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Stratigraphic, sedimentological, mineralogical, geochemical and palaeoenvironmental constraints on the rise of the Urgonian platform (Barremian-Aptien) along the northern Tethyan margin (Switzerland, France)

Thierry Adatte, Alexis Godet, Karl Foellmi, Stéphane Bodin, Eric De Kaenel, Annie Arnaud-Vanneau, Hubert Arnaud

Urgonian-type carbonates are a characteristic feature of many late Early Cretaceous shallow-marine, tropical and subtropical environments. The presence of typical photozoan carbonate-producing communities including corals and rudists indicates the prevalence of warm, transparent and presumably oligotrophic conditions in a period otherwise characterised by the high density of globally occurring anoxic episodes. Of particular interest, therefore, is the exploration of relationships between Urgonian platform growth and palaeoceanographic change. In the French and Swiss Jura Mountains, the onset and evolution of the Urgonian platform have been controversially dated, and a correlation with other, better dated successions is correspondingly difficult. It is for this reason that a series of recently exposed sections were sampled (Eclépens, Vaumarcus, Neuchâtel), in addition to the Gorges de l'Areuse section. The stratigraphy and sedimentology of these sections were analysed, and calcareous nannofossil biostratigraphy, the evolution of phosphorus contents of bulk rock, 87Sr/86Sr ratios for rhynchonellid shells, and sequence stratigraphic interpretation, and a correlation of drowning unconformities with better dated sections in the Helvetic Alps were used to constrain the age of the Urgonian platform. The sum of the data and field observations suggests the following evolution. During the Hauterivan, important outward and upward growth of a bioclastic and oolitic carbonate platform is documented in two sequences, separated by a phase of platform drowning during the late Early Hauterivian. Following these two phases of platform growth, a second drowning phase occurred during the latest Hauterivian and Early Barremian, which was accompanied by important platform erosion and sediment reworking. The Late Barremian witnessed the renewed installation of a carbonate platform, which initiated with a phase of oolite production, which progressively evolved into an Urgonian-type carbonate production under the inclusion of corals and rudists. This phase terminated at the latest in the middle Early Aptian, due to a further drowning event. The evolution of this particular platform segment is compatible with that of more distal and well-dated segments of the same northern Tethyan platform preserved in the Helvetic zone of the Alps, in the northern subalpine chains (Chartreuse, Vercors) and in the southern France (Gard).

Facies analysis and Palaeoenvironment reconstructions during Triassic in Imini and Ighrem Nougdal area (south High-Atlas, Morocco)

Hanane Aiche, Rachid Essamoud

The Imini and Ighrem n'ougdal basin, which is the object of the present paper, is filled with Upper Triassic red beds, which rest unconformably on the Neoproterozoic Ouarzazate Group. It is located along the southern flank of the High Atlas of Marrakech (Telouet transverse), at approximately 80 km to the north of Ouarzazate. Triassic exists in monoclinal structure.

The Triassic sedimentary deposits are represented by facies with detrital predominance, made up primarily of conglomerates, coarse to fine sandstones, clays and siltstones, with an intercalation of gypsum levels then basaltic lava on the top of the series.

Sedimentological analysis allow subdividing the series in four formations:

- The E1 Formation, twenty meters-thick, is composed of a succession of purplish conglomerates with centimetric elements of schist and rhyolite of the substratum, dominated by through cross bedding. It is overlaid by coarse sandstones with planar cross bedding and horizontal bedding, with also mud cracks and burrows at the top.
  These facies correspond respectively to: deposits as channel lag by scour and fill movements, deposits of transverse bars whose sedimentary bodies settle for the periods of water level raising and also in the shallow places in the channel. The current was enough strong to allow avalanche deposits. Paleosoils (caliches) are present in the conglomeratic levels and are evidence of a carbonated epigenesis. Sequences are several meters-thick and are all fining-upwards cycles that reflect progressively decreasing energy conditions. This formation is typically continental showing the installation of a relatively proximal braided system.
- The E2 formation, thick of about thirty meters, consists of unorganized conglomerates, rich in silty matrix, corresponding to debris flows, becoming channelized upwards. These conglomerates are overlaid by siltstones and red clays with vegetable remains and mud cracks at the top. It was deposited by vertical accretion in the calm zone of the floodplain, with a fast lowering of the water level at the end of the raising. These fine deposits receive temporarily sandy clastic rocks at the brutal phases of flood: overbank flooding. These facies contain some sandy channels. Stromatolitic levels, evidence of algae epigenesis in a floodplain are present at the top of the formation. Sequences are thinning and fining upwards and are several meters-thick in majority. This formation thus corresponds to deposit in proximal braided system passing to a more distal one.
- The E3 formation thick of about twenty meters is sandy to silty where horizontal bedding and parting lineation are dominate, evidence of upper flow regime. These facies correspond to frequent sand flat deposits in sandy fluvial system.

- The E4 formation, hundred meters-thick, is sandy at the base and silty to clayey at the top. It is characterized by evaporites as fibrous laminate but discontinuous gypsum. Sequences are metric, thinning and fining upwards. Gypsum is evidence of the containment of the generating basin of local hypersalinity.

The paleocurrent study suggests a south origin of the sediment. The Triassic formations of Imini and Ighrem N'ougdal thus correspond to continental deposits at the base which were done by sometimes brutal discharges on a Paleozoic basement where there were still reliefs, then by more regular currents. The containment is clear at the top levels by creating areas of subsidence where gypsum could accumulate, linked to the specific climatic conditions of this area.

Palynostratigraphy of the Garau Formation in Kabir Kuh (type section), Zagros Basin, SW Iran

Maryam Akhtari

Dinoflagellate cyst assemblages have been studied in the type section of the Garau Formation, with a thickness of 763 m, in Kabir Kuh area, southwestern Iran. The Garau Formation is located between the overlying Gotnia Formation and the underlying Sarvak Formation in this area.

For this research, 105 samples have been processed. All samples were productive and yielded abundant and well preserved marine palynomorphs. In the relevant slides, fifty nine species of dinoflagellate cysts were recognized and on the base of their stratigraphical distribution, seven local biozones were established throughout this formation. A Berriasian-Aptian age is suggested for the Garau Formation, based on index dinocysts. This zonation scheme as well as precise age determination is reported for the first time from this area in the Zagros Basin.

On the other hand, colour alteration index of palynomorph taxa (Dinoflagellate cysts) suggests a thermal maturity which is suitable for hydrocarbon generation, introducing the Garau Formation as a source rock.

Paleogeographical reconstructions of southwestern Siberia during the early Paleogene by dinocysts

Galina Nikolaevna Aleksandrova, Alina Igorevna Iakovleva

During the Late Cretaceous-early Paleogene the West Siberia represented a large marine basin, which was in connection (from time to time) with the Arctic and Tethys Oceans. Here we present our results of a high-resolution dinocyst study from two new research-boreholes drilled in the southeastern part of

Western Siberia (Omsk Region). According to palynological data, the lowermost sediments (Gankinskaya Formation) of Early Maastrichtian age are overlying by the Lulinvor Formation. The lowermost Lulinvor Formation is attributed to the Tahnetian by the presence of dinocysts *Alisocysta margarita*, *Alisocysta* sp.2 Heilmann-Clausen and *Deflandrea denticulata* (~57.4-55.8?Ma), indicating the first important stratigraphical hiatus corresponding to the late Maastrichtian-Sealandian (~69.3-59.5Ma). Dinocyst assemblage with *Apectodinium augustum*, *Wilsonidium pechoricum*, *Apectodinium hyperacanthum*, *A. paniculatum*, *A. parvum* and *A. summissum* is recognized within the middle Lulinvor Formation, suggesting the presence of the PETM interval (~55.8-55.6Ma) in studied section. The overlying part of the Lulinvor Formation is characterized by the ~continuous succession of important early Eocene dinocyst events and attributed to the Ypresian (~55.6-48.6Ma), suggesting the marine settings in the southeastern part of Siberian marine Basin until the transition from the early to the middle Eocene.

Biostratigraphical context of the South-Atlas foreland domain: the Paleogene of the M'Goun valley (Morocco)

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Introduction:

The Sub-Atlas foreland domain comprises the Ouarzazate foreland basin and a well developed piedmont characterized by an important shortening and the formation of thrust sheets (Teson *et al.*, 2006). The folds and thrusts correlated to this piedmont allow the tertiary sedimentary series of the foreland domain to outcrop. The high resolution sedimentary and biostratigraphical study of the marine Palaeogene Group in the M'Goun valley permits to refine the stratigraphical limits and gives more information on the depositional environments. Marine and continental faunal elements were studied: reptiles, echinoderms, crustaceans and cephalopods (Tabuce *et al.*, 2005; Augé *et al.*, 2006; Alloin & Bourguiba, 2009).

Geological context:

The tectonic and sedimentary history of this foreland domain is controversial. Indeed, the different authors describe the compressive deformation of this area by proposing one to four tectonics pulses with different ages, from late Cretaceous to Quaternary (Laville *et al.*, 1977 ; Görler *et al.*, 1988 ; Fraissinet *et al.*, 1988 ; El Harfi *et al.*, 2001 ; Frizon de Lamotte *et al.*, 2000 ; Teson *et al.*, 2006).

The biostratigraphical limits in the Palaeogene of the M'Goun valley:

The studied stratigraphic serie starts at the beginning of the Paleocene (marine Palaeogene – Sub-atlas Group) up to the formations of the upper Oligocene (continental Palaeogene – Imerhane Group). All this stratigraphic series is uninterrupted and could be subdivided into eight biostratigraphical units.

The Lower Paleocene: It is characterized by two mains facies: an arenaceous lacustrine limestone with a whitish to yellowish shade and red to grey-green clays. Only roots prints were observed in this facies.

The Upper Paleocene: A mud flat with abundant *Ostrea* sp. forms the base of this sedimentary unit. It is sometimes covered by a whitish laminated limestone containing a fauna of the infralittoral zone with crab burrows and *Pinna* sp.

The Lower Eocene: Its base is a marly clay interval showing several banks of whitish sandstones with tangential oblique laminations. The upper part of the Lower Eocene corresponds to a fossil-rich arenaceous bioclactic limestone: chelonians (?*Neochelys* sp., *Trionyx* sp.) and crocodilians (Gavialidea indet.), *Rhyncholampas* sp., nautiloids, *Pychnodonta* sp., *Ostrea* sp., crabs. This limestone presents numerous megaripples with oblique laminations. Deposition of the Lower Eocene occurred in an estuarine or marine coastal environment.

The Middle Eocene: It begins with a grey bioclastic limestone, composed of numerous fossils from the lower infralittoral: *Spatangus* sp., *Thylechinus* sp., nautiloids, crab burrows, bivalves, gastropods, chelonians (*Trionyx* sp.) and crocodilians. This facies is overlain by an alternation of sandstone and clay levels with thin laminations and rich in *Miliola* sp.

The Upper Eocene: Its base is an alternation of grey and green clays with black cherts and sparse white bioclastic limestones (rhodolites, *Balanus* sp.). Above, stands a massif bioclastic limestone with numerous fossils from the upper circalittoral: nautiloids, *Echinolampas* sp., shark teeth (*Lamna* sp.) and skate teeth (*Myliobatis* sp.) and bivalves.

The Lower Oligocene: It is marked in the landscape by an impressive arenaceous yellow limestone, also bioclastic (burrows of crabs, Ophiuridea and *Ostreidae*) and sometimes associated with marly turns.

The Middle Oligocene: The predominant facies is a fluvial yellowish sandstone rich in organic matter (plants residues and fish scales) and in ferromagnesian minerals (oxides).

The Upper Oligocene: It is characterized by an alternation of clays and red azoic sandstones. The sandstones present oblique laminations. The inferred depositional environment corresponds to an alluvial fan.

Conclusions and research perspectives:

These new biostratigraphical data permit to refine the limits of the Palaeogene. Paleontological novelties were discovered, particularly in the echinoderm fauna. Complementary studies are in progress within the Geosciences department of the Institut Polytechnique LaSalle-Beauvais. Cephalopods, crustaceans and vertebrates are actually under study.

Nannofossil biostratigraphy of the Paleogene sediments of the Crimea-Caucasus region (southern Ukraine and Russia)

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Calcareous nannofossils have been successfully used for detailing the age boundaries of the local stages and formations of the Paleogene over the North-Eastern peri-Tethys region (Crimea, Northern Precaucasus and Northern Caucasus).

Paleogene sediments are widely developed in this area and have been a subject of intense research on nannofossil content (Andreeva-Grigorovich, 1973, 1980; Muzylov, 1980, Bugrova *et al.*, 1990; Zernetsky & Lyulyeva, 1990, 1994; Scherbinina, 2000; Waga, 2007, and others). The Paleogene sediments are represented by marls, limestones and shale deposits enriched with carbonate content. The zonal species of the standard zonal schemes of Martini (1971) and Okada & Bukry (1980) have been identified making the regional and global correlation with stratotype areas and International Time Scales available (Berggren *et al.*, 1995; GTS, 2004).

