307/07-U2, 6814/04-U2 and 7430/10-U1) were chosen for detailed organic-geochemical investigation to characterise the palaeoenvironmental conditions which favoured increased primary production and increased preservation of organic matter. Although the "productivity" and "stagnation" models are still discussed for providing the formation of organic carbon-rich marine sediments more individual palaeoenvironmental pre-requisites have to be taken into account during periods of great oceanographic and biologic diversity.

A total number of 400 samples have been analysed using LECO instruments for bulk parameters such as total carbon (C_{TOT}, nitrogen (N_{TOT}), sulphur (S_{TOT}) and total organic carbon (TOC). Rock-Eval pyrolysis was used to rapidly evaluate the genetically (kerogen) type of the organic matter (OM), the petroleum-generative potential and the thermal maturity of the rock. A qualitative and quantitative determination of the organic con-stituents was conducted on polished blocks of selected samples with white and fluorescence light microscopy (maceral analysis). Inorganic geochemical analysis of main and trace elements was performed at the Institute for Biology and Chemistry of the Marine environments (Germany) in a separate study by LIPINSKI (in prep.) and will also be presented during the EUG meeting 2001. The sediments show very different amounts of organic carbon ranging from about 0.1 - 1.0% in core 13/1, 1.0 to 7.0% in core 6307/07, 0.5 to 4.0% in core 6814/04 and 5.0 to 36.0% in core 7430/10. The rocks are composed of mixed terrigenous and marine organic matter in a silty-argillaceous matrix. Large vitrinites and freshwater algae indicate the proximity to the hinterland and relatively short transport distances. The amount of pyrite is exeptionally high indicating oxygen-depleted bottom water conditions with almost no benthic life which is also reflected by the commonly good preservation of the organic matter. The rocks are thermally immature with type II/III and III kerogen except for core 7430/10 with spectacular type I/II kerogen and an excellent hydrocarbon-generating potential. This special core has been subjected to a high-resolution analysis within the Jurassic-Cretaceous boundary sequence. All cores have in common an abrupt termination of the cyclic sedimentation in the Valanginian stage suggesting significant changes in the palaeoenvironment.

EVO5 : SUpo03 : PO
Rapid Changes in Calpionellid and Calcareous Dinoflagellate Associations Recorded in Upper Jurassic - Lower Cretaceous Pelagic Environments (Western Carpathians, Slovakia)

Daniela Reháková (geolreha@savba.savba.sk)
Geological Institute of Slovak Academy of Science, Dubravska cesta 9, 842 26 Bratislava, Slovak Republik

A series of diversification and diversity reduction bio-events recorded among the evolution lineagues of the planktonic groups studied have sensitively recorded the whole complex of environmental changes. Mass abundance of these microfossils was closely connected with elevated zones and shallow intrashelf basins opened to nutrients bringing currents. There were several Late Oxfordian to Upper Albian bio-events evoked by eustatic pulses. It seems, that the sea-level transgressive stages were favourable for development of planktonic organisms, their acme concentrations were controlled by a sea-level high-stand phases. On the other hand, during the sea-level regressive stages several distinct diversity reduction events were recorded in the frame of these groups (Reháková, 2000a). The first widespread (covering shallow coastal and basinal areas) dinocyst diversification event appears during the Late Oxfordian. Diversified orthopithonelloid associations dominated at the beginning of the Kimmeridgian. Further two dino acme accumulations were recorded also during the Early Tithonian (Reháková, 2000b). The regular evolutionary pattern (extinction-radiation sequence) were recorded in chitinoidellids (Middle Tithonian) and crassicollarians which disappeared at the Jurassic Cretaceous Boundary. Also calcdinocysts decrease in abundance during that time. Rapid changes in planktonic associations were always preceded by distinct erosional events. More turbiditic water masses and enhanced productivity could lead to diminishing penetration of sunlight into the photic zone, what have not been optimal for plankton associations. Acme of obliquipithonelloids appeared in the interval of increasing calpionellid diversity during the Late Berriasian. Regressive pre-phase, at the end of Late Berriasian leading to calpionellid extinction, ultimately caused an increase in evolutionary rate of nannoplankton associations. Further acme of obliquipithonelloids are known from the topmost part of the Lower Valanginian deposits. The siliclastic input at the beginning of Valanginian led to total calpionellid decimation almost in the whole Tethyan region. Calpionellids did not survive among a nannoconid blooming. Graded rich radiolaria and sponges accumulations could have been linked with the periodically active contour currents persisting until the Early Hauterivian. The evident depletion in dino diversification is observed in Lower Barremian deposits. Nevertheless, the nannofloral speciation have still continued. At the beginning of the Early Aptian cadosinids became prevailing. There was the dramatic decrease in nannoconids. New forms of micro-granular praecolomiellids appeared among dominant planktonic foraminifers. Rich accumulations of radiolarians and sponges, periodically intercalated by black shale sequence, point to a renewed contourite current activity.Something like a restriction phase of calcareous dinocyst production is observable at the beginning of the Albian, where a new explosive phase of nannoconids is recorded. Microgranular calpionellid were substituted by a new group of hyaline colomiellids. Since the Middle until the Late Albian, calcareous dinoflagellate development originated in the Tethyan area. Their innovation and radiation phases may be also correlate with a broad second-order eustatic rise.

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EVO5 : SUpo04 : PO
Drowning of the Lower Cretaceous Carbonate Platform along the Northern Tethyan Margin; Evidence from the Rawil Area (Helvetic Alps, Central Switzerland)

François Gainon (fgainon@hotmail.com) &
Karl Föllmi (karl.foellmi@unine.ch)
Institut de Géologie, Université de Neuchâtel, 2007 Neuchâtel, Switzerland

The Rawil area (Wildhorn nappe, Helvetic Zone) is a key area to improve our understanding of the final drowning phase in the evolution of the lower Cretaceous carbonate platform. The "Urgonian" stage in the development of the carbonate platform in this area has been investigated by T. Schenk (1992), who distinguished a phase of platform development under normal, presumably oligotrophic conditions during the late Barremian and the earliest Aptian (lower and upper "Schrattenkalk"), interrupted by a regressive phase near the Barremian-Aptian boundary ("Rawil Beds" = Lower Orbitolina Beds). The Schrattenkalk Formation is overlain by the Upper Orbitolina Beds, which are rich in quartz sand, crinoidal remains, and micritized lithoclasts. This formation occurs only locally, in the form of lenticular bodies, as was already noted by Schaub (1936). Within the Upper Orbitolina Beds, a phosphatic bed is present, in which a specimen of Deshayesites was found. Where the lenticular body of the upper Orbitolina Beds disappears, this phosphatic bed unifies with the overlying phosphate-rich Luitere Bed. The Luitere Bed is part of the Garschella Formation. Ammonites obtained from this bed suggest a early late Aptian age (Colombiceras sp. and Epicheloniceras sp.; both indicative of the subnodosocostatum Zone). It is overlain by a coarse-grained, obliquely bedded sandstone, which grades into a coarse-grained calcarenite, the Brisi sandstone and limestone (max. total thickness 5.5 m). The Brisi beds are covered by a dark and fine-grained clayey marlstone (Gams Beds?, 1-2.5 m, in the northern part of the Rawil area) or directly by a phosphatic bed of varying thickness (Plattenwald Bed; 10 to 50 cm). The phosphatic bed yields an interesting ammonite fauna, which in terms of markers is restricted to Hypacanthoplites, Leymeriella, and Douvilleiceras south of the Col de la Plaine Morte (i.e., tardefurcata and mammillatum Zones; early Albian) but contains also younger elements in the Rawil area further north. The Plattenwald Bed is directly overlain by pelagic carbonates of the Seewen Formation. With regards to the drowning history of the northern Tethyan carbonate platform, an important drowning phase (D4 in Föllmi et al., 1994), is dated here to start as early as in the deshayesites zone (middle early Aptian), and to last at least until the early late Aptian. This is considerably older than previously assumed for the Swiss area; its age, however, is more conform to ages obtained in Vorarlberg and southern Germany (Gebhard, 1983; Föllmi, 1989). The final drowning event follows after deposition of the Brisi Limestone, a calcarenite rich in crinoidal, bryozoan, and bivalve debris, and is identical to phase D5 (limit Aptian-Albian) in Föllmi et al. (1994).

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EVO5 : SUpo05 : PO
Lower Aptian OAE-1 Deposits in the Pieniny Klippen Belt, Western Carpathians, Slovakia

Jozef Michalik (geolmich@savba.savba.sk)[1],
Otilia Lintnerova (lintnerova@fns.uniba.sk)[2],
Daniela Rehakova (geolreha@savba.savba.sk)[1],
Eva Halasova (halasova@fns.uniba.sk)[2],
Dagmar Gregorova (geofdage@savba.savba.sk)[3],
Marta Bak (bak@ing.uj.edu.pl)[4] &
Petr Skupien (petr.skupien@vsb.cz)[5]
[1] Geological Institute, Slovak Academy of Sci., Bratislava, Slovakia
[2] Comenius University, Dept.Economic Geology, Bratislava, Slovakia
[3] Geophysical Institute, Slovak Academy of Sci., Bratislava, Slovakia
[4] Inst.Geological Sciences, Jagiellonian University, Cracovia, Poland
[5] Technical University, Mining Faculty, Ostrava - Poruba, Czech Republic

The Konhora Formation (5 - 7 m thick) inserted in a monotonous pelagic majolica limestone sequence consists of dark shale (27 to 60% of $CaCO_3$), enriched in Corg (TOC 0.1 to 3%). Lintnerová (1999) and Michal'k et al. (1999) correlated it with the 1a OAE (the Selli Event). Terrestrial wood fragments and oxidized organic matter may have suppressed the TOC vs redox sensitive elements (V, Mn, Ba, Ni, Co, Cr). In the G. blowi Zone, a slight $\delta^{13}C$ decrease (+1.0 to +1.9‰ vs. the Berriasian +2.1 to +2.8‰ average) correlates with the highest TOC (up to 3 wt%) and with oxic to euxinic variation in the bottom water (Mn: 25 - 600, V: 42 - 140 ppm). A remarkable synchroneity was observed between $\delta^{13}C$ excursion, nannoplankton decrease and non-calcareous dinoflagellate cysts increase. A common European dino - assemblage type consists mostly of *Achomosphaera verdieri*, *A. triangulata*, *Callaiosphaeridium trycherium*, *Coronifera tubulosa*, *Florentinia laciniata* and *F. mantellii*. Less frequent bissacate pollen grains and, subordinately, brackish and littoral dinocysts were redeposited from the nearshore environment with eutrophic and less salinary surface waters. Both marine fossils and organic matter increase upwards, where radiolarian limestone layer with increased Ba (600 to 1900 ppm) content occurs. A rich and diverse radiolarian fauna with massive tests is represented by nassellarians: *Holocryptocanium barbui*, *Williriedellum petterschmittae*, *Cryptamphorella dumitricai*, *Sethocapsa simplex*, *Sethocapsa trachyostraca*, *Sethocapsa (?) orca*, *Archaeodictyomitra chalilovi*, *Dictyomitra pseudoscalaris*, *Pseudodictyomitra puga*, *Stichomitra aff. asymbatos*, and *Eucyrtis sp.* prevailing over spumellarians: *Angulobracchia (?) portmanni portmanni*, *Cenosphaera ssp.*, *Godia tecta*, *Acaeniotyle umbilicata*. Although occasional bioturbation indicates oxic condition of bottom water, the abundance of well preserved organic remnants along with high content of diagenetic pyrite indicate euxinism to anoxia in the sediment. Siliclastic- and terrigenous organics input was accompanied by a high negative $\delta^{18}O$ excursion, indicating temperature- and/or salinity changes (evaporation vs monsoonal water dilution) in the surface waters and their responses in bottom waters.

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EVO5 : SUpo06 : PO
C-Isotope Geochemistry and Sedimentary Development of Shallow Water Environments of the Lusitanian and Algarve Basin (Portugal) during Times of Global Oceanic Perturbations

Stefan Burla (stefan.burla@erdw.ethz.ch),
Uli Heimhofer (heimhof@erdw.ethz.ch),
Helmut Weissert (weissert@erdw.ethz.ch),
Peter Hochuli (hochuli@erdw.ethz.ch) &
Nils Andersen (nils.andersen@erdw.ethz.ch)
Institute of Geology, ETH Zentrum, Sonneggstrasse 5, 8092 Zuerich, Switzerland

Earth history provides well-documented examples of carbonate platform and reef collapse and the subsequent recovery of these shallow water environments. One of the best-studied examples is the Barremian to Aptian (125-110 Ma) platform crisis in the Tethyan-Atlantic realm, which coincides with an episode of black shale formation (oceanic anoxic event 1A) in deep water environments. High-amplitude fluctuations (up to 2‰) of the C-isotope curve in Tethyan pelagic and shallow water limestones

indicate perturbations of the global carbon cycle, changes in paleoceanography and marine productivity. The evolution of coastal marine environments and the changes in shallow water ecosystems during the Barremian-Aptian are investigated in well-preserved, mixed siliciclastic-carbonate coastal successions in Portugal (Lusitanian and Algarve basins). In the Algarve Basin, a mixed siliciclastic-carbonate succession of Barremian to Early Bedoulian age is overlain by up to 140 m of Aptian marls (Luz marls). The carbonate-poor marls were deposited in an estuarine setting. A 6 m thick silty debris flow and a distinct package of carbonate beds split the marls into a lower and upper unit. Near the Aptian-Albian transition the Luz marls are replaced by a succession of alternating marlstones and limestones. In the Lusitanian Basin, the investigated Barremian-Aptian sediments are characterised by carbonates interchanging with silts, followed by a reefal sequence that is cut by fluvial quartzose sandstones. C-isotope studies on the coastal sections of the Algarve indicate that the global carbon isotope pattern is, in part, overprinted by local factors. Values vary between ?5‰ to +2‰ VPDP and the curve is marked by two distinctive negative spikes at the base of the Aptian marl succession. A positive excursion following the negative spikes is recorded in both C_{carb}- and C_{org}-isotope values. But organic C-isotope values follow the pattern of the carbonate C-isotope curve with an estimated time lag of up to 80 ky.

EVO5 : SUpo07 : PO
A Terrestrial Record from the Mid-Cretaceous Algarve Basin: Carbon-Isotope Geochemistry and Palynofacies

Ulrich Heimhofer (heimhofer@erdw.ethz.ch),
Stefan Burla (stefan.burla@balcab.ch),
Peter A. Hochuli (hochuli@erdw.ethz.ch),
Nils Andersen (andersen@erdw.ethz.ch) &
Helmut Weissert (helmi@erdw.ethz.ch)
ETH Zürich, Institute of Geology, Sonneggstr. 5, 8092 Zürich, Switzerland

Mixed siliciclastic-carbonate coastal successions from the Portuguese Algarve and Lusitanian basins have been chosen for a high-resolution study on the evolution of shallow water depositional systems during mid-Cretaceous oceanic anoxic events. Inorganic and organic carbon content, HI, carbon-isotope composition ($\delta^{13}C$) of selected phytoclast particles (charcoal, lignite, different types of cuticle, leave fragments) and $\delta^{13}C$ of bulk organic matter were measured throughout the Algarve section in order to evaluate changes in the ocean-atmosphere system. In combination with the geochemical data, detailed studies on composition and distribution of the sedimentary organic matter (OM) were carried out. Although $\delta^{13}C$ of bulk OM show strong variations of up to 10 ‰ (-18 to -28 ‰), distinct trends can be observed and seem to reflect a terrestrial signal. This is indicated by comparison with $\delta^{13}C$ data of selected terrestrial phytoclasts. The range of these different phytoclasts in individual beds is up to 4 ‰, whereas their overall fluctuation throughout the section is up to 8 ‰. Charcoalified plant fragments show the highest $\delta^{13}C$ values, whereas lignite particles have a distinctly more negative isotope composition. Cuticles and leaves show the most negative values. However, the $\delta^{13}C$ range of the entire phytoclast assemblage matches the overall trend of the $\delta^{13}C$ record of bulk OM. Shifts in the carbon-isotope composition of bulk OM are influenced by varying amounts of different terrestrial phytoclast particles, even if no or a minor amount of marine derived OM occurs. On the other hand, shifts in the $\delta^{13}C$ range of the entire phytoclast assemblage can be related to environmental changes and might reflect changes of the floral assemblage, climate, and/or isotopic composition of CO_2. The $\delta^{13}C$ data have been compared with the results of palynofacies analysis and HI-data obtained from Rock-Eval pyrolysis. The lower siliciclastic part of the Algarve section is dominated by continent derived phytoclasts and varying ratios of marine to terrestrial palynomorphs. The upper calcareous part shows stronger marine influence, indicated by lower phytoclast content, the occurrence of fluorescent amorphous OM and foraminiferal test linings. Compositional variations in the dinoflagellate cyst assemblages can be related to salinity changes and reflect fluctuations in fresh water input and/or evaporation. Our results indicate, that the combination of optical studies of the sedimentary OM, HI and $\delta^{13}C$ data of selected phytoclasts is crucial for the interpretation of $\delta^{13}C$ bulk OM records in coastal depositional systems.

EVO5 : SUpo08 : PO
Changes in the Marine Sulphur Budget during the Deposition of the "Livello Selli" (OASE 1a, Aptian). Evidence from the Sulphur Isotope Record

Benjamin Brunner (beno@erdw.ethz.ch)[1],
Stefano Bernasconi (stefano@erdw.ethz.ch)[1],
Helmut Weissert (helmi@erdw.ethz.ch)[1] &
Bruno D'Argenio
(ciclisti@gms01.geomare.na.cnr.it)[2]
[1] Geological Institute ETH-Z, Sonneggstrasse 5, CH-8092 Zürich, Switzerland
[2] Geomare, Via Vespucci 9, I-80142 Napoli, Italy

In order to reconstruct changes in the sulfur cycling during the oceanic anoxic black shale deposition, we investigated sulfur isotopic composition of Cretaceous limestones. The Aptian-Albian time slice we chose is known as a major turning point in the Mesozoic sulfur isotope record. Using a sequential leaching method (Kajiwara et al., 1997), 38 rock samples of three different sections from the Aptian and Albian deposited in the western Alpine Tethys realm were analyzed for the sulfur isotopic composition of structural bound sulfate in carbonates. The Gorga a Cerbara-section (Umbro-Marchean Apennines, Central Italy) and the Cismon-section (Venetian Alps, Northern Italy) consist of pelagic limestones, marls and shales. In these two sections the Livello Selli black shale is well developed, whereas in the Monte Raggeto-section (Southern Apennines, Italy), located in a carbonate platform setting, no black shale has been deposited. The sulfur isotope data indicate a trend from relative high values of 18.5‰ ±0.5‰ CDT to lower values of 17‰ ±0.5‰ during the Aptian and an opposite trend to higher values of 19‰ ±0.5‰ with the beginning of the Albian. At the stratigraphic level of the Livello Selli black shale, sulfur isotope measurements of shallow-water limestones from the Monte Raggeto-section scatter from 17.2‰ to 20‰. Since the low values are interpreted as consequence of a contamination with sulfate derived by early diagenetic processes, the data point to a change from 18‰ ±0.5‰ to 19‰ ±0.5‰. Despite the scatter in our data, we speculate that the positive shift in the sulfur isotopic composition of seawater during the OASE 1a reflects an enhanced burial of isotopically light pyrite during the deposition of the Livello Selli black shale.