The *Bakhchisarai stratotype area* of Crimea is the most well examined section representing almost the whole Paleogene interval. According to the Stratigraphic committee of Ukraine (Stratigraphic codex of Ukraine, 1997) and the stratigraphic zonation scheme of Ukraine (Zernetsky *et al.*, 1993), the Paleogene is characterized by the following formations: *Bilokamian* (Danian-lower Selandian stages;), *Kachian* (upper Selandian – Thanetian stages), *Bakhchisarian* (Ypresian stage), *Simferopilian* (upper Ypresian-lower Lutetian stages), *Kuberlinian* (Lutetian stage;), *Kerestinian* (Lutetian stage), *Kumian* (Bartonian stage), *Almian* (Priabonian stage). In some stratigraphic schemes, the *Kuberlinian* and *Kerestinian stages* are combined into one *Novopavlian stage*.

We reexamined the nannofossil content of 150 samples of the *Kachian*, *Bakhchisaraian*, *Kerestinian*, *Kumian* and *Almian stages*. The *Kachian formation* comprises the upper part of the *Fasciculithus tympaniformis* (NP5), *Heliolithus kleinpelli* (NP6), *Discoaster gemmeus* (NP7) and *Heliolithus riedelii* (NP8) zones. The *Bakhchisaraian stage* of the Ypresian unconformably lies above the *Kachian stage* of the Thanethian. This is evident through the absence of the *Discoaster multiradiatus* (NP9), *Tribrachiatus contortus* (NP10) and the lower part of the *Discoaster binodosus* (NP11) nannozones of the Martini (1971) zonation, suggesting that this interval corresponds to the stratigraphical volume of the unconformity. The *Bakhchisaraian stage* is characterized by the upper part of the *Discoaster binodosus* (NP11), *Tribrachiatus orthostylus* (NP12) and the lower part of the *Discoaster lodoensis* (NP13) nannozones. In the 1993 stratigraphic scheme the *Kerestinian* and *Kumian stages* correspond to the *Discoaster tani nodifer* (NP16) and the *Discoaster saipanensis* (NP17) nannozones. According to our results the *Kerestinian stage* and the lower part of the *Kumian stage* correspond to the undifferentiated *Nannotetrina fulgens* (NP15)-*Discoaster tani nodifer* (NP16)

zone. The upper part of the *Kumian stage* is characterized by the *Discoaster saipanensis* (NP17) and the lowest part of the *Chiasmolithus oamaruensis* (NP18) zone.

Scherbinina (2000) fairly notices that the middle Eocene zonation represents a severe difficulty for subdivision and correlation of sediments of this age over the Crimea-Caucasus region. In most sections of the region it is almost impossible to differentiate the *Nannotetrina fulgens* (NP15) –*Discoaster tani nodifer* (NP16) nannozones of Martini (1971), or the *Nannotetrina quadrata* (CP13) and *Reticulofenestra umbilica* (CP14) zones of Okada & Bukry (1980). The reason is that the events of the zonal markers – LO of *Blackites* (*Rhabdolithus*) *gladius* and FO of *Discoaster bifax* used in both coexisting nannofossil standard zonal schemes appear at either much lower or higher levels than accepted. For example, the LO of *Blackites* (*Rhabdolithus*) *gladius* in the Bakhchisarai and Kheu sections disappears much higher within the samples assigned to the *Discoaster tani nodifer* (NP 16) zone. The FO of *Discoaster bifax* seems to occur somewhat earlier in the samples characterized by the *Nannotetrina fulgens* (NP15) zone. The *Almian stage* comprised the *Chiasmolithus oamaruensis* (NP18) and *Isthmolithus recurvus* (NP19).

42 samples from the *Kheu section* of the Northern Caucasus were studied. Despite the fact that this section has been studied by various researchers, there are still some discrepancies in the proposed zonations. A zonal stratigraphic scheme of Paleogene sediments with regional stages (formations) was introduced by Akhmetiev and Beniamovsky (2003). The Paleocene is characterized by the *Elburganian* (Danian-Selandian), *Horyachiy Kluch* (upper Selandian-lower Thanethian) and *Abazinian* (upper Thanethian) *formations*. Eocene is presented by the *Cherkessian superformation* (Ypresian-middle Lutetian), *Kerestinian formation* (upper Lutetian), *Kumian formation* (upper Lutetian-Bartonian), *Beloglinian formation* (Priabonian) and *Maikopian superformation* (Rupelian-Chattian). The *Cherkessian superformation* subdivides into three formations: *Georgievskiy*, *Druzhbinskiy* and *Kuberlinian*.

Only the Eocene section was examined, notably, the *Cherkessian superformation* (*Georgievskiy*, partly *Druzhbinskiy* and *Kuberlinian formations*), *Kerestinian formation*, *Kumian formation* and the lower part of the *Beloglinian formation*.

The *Cherkessian formation* comprises four nannofossil zones. These are the *Discoaster binodosus* (NP11), *Tribrachiatus orthostylus* (NP12), *Discoaster lodoensis* (NP13), and the lower part of the *Discoaster sublodoensis* (NP14). In this part of the section the zonation of Steurbaut (1990) can be successfully applied for more detail correlation. The *Kuberlinian formation* is characterized the upper part of the Discoaster sublodoensis (NP14) zone and the *Nannotetrina fulgens* (NP15) zone. A further subdivision of these zones into subzones is possible following the Okada & Bukry (1980) zonation. The approximation of the problematic limit between the *Nannotetrina fulgens* (NP15) and *Discoaster tani nodifer* (NP16) zones can be tentatively drawn in the lower part of the Kerestinian formation by applying the zonations of Roth *et al.* (1971), Perch-Nielsen (1971) and Varol (1998). A short lasting hiatus is suggested between the two nannozones. The dominant part of the *Kerestinian* and lower part of the *Kumian stages* is characterized by the *Discoaster tani nodifer* (NP16) zone. More detail zonation after Roth *et al.* (1971) is possible. Alike with the Bakhchisaray section of Crimea, the upper part of the *Kumian*

stage is characterized with the *Discoaster saipanensis* (NP17) and lower part of *Chiasmolithus oamaruensis* (NP18) zone. The *Beloglinian formation* contains the upper part of the *Chiasmolithus oamaruensis* (NP18) zone and the lower part of the *Isthmolithus recurvus* (NP19).

These results reveal severe differences from the zonations proposed in the stratigraphic schemes of Zernetsky *et al.* (1993) and Akhmetiev and Beniamovsky (2003). Further investigations are recommended in order to compile a detail zonal stratigraphic scheme for this region.

Sequence Stratigraphy of Permian deposits in Kalmard and Tabas blocks, east-central Iran

Sakineh Arefifarad

In east-central Iran, Permian rocks grade westward from marine carbonates (Jamal Formation in Tabas block) to siliciclastic-carbonates (Khan Formation in Kalmard block) and show well defined sequences in juxtaposed Early and Late Permian biogeographic provinces. The Lower Permian (Sakmarian-Early Artinskian) Khan Formation displays cyclic sedimentation of thick compositionally and textually mature sandstones and thin carbonates that are deposited in a near shoreline environment . The asymmetric parasequences reveal a vertical facies change commensurate with seaward progradation of the shoreline. The Khan Foramation can be divided into second- and third-order, shallowing-upward depositional sequences. Each sequence records a transgression and a regression. Glacio-eustatic sea-level fluctuations are most likely responsible for its asymmetrical cyclicity. The Middle-Upper Permian Jamal Formation, comprised mostly of carbonate rocks, consists of 2ndand third-order shallowing-upward depositional sequences and represents a homoclinal carbonate ramp. The influence of Gondwana glaciation and deglaciation and associated sea level fluctuations and climate changes vary considerably in the Kalmard and Tabas blocks. However there were tectonic controls on the two blocks. Subsidence and eustatic events are distinguishable.

1. Tectonic setting

Iran is a collage of different fragments of Gondwanaland that accreted to the margins of Eurasia during several collisional orogenies. In general, eight tectonic provinces are recognized in Iran. Within these structural divisions, there is a structural province in middle part of Iran that was named central Iran block. Alavi (1991) has divided central Iran into four blocks including Lut (LB), Tabas (TB), Posht-e-Badam (PBB) and Yazd blocks (YB) based on strike-slip dextral faults. The Kalmard area is located in the Posht-e-Badam block and bounded by the Kalmard and Naeini faults. Since the Precambrian basements of the Kalmard and Tabas areas have very similar lithologies, Aghanabati (2004) considered the Kalmard block to be part of the Tabas block, and it is situated between two active faults. For this study 5 Permian stratigraphic sections in Kalmard block and 3 others in Shotori and Shirgesht areas within Tabas block were measured, collected and described. The purpose of this study was to describe and document facies analysis, depositional environments and sequence stratigraphy of the Jamal and Khan formations.

2. Depositional sequences

The Lower Permian (Sakmarian-EarlyArtinskian) Khan Formation in the Kalmard basin displays cyclic sedimentation. Four third- or second order depositional sequences have been recognized in this Formation. The upper and lower boundaries of all sequences in this Formation are type 1. LST deposits of all sequences include sandstones. The TST in the sequence 1 (3^{rd}order cycle) is composed mainly of lagoonal facies. HST deposits are really thin and recognized by a shallowing-upward progradational stacking pattern. Sequence 2 (second order cycle) is similar to sequence 1 in that the TST deposits are followed by mostly lagoonal parasequences of the HST deposits. The MFS is marked by fusulinid riched beds. Sequence 3 (third order cycle) starts with retrogradational and aggradational parasequences. The HST is missing at the Bakhshi section but it is thin and composed of tidal flat facies at the Halvan section.

The sequence 4 (third-order cycle) was deposited only at the Bakhshi section and was deposited at early Artinskian. TST deposits are characterized by an aggradational stacking pattern. HST sediments are indicated by 2 shallowing-upward and thinning progradational parasequences.

The Middle-Upper Permian Jamal Formation in the Shotori area consists of $2^{nd}$and third-order shalowing-upward depositional sequences. Depositional sequence 1 was deposited after a transgressive over the Carboniferous Sardar Formation siliciclastics. TST deposits are characterized by an aggradational parasequence stacking pattern. The HST shows transition from lagoon to tidal flat environments. The lower and upper boundaries of all sequences are both type 1. Sequence 2 is similar to sequence 1 in that the TST deposits are succeeded by the lagoonal and shoal parasequences of the HST deposits. The HST is characterized by a transition from open marine to shoal, lagoon and tidal flat facies.

The Artinskian- early Wuchiapingian Jamal Formation in the Bagh-e-Vang section in the Shirgesht area consists of 2 second order and 1 third-order depositional sequences. The first sequence which is a second order cycle was deposited over the Carboniferous Sardar Formation sandstones. The TST deposits of the sequence 1 are characterized by lagoon to open marine facies. The HST is composed mainly of lagoon facies with restricted fauna and tidal flat deposits showing a progradation stacking pattern. There is no evidence of sequence 1 deposits in western outcrops (Sheshangosht location) of the studied section. The TST deposits of the sequence 2 are characterized by several shallowing- and thickening-upward parasequences. These parasequences have formed in the mid ramp setting and are not covered by shallower facies. Therefore, they are indicative of progressive progradation of mid-ramp toward deeper waters. HST deposits represent a thickening and coarsening-upward parasequences showing aggradational and progradational normal marine packstone and grainstone cycles. The TST and HST deposits at the Sheshangosht section are very thin and there is no any evidence of mid-ramp facies in this section. The Sequence 3 (third-order) of the early Wuchiapingian stage is similar to sequence 2 in that the TST is indicated by mid-ramp and is composed of three thickening-upward parasequence sets together with the presence of radiolarids, sponge spicules and calcisphere.

3. Correlations to Gondwana glaciations

In the Khan Formation a small rise and fall in the sea level could have been resulted in a major shift of the shoreline because of the low-gradient of the tidal flat. The glacio-eustatic sea level changes together with tectonic subsidence may be the best reasonable mechanism for cyclic sedimentation of the Khan Formation. The Kalmard block was more significantly affected by Gondwana glaciation than the Tabas block. After deposition of the Khan Formation during Sakmarian time a significant Late Sakmarian emergence event is consistent with regression in Gondwana. The post-glacial warming in the Shirgesht and Shotori areas began in Bolorian (late Early Permian) and Kubergandian (early Middle Permian) repectively. This is later than other epicontinental areas within Pangea, perhaps because of central Iran's position within Pangea during the late Paleozoic.