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EVO5 : SUpo09 : PO
High-Resolution Biostratigraphy and Isotope Stratigraphy in an Albian Pelagic Succession of Southern Italy

Valeria Luciani (lcv@unife.it)[1],
Miriam Cobianchi (miriam@unipv.it)[2] &
Hugh C. Jenkyns (hugh.jenkyns@earth.ox.ac.uk)[3]
[1] Dipartimento di Scienze della Terra, Università di Ferrara, Corso Ercole I d'Este 32, 44100 Ferrara, Italy.Ferrara, Italy
[2] Dipartimento di Scienze della terra, Università di Pavia, Via Ferrata 1, 27100 Pavia, Italy., Italy
[3] Department of Earth Sciences, University of Oxford, Prks Road, Oxford OX1 3PR, UK, United Kingdom

High-resolution $\delta^{13}C$ and $\delta^{18}O$ curves, calibrated against planktonic foraminifera and calcareous nannofossil events, are provided for the Upper Aptian-Lower Cenomanian pelagic succession of the Coppa della Nuvola (CN) section (Gargano Promontory, southern Italy). The succession consists of two superimposed formations: the Marne a Fucoidi and the Scaglia (lower portion only). The Marne a Fucoidi are made up of cyclically arranged couplets of bioturbated grey marlstones and off-white marly limestone; the Scaglia consists of thinly bedded, chalky and cherty, white lime mudstones. Unlike other pelagic successions of the Gargano Promontory, no black shales were observed in the CN section; it is, however, possible that they coincide with covered tracts. According to our integrated biostratigraphy, the entire succession spans the latest Aptian (planktonic foraminifera *T. bejauoensis* and calcareous nannofossil *R. angustus* zones) and Early Cenomanian (CC9b / *D. algeriana* subzones). The Marne a Fucoidi/Scaglia transition falls in the Late Albian (*R. appenninica* zone/CC9a subzone). The high-resolution $\delta^{13}C$ curve from the CN section can be subdivided into seven characteristic segments, named C10 to C16 with reference to those documented by Bralower et al. (1999) in northeastern Mexico. The CN curve records three negative shifts of $\delta^{13}C$, respectively in the Early Albian (C11, followed by a sharp increase of the values in the segment C12), in the Late Albian (C14) and in the Early Cenomanian (C16). The Cenomanian shift (*R. reichei/R. cushmani* boundary-*E. turriseiffellii* zone) probably correlates with that recorded in the Umbria-Marche Basin (Stoll & Schrag, 2000). Three intervals of relatively constant carbon-isotope values occur during the Late Aptian-Early Albian (C10), the Middle Albian (C13) and the Late Albian-Early Cenomanian (C15). Even if in the CN section carbon-rich levels are covered by Quaternary deposits, the Lower Albian (*T. primula/ P. columnata* zones) and the Upper Albian (*T. praeticinensis* subzone/*P. achlyostauriozone*) negative $\delta^{13}C$ trends of (as seen in segments C11/C14) seem to be coeval with the black shales known as the Urbino Level and Amadeus segment previously described from the Umbria-Marche Basin (Coccioni & Galeotti, 1991). Equivalent levels are known in the Gargano Promontory (Cobianchi et al., 1997). The $\delta^{18}O$ curve recorded in the CN section shows a similar trend to the $\delta^{13}C$ curve. If not of diagenetic origin, the negative shifts in the Early Albian, Late Albian and Early Cenomanian may be interpreted as the record of warming events.

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EVO5 : SUpo10 : PO
Cenomanian-Turonian Anoxic Event in South-Western Crimea (Lithological, Palaeontological and Palaeoenvironmental Aspects)

Tatyana Kuzmicheva (ienn@hotmail.com)
1, Angliisky ave., VNIIOkeangeologia, 190121 S.-Peterburg, Russia

An Upper Cenomanian-Lower Turonian sections have been sampled in the vicinity of Bahchisarai, South-Western Crimea. Lithological, palaeontological and some geochemical characteristics were studied. Upper Cenomanian-Lower Turonian sediments are composed by carbonate and clayey carbonate facies with terrigenous admixture and «black shales» on the boundary. Studied sections are divided to three groups: 1.) discontinues sections with "black shales" on the boundary (Belaia, Aksudere), 2.) sections where the border is represented by thin clay and gray carbonaceous layers with organic matter (Selbuhra) and 3.) reduced sections with hard ground on the boundary (Kizil-Chigir, Mender). All these sections occur in a very small area of South-Western Crimea). Biostratigraphy is based on planktonic forams with some data from nannofossils, radiolarians and rare inoceramids (Fig. 2). Three planktonic foraminiferal biozones and following changes are recognized on the border of Cenomanian-Turonian sediments: *Rotalipora cushmani* Zone - (1) white limestone contain high diversity planktonic and benthonic assemblage; the last occurrence of genus *Rotalipora* is in the top of this interval. *Whiteinella archaeocretacea* Zone - (2) clayey limestone with pyrite and fish remains characterize reduction diversity and quantity planktonic forams, temporary disappearance of keeled forms from assemblages; rare benthic forams are dysoxic species; appearance radiolarians; (3) the "black shale" laminated with pyrite, fish remains and *Chondrites* almost does not contain planktonic and benthic forams; the layers abundant of radiolarians are present. This interval ((2)+(3)) is marked by high $\delta^{13}C$ values of up to +4‰ - +5‰, and total organic carbon content is between 0.12% and 7.2% (Naidin, 1994), mainly marine planktonic origin. (4) light bioturbated limestone with glauconite is characterized by the «bloom» of big non-keeled forms like *Whiteinella*, increase diversity and quantity planktonic forams and first occurrences *Dicarinella hagni* and zonal species nannofossils *Quadrum gartneri*; *Praeglobotruncana oraviensis* (analog *Helvetoglobotruncana helvetica*) Zone - (5) white limestone shows planktonic foraminifera deversify again and become very abundant, both keeled and non-keeled forms occur; first occurrences of *Praeglobotruncana oraviensis* and Turonian inoceramid *Mytiloides gr. labiatus*; layer with abundant radiolarians *Alevium superbum* is present. (Fig. 3) The investigated area in the Late Cenomanian-Early Turonian displayed on the eastern part of the northern Peri-Tethys ocean. The absence of *Helvetoglobotruncana helvetica* and some features of radiolarian skeletons struc-

ture can do the evidence of the relatively more cold water conditions of this basin than Thetys. The process of the accumulation of bituminous sediments in Soth-Western Crimea occurred together with wide spread anaerobic conditions, the activation of geodynamic processes and high sea level with short periodic regressions (Fig. 4). The opening of the Black Sea and the formation of the continental slope of the passive margin (Nikishin et al., 2000) could cause significant changes in depth of the investigated area. The upper part of the continental margin was complicated by a series of small faults, where sequences with varying degrees of completeness were forming on their steps. Organic material had been buried primarily in the depressions at the rear part of the steps.

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EVO5 : SUpo11 : PO
Sea-Level and Climate Fluctuations at the Cenomanian-Turonian Boundary of the Anglo-Paris Basin, Comparison with the European Tethyan Margin

Rais Pauline (pauline2.rais@unine.ch)[1],
Adatte Thierry (thierry.adatte@geol.unine.ch)[1] &
Keller Gerta (gkeller@princeton.edu)[2]
[1] Institut de Géologie, Université de Neuchatel, Neuchatel, Switzerland
[2] Dept. Geosciences, Princeton University, Princeton, USA

The Cenomanien-Turonian oceanic anoxic event is worldwide associated with a great marine transgression, the coeval deposition of organic rich sediments and a significant $\delta^{13}C$ positive excursion. 3 sections characterized by different paleogeographical features are compared here, in order to reconstruct the sea-level and climate fluctuations which prevailed during the Cenomanian-Turonian anoxic event. Lithology, stable isotopes and planktic foraminiferal analyses of the Eastbourne section at Gun Gardens (south-east England) reflect sea-level fluctuations and changing climatic and oceanographic conditions across the Cenomanian-Turonian transition. The $\delta^{13}C$ excursion began with a 1.8‰ positive shift in Plenus Marls Beds 1 to 3 (*R. cushmani zone*), a trough in Bed 4, a second $\delta^{13}C$ shift of 0.8‰ in Bed 7 and a gradually decreasing plateau during deposition of the Ballard Cliff Member. Lithological variations, sharp erosion surfaces, bioturbation and increased detrital influx indicate sea-level fluctuations, cooling and a major marine regression accompanied the $\delta^{13}C$ excursion within the Plenus Marls followed by warming and a major marine transgression in the upper part of the Plenus Marls and Ballard Cliff Member. Thus, our data suggest that the marine transgression generally considered as coincident with the $\delta^{13}C$ excursion and oceanic anoxic event actually followed a major regression and the onset of the $\delta^{13}C$ excursion, but coincided with the second $\delta^{13}C$ shift and subsequent high $\delta^{13}C$ values The Cassis section is located close to Cassis in the l'Anse de l'Arène (France). These 95 m thick sequence consists of basinal deposits, characterized by regularly cyclic alternation of pelagic limestone and marls. Similar to the England section, the total organic carbon content is low (>0.7%). But the decrease in bioturbation observed during the *Cushmani* and *Helvetica* Zones indicates hypoxic conditions during the maximum of transgression. The Vergons section located in the eastern part of the Vocontian Basin (France), is characterized by deeper paleo-environments with ryhthmic alternate marls-marly limestones. The top of Cushmani Zone is marked by an erosive contact, suggesting the presence of a significant hiatus. Above, the Archeocretacica Zone began with the deposition of the main black shale horizon (BSH) of the Thomel level which consists of laminated layers enriched in organic matter (1-2%). The decimetric alternance of laminated BSH and well bioturbated organic depleted marls indicates that the oxygen minimum zone periodically reached the basin floor. This rhythmicity ends abruptly in the upper part of the laminites layer which is affected by significant slumping. Paleogeographical features may have controlled the distribution of organic rich sediments. High frequency climatic and sea level changes (glacio-eustatism ?) seem to be a promising alternative hypothesis to explain the Cenomanian-Turonian anoxic event.

EVO5 : SUpo12 : PO
Contrasting Chemostratigraphic Models for two Latest Cenomanian Bonarelli Levels from Sicily, Italy

Giovanna Scopelliti (giovanna-s@libero.it)[1],
Adriana Bellanca (bellanca@unipa.it),
Rodolfo Neri (neri@unipa.it),
Mario Sprovieri (marios@unipa.it),
Rodolfo Coccioni (cron@info-net.it)[2] &
Francois Baudin (frbaudin@ccr.jussieu.fr)[3]
[1] Dipartimento di Chimica e Fisica della Terra C.F.T.A., Via Archirafi, 36, 90123 - Palermo, Italy
[2] Istituto di Geologia, Università degli Studi, Campus scientifico, 61029 Urbino, Italy
[3] CNRS-ESA 7073 et RF 32, Département de Géologie Sédimentaire, Université P. et M. Curie, 75252 Paris Cedex, France

The latest Cenomanian Bonarelli Level (BL) is a well-known organic carbon-rich black shale horizon which is considered to be the sedimentary expression of a short-term global Oceanic Anoxic Event (OAE2). It has been recognized in different settings throughout Italy, from the Southern Alps to Sicily. The present work is focused on two stratigraphic successions outcropping at Novara di Sicilia (NS, northeastern Sicily) and Seno di Guidaloca (SG, northwestern Sicily). The biostratigraphic study based on planktonic foraminifera, calcareous nannofossils, and radiolarian associations indicates the presence of *Whiteinella archaeocretacea* comparable biozone (Bellanca et al., 1998; this work). Various lithofacies (black shales, marlstones, radiolarites, mudstones) present in the two sections exibit significant organic-carbon contents. In particular, the black shales show extraordinarily high TOC values ranging up to 23% at NS and 26% at SG. High hydrogen values (HI) and low oxygen indices (OI) reflect the predominance of marine organic matter. The chemostratigraphy of paleo-redox proxies (Mn*, V/V+Ni) give evidence of drastic changes from oxic to anoxic-euxinic conditions in coincidence with the black shale deposition. Substantial enrichments of trace metals (V, Cr, Zn, Mo, Cd, Sb, U) in the BL from the two sections are consistent with the environmental variations, element concentrations being several times higher than that of the average shale. A distinct positive excursion in the carbon isotope curve is recorded for both the studied sections. This shift is correlated with analogous signals recognized for the same stratigraphic interval in sequences from Italian Apennines and southern Alps as well as from various sections in the world in correspondence with the global OAE2. Barium enrichments, commonly related to enhanced primary productivity of surface waters, are recorded throughout the BL at SG but not at NS. We suggest that the low Ba concentrations of the black shales from NS can be reasonably explained as due to a reduced preservation of barite with water depth. This suggestion is supported by K/Al ratios lower than those of SG and other sections in Italy. Low K/Al ratios are related to a smectite-dominated clay mineralogy, indicative of a distal depositional setting, as opposed to the generally illite-rich mineralogy at SG, suggestive of a more proximal setting.

Bellanca A, Erba E, Luciani V, Masetti D, Neri R, Premoli Silva I, Salvini G, Scopelliti G, Scotti P, Sprovieri M, *Atti Soc. Geol. It*, **Vol. A**, 145-147, (1998).

EVO5 : SUpo13 : PO
Multidisciplinary Study of the Cenomanian/Turonian Oceanic Anoxic Event 2: Preliminary Results from the Gubbio Core (Central Italy)

Elisabetta Erba (elisabetta.erba@unimi.it)[1],
Isabella Premoli-Silva[1],
Jaap Sinninghe Damste (damste@nioz.nl)[2],
Hugh Jenkyns (hughj@earth.ox.uk)[3],
Paul Farrimond (paul.farrimond@ncl.ac.uk)[4],
Michael Boettcher (mboettch@mpi-bremen.de)[5],
Hans Brumsack (brumsack@icbm.de)[6] &
Wolfgang Kuhnt (wk@gpi.uni-kiel.de)[7]
[1] Università degli Studi di Milano, Dipartimento di Scienze della Terra, Via Mangiagalli, 34 - Milano, Italy
[2] NIOZ - Dept. of Marine Biogeochemistry and Toxicology, Lansdiep 4, 1790-AB Den Burg, The Netherland
[3] Dept. of Earth Sciences, Univ. of Oxford, Parks Road, OX1 3PR Oxford, UK
[4] Univ. of Newcastle, Fossil Fuels & Environmental Geochemistry, Drummon Building - NE1 7RU Newcastle, UK
[5] Dept. of Biogeochemistry, Max Planck Institute for Marine Microbiology, Celsiusstrasse 1 - 28359 Bremen, Germany
[6] Institut fur Chemie und Biologie des Meeres, Carl-von-Ossietzky 9-11, 26111 Oldengurg, Germany
[7] Istitut fur Geowissenschaften, Olshausenstrasse 40, 24098 Kiel, Germany

The C/T- Network " Rapid global change during the Cenomanian/Turonian oceanic anoxic event: Examination of a natural climatic experiment in Earth history" (HPRN-CT-1999-00055) was designed to investigate causes and consequences of a major perturbations of the Earth's carbon cycle. The network consists of seven partner institutions (NIOZ, ICBM-UO, UNEW, CA, MPI-MM, DSDT-UM, UOXF- DG) with specific expertise in the fields of molecular paleontology and organic facies, inorganic and isotope geochemistry, biostratigraphy and palaeontology. Key sections of Cenomanian-Turonian age have been selected in oder to investigate the OAE2 at a variety of oceanographic settings and at different latitudes. Objectives of the project are: (1) to quantify organic-carbon accumulation rates at a wide variety sites to assess on a global basis where the increase in organic-carbon burial took place, (2) to assess whether either changes in productivity or preservation of organic matter or both account for the changes in organic-carbon burial rate, (3) to understand the causes for changes in productivity and/or water-column anoxia, (4) to assess the effect of the organic-matter burial event on atmospheric CO_2 and O_2 concentrations, (5) to assess the role of changing levels of underwater volcanism and sea level, tectonic events and consequent changes in global ocean circulation on variations in organic-carbon burial, (6) to understand concurrent changes in carbonate accumulation rates, (7) to recognise Milankovich cycles in the C/T sedimentary record, use them as a time control and understand their impact on climate and global ocean circulation, (8) to assess the influence of changing oceanic and atmospheric conditions on marine and terrestrial life, especially on the C/T extinction event. The Bonarelli Level was defined in the Umbria-Marche Basin and consists of approximately 1.5 m of black shales and radiolarian-rich layers. A continuous core was cut as the Bonarelli type locality, in the Contessa Quarry (Gubbio). Coring was repeated 5 times at slightly offset sites in order to have at least a double complete recovery of the Bonarelli Level and the limestone section above and below. The Gubbio 2 site penetrated 40 m of pelagic limestones, marlstones and black shales. The cored interval extends from the lowermost Turonian to the Middle Cenomanian, and freshly cored material provide a very informative record. The Bonarelli Level was sampled at a cm scale in the Gubbio 4 and Gubbio 2 sites, while the entire Gubbio 2 section was sampled every 10 cm. We present the preliminary results including planktonic foraminiferal and nannofossil biostratigraphy, organic and inorganic geochemistry, and stable isotopes.

EVO5 : SUpo14 : PO
Timing and Pattern of Biotic Changes Across the Bonarelli Level of the Southern Alps (Italy)

Rodolfo Coccioni (cron@info-net.it)[1],
Valeria Luciani (lcv@unife.it)[2] &
Miriam Cobianchi (miriam@unipv.it)[3]
[1] Istituto di Geologia, Università di Urbino, Campus Scientifico Località Crocicchia, 61029 Urbino, Italy, Italy
[2] Dipartimento di Scienze della Terra, Università di Ferrara, Corso Ercole I d'Este 32, 44100 Ferrara, Italy
[3] Dipartimento di Scienze della Terra, Università di Pavia, Via Ferrata 1, 27100 Pavia, Italy

The latest Cenomanian Bonarelli Level (BL) is a remarkable carbonate-free, radiolaritic-ichthyolitic, organic carbon-rich, 0.5-2 m-thick regional marker-bed of the Umbria-Marche Basin (central Italy) which is considered to be the sedimentary expression of the short-lived, global Oceanic Anoxic Event 2. The BL is recognised in different settings throughout Italy from the Southern Alps to Sicily as well as worldwide. In order to analyse, describe, and interpret the biotic and abiotic changes across and within the BL of Italy, an international project was promoted and organised since 1997. In the Southern Alps, the BL crops out in several localities belonging to different palaeoenvironmental and palaeoceanographic settings (i.e. Trento Plateau and Belluno Trough) where lithology, sedimentology and thickness vary remarkably. However, the 0.3-5 m-thick BL of the Southern Alps, similarly to the BL of the type area, is sandwiched between limestone beds and mainly consists of olive-green to black mudstones and black, organic-carbon rich, finely laminated shales alternated with radiolarian silty and sandy layers. A high-resolution, up to cm-scale multidisciplinary study (micropaleontology; organic, elemental, and isotope geochemistry; mineralogy; sedimentology) were undertaken based on the analysis of thirteen sections. Investigations on foraminifera, calcareous nannofossils and radiolaria highlight significant changes in assemblages composition and relative abundance of communities across the BL. Remarkable differences in terms of timing and pattern of the biotic changes occur throughout the investigated area, suggesting that the environmental perturbation leading to the deposition of the BL in the Southern Alps would have occurred within a complex and articulated scenario. Timing and pattern of the biotic turnover recognised in the southern Alps differ also in some features from the biotic changes recorded in the BL of the Umbria-Marche Basin.

EVO5 : SUpo15 : PO
Development of Photic Zone Anoxia and Associated Black Shale Formation across the Cenomanian/Turonian Boundary: New Biomarker Evidence from the Tafraya Basin (Southern Morocco)

Sadat Kolonic (skolonic@uni-bremen.de)[1],
Thomas Wagner (twagner@uni-bremen.de)[1],
Jaap Sinninghe-Damsté (damste@nioz.nl)[2],
Wolfgang Kuhnt (wkuhnt@gpi.uni-kiel.de)[3],
Ulrich Wand (uwand@awi-potsdam.de)[4] &
Hermann Wehner (hermann.wehner@bgr.de)[5]
[1] University of Bremen, Department of Geosciences, Germany
[2] Netherlands Institute for Sea Research (NIOZ), Department of Marine Biogeochmistry, Netherlands
[3] University of Kiel, Department of Geosciences, Germany
[4] Alfred Wegner Institute Potsdam, Germany, Germany
[5] German Federal Institute for Geosciences and Natural Resorces Hannover, Germany

The Cretaceous black shale-marl sequences of the Tafaya Basin in southern Morocco have been extensively studied by the oil industries and recently became re-opened for scientific research. Due to the gentle tectonic deformation and exceptionally high time resolution of these Cretaceous deposits, the Tarfaya Basin has became a global reference position to study rapid global changes in the late Mesozoic.

Across the Cenomanian/Turonian boundary event (CTBE), cyclic black shales where deposited in response to enhanced marine productivity and the development of an extended oxygen minimum zone across the West-African paleo-shelf. These laminated beds are characterized by high organic carbon contents (up to 18%) and kerogen type II organic matter which qualify them as oil-prone source rocks. Spectral analysis of high resolution logging profiles confirm a stong power at the obliquity band (41 kyrs) of orbital frequencies, suggesting a similar depositional control as demonstrated for late Quaternary upwelling cycles of NW-Africa.