Upper Paleozoic Faraghan and Dalan Formations of Zagros area: summary on biostratigraphy and chronostratigraphy and some preliminary results of current study

Sakineh Arefifarad, Vladimir I. Davydov

Zagros region that stretches from southwest Iran to south-west Iraq is one of the major global oil production provinces in the Middle East that extends towards the Arabian Plate. Many outstanding studies of Carboniferous and Permian sequences were performed in the region particularly in general and petroleum geology, sedimentology, tectonics (Sampo, 1969; Setudehnia, 1973; Kashfi, 1976; Bahrodi, 2003; Alavi, 2004, Insalaco, 2006; Zamanzadeh, 2009). Surprisingly, biostratigraphy and chronostratigraphy of Carboniferous and Permian in the region still remains quite poor. Thus, *besides poor chronostratigraphic control*, the important for palaeogeographic reconstructions biogeographic component is not available in the area. The Faraghan Formation consists of red and gray shale intercalated with sandstone and pebble conglomerate. This unit is underlain unconformably by the limestone and shale of Upper and Middle Cambrian age at Kuh-e Garreh and Kuh-e Dinar and Lower Ordovician shale in Zard Kuh. The upper contact of this Formation with overlying Permian carbonates is considered gradational with intercalation of sandstone and limestone beds in the southeast, *i.e.* at Kuh-e Faraghan and Zard Kuh and Chalisheh sections in the northwest.The thickness of Formation ranges from about 20 m in Kuh-e Dina in the northeast up to 500 m northwest in Chalisheh section.The Formation outcrops in both folded belt and high Zagros. The age of the Formation is somewhat controversial and ranges from Devonian (Ghavidel Syooki, 2001) or Carboniferous (Seward, 1932; Setudehnia, 1973) to the Permian (Szabo and Kheradpir, 1978, Ghavidel Syooki, 1993). The following fossils were found there: plant remains (*Sigilaria persica*), pollen species (*Hamiapollenites perisporites*, *Vittatina costablilis*, *Nuskoisporites triangularis*,...), trilobites fragments. It seems sections in the western Zagros, towards Qali Kuh and also in Southeast Zagros at Kuh-e Faraghan, where Faraghan Fm possesses marine intercalations is the most promising area to establish reliable age (Szabo and Kheradpir, 1978;

Ghavidel Syooki, 1993). It seems the base and the top of the Foramtion are diachronous laterally.

Dalan Fm is entirely marine sequences and consists of carbonate and evaporates rocks. The Dalan Fm divided into three units: lower Carbonates, evaporitic Nar and upper Carbonates. In Kuh-e Surmeh which is a surface reference section, the Formation is slightly over 600 m thick (Szabo & Kheradpir, 1978). The lithology and thickness of Permian strata in western Zagros, Zard Kuh, Kuh-e Gereh and Kuh-e Dinar, are rather different compared to Faraghan and Surmeh sections in southeast Zagros. In Zard Kud the Permian deposits are over 900 m thick and consist of lower limestone unit and upper dolomite unit, while at Kuh-e Dinar the middle sandstones rest between lower limestone and upper dolomite. The thickness of Permian sediment in Zard Kud decrease down to 300 m. The Nar unit of Dalan Formation in the western Zagros outcrops is missing. The lower contact of the Dalan Formation is gradational with the clastics Faraghan Formation and its upper boundary is marked with a minor unconformity with early Triassic. According to fossil content the Dalan Formation has been divided into two foraminiferal assemblages zone. Zone A that is equal to lower Dalan Formation includes *Schwagerina* (s.l.) sp and *Afghanella* sp., and assigned to the Guadalupian age (Szabo & Kheradpir, 1978). Sampo reported *Eopolydiexodina* also from perhaps lower Dalan Fm. that suggests Murgabian (lower Wordian) age. The age of middle Dalam Nar member is somewhat controversial. *Shanita* was reported from Nar unit together with *Dagmarita chanakchiensis*. The first taxon usually characterized Murgabian and lower Midian (Wordian) (Huang *et al.*, 2007), whereas *Dagmarita chanakchiensis* - is a prominent index of lower Dzhulfian (Wuchiapingian) age (Kotlyar *et al.*, 1989).

The upper Dalan Fm (above the Nar Member) belongs to Zone B that contains *Codonofusiella* sp and *Reichelina* sp. as well as *Paraglobivalvulina mira*, *Dagmarita chanackchiensis*, *Ichthyolaria* sp. These taxa characterized Dzhulfian and Dorashamian in the type area (Kotlyar *et al.*, 1983).

According to recent data (Insalaco *et al.* 2006) lower Dalan assemblage includes *Chusenella* ex gr. *conicocylindrica*, *Dagmarita*, *Neoendothyra and Dunbarulla* and assigned to Wordian and Capitanian. The age of Nar unit with *Shanita* considered as Capitanian and upper Dalan with *Reichelina simplex*, *Paradagmarita*, *Paraglobuvalvulina mira* etc. reasonably assigned to Dzhulfian and Dorashamian.

In our preliminary studies of lower Dalan Fm following species were identified: *Chusenella minuta* Skinner & Wilde, *Ch. dainelli* (Skinner & Wilde), *Ch. conicocylindrica* (Chen), *Ch. sinensis* Sheng, *Ch. schwageriniformis* Sheng *Ch. xariensis* Wang & Zhou and *Eopolydiexodina sp.* First two species were described from lower Midian (upper Wordian) in Sicily and central Turkey (Skinner & Wilde, 1966, 1969). *Ch. minuta* also reported from KhachKhachik Fm (Capitanian) in Transcaucasia (Chedia in Kotlya *et al.*, 1989). *Chusenella sinensis*, *Ch. schwageriniformis* and *Ch. xariensis* are described from upper Maping in S. China and reported from Gnishik and Arpa Formations in Transcaucasia. The found *Eopolydiexodina* represented by juvenile and incomplete specimens that cannot be identified further. The range of the genus is upper Kubergandian (upper Roadian) to Murgabian (lower Wordian). The taxonomic composition of lower Dalan foraminiferal assemblage is quite poor and dominated by *Chusenella*. No verbeekinids that are most characteristic at

this time in Tethys were found. This might suggests relatively cooler water environments. Perhaps during Wordian through Capitanian time Zagros located within the high latitude (around 35 to 40 degree south) and belongs to Perigondwana. This conclusion also supports by presence *Shanita* in the Nar unit. The *Shanita* fauna during middle-late Guadalupian time occupied relatively high latitude climatic belt (35-45 degree) and considered Peri-Gondwanian fauna (Huang *et al.*, 2007).

The challenge of a global stratigraphic division for the Carboniferous – Status quo and outlook

Markus Aretz

The global stratigraphic division of the Carboniferous has been now debated for several decades and the debate is still ongoing, but some general lines have been emerged. The Carboniferous has the peculiarity of being divided into two subsystems. Compared to other systems relatively few GSSPs have defined and open questions for several stages still remain. In a time when the stratigraphic communities of other systems put forward the division of stages, the Carboniferous seems to have fallen behind.

Problems are partly connected to the geological history of the Carboniferous. It is a time of profound global changes in the geosphere and biosphere. The onset of the icehouse climate with a large climatic gradient between low-and high-latitudes and several tectonic processes like the collision of Gondwana and Laurussia result in many (often regional) sedimentary patterns and lithologies, and faunal associations. Basins have been isolated and the connections via marine gateways were unsteady. Thus a series of facies realms and faunas with a significant degree of endemism must be treated.

A second set of problems result from the decline of economic activities related to Carboniferous strata (*e.g.* coal mining in the Central Europe) and a consequently lower number of active Carboniferous researchers. The bias between the regions of active stratigraphic research and traditionally important regions constantly increase (*e.g.* Tournaisian-Viséan: England vs. Belgium). A community becoming steadily smaller will certainly become a substantial problem for further stratigraphic work and decision-making in the Carboniferous. Looking on the composition of the actual working groups of SCCS shows already the multi-tasks of many colleagues.

The GSSPs for the base of the two subsystems have been recently challenged (*e.g.* Kaiser 2006, Barnett 2008). The future of the Devonian-Carboniferous boundary will be re-evaluated in a joined task group of SDS-SCCS; the base of the Mississippian seems to be so far more stable. However, when following the discussions about the Carboniferous GSSPs or potential candidates, three principle problems arise: (a) continuity of the section(s) without lithological changes, (b) biotic diversity and provincialism, and (c) the phylogeny of possible markers. These are certainly questions common for many GSSPs. Some of the problems may be less obvious in condensed deeper water sections. The temporal resolution of distinctive biological and geological events in these sections is low, and sharp differences or peaks only reflect a time-

averaging effect under low sedimentation rates in these settings. Additionally the input of rare turbidites in these sections, which help to correlate with shallow water faunas and sections, only pretend a higher degree of precision, because the moment of the sediment transport is random. It can hardly be reconstructed and does not necessarily coincide with a precise position in a biozonal scheme.

The stratigraphic division of the Carboniferous is mainly based on biostratigraphic dates. However, precise radiometric data are becoming more and more available (*e.g.* Davydov *et al.* 2010) and correlations based on sequence stratigraphy (*e.g.* Hance *et al.* 2002, Heckel *et al.* 2007) start to become a very useful tool. Their relevance for the Carboniferous will steadily increase and they may help to overcome problems caused by faunal provincialism and lack of fossils. These techniques will also help to elucidate the speed and function of faunal migration, which can certainly be held responsible for causing some confusion in long-distance correlations.

Bioevents have gained little attention in the Carboniferous. When focussing on the Mississippian, bioevents can be found on regional, basinal and global scales. Especially the basinal and global scales are important for the future establishment of the Carboniferous time scale. The late Asbian *crenistria* event (Mestermann 1998) is one example for the regional relevance. It can be traced throughout the deeper water facies of the Rhenohercynian Basin, but it becomes indistinct in the shallow water successions of the basin. Thus biovents of broader distribution with less facies dependence are of interest for the global Mississippian stratigraphy. Bioevents which may be a powerful tool are: Mid-Tournaisian Lower Alum Shale Event (Siegmund *et al.* 2002), upper Tournaisian Awins Event (Poty 2006), basal Viséan Event, *Bollandoceras-Donbanites* Event in the Middle Viséan, and the MCB Event (Saunders & Ramsbottom 1986) at the end of the subsystem. These events seem to be bound to important sea-level fluctuations, which open or close oceanic gateways. However, most of these events are only partly studied so far.

The study of bioevents, sequence stratigraphy, biotic composition and migration seems to be a promising path for future Carboniferous stratigraphic research, which has to be enhanced by radiometric dating. The integration of data on stable isotopes and magnetostratigraphy has to be another task for the Carboniferous community. The first type of data sets is already largely available (*e.g.* Buggisch *et al.* 2008), but has not been intensively used for stratigraphic questions. The second type of data is only very rarely available and far from being a general powerful tool for the Carboniferous community (Hounslow 2009).

Paleocene/Eocene boundary events: discovery, current thinking and perspectives

Marie-Pierre Aubry

The diversity and intensity of events associated with the Paleocene/Eocene boundary had not been anticipated from early stratigraphic studies. The discovery in the late 1980s of a negative carbon isotopic excursion (CIE) of large amplitude in marine carbonates recovered from the Southern Ocean changed this situation, resulting in a cascade of unusual findings that have transformed an obscure interval of time into the most fascinating moment of the Cenozoic, now known as the Paleocene/Eocene Thermal maximum (PETM). The characteristic isotope signature left in the sedimentary record by the abrupt disruption of the carbon cycle associated with the PETM has fostered a sudden and continued scientific interest that has united the stratigraphic (sensu lato) community around a central problem, that of global warming, its causes and its consequences in the ocean, epicontinental seas and the continents. An incomparable means of correlation, the CIE has been instrumental in helping to tie disjunct stratigraphies based on the integration of an ever increasing number of datasets obtained through both classical and novel methodologies. If the sedimentologic, biologic and chemical events associated with the PETM are well described, there remains much to be resolved, in particular concerning the cause(s) of the global warming. I will review the events associated with the PETM, explain the difficulty in dating it and in establishing its duration, and stress the strengths and weaknesses of competing theories of what may have happened at the Paleocene/Eocene boundary which we now understand to have been a major turning point in the evolution of life in the ocean and on land.

Évolution spatio-temporelle de la végétation et du climat du sillon sud rifain au Miocène supérieur (Maroc)

Naima Bachiri Taoufiq, Nadia Barhoun, Jean-Pierre Suc

L'étude palynologique des sédiments néogène du corridor sud rifain fournit des informations sur la flore, la végétation, le climat et leurs évolutions sapatio-temporelle .

L'analyse floristique révèle la présence d'une flore diversifiée, composée d'éléments habitant aujourd'hui les régions intertropicales, les régions subtropicales à tempérées-chaudes d'Amérique et d'Asie à côté d'éléments vivant actuellement toujours en Europe et dans les régions méditerranéennes. Les éléments représentatifs des milieux subdésertiques et des formations végétales ouvertes généralement xériques réalisent des pourcentages élevés. La diversité de cette flore a permis d'individualiser une végétation de basse altitude dominée par des formations ouvertes subdésertiques ressemblant

fortement à celles qui caractérisent encore les régions subdésertiques du Maroc comme la région de Guercif. La mangrove à *Avicennia* se développait sur le littoral. En moyenne altitude des formations végétales forestières mixtes relayaient la végétation herbacée. Les groupements de haute altitude à *Cedrus* et *Abies* qui peuplent aujourd'hui les montagnes du Maroc n'ont pas été enregistrés.

L'ensemble de ces groupements végétaux témoigne de l'existence d'un climat chaud, tropical à subtropical, et xérique sur la plaine littorale mais plus humide en altitude.

La comparaison des données palynologiques des coupes étudiées tout le long du corridor rifain (du bassin du Rharb au bassin du Guercif) a permis d'apprécier l'évolution spatio-temporelle de la végétation et du climat du sillon sud rifain au Miocene supérieur.

Au Tortonien moyen, le domaine du corridor sud rifain était relativement un peu humide. Les éléments méga-mésothermes prédominent et sont plus diversifiés par rapport aux sites du domaine méditerranéen. Au Tortonien supérieur, une certaine humidité continue de régner dans le domaine atlantique, alors que, dans le domaine méditerranéen, la xéricité augmente progressivement. Une des causes réside peut-être dans la disparition du domaine marin dans le bassin de Taza-Guercif. Les influences atlantiques et la proximité des reliefs favorisent la diversification des éléments méga-mésothermes. Au Messinien inférieur, le climat devient de plus en plus sec, peut-être en relation avec la baisse du niveau marin enregistrée à la limite Tortonien-Messinien. En moyenne altitude les éléments méga-mésothermes, mésothermes et *Cathaya* prédominent et se développent davantage vers l'Ouest. Cette diversité peut être due d'une part aux influences océaniques et d'autre part à la proximité des reliefs.

Cette comparaison illustre bien l'existence d'un gradient de sécheresse qui augmente dans le temps et ceci de l'Ouest vers l'Est.

Végétation, climat et environnements marins du Miocène terminal au Pliocène supérieur en Tunisie méridionale d'après l'analyse palynologique du sondage Jiriba 1 (Golfe de Hammamet)

Naima Bachiri Taoufiq, Zakia Mriqo, Jean-Pierre Suc, Nadia Barhoun

L'analyse pollinique du forage Jiriba1, calibré astrochronologiquement (Hilgen *et al.*, 2008) à partir des foraminifères planctoniques, permet de reconstituer l'évolution de la végétation et du climat de l'arrière-pays du Golfe de Hammamet du Miocène terminal au Pliocène supérieur.

La végétation de basse altitude est dominée par des formations ouvertes subdésertiques. En moyenne altitude se développaient des formations végétales forestières mixtes. Entre les deux formations existait un groupement

arboré constitué d'éléments dont les représentants sont actuellement méditerranéens.

Trois phases climatiques définies dans le forage Jiriba1 autorisent des corrélations climatostratigraphiques avec les phases climatiques majeures (PI, PII et PIII) définies par Suc et Zagwijn (1983) récemment retrouvées en détail dans le Site DSDP 380 en Mer Noire (Popescu *et al.*, 2010).

Les indicateurs de distalité montrent d'une part que l'environnement de dépôt du forage Jiriba 1 est épicontinental, alimenté par d'importants apports fluviatiles, et d'autre part ils reflètent l'alternance d'un milieu néritique proximal à néritique distal.

Les changements répétitifs de la végétation et les variations relatives du niveau marin dans le Golfe de Hammamet permettent de supposer que ces changements cycliques résultent de l'influence du forçage astronomique.

La comparaison de ce travail avec ceux déjà réalisés dans la région méditerranéenne confirme l'existence de gradients thermique et xérique, latitudinaux et longitudinaux (Suc, 1989 ; Suc *et al.*, 1995 ; Fauquette *et al.*, 2007).

Guadalupian–Lopingian marine succession microfacies and paleoenvironments of Zal area (Azarbaijan), Northwest Iran

Mousa Bagheri, Rahim Shabanian

The Permian rocks can be divided into four lithostratigraphic units and including Dorud (Asselian-Sakmarian), Surmaq (Kubergandian - Murgabian) Julfa (Midian - early Dzhulfian) and Ali bashi Formations (Late Dzhulfian - Dorashamian) respectively. The Permian rocks underline non conformitably by Pre-Permian intrusive rocks and overlain Paraconformably by Elika Formation of Early- Middle Triassic age.

The Middle and Late Permian (Guadalupian–Lopingian) deposits of Zal area (South of Julfa) include the Surmaq and Julfa Formations. Outcrops of Permian succession in the north of Zal have been studied to determine their facies and depositional environments. In the study area, the Surmaq (660 meters) and Julfa Formations (430 meters) consist of dark gray limestones. These formations mainly are cosists from fossiliferous carbonate rocks with chert nodules in the. The Middle and Late Permian succession comprises twelve carbonate microfacies. The persent study indicates that these formations were deposited in tidal flat, lagoon, barrier and open marine facies belts in a carbonate platform such as ramp environment.

Stratigraphic study of the late Miocene to Pliocene section in the Abatuco area, northeast Quiriquire field, Eastern Venezuelan Basin

Noelia Baptista, Yurbis Gomez, Josaine Mendoza

The Quiriquire field is a prolific oil field located in the Eastern Venezuelan Basin in which most of its production comes from Oligocene to Pliocene sands. The reservoirs have been characterized, in its shallow part (Quiriquire Formation), for sediments deposited in alluvial fans. Although is a well known section, areas such as Cachipo and Abatuco (east of Quiriquire), are not really well known due to lack of well data. Also the relationship among different depositional environments and the evolution of progradational and retrogradational episodes (fluvial vs. alluvial) have not been studied in detail.

This study evaluates the depositional pattern and stratigraphic framework derived from the Quiriquire oil field and focused in the late Miocene to Pliocene section. Six third-order depositional sequences were defined: Four in the Pliocene (Quiriquire and Las Piedras formations) and two in the late Miocene (La Pica Formation) based on biostratigraphic analysis and sedimentological studies of sixty wells along with seismic stratigraphic interpretation and attribute analysis.

Sequence boundaries were interpreted using well data and two 3D seismic surveys (839 km^2). These surfaces limit the late Miocene and Pliocene sequences. The duration of these sequences is about 1m.a. for the late Miocene to 3 m.a. for the Pliocene.

Different stratigraphic cross-sections and maps were elaborated; isopachs, facies maps based on seismic amplitude analysis and paloenvironmental maps allowed the definition of lateral facies changes and make a prediction of the sandstone distribution. As a result of this study, a turbidite fan system in the late Miocene (La Pica Formation) is interpreted and represents a new stratigraphic trap not penetrated by any well in the area. The interpreted stratigraphic wedge constitutes an interesting opportunity for exploration.

By the late Miocene in the Abatuco area, still continues the tectonic influence of the collision of the Caribbean and South American plates. At the end of this epoch, a regional unconformity is generated and corresponds to the late Miocene-Pliocene boundary. At the beginning of the Pliocene (Las Piedras Formation), an increased sedimentation rate in the post-collision foreland basin, is evidenced by the progradation of alluvial fans and retrogradation of the fluvial system. By the late Pliocene, the fluvial system is developed and the succession is progradational towards the east while backstepping of the alluvial succession occurs. Nevertheless, the alluvial system shutdown does not occur until the Pleistocene. For the Pliocene, this study proposes mixed traps (structural-stratigraphic) in the normal fault zone towards the northeast of Abatuco (the direction of drainage is approximately perpendicular to the fault system).

Dating and weathering characterization of the Morialmé quarry (Entre-Sambre-et-Meuse, Belgium)

François Barbier, Caroline Prognon, Florence Quesnel, Christian Dupuis, Johan Yans

Dating and characterization of weathering is an important step to improve the knowledge of the terrestrial regolith and to understand the impact of the different parameters on the weathering genesis (tectonics, climates, parent rocks, geomorphology, etc.).

The Entre-Sambre-et-Meuse area (near the Condroz, Belgium) is a succession of valleys and hills composed by an alternation of calcareous synclinal (depressions) and of sandstone-shale anticlinal (crests). In the region, weathering is often associated with carboniferous limestone's karst events. The Upper Famennian sandstones and shales have also experienced weathering, but the latter have been few studied up to now.

A thick and complex weathering profile is present in the Faya's quarry. It is located in the South-West of Morialmé and constituted by the Ciney Formation characterized by brown siltites and micaceous sandstones with parallel and cross stratifications.

The purpose of this work is to study the mineralogical and geochemical characteristics as well as the weathering formation parameters. From our first results we can show that the weathered degree within the quarry is very variable: highly weathered in the centre and moderately weathered on the edge of the quarry. Several profiles have been carried out in each zone, and their study has been undertaken in order to allow a comparison of the weathering degree in three dimensions.

The fourth dimension will be also taken into account thanks to the dating. We use both the K-Ar and the paleomagnetism methods. Indeed those dating tools highlight the potential polyphased weathering. The first results obtained on K-Mn oxides give a K-Ar age ranging between 53.3 ±2.3 Ma and 58.2 ±2.4 Ma, ie around the Paleocene-Eocene boundary.

The first results obtained by paleomagnetism on oxided and weathered siltites give a large range of possible ages between 160 and 240 Ma, ie from Triassic to Jurassic. Other samples, taken along each profile, refine the dating and would authorize the estimate of a 'weathered rate'.

Those data can be compared to previous ones obtained at Transinne in Ardenne (Yans, 2003), with dating of the weathering from the Early Cretaceous to the Miocene, and to the adjacent basins' record where Triassic, Jurassic, Cretaceous and Paleogene terrestrial units contain clastic sediments reworking the weathering profiles' clay, sand and oxides.

Marine reptile biostratigraphical distribution between the Oulad Abdoun and the Ganntour phosphatic basins of Morocco

Nathalie Bardet

The phosphates of Morocco (Maastrichtian-lowermost Lutetian) are part of the Mediterranean / Western Atlantic Tethyan phosphogenic Province (Lucas and Prévôt-Lucas 1996), a large belt of sedimentary deposits located around palaeolatitude 20°S and currently cropping out widely from the Middle East to the Pernambuco Province of Brazil, passing through North and West Africa.

In Morocco, these phosphate beds are exploited as an economical resource in several basins, the most important being the Oulad Abdoun and the Ganntour basins. One of the characteristics of these phosphate basins is their richness in marine vertebrate fossils, especially fishes and reptiles. Among reptiles, mosasaurid squamate remains - especially isolated teeth which are highly diagnostic at the generic and often specific level - are very abundant in the Maastrichtian of all basins, being represented by at least ten species.

The Maastrichtian crops out widely in both the Oulad Abdoun and Ganntour basins. Whereas it represents a condensed level only a few metres thick and mainly Late Maastrichtian in age in the Oued Zem area (NE Oulad Abdoun basin), it is fully developed in the Ben Guerir area (central Ganntour basin), reaching about 50 metres in thickness and spanning the complete Maastrichtian stage.

On the basis of a large and representative sample of fossils, here we provide a comparative study of the biostratigraphical ranges of mosasaurid species in the Maastrichtian of the Oulad Abdoun and Ganntour basins. The main conclusions of this study are:

a) The mosasaurid faunal association of the Oulad Abdoun Basin is very similar to that of the Ganntour Basin.

b) Most mosasaurid species are known during the whole Maastrichtian stage.

c) The mosasaurid faunal association is considered typical of the southern margin of the Tethys and clearly differs from the contemporaneous association from the northern margin.

d) Paleobiogeographical differences observed between the assemblages of the northern and southern margins of the Tethys cannot be attributed to diachronism and are rather interpreted as revealing the occurrence of several faunal subprovinces, probably linked to palaeolatitudinal gradients.

L'apport des foraminifères planctoniques à la biochronologie et à la corrélation des bassins néogènes du Maroc septentrional

Nadia Barhoun, Haddou Achnin, Mohamed Zakaria Yousfi, Nezha Belamar

La qualité, la continuité et la richesse en foraminifères planctoniques des bassins néogènes du Maroc septentrional offrent un matériel précieux pour une étude micropaléontologique et biostratigraphique. Près de 80 espèces appartenant à 10 genres de Globigerinacea ont été recensées dans ces sédiments néogènes (Feinberg, 1986; Wernli, 1988 ; Barhoun, 1991). Les études biostratigraphiques, par ces micro-organismres, menées sur la série néogène marocaine ont permis de réaliser un découpage zonal des coupes étudiées, en utilisant principalement les niveaux (datum) d'extinction et d'apparition des marqueurs biostratigraphiques. Douze zones et sous-zones ont été identifiées et caractérisées par Wernli (1988) dans le Néogène post-nappes du Maroc septentrional.

Néanmoins, la précision apportée par cette biozonation était insuffisante pour l'établissement de corrélation entre le domaine atlantique et le domaine méditerranéen au Maroc. L'apparition de travaux de stratigraphie à haute résolution réalisés sur les bassins néogènes de Méditerranée et de l'Atlantique adjacent (Sierro *et al.*, 1993 ; Hilgen *et al.*, 1995; Krijgsman *et al.*, 1995) a incité les spécialistes du Néogène marocain à entreprendre des études biostratigraphiques en utilisant ces nouvelles méthodes. Ces dernières sont basées principalement sur la mise en évidence d'événements biostratigraphiques calibrés directement sur l'échelle magnétostratigraphique et l'échelle du temps astronomique.

Une synthèse de ces travaux récents (Rakic El Bied & Benson (1996) ; Krijgsman *et al.*, 1999 ; Barhoun ; 2000 ; Barhoun *et al.* 1999 a,b, 2006; Dayja, 2002 ; Dayja *et al.*, 2005 ; Van Assen *et al.*, 2006) ont permis de repérer 14 événements biostratigraphiques, corrélés sur l'échelle de polarité géomagnétique et efficace pour dater les sédiments tortoniens, messiniens et pliocènes et pour caractériser la limite Tortonien – Messinien et la base du Pliocène inférieur. Cette stratigraphie représente une nouvelle orientation de la recherche sur le Néogène marocain. Elle a permis d'établir des biocorrélations à haute résolution entre les différentes séries néogènes marocaines et de replacer les bassins néogènes marocains dans le cadre de l'échelle événementielle établie au cours de la dernière décennie sur le pourtour méditerranéen et la façade atlantique. Elle a fourni également un cadre stratigraphique suffisamment précis pour pouvoir identifier les événements intervenant dans la crise de salinité messinienne.