The temporal development of an euxinic southern North Atlantic has been recently proposed based on advanced biomarker data from exploration wells of the Tarfaya Basin and North Atlantic deep sea DSPD/ODP sites. We present a high resolution organic geochemical study to refine this general model and to reconstruct the CTBE-hydrogen-sulfide (H_2S) chemocline along a paleo-transect from the deepest part of the Tarfaya basin (Shell exploration wells 13 and 75) towards to the paleo-coastline (Mohammed Plage outcrop profile). The data are discussed in respect to high order sea-level fluctuations which are proposed to have occured during the CTBE. Biomarker records from the three sites confirm the occurrence of isorenieratane derivates of the green sulfur bacterial Chlorobiacea orgin which supports the conclusion that Photic Zone Anoxia had at least temporarely reached shallow water depths in vicinity of the paleo-coastline. We also observe fluctuations in the depth of the H_2S chemocline during the CTBE as well as the absence of Isorenieratane derivates. These results may support the conclusion that the extend of Photic Zone Anoxia in the Tarfaya Basin was linked to changes in primary productivity, which, in turn, was controlled by orbital forced continental upwelling processes.

EVO5 : SUpo16 : PO
Orbital Forcing of Tropical Atlantic Black Shale Formation: High Resolution Records of the Coniacian-Santonian OAE 3 (ODP Site 959, Ivory Coast/Ghana)

Thomas Wagner (twagner@uni-bremen.de)[1],
Peter Hofmann (adg03@uni-koeln.de)[2],
Britta Beckmann,
Thomas Pletsch (thomas.pletsch@uni-koeln.de)[2],
Ulrich Wand (u.wand@awi-bremerhaven.de)[3] &
Hermann Wehner (hermann.wehner@bgr.de)[4]
[1] University Bremen, Geosciences, Postfach 330440, Bremen, 28335, Germany
[2] University Cologne, Geosciences, Germany
[3] Alfred-Wegener-Institut, Potsdam
[4] Bundesanstalt fuer Geowissenschaften und Rohstoffe, Hannover

Extremely high sea levels and a generally sluggished deep-water circulation characterize certain periods of the Late-Cretaceous southern North Atlantic Ocean. These boundary conditions promoted the development of extensive oxygen-deficiency, anomalously enhanced organic-carbon deposition, and global climate change. Time envelopes of enhanced sequestration of organic-carbon, commonly termed Oceanic Anoxic Events (OAEs), were particularly favourable for petroleum source-rock formation and are now understood as natural climatic experiments in Earth history that may provide fundamental information on the functioning of global biogeochemical cycles and their possible internal and external feed-back mechanisms. The Coniacian-Santonian anoxic event (OAE3) is the final of the Cretaceous OAEs and documents one important step in the transition from the Cretaceous greenhouse-world to the Cenozoic icehouse-world. Compared to extensive research on early and mid-Cretaceous OAEs little is known about the evolution and climate impact of the Coniacian-Santonian OAE3. We present high-resolution records of Coniacian-Santonian black shale units recovered at ODP Site 959 (off Ivory Coast/Ghana). The recovery of a complete, 1200 m long sequence at Site 959, which covers the time-span from the Albian to the present day, make it a key location to study long-term paleoenvironmental trends in a tropical oceanic setting. Recent studies have shown that deposition of TOC-rich sediments along the C(tm)te d´Ivoire-Ghana Transform Margin was intimately linked to the plate tectonic and palaeoceanographic evolution of the Equatorial Atlantic Gateway. Notably, the formation of a basement ridge on the southeastern border of the transform margin provided an efficient shelter against erosive and potentially oxidizing currents for the landward Deep Ivorian Basin. TOC-rich sediments occur throughout almost the entire Cretaceous section, but deposition of black shales commenced only after separation of Africa and South America was far enough advanced to allow permanent oceanic midwater exchange after the late Albian. Our new color scanner, magnetic susceptibility, organic geochemical (elemental, pyrolytic, isotopic), and inorganic geochemical (XRD, RFA) data of Coniacian-Santonian black shales consistently reveal high amplitude cyclic variations which apparently correspond to the main frequencies of orbital forcing. According to the given time resolution and time control, formation of Coniacian black shale cycles mainly responded to the excentricity band (400 and 100 kyrs) to produce oil-prone source rocks with peak organic carbon concentrations exceeding 17%. Overlying higher-accumulating Santonian black shale units still exceed 10% organic carbon and reveal a cyclicity at the obliquity (41 kyrs) and the precessional (23 kyrs) bands.

EVO5 : SUpo17 : PO
Calcareous Nannoflora Bio-Geochemistry as a Potential Tool for Reconstructing the Trophic and Thermic Structure of the Past Ocean: Application to the Maastrichtian/Danian Transition

Fabrice Minoletti (minolet@ccr.jussieu.fr),
Silvia Gardin (gardin@ccr.jussieu.fr) &
Maurice Renard (renard@ccr.jussieu.fr)
Département de Géologie Sédimentaire, 4, place Jussieu 75252 Paris Cedex 05, France

The geochemical signature of micro- and nannofossils is an essential tool to trace the variations of productivity, nutrients and temperatures in time. Such geochemical analysis, coupled with micropaleontological studies, are usually performed on bulk samples or on easily separated biological fractions (mainly planktonic and bentonic foraminifera). Up to day, such analysis have never been performed on isolated fractions of calcareous nannofossils, due to their reduced size (about 2 - 20µm). The analysis of isolated fractions of nannofloras is now possible *via* an experimental protocol which allows to: 1. separate the microcristalline (diagenetic) calcite of the sample; 2. separate the micro- and nannofossils groups according to their dimensions; This protocol has been applied to Upper Maastrichtian and Danian samples from Elles (Tunisia) and Bidart (Pays basque, France) sections. In the Maastrichtian, it is possible to perform geochemical (stable isotopes and trace elements) and morphological (mean size and variability) analysis on each obtained fractions : - bulk sample (untreated sample); - 2 coarse fractions, one composed of planktonic foraminifera (>50µm) and one of juvenile stages of foraminifers (>20µm); - 3 nannofossils frations caracterising the photic zone; the first (10-8µm) with a high percentage of *Arkhangelskiella cymbiformis*, the second (8-5µm) enriched in *Micula decussata* of 6µm and the last (5-3µm) with *Micula decussata* of 3/4µm; - the finest fraction (<3µm) composed of microcristalline (diagenetic) calcite.

In the Danian samples, we have obtained the geochemical signature of well preserved specimen of Thoracosphaera spp. (>10µm) and Braarudosphaera spp.(10-8µm). Both are "disaster species" *sensu* Harries *et al.* (1995) which occupied the vacant nannoplancton niches in the earliest Danian post-impact phase. The geochemical analysis allows: - to take into account the diagenetic and the original signal; - to evaluate, with the $\delta^{13}C$, if the "Cretaceous" species found in the earliest Tertiary are survivors or reworked forms; - to better know the relative calcification depth of *Thoracosphaera* and *Braarudosphaera*; - to more precisely trace the thermal ($\delta^{18}O$) and trophic ($\delta^{13}C$) structure of the past ocean during the KTB.

EVO5 : SUpo18 : PO
4D History of the Black Sea Methane Hydrates from the Last 18,000 Years

Atanas Vassilev (geo@io-bas.bg) &
Lyobomir Dimitrov
Institute of Oceanology, PO Box 152, Varna 9000, Bulgaria

The 4D history of the Black Sea methane hydrates is reconstructed using the **next** input data:

- sea level variations; palaeoclimate; bathymetery; bottom temperatures and variations of the temperature in the sea-bed water; heat flow (almost 487 quoted in situ measurements are considered); temperature gradient; thermal conductivity of the sediments; pressure-temperature phase relations; - clathrate formation and dissociation kinetics; sediment porosity-depth curves; pore filling - the percentage of hydrate occupying the HSZ; and volumetric gas expansion factor.

The estimations are based on the two main theories of gas hydrate formation, in situ bacterial production and pore fluid expulsion models. The data are processed by applying different parameters depending of the geology and tectonic evolution of the single area; sedimentation rates during geological stages; local sedimentation environment as submarine fans and canyons; and evidences of shallow gas

as seepages, pockmarks, mud volcanoes etc. The equations governing the methane hydrate stability curve are also conformable to average hydrogen sulfide content and salinity of the bottom and pore waters. The implications of these models on atmospheric methane release, due to global climate change or massive sediment liquefy and slumping are examined.

Monday AM Session

EVO5 : MOam01 : F5
The Recovery of Planktonic Foraminifera after the Early Aptian Oceanic Anoxic Event 1a: Evidence from the Italian Pelagic Sequences

Isabella Premoli Silva (isabella.premoli@unimi.it) & **Davide Verga**
Università degli Studi di Milano, Dipartimento di Scienze della Terra, Via Mangiagalli 34, Milano, Italy

The early Aptian Oceanic Anoxic Event 1a has its sedimentary expression in Italy by the Livello Selli and its equivalents. Premoli Silva et al. (1999) showed that planktonic foraminifera change cyclically in abundance and composition through the Livello Selli equivalent, investigated in detail in the Cismon core (northern Italy) and in the Calabianca section (Sicily). Peculiar to the planktonic assemblages at both localities is the presence of faunas dominated by either clavate morphotypes and/or leupoldinids alternating with faunas consisting of normal-sized, round-chambered morphotypes. The patterns at the two sites are overall similar, but at Cismon the more elongate chambered leupoldinids predominate over the clavate morphotypes, whereas at Calabianca it is opposite. Elongation of chambers in planktonic Foraminifera has been interpreted as an adaptation to low oxygen levels in upper water column with leupoldinids inhabiting the lowest oxygenated waters and the clavate morphotypes waters slightly richer in oxygen. According to this hypothesis the paleoenvironmental conditions through the Selli equivalent were much more extreme at Cismon than at Calabianca. This interpretation is supported also by the presence at Calabianca of several levels yielding well-developed, round-chambered faunas intercalated within levels yielding faunas dominated by clavate taxa. After the maximum of the paleoenvironmental perturbation, more oxygenated water conditions resumed as supported by the increase in size, abundance and diversity of round-chambered taxa. However, clavate taxa and leupoldinids are still present about one million year later after the OAE1a and co-occur with the normal morphotypes. The co-occurrence of normal and clavate morphotypes suggests that part of the water column was still poorly oxygenated probably at some depth, whereas more oxygenated conditions characterized the surface waters accomodating the round-chambered taxa. This implies that the upper water column became weakly stratified with the presence of a sort of oxygen minimum zone underlying an oxygenated surface zone. This trend was not continuous but fluctuated at least through the entire *Leupoldina cabri* Zone, even if it was less intense at Calabianca with respect to Cismon. The effects of the perturbation related to the OAE1a definitely terminated by the*Globigerinelloides ferreolensis* Zone.