Biostratigraphie des bassins méditerranéens marocains au Miocène supérieur par les foraminifères planctoniques

Nadia Barhoun, Achnin Haddou, Mohamed Zakaria Yousfi, Nezha Belamar

Les bassins sédimentaires méditerranéens du Maroc nord oriental (bassins de Boudinar et de Mellilia-Nador) situés dans la partie orientale du corridor sud rifain, ont enregistrés les différents événements ayant précédés la crise de salinité messinienne. La sédimentation du Miocène supérieur est généralement détritique dans le bassin de Boudinar; seule une courte phase essentiellement carbonatée a marqué la sédimentation au cours de cette période. Alors que le remplissage sédimentaire du bassin de Melillia – Nador au Miocène supérieur se compose d'une série marine peu profonde, évoluant latéralement à un complexe de plate forme carbonatée marginale. Dans les deux bassins, la cyclicité lithologique, représentée par les alternances marno-diatomitiques, constituait une composante principale de la sédimentation messinienne.

L'objectif de ce travail est de contribuer, à partir des foraminifères planctoniques, à la réalisation d'un cadre chronologique précis pour les sédiments marins du Miocène supérieur dans les bassins méditerranéens marocains (bassins de Boudinar et de Melillia – Nador) et d'établir des corrélations avec d'autres bassins méditerranéens.

L'étude biostratigraphique basée sur les foraminifères planctoniques permet de mettre en évidence des bio-événements, qui sont calibrés directement sur l'échelle magnétostratigraphique et l'échelle du temps astronomique (Hilgen *et al.*, 1995, 2000 ; Hilgen et Krijgsman, 1999 ; Sierro *et al.*, 2001), de dater avec précision les sédiments du Miocène supérieur et d'établir des corrélations à haute résolution entre les différents bassins méditerranéens et extra-méditerranéens. L'analyse détaillée des assemblages de foraminifères planctoniques a permis d'identifier la succession de neuf bio-événements :

- cinq dans le Tortonien supérieur et le Messinien pré-évaporitique du bassin de Boudinar ;
- quatre dans le Messinien pré-évaporitique du bassin de Melillia – Nador.

Ces événements biostratigraphiques avaient déjà été reconnus par Sierro *et al.* (2001) dans la section de référence du Messinien 'Abad composite' en Espagne. Ainsi, cette succession de bio-événements permet de déduire que la série des alternances marno-diatomitiques du bassin de Boudinar représente la base de celle du bassin de Melillia – Nador. La corrélation entre les différentes coupes géologiques appartenant aux deux bassins permet de déduire une coupe synthétique relativement comparable à la coupe de référence (Abad composite) du Messinien méditerranéen.

The Coniacian-early Santonian depositional sequence in the Iberian basin (Spain): stratigraphic and palaeontological frameworks

Fernando Barroso-Barcenilla, José Francisco García-Hidalgo, Javier Gil, Manuel Segura

The Iberian Basin was a long and narrow intracratonic trough that during the Late Cretaceous comprised the N, central and SE regions of the Iberian Subplate, being located between the Hesperian and the Ebro massifs. This interval represented a phase of thermal subsidence with the development of a single, shallow, and relatively uniform basin, lacking evidences of significant local tectonic activity. Its privileged palaeogeographic location and the opening of the Biscay Gulf favored that the Iberian Basin was temporally or permanently flooded by the Protoatlantic Ocean (from N), the Tethys Sea (from SE) or both of them, at different intervals of the Late Cretaceous. The depositional framework of the Late Cretaceous in the Iberian Basin shows several 3rd order sequences with a similar palaeogeographic pattern, inner carbonate platform facies in the central area and siliciclastic facies in the coastal margin of the basin. Two of these 3rd order depositional sequences, however, are notably different, showing open platform facies in wide areas of the basin, including the coastal margin, and are related to the globally recognized Late Cenomanian-Early Turonian and Late Coniacian-Early Santonian eustatic peaks.

The second of these two main 3rd order sequences, here named DS-2, is a fine example of a symmetric, retrogradational and progradational depositional event, with facies and faunas of both open and shallow platform environments. DS-2 is a sedimentary wedge prism with thicknesses ranging from 90 m in the platform central areas of the basin (N) to 20 m in the coastal margin areas (SE). From N to SE, it consists in nodular limestones, fossiliferous marls and bioclastic limestones of the Hortezuelos Formation, and green marls and thin-bedded dolostones of the Alarcón Formation. Sedimentary succession of the nine sections studied shows three main lithosomes in the Hortezuelos Formation: A lower calcareous lithosome (L1), consisting of nodular micritic limestones, fossiliferous and intensely burrowed, with thin marly levels and clayey joints at the base, showing a thickening-upwards trend. It can be interpreted as a carbonate transgressive platform (early TST), and is especially well-developed in the N sections of the basin. An intermediate marly lithosome (L2), consisting of fossiliferous grey marls and calcareous mudstones, with a thickness that progressively decreases southwards. It can be interpreted as a marly transgressive open platform (late TST, containing the mfs), having remarkable thickness in the N and central sections of the basin. An upper calcareous lithosome (L3), consisting of thick and poorly-bedded nodular limestones and bioclastic and/or oolitic limestones at top, showing a very distinctive morphological expression. Thickness of this upper lithosome increases southwards reaching over 50 m. It can be interpreted as originated by the development and progradation of a shallow carbonate (shoal and related restricted lagoon environments) within the HST, and is especially well-developed in the central sections of the basin. The Alarcón Formation can be

regarded as another main lithosome (L4), consisting of thin-bedded dolostones with ripples, wavy and flaser beddings, algae laminations and ferruginous surfaces, and green marls and thin-bedded red dolostones or dolomitized breccias of pedogenetic nature. It can be interpreted as a muddy intertidal-supratidal coastal plain with a regressive trend within the HST, being the only deposits of the sequence in the S sections of the basin.

Analyzing the palaeontological content of DS-2, four main fossil assemblages can be distinguished. The first assemblage (A1), which can be identified in L1, is dominated by Middle Coniacian ammonites. These cephalopods are scarce and represented mainly by ornamented platycones, especially by *Tissotiodes hispanicus* and *Prionocycloceras iberiense*. The second assemblage (A2), which can be observed in L2, is dominated by Upper Coniacian ammonites. These cephalopods are abundant and characterized mostly by smooth oxycones, principally by *Tissotia* sp., *Hemitissotia celtiberica* and *Hemitissotia turzoi*. Comparing the morphology of the ammonites of these two assemblages, a clear change from platycones (*Tissotioides* and *Prionocycloceras*) to oxycones (*Tissotia* and *Hemitissotia*) can be observed. This gradual substitution by more hydrodynamic and less ornamented forms suggests a continuous adaptation to the progressively deeper environments of L2. The third assemblage (A3), which can be identified in the S sections of L3, is dominated by rudists, usually attributed to the Upper Coniacian. It consists of the best and well-exposed rudist lithosomes known in the Iberian Basin, whose quality of preservation has allowed to redefine species to global scale. These lithosomes show both open and densely packed autochthonous fabrics, parautochthonous fabrics and bioclastic levels of reworked fragments with floatstones to rudstones textures. Their fabrics and textures correspond to both matrix-supported cluster and segment reefs and, even, skeleton-supported frame reefs, according to the structural categories of organic reefs. These lithosomes contain, from N to SE, mono- and paucispecific associations with *Biradiolites canaliculatus*, *Biradiolites angulosus*, *Praeradiolites requieni*, *Radiolites sauvagesi*, *Apricardia* sp., *Hippurites incisus*, *Vaccinites giganteus* and *Vaccinites moulinsi*, and monospecific associations of *Bournonia gardonica*. Finally, the fourth assemblage (A4), which can be observed in the N sections of L3, is dominated by ammonites, generally attributed to the Lower Santonian. These cephalopods are scarce and represented mainly by intermediate morphologies between platycones and oxycones (such as *Placenticeras* and *Eulophoceras* or *Pseudoeschoenbachia*).

Recent advances on the Permian-Triassic boundary studies

Aymon Baud

Recent advances on the Permian-Triassic boundary studies and improvements concern mainly:

- The Late Permian and Early Triassic timescale and the timing and tempo of extinction and recovery events within this interval (Galfetti *et al.*, 2007), as the timing and extent of the eruption of the Siberian Traps (Reichow *et al.*, 2009);
- The biochronology of conodonts (Chen *et al.* 2009);
- A cyanobacterial bloom and the widespread occurrence of microbialites interpreted as anachronistic facies or considered as a return to paleoenvironmental conditions typical of the Late Proterozoic or Early Phanerozoic (Baud *et al.*, 2007, Kershaw *et al.*, 2009;
- A detailed examination of the carbon isotopic excursions (Kaiho *et al.*, 2009, Richoz et al, 2010);
- A quick changes of the shallow marine environments from carbonate under saturated to oversaturated, from submarine erosion to seafloor fan depositions (Payne et al, 2007 and discussion, in Payne *et al.*, 2009, Collin *et al.*, 2009);
- The precise correlations between marine and continental environments (cf. Peng & Shi. 2009);

- New geochemical tools for paleoenvironmental interpretations;

Recent studies concern mainly South China with numerous papers on the Meishan stratotype (ref. in Cao & Zengh, 2009) and examination of detailed traverse from continental to shallow marine and deep-water environments. Himalaya (Tulong, Brühwiler *et al.*, 2009) have been subject to detailed works as Zagros (Kuh e Surmeh, Insalaco *et al.*, 2006), Central Iran (Abadeh, Shahreza, Richoz et al, 2010) and NW Iran (Zal, Julfa).

Leading the two field workshops of IGC 572 Program, we had the opportunity to show recent advances on Permian-Triassic Boundary profiles in South Turkey (Curuk dag, Demirtas et Oznurtepe, Crasquin *et al.*, 2009) and in the Sultanate of Oman (sections of Saiq Plateau, Wadi Wasit, Wasit block, Buday'ah and Wadi Maqam, Baud & Bernecker, ed., 2010). In the Dolomites (N. Italy) the Bulla section has been proposed as parastratotype of the Meishan section. From Arctic regions new data have been published from Elesmere and Axel Heiberg Islands (Grasby & Beauchamp 2009), Greenland, Norway and Spitzberg (Hounslow *et al.*, 2008, Hochuli *et al.*, in press).

A panorama of these recent researches, new data and hypothesis will be presented.

Continental signature of global events: the Middle Miocene Climatic Optimum recorded in coastal deposits, Digne-Valensole Foreland Basin, SE France

Hugues Bauer, Jean-Jacques Châteauneuf, Isabelle Cojan

The 'Middle Miocene Climatic Optimum' (MMCO) is a thermic maximum reached by the global climate, from 17 to 14.5 Ma, related to a regain of volcanic ridge activity. It is the last warm period of the Earth, which preceded the unrelenting cooling related to the development of the EAIS (East Antarctic Ice Sheet) and then to the Greenland Ice Sheet growth.

Details on the timing and structure of the MMCO were mostly provided through studies on marine sediments. The fact is, stratigraphy is most often too poor in continental settings to study in detail the MMCO record in associated deposits.

The purpose of the study is to report the record of the MMCO in a coastal environment where continental and (restricted) marine influences are interfingered. An integrated study combining palynology, isotope stratigraphy, sequence stratigraphy and clay mineralogy has been conducted along the Middle Miocene continental series of Châteauredon (Digne-Valensole Foreland Basin). Within a very detailed time framework, the MMCO timing and structure has been studied both from a sequence stratigraphy and a climatic point of view.

The Middle Miocene coastal deposits in the Châteauredon area cover 2 third order sequences and at least 8 high frequency sequences. The sequence boundaries are marked by emersion evidences like pedogenesis (paleosols and palustrine facies), associated with high palygorskite or sepiolite content in clay minerals. The MFS are recorded as tidal deposits (tidalites), associated with diversified dinocysts assemblages. As compared with eustatic charts, age and amplitude of the MFS look different. The major MFS recorded in the Châteauredon succession is the Serravallian one, not the globally known MFS of the Langhien, associated with the MMCO.

Evidence for the climate change in the Châteauredon succession is first given by palynological assemblages, which show high megathermic elements content. A classically associated mangrove environment is attested by Avicennia pollens, but curiously, it persisted a long time after the MMCO, up to Early-Middle Serravallian. This suggests that the mangal development was controlled by local environmental conditions, as illustrated by the palaeogeography setting (marine gulf). Other proxies for climatic reconstruction are found within paleosols and clay mineralogy. The former are calcic paleosols, implying contrasted seasons; clay assemblages show high content in smectite, palygorskite and sepiolite. If smectites are probably partly inherited, palygorskite and sepiolite are likely to be primary and so indicate very dry conditions. The high frequency sequences are probably climate-driven and confirm the existence of more rapid climate fluctuation inside the MMCO which were reported from marine deposits.

Finally, the Châteauredon section shows that a global, climate-related event can be recorded in continental/coastal settings, and that even shorter climatic fluctuation are likely to be recorded, despite of the high tectonic control in foreland basins.

Le projet CINERGY pour un forage profond dans le graben de Rennes

Hugues Bauer, Robert Wyns, Michel Leclercq, Eric Palvadeau, François Guillocheau

Implications géodynamiques de la nature du remplissage et potentiels géothermique et hydrogéologique.

Le projet CINERGY (Connaissance de la géologIe profoNde du bassin tErtiaire Rennais, à visée Géothermique et hYdrogéologique) est né d'une problématique scientifique liée à la géodynamique du Massif armoricain et d'un intérêt des acteurs locaux pour le potentiel géologique (eau, chaleur) du bassin tertiaire de Rennes.

Le graben de Rennes fait partie de la famille des petits bassins d'effondrement tertiaires parsemant le Massif Armoricain selon une orientation NNW-SSE. Les campagnes géophysiques du BRGM des années 50 et 60 avaient révélé une anomalie légère particulièrement importante (-8.5 mgal) au droit de ce bassin témoignant d'un remplissage d'environ 500 m. Les étude stratigraphiques ultérieures n'ont pas dépassé les 140 premiers mètres du bassin, atteignant le Stampien (Rupélien), bien que l'Eocène soit connu ailleurs dans le bassin à moindre profondeur. Par comparaison avec le bassin jumeau de Saffré plus au sud, il apparaît que la série de Rennes serait plus condensée. Le bassin de Saffré est rempli de plus de 300 m de dépôts tertiaires, débutant à l'Eocène (Lutétien). Par conséquent, la question de la nature des 350 mètres restants du remplissage du bassin de Rennes a été posée. Une campagne sismique a été lancée en conséquence par le BRGM dans le cadre de GéoFrance 3D/ARMOR2 en 2000. L'image du sous-sol a alors permis de proposer un modèle de remplissage comprenant le Tertiaire mais aussi une série mésozoïque (Jurassique + Crétacé supérieur) reposant sur un socle probablement paléozoïque (Wyns *et al.*, 2002).

Les implications géodynamiques de cette interprétation sont doubles : d'une part, la présence de dépôts mésozoïques confirmerait sans ambigüité l'existence d'une couverture sédimentaire, fût-elle fine, sur le Massif armoricain, vision encore controversée aujourd'hui. D'autre part, la profondeur et la nature du socle permettrait de revoir à la hausse la quantification de la composante verticale de la déformation de grande longueur d'onde (lithosphérique) subie par le Massif armoricain depuis la fin du Crétacé, aujourd'hui estimée à 150 m (Wyns, 1991).

Pour aller plus loin et confirmer ou réviser cette interprétation aux implications géodynamiques majeures, un forage est nécessaire. Le BRGM, via ses services Géologie et Région Bretagne, propose un projet de forage profond dans le bassin, au droit du centre de l'anomalie et proche du profil sismique

(réinterprété pour préparer au mieux le forage), qui sera implanté sur la commune de Chartres-de-Bretagne (sud de Rennes). Le projet, qui doit démarrer cet été, comprend une phase de forage, incluant le carottage en continu de la pile sédimentaire et d'au moins 100 m de socle, assorti de diagraphies, tests hydrogéologiques, échantillonnages de fluides, mesures de température..., qui serviront à la fois pour l'étude géologique mais aussi à l'évaluation de la ressource en eau et en chaleur. Les analyses et l'étude géologique seront partagées entre les partenaires scientifiques du projet (BRGM et Géosciences Rennes).

Ce projet est soutenu financièrement par la commune de Chartres-de-Bretagne, le Conseil Général d'Ille-et-Vilaine, le Conseil Régional de Bretagne, Rennes Métropole, l'Etat, le SMPBR (Syndicat Mixte de Production d'eau du Bassin Rennais), le SMG35 (Syndicat Mixte de Gestion des eaux d'Ille et Vilaine), l'ADEME (Agence De l'Environnement et de la Maîtrise de l'Energie), l'AELB (Agence de l'Eau Loire-Bretagne), l'IAV (Institution d'Aménagement de la Vilaine) et le BRGM (Bureau de Recherches Géologiques et Minières).

Revised geological map of the Bay of Seine

Massinissa Benabdellouahed, Olivier Dugué, Bernadette Tessier, Isabelle Thinon, Pol Guennoc

The Bay of Seine is a specific 'semi-enclosed' area ensuring the transition between the Eastern English Channel and the land areas of the Paris Basin to the South and the Armorican Massif to the Southwest and West.

Many studies have been performed in the 1970's in the Bay of Seine that allowed to establish the geological map of the Mesozoic and Cenozoic substrate, and the map of the drowned incised valley network of the Seine River and its Quaternary infill (Larsonneur, 1971, Groupe Norois, 1972, Auffret and Larsonneur, 1977, Alduc, 1979).

In order to update our knowledge of this specific area, we have acquired about 3 000 km of high quality seismic lines throughout the Bay of Seine during three high-resolution and very-high-resolution seismic surveys performed in 2007 and 2008 (survey BaiSeine07, RV INSU/CNRS Côte d'Aquitaine; Survey SeineTHR, RV INSU/CNRS Côte d'Aquitaine; Survey SeineHR, RV INSU/CNRS Côte de la Manche), In addition, a sampling survey using a 'rock-corer' (cnexo-ville rock catcher) was carried out in 2009 (Survey Carobseine, RV Ifremer/Génavir Thalia) in order to ground-truth seismic data on outcropping geological sites. All these new data, completed with previous results, allow us to propose a revised and more detailed geological map of the Bay of Seine (approximatively 1:100 000 scale).

From these new data and studies a much more precise land-to-sea geological correlation and transition have been established. All the successive Mesozoic formations are mapped with almost the same degree of detail to that known onshore (*i.e.* from West to East, in the Cotentin, Bessin, campagne de Caen, pays d'Auge and pays de Caux). This improvement includes the recognition of some major unconformities that were rarely observed previously offshore.

Structural features (faults and folds) are mapped with much more details. Finally, new features characterizing post-Lutetian formations are pointed out.

Most of the main unconformities known onshore have been recognized thanks to the new seismic data. They include the Osmanville surface (Hettangian/Sinemurian tectonic unconformity), infra Aalenian – Bajocian surfaces (reflecting carbonate to terrigeneous regime changes in relation with the North Sea Basin uplift and the mid-Cimmerian unconformity), the Bénouville surface (Middle/Upper Bathonian in relation with the southward tilting of the Armorican block SE edge), the Lion surface (late Upper Bathonian, transgressive surface), the Blangy surface (Middle/Upper Oxfordian, due to the onset of the Oxfordian tectonic destabilisation of the western edge of the London-Paris Basin), the Villerville surface (early Upper Oxfordian, continuing the Oxfordian tectonic instability with the Late-Cimmerian unconformity).

The new seismic data have allowed imaging into the Mesozoic formations some specific sedimentary features well-known onshore but that were not recognized previously offshore. For example, the different Bathonian carbonate formations, renowned onshore for the exploitation of building stones (*e.g.* Pierre de Caen Fm., Pierre de Creuilly Fm.), have been precisely identified offshore. Sponge reefs described in one of these formations along the Bessin cliffs (Caillasses de la Basse-Écarde Fm., Upper Bathonian) are recognized on seismic lines as mounts of metre-scale amplitude and hectometre-scale wave length. Seismic images of the Ranville Limestone (Calcaire de Ranville Fm., Upper Bathonian) display prograding sedimentary bodies, about 10 m high, a few 100 m long that corresponded probably to progradational shoreface units.

At last, in the northern part, seismic profiles through Cenozoic formations demonstrate the presence of sliding blocks into large-scale trough morphologies. The sliding process is assumed to be submarine, occurring along tectonically induced slopes. A post-Lutetian age has been found for these features. Their formation is thought to be related to the onset of the Pyrenean-Alpine intraplate compressive deformations in the Armorican domain that gave way to the Cenozoic syncline.

The main structural organization of the Bay of Seine is characterized by a general northeastern monoclinal orientation. Three main orientations of faults are found. The main trend is the NE-SW Variscan direction of normal faults dipping NW that separate successive half-grabens. The NW-SE trend (Armorican direction) characterizes SW dipping normal faults observed mainly off the pays d'Auge coast. Finally, the E-W trend corresponds to N dipping normal faults located off the Bessin and 'campagne de Caen' coast. This E-W direction is not well represented in the Bay of Seine area but it becomes the dominant orientation., in the Cenozoic syncline area, at the transition with the Central English Channel,.

The drowned incised valley network of the Seine River is superimposed on this Mesozoic and Cenozoic substrate. Its morphology and infill are described by Benabdellouahed and al. (cf. second abstract in this volume Strati 2010).

Morphology and infill geometry of the Seine River drowned valley (Bay of Seine). Bedrock, tectonic and climato-eustatic controls

Massinissa Benabdellouahed, Olivier Dugué, Bernadette Tessier, Isabelle Thinon, Pol Guennoc, Fabien Paquet, Chantal Bourdillon

In order to update our knowledge of the Bay of Seine, a transition area between the Paris Basin, the Armorican Massif and the Central English Channel, three high-resolution and very-high-resolution seismic surveys (BaiSeine07 survey, RV INSU/CNRS Côte d'Aquitaine; SeineTHR survey, RV INSU/CNRS Côte d'Aquitaine; SeineHR survey, RV INSU/CNRS Côte de la Manche) have been recently performed. The seismic data were completed by sampling with a 'rock-corer' (Carobseine survey, RV Ifremer/Génavir Thalia) in order to determine the geological nature and age of outcropping formations.

The main objectives of this program were to establish a revised and more precised geology (stratigraphy and geological mapping) of the Mesozoic and Cenozoic substratum (cf. Benabdellouahed *et al.*, this volume Strati 2010) and to perform a detailed study of the drowned incised valley network of the Seine River and its Quaternary infill, taking advantage of the very high resolution and high quality of the newly acquired seismic data.

The previous geological map of the Bay of Seine was provided thanks to the studies of Larsonneur (1971) and Groupe Norois (1972), while the pioneer works of Auffret & Larsonneur (1977) and Alduc (1979) provided a reconstruction of the incised offshore paleovalley of the Seine river as well as its connection with the Hurd Deep system in the Central English Channel. These works pointed out the transition between the present-day Seine River valley characterized by meanders incised in the chalk substrate (Late Cretaceous) and a network incised in the Bay of Seine, made of a wide braided system composed of at least two generations of strath terraces, and connected to the north with the Hurd Deep via nested terraces.

From the new VHR seismic data we can re-examine in details this Quaternary braided network of paleovalleys in the Bay of Seine and its connection with the Central English fluvial system.

The main orientation of the network is SE-NW in the Bay of Seine. In the Northern part, where the network incises into the Cenozoic substrate, it turns westwards, *i.e.* towards the Hurd Deep. These two main orientations are directly controlled by the morphostructure of the substratum. *i.e.* the SE-NW cuesta of the Mesozoic substrate in the Bay of Seine and the Cenozoic W-E syncline in the Northern part.

In the syncline, samples collected in the infill of the nested terrace system are Bartonian in age. The infilling units are characterized by the presence of slided blocks into large-scale trough morphologies. The sliding process is assumed to be submarine, occurring along tectonically induced slopes. These post-Lutetian features are thought to be related to the onset of the Pyreneo-alpine

compression that gave way to the Cenozoic syncline and to the partial (?) ablation of the Cenozoic cover.

In the Bay of Seine, the Quaternary network is composed of at least three distinct strath terraces as shown from the VHR seismic data. Seismic facies also suggest quite homogeneous coarse sediments organized as amalgamated sheets, rather indicative of a braided fluvial system. However, from our detailed analysis of seismic data we demonstrate that along an upstream-downstream profile, the second generation terrace evolves from braided to meandering pattern, whereas the third one evolves from braided to anastomosed-like pattern. Such evolutions are attributed to changes in the longitudinal profile or/and sediment supplies in a context of dramatic sea-level fluctuations and climatic changes. The influence of various bedrock lithologies and structures are discussed.

Finally, the spatial distribution of the three terraces highlights a south-westward migration of the fluvial system that could be partly explained by a Quaternary uplift of the Northern Normandy.

Palaeoenvironmental analysis of the Early Triassic red beds in the northern part of Marrakech High Atlas and correlation with adjacent areas

Naima Benaouiss, Abdelilah Tourani, Sylvie Bourquin, Jean Broutin, Georges Gand

The basal conglomerates of the Triassic series in the northern part of Marrakech High Atlas will be studied in terms to reconstruct the paleoenvironments and their spatio-temporal evolution. These conglomerates, recently dated as Early Triassic by chirotherioïd traces in Argana basin, rest unconformably on Permian or Precambrian to Paleozoic strata. This coarser clastic succession is about 0 to 50 m thick; and displays: (1) breccias, microconglomerates and conglomerates with gravel to pebble sized grains, (2) coarse to fine-grained sandstones and (3) siltstones to silty mudstones. The identified facies types and association of facies reveal deposition of the succession in an alluvial fan environment with the development of gravel-sand rich mid fan subenvironments. The fan succession is composed of two climate cycles, separated by paleosol horizons of regional extent and/or aeolian dunes. Cycle I is characterized by matrix-supported gravely debris flows and clast-supported gravely stream flow to sandy, silty and muddy alluvial plain deposits with locally aeolian dunes. The overlying fan expansion cycle II displays clast-supported gravely stream flow, sandy to muddy alluvial plain and aeolian dune deposits. Correlation of the basal conglomerates in the northern part of Marrakech High Atlas and their time equivalent in the adjacent areas will be discussed.