Premoli Silva I, Erba E, Salvini G, Locatelli C & Verga D, *J. Foram. Res*, **29**, 352-370

EVO5 : MOam02 : F5
Dinoflagellate Cyst Fluctuations in Mid-Cretaceous Flysch Deposits of the Bavarian Area (S-Germany) – Changes in Climatic or/and Oceanographic Circulation Patterns in the Alpine Tethys

Karl-Heinz Kirsch (kh.kirsch@lrz.uni-muenchen.de)[1], **Uli Wortmann**[2] & **Jürgen Hauck**[3]
[1] Institut für Paläontologie und Hist. Geologie, Richard-Wagnerstr. 10, D-80333 München, Germany
[2] Geological Institute, ETH-Zürich, CH-8092 Zürich, Switzerland
[3] Institut für Allg. und Angewandte Geophysik, Theresienstr. 41, D-80333 München, Germany

A multidisciplinary geological and paleontological project, financed by the "Deutsche Forschungsgemeinschaft", is currently done on Cretaceous light/dark rhythms of the Boreal and limestone/marl sequences of the Tethyan realm in order to reconstruct environmental control on their sedimentation.

The palynomorphs from samples of a marine dark/light/dark clay/marl-sequences of Lower Cretaceous sediments (Barremian - Aptian) from Niedersachsen (Germany) and hemipelagic black and green shales (Barremian - Albian) from Bavaria (S-Germany) have been studied with traditional palynofacies-analysis as well as with a new approach of quantitative analysis of fossil dinoflagellate-cysts (Kirsch 2000, in prep.).

While the record of cyclic sedimentation above the CCD has gained wide attraction, almost nothing is known about the deep Cretaceous Tethys sediments. Therefore profiles of the Rheno-danubian flysch zone have been investigated according to Hesse 1972 (Hauck 1998, Wortmann 1996, Wortmann et al. 1999).

The organic matter contains dinoflagellate cysts, prasinophytes, bisaccate pollen and spores as well as amorphous kerogen and phytoclasts. Especially the composition of the palynomorph assemblage often shows characteristic changes within the flysch sections.Trends and significant events are presented within the quantitative composition of the dinoflagellate-cyst assemblages as well as the stratigraphic distribution of dinoflagellate-cyst species.

Especially in the area of flysch deep water sedimentation of the upper Bavarian area was it possible to establish the first palynological stratigraphic schedule (Kirsch 2000).

For the Lower Cretaceous sediments (Boreal and Tethys) following stratigraphic important markers are: *Aptea polymorpha* Eisenack 1958, *Cerbia tabulata* (Davey & Verdier 1974) Below 1981a, *Cepadinium variabile* Duxbury 1983, *Occisucysta tenuiceras* (Eisenack 1958a) Below 1981a, *Subtilisphaera terrula* (Davey 1974) Lentin & Williams 1976, *Phoberocysta neocomica neocomica* (Gocht 1957) Millioud 1969, *Ovoidinium incomptum* Duxbury 1983, *Ovoidinium incorporeum* Duxbury 1983, *Litosphaeridium arundum* (Eisenack & Cookson 1960) or *Litosphaeridium siphoniphorum* (Cookson & Eisenack 1958) Davey & Williams 1966b.

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EVO5 : MOam03 : F5
Stability of Tropical Warmth and Global Carbon Cycle Perturbation in the Mid-Cretaceous Greenhouse

Paul A. Wilson (paw1@soc.soton.ac.uk)[1] & **Dick Norris** (rnorris@whoi.edu)[2]
[1] SOC, SOES, European Way, Southampton, SO14 3ZH, UK
[2] WHOI, Woods Hole, Mass, USA

The mid-Cretaceous (~120 to 80 Ma) witnessed some of the warmest polar temperatures yet experienced by multicellular life on Earth, repeated reef drowning in the tropics and a series of 'oceanic anoxic events' (OAEs) that promoted widespread deposition of organic carbon (Corg)-rich marine sediments and biotic turnover. The underlying cause of mid-Cretaceous warmth is widely attributed to tectonically driven increases in atmospheric levels of greenhouse gases (e.g. CO_2) while a wide range of competing hypotheses seek to explain the climatic causes and effects of OAEs.

We present new stable isotope data from multiple species of remarkably well-preserved planktonic foraminiferal from DSDP & ODP Sites (Blake Nose & Demerara Rise) including a two million year record that shows the following: (i) The thermal structure of surface waters in the western tropical Atlantic underwent pronounced variability during the Late Albian with maximum sea surface temperatures (SSTs, ~32 to 33±3°C) between 3 and 5°C warmer than those of today. (ii) This variability culminated in abrupt cooling of tropical SSTs, pronounced warming in the thermocline and complete collapse of surface water stratification during the latest Albian 'Breistroffer' OAE-1d. (iii) OAE-1d was a globally significant interval of massive Corg-burial with fundamental similarities in geochemical expression to the Toarcian and Aptian OAEs.

Our carbon isotope records provide a chemostratigraphic marker for the boundary between the lower and upper Cretaceous. Our oxygen isotope records are consistent with greenhouse forcing as the mechanism for mid-Cretaceous warmth but contradict both the predictions of ocean stagnation models for OAEs and traditional interpretations of past warm climates having been somehow more stable than

today. Our findings have important implications for the likely variability of high latitude temperatures and the vigour of the global hydrological cycle during extreme Cretaceous climates and for the mode of black shale deposition during the major carbon cycle perturbations of the last 200 Ma of Earth history.

EVO5 : MOam04 : F5
Evidence for a Higher Magnitude of the Carbonate δ^{13}C-Excursion at the Cenomanian-Turonian Boundary from Brachiopod Calcite of North Cantabria

Silke Voigt (silke.voigt@uni-koeln.de)
Geological Institute, Zülpicher Str. 49a, 50674 Cologne, Germany

The Cenomanian-Turonian (C/T) boundary is characterized by a remarkable positive δ^{13}C excursion identified worldwide in marine carbonates and in marine and terrestrial organic matter. The magnitude of this excursion has been considered to be ~2.5 ‰ in carbonate carbon and 4-6 ‰ in organic matter of marine phytoplankton. This decrease in isotopic fractionation between the organic and carbonate carbon reservoir has been interpreted as a remarkable reduction of atmospheric CO_2 in consequence of increased organic carbon burial during the C/T oceanic anoxic event. However, variations in the carbonate δ^{13}C record base on data of micrite or bulk-rock samples, which experienced a significant diagenetic overprint. Low-Mg calcite of articulate brachiopod shells is a much better preserved recorder of palaeoenvironmental signals. The rate of brachiopod metabolism is more than 50% lower than that of comparable gastropods and bivalve mollusks, and modern individuals seem to precipitate their shells in equilibrium with the ambient sea water. Therefore, about 60 brachiopod samples were collected from Cenomanian-Turonian sections (*M. mantelli* to *R. kallesi* zones) in northern Spain. Preservation and structure of the brachiopod shells was carefully checked with cathodoluminescence and scanning electron microscopy, and is very good in Cenomanian specimens, and moderate in Turonian samples. Mean δ^{18}O values of Cenomanian brachiopods (~-2.78 ‰) show nearly stable paleotemperatures of 23-25°C (with $\delta^{18}O_w$=-1.0 ‰ for an ice-free world). In the Lower and Middle Turonian, δ^{18}O values are slightly increased (~-2.36 ‰), reflecting cooler paleotemperature conditions, although the less excellent shell preservation might indicate an additionally diagenetic impact. Mean δ^{13}C values of brachiopod shell calcite show a clear trend through the studied time interval that resembles the Cenomanian-Turonian pattern obtained by whole-rock isotope data. However, carbon isotopic composition of brachiopods is about 0.7 to 2.0 ‰ heavier than that of whole-rock samples, and especially specimens from the Upper Cenomanian *M. geslineanum* zone show an δ^{13}C increase of about 4 ‰ (mean δ^{13}C=6.75 ‰). The positive offset in the isotopic composition of brachiopod shells is probably caused by diagenetic alteration of the bulk-rock samples, which can also cause a dumpening of temporal δ^{13}C variations. The higher magnitude of the brachiopod δ^{13}C spike during the C/T event would account for a lower decrease in the isotopic fractionation between organic and carbonate carbon, and for a minor reduction of atmospheric CO_2 than previously assumed. However, an impact of vital effects during brachiopod shell calcification, which are not known so far, can not be excluded.