New model for thick Eocene limestone successions in Syrian Arc depressions of the northwest Arabian margin

Chaim Benjamini

The Lower and Middle Eocene of the north Arabian platform region was deposited in relatively deep waters during a time of tectonic quiescence. The most widely distributed lithofacies is pelagic chalk, with chert horizons indicating diagenetic remobilization of siliceous biogenic components. Such chalks are rarely more than 200 m in thickness for the full time interval, and often less where glauconitic horizons indicate condensation.

However, in northeastern Israel and in parts of the Negev (southern Israel) nummulitic limestones of shallow-water origin are interbedded with these chalks, in successions commonly >350 m thick, locally exceeding 1 km. These thick successions commonly accumulate in synclinal depressions on the flanks of anticlinal folds of the Syrian Arc system. For this reason the origin of the nummulitic facies has been considered to be shallow-water carbonate platform facies developed on anticlinal crests, interfingering with the pelagic chalk facies deposited in synclinal basins. An Eocene phase of tectonic uplift of the Syrian Arc synsedimentary to deposition of the nummulitic facies, has been inferred, as larger foraminiferal facies are absent in underlying Late Cretaceous or Paleocene deposits in the same localities.

Several sedimentary oddities suggest a disconnection between Syrian Arc features and Eocene nummulite-bearing successions:

- Very thick nummulitic limestones form on the slopes only of selected Syrian Arc structures, and not on the flanks of some of the most prominent ones, most notably those from the northern Negev to the Jerusalem hills in central Israel.
- Shallow-water facies often occur asymmetrically on only one structural flank.
- A pelagic chalk facies is always present with or without nummulitic interbeds, in some cases close to the axis of the most prominent structure in the vicinity.
- There is insufficient structural relief between purported anticlinal crest source and the depositional environment on the flank to generate the observed facies range, from foraminiferal sea-grass meadows of the nummulitic facies to the presumably soupy chalk bottom of the fully pelagic facies, with a great variety of interim facies types represented as well.
- Slope failure features such as debris flows, mud flows, calciturbidites, conglomeratized partially-cemented algal limestones, etc commonly make up the nummulitic facies. These sedimentary features accumulate as lower-slope to basinal deposits, not upper-slope features.
- Failure in fully pelagic chalks is also observed.

A model is here proposed that can explain the inordinate thickness of Eocene 'shallow-water' facies without inferring local tectonic uplift, or subsidence.

Biotic components of the outer parts of the carbonate ramp environment, in particular those that form out of reach of the zone of early cementation, are transported basinward; shallow inner ramp biotic zones are not represented. Syrian Arc structural features represent a system that usually must be bypassed, and are irrelevant to the genesis of the nummulitic biota. Some of them form steps, barriers, and occasionally traps for material moving downslope. Evidence for such trapping, *e.g.*, 'fill and spill' at the foot of anticlinal structures on the paleoslope, is found in northern Israel.

The depositional setting for the emplacement of the thick limestones is in fact the outer slope or basin floor at bathyal depths, with the autochthonous setting represented by a variety of chalky lithofacies.

The paleotopographic and underlying structural relief required for this model is not dissimilar to that of the present day Levant margin.

Permian continental paleobiogeography in southeastern Asia: new insights from the area of Luang-Prabang (Laos)

Antoine Bercovici, Sylvie Bourquin, Jean Broutin, Bernard Battail, Jean-Sébastien Steyer

Throughout Permian time, climate evolution generated profound changes in terrestrial-plant ecosystems, starting as early as the Pennsylvanian/Permian boundary in the United States, and propagating progressively to the East within Pangea. The migration of these changes is tracked across the European sedimentary basins, also starting at the Carboniferous/Permian transition and especially later materialized by the change from 'Autunian' to 'Thuringian' type floras in the Middle-Late Permian. However, little effects can be observed on the eastern part of Pangea: it is now established that the nature and preservation conditions of the flora stayed consistent in most parts of the Cathaysian province (such as South China).

In Laos (South-Eastern Asia), late Paleozoic sediments were identified by the early french colonial missions across Indochina (Pavie missions), but little work was undertaken to characterize the sedimentological and stratigraphical context until now. The studied sedimentary outcrops are located on the northern part of the Mekong river near Luang-Prabang, with the following progression from South to North and from the base to the top of the section:

1) Marine limestone containing numerous biostratigraphically significant fossils (corals and fusulinids) indicating a Guadalupian age.

2) A succession of coastal limestone and calcareous sandstone, abruptly changing to dark continental claystone containing numerous plant remains. This flora consists of very well sorted fragments (mostly individual pinnules), indicating transport and maceration before deposition in lagoonal settings. The assemblage displays affinities with middle-Permian Cathaysian floras with the following typical elements: *Sphenopteris taiyuanensis*, *Fascipteris* sp., *Rajahia guizhouensis*, *Lobatannularia* cf. *multifolia*, *Lobatannularia ensifolia*,

Gigantopteris cf. *dictyophylloides* and *Gigantonoclea* sp. The presence of possible *Glossopteris* sp. would indicate a Gondwanan influence as well.

3) Red siltstones which are difficult to observe due to very limited outcrop areas

4) A succession of thick (at least 300m) purple siltstone and sandstone, with variable content of volcaniclastics. The sequential evolution shows an increasing frequency of occurrence for conglomerates and paleosols towards the top of the formation indicating basinal infill. This trend is also associated with the increase in volcaniclastic input. This formation preserve a relatively abundant upper-Permian fauna composed of Gondwanan amphibian and *Dicynodon* cranial elements.

Results from the analysis of the paleontological associations in the Luang-Prabang area suppose that communication with Laurasia existed up to the Late-Permian, allowing for migration of the strictly terrestrial *Dicynodon* fauna from the North. In regards of the paleobotanical data, the plant association sections tend to indicate an intermediate domain where coal-forming floras persisted later in time in comparison to Europe. However, preservation conditions and associated paleoclimatic settings seem to degrade in the upper part of the section represented by the purple claystone formation.

Cenozoic stratigraphy : application to the Molasse Basin, Upper Rhine Graben, Bresse Graben and Limagne Graben

Jean-Pierre Berger

Following the stratigraphic correlation chart for the Cenozoic deposits of the Upper Rhine Graben and Swiss Molasse basin by Berger *et al.* 2005, several papers dealing with Cenozoic stratigraphic correlations have been published, including

- new accepted or proposed GSSP (Danian, Ypresian, Chattian, Tortonian, Plio-Pleistocene redefinition, see references in Int. Comm. on Stratigraphy website)
- new global correlation and calibration (for example between Magnetostratigraphy and Astronomic Time Scale)
- new continental stratigraphic correlation, especially between non-marine biozones, (mammals, charophytes, otolithes) according to Magnetostratigraphy and/or Astronomic Time Scale

We present here a synthesis of these different results in form of 2 correlation charts (one for Paleogene, one for Neogene). These new studies modify the history of sedimentary basins. We present here new litho-bio-chronostratigraphic charts concerning the Swiss and German Molasse basin, as well as the Upper Rhine - , Bresse and Limagne Graben.

These correlations propose a new light on the paleogeographic and geodynamic changes affecting these basins during the Paleogene and Neogene.

A focus will be given on the Paleogene, with the initial phase of the foreland basin (Molasse) as well as the European Continental Rift System (Rhine-Bresse-Limagne), the Oligocene transgressive events and the Oligo-Miocene transition.

A detailed lithostratigraphic subdivision of the Swiss Molasse will be also presented: our model will subdivide the 4 classical groups (UMM = Lower marine Molasse, USM = Lower freshwater Molasse, OMM = Upper marine Molasse, OSM = Upper freshwater Molasse) into several subgroups characterized by a particular situation and/or a succession of facies that can be used in geological maps and legends.

- UMM 1, 2, 3 subdivided by the facies (deep /shallow) and the geodynamic context (subalpine molasse or Jura-URG)
- USM 1, 2, 3, 4, 5 subdivided by the facies (sandstones and marls, conglomerates, freshwater limestones and evaporites…) and partly by their stratigraphic position (Oligocene versus Miocene)
- USM 6 will be proposed for the limnic equivalent of the OMM (very restricted area)
- OMM 1, 2, 3 subdivided by the facies (Luzern versus St Gall formation in the Plateau Molasse + OMM sandstones in the Jura, and red marls type in the Jura)
- OSM 1, 2, 3 (+ ??4, +??5) subdivided by the facies (alpine conglomerates, JuraNagelfluh, freshwater marls & limestones…and or Vogesen sandstones types.

A comparison with the German Molasse stratigraphy and the French part of the Molasse will be also discussed

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A new marine vertebrate fauna from the latest Cretaceous of Quintanilla la Ojada (Burgos, Basque-Cantabrian Region)

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A new shallow marine vertebrate fauna from the latest Cretaceous of Quintanilla la Ojada (Burgos, Spain) is described. The material consists of many isolated teeth and a few fine osteichthyan spines. This suggests the total disarticulation of the individuals, probably as result of an intense selective transport. At least 26 different species, including selachians (lamniform, orectolobiform and carchariniform sharks; rajiform and myliobatiform rays),

osteichthyans (teeth of pycnodontiforms, amiiforms, elopiform and aulopiform teleosts, as well as acanthomorph spines) and marine reptiles (mosasaurids) are represented in Quintanilla la Ojada. Paralbuline and rhombodontid teeth are the most abundant components of the assemblage. The vertebrate-bearing beds of Quintanilla la Ojada are related to a transgressive *lag* at the base of the Valdenoceda Formation (Early to early Late Maastrichtian). The sedimentological features of the fossiliferous beds are consistent with coastal deltaic deposits. The vertebrate association of Quintanilla la Ojada (Villarcayo Syncline) is similar in composition to that discovered in Albaina (Miranda-Treviño Synclinorium), both located in the Basque-Cantabrian Region. The selachian and mosasaurid associations of Quintanilla la Ojada and Albaina are characterized by a mixture of species from the northern (north-European outcrops) and southern (north-African outcrops) margins of the Mediterranean Tethys.

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Modèle 3D et caractérisation des réservoirs du Trias du bassin de Paris. Application à l'évaluation du potentiel géothermique

Anne Bialkowski, Aurélie Colnot, Claire Castagnac, Simon Lopez, Christophe Rigollet, Vincent Bouchot

L'exploitation du réservoir du Dogger dans le bassin de Paris à des fins d'exploitation géothermique est en œuvre depuis le début des années 70 mais le contexte actuel associant les enjeux énergétiques et la réduction des gaz à effet de serre dans le cadre du Grenelle de l'Environnement tendent à relancer l'évaluation du potentiel géothermique en France. L'objectif est d'améliorer la connaissance géologique du bassin afin de développer et d'optimiser l'offre géothermique, notamment en explorant les réservoirs argilo-gréseux du Trias. Ces réservoirs-cibles, plus profonds (2000-3000 m) mais aussi plus chauds (80-150°C), dont les essais dans les années 80 se sont révélés infructueux, méritent d'être mieux compris pour envisager le développement de futurs projets opérationnels de type basse à moyenne température. Ces objectifs s'inscrivent dans le programme de recherche sur les ressources géothermales des réservoirs clastiques en France (CLASTIQ-2), cofinancé par l'ADEME et le BRGM.

Le travail présenté ici a pour objectif de mieux caractériser les réservoirs silicoclastiques à l'échelle régionale pour réduire l'incertitude en vue de l'implantation de forages d'exploration, tout en en associant la proximité de zones fortement urbanisées et un fort potentiel géothermique. Ainsi, la zone d'étude est ciblée à l'Est de la région Ile-de-France, densément peuplée, où les premières évaluations du potentiel géothermique semblent intéressantes.

L'ouest du bassin de Paris a été comblé au cours du Trias par des sédiments silicoclastiques dans des environnements fluviatiles et de plaine côtière. Les campagnes pétrolières entreprises ces dernières décennies ont permis

d'acquérir des données de subsurface (sismique et forages pétroliers) dont de nombreux enregistrements diagraphiques.

Le découpage en stratigraphie séquentielle que nous avons utilisé s'appuie sur les travaux de référence de Bourquin *et al* (1990, 1993), Bourquin et Guillocheau (1996) qui ont permis d'établir un découpage séquentiel du Trias du bassin de Paris (Grès de Donnemarie, Argiles Intermédiaires et Grès de Chaunoy) en réalisant une analyse facio-séquentielle à partir des diagraphies haute résolution. Les séquences de dépôt identifiées font apparaître 5 cycles stratigraphiques mineurs au sein du Trias, jusqu'à 6 unités séquentielles pour les Grès de Donnemarie et de 4 à 8 unités pour les Grès de Chaunoy.

La méthodologie mise en œuvre s'appuie sur la corrélation de séquences de dépôts, définies à partir des enregistrements diagraphiques de 64 forages pétroliers atteignant le Trias ou le socle anté-triasique. Les forages sont assemblés en une vingtaine de transects distribués sur la zone d'étude, qui s'étend sur une superficie de 100 x 120 km, entre Reims, Troyes, Etampes et Beauvais.