EVO5 : MOam05 : F5
Cyanobacterial N_2 Fixation Fuelled Enhanced Production in the Euxinic North Atlantic during the Late Cenomanian Oceanic Anoxic Event

Marcel M. M. Kuypers (kuypers@nioz.nl)[1],
Richard D. Pancost (r.d.pancost@bristol.ac.uk)[2],
Ivar A. Nijenhuis (i.a.nijenhuis@siep.shell.com)[3] &
Jaap S. Sinninghe Damsté (damste@nioz.nl)[1]
[1] Netherlands Institute for Sea Research (NIOZ), Department of Marine Biogeochemistry and Toxicology, PO Box 59, 1790 AB Den Burg, The Netherlands., and Max-Planck-Institute for Marine Microbiology (MPI), Department of Biogeochemistry, Celsiusstr.1, D-28359 Bremen, Germany
[2] Organic Geochemistry Unit, School of Chemistry, University of Bristol, Cantock's Close, Bristol BS8 1TS, United Kingdom
[3] Shell SEPTAR, EPT-AGI, Volmerlaan 8, P.O. Box 60, 2280 AB, Rijswijk, The Netherlands

The widespread deposition of laminated organic matter (OM) rich marine facies (black shales) during the Cenomanian/Turonian (C/T ~93.5 Ma) Oceanic Anoxic Event (OAE) has been attributed to either decreased OM remineralisation resulting from a decreased oxygen flux or increased primary productivity (PP) overwhelming the oxic OM remineralisation potential of the water column. This study focuses on the environmental conditions that led to the deposition of the particularly thick C/T OAE black shales from the proto-North Atlantic. The C/T sections of four proto-North Atlantic sites were correlated by stable carbon isotope stratigraphy using the characteristic excursion in δ^{13}C values of both bulk OM and specific molecular fossils of phytoplankton. All four sites show a significant increase in marine OM accumulation rates during the C/T OAE. The occurrence of molecular fossils of anoxygenic photosynthetic green sulfur bacteria and high abundance of redox sensitive trace metals indicates sulfidic conditions, periodically reaching up into the photic zone before as well as during the C/T OAE, which we attribute to the tectonically isolated nature of the proto-North Atlantic. During the C/T OAE there was a significant rise of the chemocline in the southern part of the proto-North Atlantic as indicated by the increase in concentrations of molecular fossils of green sulfur bacteria. The presence of molecular fossils of the green strain of green sulfur bacteria indicates that euxinic conditions periodically even occurred at very shallow water depths of 15 m or less during the C/T OAE. Bottom water conditions did not dramatically change as indicated by more or less constant concentrations of redox sensitive trace metals. This suggests that the increase in OM burial rates resulted from enhanced PP rather than increased anoxia, which is supported by stable carbon isotopic evidence and a large increase in Ba/Al ratios during the C/T OAE. The occurrence of the productivity event in the proto-North Atlantic during a period of globally enhanced OM burial rates (i.e. the C/T OAE), points to a common cause. We propose that increased upwelling of nutrient-rich, proto-Atlantic deep water, resulting from the formation of a deep water connection between the North and South Atlantic basins globally enhanced PP. The proto-North Atlantic basins likely contained high levels of nutrient P as a result of preferential regeneration of P from sedimenting algal OM but extensive denitrification in these stagnant anoxic basins should have led to a severe nutrient N limitation of phytoplankton growth. The ^{15}N-depletion of OM-rich marine sediments (δ^{15}N = -2-0 ‰) typical for newly fixed N_2 and the abundance of cyanobacterial membrane lipids indicate that N_2 fixation supplied the additional nutrient N required to increase PP in the proto-North Atlantic during the C/T OAE.

EVO5 : MOam06 : F5
A Climate Model/Geochemical Model on the Influence of Precessional Insolation Cycles on the Late Creataceous Climate System: A Case Study for the Western Interior Seaway

Sascha Floegel (sfloegel@geomar.de)[1],
Robert DeConto (deconto@geo.umass.edu)[2] &
William Hay (whay@geomar.de)[1]
[1] GEOMAR-Research Center, Wischhofstr. 1-3, 24148 Kiel, Germany
[2] University of Massachusetts, Morrill Science Center, Amherst, MA 01003-5820, U.S.A.

The Late Cretaceous sediment record for the Western Interior Seaway of North America (WIS), such as the Colorado Greenhorn Formation (Bridge Creek Interval) shows cyclical bedding in carbonate sequences. These limestone-marl couplets show periodicities similar to those associated with changes of the earth's orbital parameters, which influence the latitudinal and seasonal distribution of the solar energy received by the earth. Proxies like TOC, TC, δ^{13}C and sedimentation rates suggest that changes of the precessional insolation cycle, which has a mean periodicity of about 21700 ky are of particular interest for the Cenomanian/Turonian boundary. Variations in the precessional cycle (precession of the equinoxes) affect the timing of perihelion with respect to the seasons (distance between the earth and the sun at any given season), and therefore increasing seasonality. The orbital variations do not cause any overall (annual) change in solar radiation receipts; they simply result in a seasonal and latitudinal redistribution, such that a "low" summer radiation total is compensated for by a "high" winter total, and vice versa. We completed a series of atmospheric general circulation model (GCM) simulations using a new global Cretaceous paleogeography from. The G model experiments have been examined on a regional (for the WIS) and on a global scale to determine the significance of changes in the precession orbital parameter. A suite of sensitivity tests under diferent orbital parameters simulating the precessional cycle has been run to analyze the impact on of surface temperature, precipitation and snow cover (and therefore runoff). The effect of precession changes the distribution and seasonality of surface temperature, precipitation and snow cover, which may have produced significant in runoff, weathering rates, and sediment flux into the WIS.

EVO5 : MOam09 : F5
Paleoenvironmental Controls on Turonian Black Shale Deposition within the Western Interior Basin (U.S.A.): Evidence for Changes in Paleoceanography

Astrid Forster (forster@nioz.nl)[1],
Lorenz Schwark (lorenz.schwark@uni-koeln.de)[2],
Jean Thein (thein@geo.uni-bonn.de)[3] &
Joerg Trappe (trappe@geo.uni-bonn.de)[3]
[1] Netherlands Institute for Sea Research (NIOZ), Department of Biogeochemistry and Toxicology, P.O. Box 59, 1790 AB Den Burg, Texel, The Netherlands
[2] Cologne University, Geol. Institut, Zuelpicher Str. 49 a, 50674 Koeln, Germany
[3] Bonn University, Geol. Institut, Nussallee 8, 53115 Bonn, Germany

Three major black shale bearing-sequences are recorded during Albian to Santonian time in the central part of the Western Interior Basin (WIB) related to long-term sea-level fluctuations. During transgressions, an epicontinental seaway extended meridional from northern Canada to the Gulf of Mexico. An east-west transect through the WIB extending from Iowa to Utah was established by seven cores of the Middle Turonian Carlile Shale to set up a basin-wide study focussing on the paleoenvironmental controlling factors. Sedimentary facies were investigated by screening samples for the amount and maturity of organic matter, analysis of the element-spectrum and the main mineral compounds. The Amoco Rebecca Bounds core located in the central WIB (Kansas) and the U.S.G.S. Portland core at a more proximal setting (Colorado) were chosen for high-resolution investigations of biomarkers and stable isotopes (bulk kerogen and carbonate).

At the Bounds core locality, the lowermost Fairport Member of the Carlile Shale consists of laminated marlstones, deposited under oxygen-depleted conditions. The organic matter is immature and predominantly of marine origin, but a strong freshwater influence is indicated by biomarkers and δ^{18}O-data. The silty shales of the succeeding Blue Hill Member represent a transition to shallower water in a still oxygen-deficient setting, but with an increased influx of terrigenous organic matter. The deposition of the Codell Sandstone Member took finally place in an oxic near-shore environment. The long-term development of the Carlile Shale is linked to a continuous regression, nevertheless, the Upper Fairport Member shows a sudden increase in organic matter concentration coinciding with a fourth-order sea-level rise. Simultaneously, an intensified oxygen-depletion is observed. Small-scale cycles in the Fairport and Blue Hill members are expressed by variations in lithology and geochemistry. They can be correlated to the Portland core, where the Carlile Shale interval is more condensed and incomplete. Considering the sequence-stratigraphic framework published for western basin-margin, these cycles observed at both sites are probably related to high-order trans- and regressions.

An integrated model combining sea-level history with constraints from the basin's morphology and salinity-proxies is proposed. This is based on the different contribu-

tion of the two main water-masses in the WIB. Each transgression caused a renewed incursion of both water-masses into the basin, but to a different extend depending on the transgression's magnitude. At Fairport-time, the Portland location was strongly influenced by the relatively freshened, cooler water-mass entering the WIB from the north, while the Bounds site was dominated by the more saline, warm water-mass derived from the south. During the deposition of the Blue Hill Mbr., the sill at the southern entrance of the WIB blocked the warm, southern waters more or less completely from entering the basin, resulting in dominance of the cooler, northern water-mass.

EVO5 : MOam10 : F5
A Santonian Cooling Event? Evidence from the Late Cretaceous Planktonic Foraminifera of the Exmouth Plateau (NW Australia, Indian Ocean)

Maria Rose Petrizzo
(mrose@e35.gp.terra.unimi.it)
Università di Milano, Dip. Scienze della Terra, via Mangiagalli, 34 I-20133 MILANO, Italy

The evolution of planktonic foraminifera from Turonian to Campanian is overall characterized by increasing species richness (or diversity) and morphologic complexity. This evolutionary trend shows a short period of rapid diversification in the Turonian with the appearance of complex morphotypes (marginotruncanids) followed by a longer period of stasis interrupted in the Santonian by the disappearance of the marginotruncanids and the contemporary increasing importance and diversification of another group of more complex taxa, the globotruncanids. In order to analyse the faunal turnover, the upper Turonian to lower Campanian planktonic foraminiferal assemblages from Hole 762C and Hole 763B (Ocean Drilling Program, Leg 122-Exmouth Plateau, 47°S paleolatitude) were studied in detail to evaluate the compositional variations at genus and species level based on the assumption that, in the Cretaceous oceans as in the modern oceans, any faunal change is associated with changes in the characteristics and the degree of stability of the oceanic surface waters. Three major group were recognized based on the gross morphology and following the assumption that Cretaceous planktonic foraminifera, although extinct, had a life-history strategies comparable to the modern planktonics: 1) r-selected opportunists; 2) k-selected specialists; 3) r/k intermediate morphotypes group which include all genera that display a range of life strategies in between opportunist and specialist taxa. Variations in number of species and specimens within genera has allowed to recognize five discrete intervals throughout. Although planktonic foraminiferal assemblages are characterized by a progressive appearance of complex taxa (from old to young), this trend is discontinuous: planktonic forms show cyclic fluctuations in diversity and abundance of cold taxa (r-strategists) versus warm taxa (k-strategists) related to alternate phases from unstable conditions, suggesting a weakly stratified upper water column in a mesotrophic environment, to well stratified surface and near surface waters indicating a more oligotrophic environment. A positive peak in the Coniacian characterized by the maximum diversification of k-strategists seems to correspond to a warmer episode resulting from an increase in temperature. It is followed by a marked decrease of warm taxa (k-strategist crisis) with the minimum value in the Late Santonian to reflect a decrease in temperature. Finally, the detailed analysis of the faunal variations allows to ascribe the Santonian faunal turnover to a cooling event strong enough to cause the extinction of the marginotruncanids.

EVO5 : MOam11 : F5
Evidence for Late Jurassic Release of Methane from Gas Hydrate: Opening of a Pangean Gateway?

Maureen Padden (padden@erdw.ethz.ch)[1],
Helmut Weissert (weissert@erdw.ethz.ch)[1] &
Marc de Rafelis (rafelis@ccr.jussieu.fr)[2]
[1] Geological Institute, ETH-Zuerich, CH-8092 Zuerich, Switzerland
[2] Geologie Sedimentaire, UPMC, 75252 Paris, France

The presence of methane hydrates along continental margins and in permafrost regions has spurred new research into the possible causes and consequences of sudden methane release. The distinctive isotope signature of methane derived carbon opens up the possibility of recognising such events through geologic history. We present evidence of methane release during the Late Jurassic, a time of major climate and ocean reorganisation. Four Late Jurassic carbonate successions were chosen for the isotope study. They were deposited along a shelf transect of the northern alpine Tethys. A proximal carbonate ramp section is located in the Swiss Jura Mountains, two distal ramp successions are outcropping in the Helvetic nappes of Eastern Switzerland. The hemipelagic "Vergons" section was deposited in the Vocontian Basin of Southeastern France. All records display a negative carbon isotope excursion of at least 2 ‰ within the Oxfordian Transversarium ammonite zone. The excursion is present in both organic and carbonate carbon records. It is comparable in magnitude and duration to isotopic changes during the late Paleocene thermal maximum. A negative carbon isotope event measured in Oxfordian sediments of North America (Humphrey et al., 1986) may be correlated with the Tethyan isotope anomaly. These results indicate that during the Oxfordian, considered a warm greenhouse time, additional greenhouse gas was contributed to the atmosphere by a sudden release of methane from the dissociation of buried gas hydrate. A potential triggering mechanism may have been the opening of an oceanic gateway through the early Atlantic between the ancient Tethys and Pacific Oceans coupled with a change in deep water conditions along the Tethys-Atlantic seaway

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EVO5 : MOam12 : F5
Hot LIPs, Methane and the Carbon Isotope History of the Apticore

Bradley Opdyke (bno@geology.anu.edu.au)[1],
Elisabetta Erba (elisabetta.erba@unimi.it)[2],
Roger Larson (rlar@gsosun1.gso.uri.edu)[3] &
Timothy Herbert[4]
[1] Dept. of Geology, Australian National University, Canberra ACT 0200, Australia
[2] Dipartimento di Scienze della Terra, Università degli Studi di Milano, Via Mangiagalli 34 - 20133 Milano, Italy
[3] Graduate School of Oceanography, University of Rhode island, Narragansett 02882, USA
[4] Dept. of Geological Sciences, Brown University, Box 1846 - Providence, RI 02912-1846, USA

During the Cretaceous, black shale formation, enhanced organic carbon deposition, and biotic crises have been linked with 'global anoxia' in the oceans. The possible causes of Oceanic Anoxic Events (OAEs) have been debated for decades. The high-resolution stable isotope record from the Cismon Apticore (northern Italy) allowed a detailed investigation of the relationship between the timing of methane clathrate release and the sequestration of carbon during the early Aptian OAE1a event that began about 119 my ago. The Cismon section was chosen because its paleodepth was sufficiently shallow to preserve carbonate carbon in the Selli black shale interval, which is the pervasive organic carbon rich horizon found throughout Italy. The strong precessional cyclicity of the Cismon core allows the quantification of the duration of the Selli interval, which has a thickness of over 5-m and lasts 700,000 years. Based on both cyclostratigraphy and isotope stratigraphy, the changes in the magnitude of the fluxes from the important global carbon reservoirs can be quantified. Despite the massive deposition of excess organic carbon globally at the beginning of OAE1a, $\delta^{13}C$ of the carbonate moves sharply negative 1.2 permil. This negative perturbation lasts approximately 140,000 years before recovering to pr-Selli values. The second phase of the Selli is a 'plateau' in $\delta^{13}C$ values that lasts 490,000 years while the deposition of excess organic carbon continues. There is an abrupt rise in the $\delta^{13}C$ of 1.2 permil just before the end of the Selli. $\delta^{13}C$ continues to rise for another million years after the end of the Selli. This "positive excursion" is well documented globally and occurs after the main instance of anoxia and shallowing of the CCD coincident with the occurrence of the Selli. Both the negative excursion and the $\delta^{13}C$ "plateau" can be explained by the release of methane clathrates into the Cretaceous ocean. The methane flux would have been large early in the interval then continued at a lower level during the $\delta^{13}C$ "plateau". If total carbon concentration in the Cretaceous ocean was similar to the present day, total methane released during the Selli interval, according to this model, would be conservatively calculated at 5370 Gt of carbon. We propose that the methane release and the increased oceanic productivity during the Selli interval is triggered by warming of intermediate waters by the eruption of the Ontong Java Plateau LIP. Methane release further warms the Earth through a subsequent "super-greenhouse" temperature rise, which is coincident with the "plateau" phase of methane release. After the methane input stops, CCD quickly recovers and organic carbon is no longer preferentially sequestered in the deep ocean. The positive shift in $\delta^{13}C$ implies organic carbon deposition elsewhere, perhaps in shallower water environments.

EVO5 : MOam13 : F5
Orbital Chronology for the Late Paleocene Thermal Maximum

Ursula Roehl (uroehl@allgeo.uni-bremen.de)[1] &
Timothy J Bralower (bralower@email.unc.edu)[2]
[1] Geosciences Department, Bremen University, PO Box 330440, 28334 Bremen, Germany
[2] Department of Geological Sciences, University of North Carolina, Chapel Hill, North Carolina 27599, USA

The late Paleocene thermal maximum (LPTM) is associated with a transient, but intense, interval of global warming and a massive perturbation of the global carbon cycle. We have developed an orbital chronology for LPTM records drilled at Ocean Drilling Program (ODP) Sites 690 (Weddell Sea, Southern Ocean) and 1051 (western North Atlantic). The Late Paleocene pelagic sediments display pronounced cyclicity in color, magnetic susceptibility, and high-resolution geochemical (Ca and Fe) profiles. Well defined magnetostratigraphies were found at both sites, chron assignments were confirmed with planktic foraminifera and calcareous nannofossil biostratigraphy. We believe that the sedimentary rhythms are precession cycles with ~21 ky duration. We have applied spectral analysis methods to these high-resolution geochemical scans of Paleocene sediment cores from distant sites and obtained a consistent cycle-tuned duration of the LPTM. The LPTM interval spans 11 precessional cycles yielding a duration of 210 to 220 k.y.. The $\delta^{13}C$ anomaly associated with the LPTM has a magnitude of about -2.5‰ to -3‰; we show that about -2‰ of the excursion occurs within less than 5,000 yrs. The remainder developed over ~52 k.y.. The timing is consistent with a catastrophic release of methane from gas hydrates. Further, we are able to correlate the records between Sites 690 and 1051 on the scale of 21 k.y. cycles, which demonstrates that the details of the $\delta^{13}C$ excursion are recognizable between distant sites drilled in low- and high-latitudes. Comparison of cycle records at Sites 690 and 1051 suggests that sediment representing the interval ~30 k.y. just prior to and at the onset of the LPTM are missing in the latter location. This unconformity probably resulted from slope failure accompanying methane hydrate dissociation within 10 k.y. of the start of the LPTM.

EVO5 : MOam14 : F5
Expanded Carbon Sinks at the Palaeocene/Eocene Boundary: A Global Biological Response to Clathrate Induced Climate Change

Santo Bains (santo.bains@earth.ox.ac.uk)[1],
Richard Norris (rnorris@whoi.edu)[2] &
Richard Corfield
(richard.corfield@earth.ox.ac.uk)[1]
[1] Department of Earth Sciences, University of Oxford, Oxford, OX1 3PR, UK
[2] Department of Geology and Geophysics, Woods Hole Oceanographic Institution, Woods Hole, MA 02540-1541, USA

A stepped global $\delta^{13}C$ excursion at the Palaeocene/Eocene (P/E) boundary (some 55.5 million years ago) may have been caused by a mechanism involving the input of isotopically light carbon into the exchangeable reservoir from the sublimation of gas hydrates (e.g. Dickens, 2000). Gas hydrates are frozen solids containing short-chain hydrocarbons, mostly methane, which accumulate in sea-floor environments by microbial activity. A global warming of surface temperatures by ~ 5 - 7°C is also documented at this time (e.g. Kennet & Stott, 1991), suggesting that methane injections from such reservoirs can significantly alter the Earth's climate as well as perturbing the entire carbon cycle.

The effects of these global disruptions to life on Earth were extensive. For example, the number of species of benthic foraminifera recorded at this time dropped by ~ 50% (Thomas, 1990). Conversely, planktonic foraminifera apparently flourished, and a number of short-lived species appeared in the oceans for the first time (Kelly *et al.*, 1998). On land, many of the dominant modern mammalian orders emerged and migrated across the continents (Gingerich, 1989). Further examples of biotic change at this time are numerous, and thus clearly indicate that hydrate destabilisation and associated global warming can cause a dramatic reorganisation of most ecosystems that constitute the biosphere.

Here we present evidence to suggest that the climate-biosphere systems were mutually dependent at the P/E boundary, in such that changes to the abundance of life on Earth (caused by the environmental transformation) in turn modulated the global conditions through negative feedback. Our marine data include barium mass accumulation rates ($Ba_{biogenic}MAR$; an export productivity proxy) from various Ocean Drilling Program (ODP) cores. These show that as the Earth warmed at the P/E boundary the abundance of life in the surface oceans increased (on average) around the globe, thus intensifying the carbon 'pump'. These findings are consistent with recent mass-balance calculations and interpretations of high-resolution oceanic $\delta^{13}C$ records from this time, which reveal that the sequestration of carbon occurred more quickly than would be expected through a steady-state carbon 'pump' (Dickens, 2000). To illustrate the terrestrial response, we present a detailed $\delta^{13}C$ record from Wyoming that shows evidence of an increased plant respiration rate in the local ecosystem following hydrate dissociation, which is in support of a recent modelling exercise that proposes that a heightened production on land would be expected in reaction to P/E boundary conditions (Beerling, 2000). These combined data suggest that the whole Earth may have temporarily developed expanded carbon-sinks during the P/E boundary climate event, and that this dynamic productivity feedback mechanism helped the Earth return to normal conditions.

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