Les associations de logs diagraphiques et sédimentologiques disponibles permettent de caractériser des électrofaciès dont l'interprétation traduit 5 environnements de dépôts, depuis le cône alluvial proximal jusque la plaine côtière de type sebkha. Pour un même demi-cycle stratigraphique, une carte paléogéographique a été réalisée par l'interprétation des géologues et une carte similaire a pu être obtenue dans une seconde phase par interpolation des environnements de dépôts précédemment identifiés, à partir du logiciel de modélisation 3D Petrel. Ces cartes apportent des informations nouvelles sur la distribution spatiale et l'évolution temporelle des environnements de cônes alluviaux. Elles apportent également une contrainte supplémentaire dans la propagation spatiale des paramètres pétrophysiques pour chaque réservoir ciblé.

La construction géométrique du modèle géologique 3D du Trias est ancrée sur la base du découpage séquentiel réalisé sur l'ensemble des forages pétroliers étudiés. Ce modèle intègre le schéma structural des failles majeures du bassin de Paris (issues de plusieurs horizons pointés sur les lignes sismiques du bassin de Paris). La base du modèle 3D est délimitée par une surface représentant la base du paléozoïque (grille de points interpolée à partir des forages et de leurs diagraphies atteignant le socle).

L'étape suivante, en cours de réalisation, consiste à construire un modèle 3D renseigné pour chaque maille (1 x 1 km) où le remplissage correspond aux faciès, ainsi qu'aux paramètres pétrophysiques tels que la porosité et la perméabilité. En effet, les forages pétroliers utilisés pour contraindre les géométries des réservoirs disposent tous d'un log pétrophysique qui comporte, entre autres paramètres, la valeur calculée de la porosité à partir des diagraphies. Les valeurs des couples porosité-perméabilité mesurées sur carottes, recueillies dans les rapports de fin de sondages des forages étudiés, nous ont permis de calculer des lois phi-K pour chaque réservoir (Grès de Chaunoy et Grès de Donnemarie). Les simulations stochastiques (conditionnées par les lois Phi-K et les électrofaciès) réalisées dans le modèle 3D permettent de proposer un modèle statique du Trias du bassin de Paris c'est-à-dire une modèle géologique volumique renseigné en faciès, porosité et perméabilité. Ces paramètres permettront en particulier de répondre plus

précisément aux besoins de la géothermie en affinant la méthodologie de calcul du potentiel géothermique réel pour chaque réservoir cible. L'objectif de la réalisation d'un tel modèle géologique est également de mieux comprendre les facteurs qui contrôlent la variabilité des réservoirs argilo-gréseux afin d'améliorer la prédiction de la productivité et de l'injectivité des puits d'exploitation futurs.

Early vertebrates and Middle Palaeozoic biostratigraphy – a summary

Alain R. M. Blieck

Vertebrates (*) are perhaps known as early as the Early Cambrian (Myllokunmingia from the Konservat-Fossil-Lagerstätte of Chengjiang, China), and certainly from the Ordovician (Turner *et al.*, 2004). Their first ossified (armoured) representatives from the Ordovician are mostly of agnathan species, but jawed species (gnathostomes) did already exist. After the end-Ordovician extinction event and the earliest Silurian (Rhuddanian) Talimaa's Gap (Turner *et al.*, 2004), vertebrates made their first important radiation in the Silurian. At that time, they are known in marine environments from very nearshore, restricted (lagoonal) marine environments to offshore, deep marine environments (Schultze, 1999). A Silurian microvertebrate biostratigraphic scale has been defined mostly after data from Laurentia and Baltica; it is based upon agnathan (thelodont) and gnathostome (acanthodian, osteichthyan) microremains (Märss *et al.*, 1995; Märss in Blieck & Turner, 2000). This scale is correlated to the standard conodont zonation.

Vertebrates had a second important series of radiations in the Devonian, with two main peaks of diversification in the Early Devonian and the Frasnian (Late Devonian) (Long, 1993). In the Devonian, they are known in marine environments and in environments of the Old Red Sandstone magnafacies which are still diversely interpreted. The latter are classically thought to be of 'continental' origin, that is, terrestrial and freshwater (*e.g.*, Dineley, 1984); however, critical evaluation of this paradigm leads to consider that most, if not all, Devonian vertebrates were marine and occupied a very wide range of environments from very nearshore to offshore biotopes (*e.g.*, Blieck, 1985; Schultze & Cloutier, 1996; Schultze, 1999; Lelièvre, 2002; Carr & Jackson, 2009). Vertebrates suffered of the two end-Devonian extinction events : armoured agnathans (ostracoderms) became extinct at the Frasnian-Famennian boundary, and armoured gnathostomes (placoderms) at the Devonian-Carboniferous boundary. Several Devonian, macro- and micro-vertebrate biostratigraphic scales have been defined from the Old Red Sandstone Continent (ORSC), East Gondwana and South China; they are based upon agnathan (heterostracan, thelodont, galeaspid) and gnathostome (acanthodian, placoderm, chondrichthyan) remains (refs. in Blieck & Turner, 2000). These scales are correlated to either the conodont zonation, or to the miospore zonation of the ORSC which, in turn, is correlated to the conodont one.

So, Mid-Palaeozoic vertebrates appear to be good biostratigraphic indicators in marine series. They are often the only biostratigraphic markers of the Old Red Sandstones. Where abundant micro- and macro-remains of mostly marine carbonate facies have been collected and analysed (*e.g.* in the Wenlock), they help to define interval biozones of ca. 1 My of duration (Märss in Blieck & Turner, 2000). Otherwise, in the Old Red Sandstones, their interval biozones are of ca. 3 My of duration (Blieck *et al.*, 1995).

(*) Vertebrates are here considered in their classical definition, *i.e.*, excluding conodonts (Turner *et al.*, in press).

Carbonate platform survival during Oceanic Anoxic Event 2, example from Mexico

Brahimsamba Bomou, Thierry Adatte, Karl B. Föllmi, Annie Arnaud-Vanneau, Dominik Fleitmann

Most of published sections, during the Cenomanian-Turonian oceanic anoxic event, has been studied in the Atlantic, western Tethys and Western Interior, where black-shale production was at a maximum (Kerr, 1998). These depositions are the result of an interruption of normal pelagic sediment deposition by several distinct intervals of widespread oceanic anoxia (Schlanger & Jenkyns, 1976; Jenkyns, 1980; Arthur *et al.*, 1990) coinciding with a positive shift in $\delta^{13}C$ isotope excursion. Some authors show a relationship between OAEs and massive volcanic events associated with the emplacement of large igneous provinces (LIPs) and sea floor spreading at mid-ocean ridges (Kuroda *et al.*, 2007; Snow *et al.*, 2005). High metal abundance anomalies recorded in pelagic sections (*e.g.* Pueblo, Colorado) coincide with the massive volcanism that built the Carribean plateau (around 93-94 Ma), associated with the onset of OAE2 (Snow *et al.*, 2005). Several studies show that the onset of the OAE 2 was triggered by a short-lived but significant increase in phosphorus burial (Mort *et al.*, 2007). The bottom waters became anoxic and switched from being a P sink to a P source, sustaining the productivity in a positive feedback loop.

The behaviour of Total Phosphorus (Ptot) and trace metals at larger scale, away from main black-shale depocenters in different paleogeography and paleodepht is still poorly known in particular in shallow carbonate platform of central Mexico.

The Axaxacualco and Baranca el Cañon sections, located at the Guerrero-Morelos carbonate platform in southern Mexico exhibit a fully correlateable $\delta^{13}C$ curves. In the distal part of the carbonate platform at Axaxacualco, the maximum $\delta^{13}C$ positive excursion coincides with oligotrophic carbonate platform environments supported by low concentrations in P and characterized by abundant and diversified benthic microfauna and rudists. The impact of OAE appears may be more significant in the proximal part of the carbonate platform at Barranca, characterized by the deposition of thick laminated microbialites indicative of mesotrophic conditions. The Morelos Carbonate platform with oligotrophic to mesotrophic conditions was persistent throughout the entire OAE2 in Central Mexico despite the proximity of the Carribean Plateau. The

definitive carbonate platform drowning, marked by the deposition of black shales and turbidites, occurs only in the lower Turonian (*P. flexuosum*), well above the end of the $\delta^{13}C$ shift.

New Paleontological and Sedimentological data on the Miocene Basin of Savigné-sur-Lathan / Noyant-sous-le-Lude (Indre-et-Loire / Maine-et-Loire, France)

Élise Bouchet, Cyril Gagnaison, Nathalie Sterbik, Rémi Rateau

General Context:

The basin of Savigné-sur-Lathan /Noyant-sous-le-Lude is located in the extreme South-West of the Paris Basin between Tours (Indre-et-Loire) and Angers (Maine-et-Loire). This region has been a focus of extensive quarrying since the eighteenth century for its marine shelly sands dating from the Miocene. Since this time, several studies in geology and paleontology have been conducted on different subjects encompassing these deposits: the genesis of the shelly sands; the fossils of invertebrates (Bardot, 1980); and marine and continental vertebrates (Ginsburg & Mornand, 1986).

The Basin Geomorphological Situation:

Regional tectonics are characterized by numerous faults and folds oriented NNW-SSE (Charrier *et al.*, 1977). Of these, three major folds stand out: the Esvres syncline running through the villages of Noyant-sous-le-Lude and Savigné-sur-Lathan, this later being delineated by the Graçay anticline to the north and the Ligueil anticline to the south (Charrier *et al.*, 1977). During the Miocene, different deposits were channeled in the morphological groove of the Esvres syncline (Temey, 1996; Bouchet, 2009).

Miocene Facies:

Miocene deposits overlay a Late Oligocene lacustrine limestone. Four Miocene layers are to be found in the shelly sand quarries of Savigné-sur-Lathan/Noyant-sous-le-Lude: Burdigalian fluviatile sands; the Langhian calcarenite also including *Parascutella faujasi* (Defrance, 1827) and *Amphiope bioculata* (Desmoulins, 1935); clayey shelly sands comprising bryozoans such as *Cellepora* sp. and *Retepora* sp. (Langhian to Serravalian); and an *Anadara turonica* (Dujardin, 1837), platy calcarenite (Temey, 1996).

The Basin Sedimentological Context:

During the Burdigalian, rivers coming down from the Massif Central spread widely through Sologne and as far as Anjou-Touraine before heading towards the Parisian Region or the English Channel (Charrier *et al.*, 1977). From Middle to Late Miocene, the region underwent three successive transgressions: Langhian, Langhian to Serravalian and Tortonian. At that time, the 'shelly sands sea' entirely flooded the North of the Loire Basin, according to the structural direction of the Esvres syncline (Ginsburg, 2001; Bouchet, 2009).

Two New Paleontological Sites located near Noyant-sous-le-Lude (La Guimardière and Pelmer):

Between 1998 and 2003, nearly 1500 fossils of Miocene vertebrates were unearthed from the La Guimardière site. Among them, an exceptional fauna was discovered *in situ* in the fluviatile sands from the Burdigalian. Species observed included *Andegameryx andegaviensis* (Ginsburg, 1971); *Ligeromeryx praestans* (Stehlin, 1937); *Procervulus praelucidus* (Obergfell, 1957); *Diaceratherium aurelianense* (Nouel, 1866); *Brachyodus intermedius* (Mayet, 1908) and *Eucricetodon infralacorensis* (Viret, 1930), indicated the MN3a biozone (Fahlbuch, 1991; Bruijn *et al.*, 1992) as well as the A5 sub-biozonation from Aguilar *et al.* (1997), which forms the end of Early Burdigalian (Gagnaison, Gillet & Fucci, 2004).

Between 1980 and 1990 the Pelmer site was investigated by J-P. Hartmann an amateur paleontologist and a series of 3500 vertebrate fossils were found in the marine shelly sands from Middle to Late Miocene. An exceptional fauna of carnivorous land mammals dating from the Langhian-Serravalian (MN4 and MN5 biozones according to Ginsburg & Mornand, 1986) stands out: *Amphicyon* sp.; *Pseudarctos bavaricus* (Schlosser, 1899); *Hemicyon* sp.; *Hemicyon stehlini* (Hürzeler, 1944); *Hemicyon sansaniensis* (Lartet, 1851); *Martes* sp.; *Semigenetta repelini* (Helbing, 1927); *Pseudaelurus lorteti* (Gaillard, 1899); *Pseudaelurus transitorius* (Depéret, 1892); *Prosansanosmilus peregrinus* (Heizmann, Ginsburg & Bulot, 1980).

New Fossils of Vertebrates from the Miocene:

New paleontological material coming from Middle to Late Miocene shelly sands of Savigné-sur-Lathan / Noyant-sous-le-Lude are currently being studied within the IPL-B laboratory: a 'moonfish' (*Orthagoriscus* (*Mola*) *lathanicus* (Gagnaison & Bouilly, 2009)), a 'scorpionfish' (*Prionotus* sp.), a great squamate reptile (Boidae, close to the *Python* (Daudin, 1803) type), two new skulls of *Metaxytherium medium* (Desmarest, 1822) and new dental remains of *Chalicotherium grande* (Lartet, 1851).

1.2 myr obliquity cycles controlled third-order glacioeustatic sequences in Cenozoic icehouse world

Slah Boulila, Bruno Galbrun, Kenneth G. Miller, Michelle A. Kominz, Stephen F. Pekar, James V. Browning, Jacques Laskar, James D. Wright

The New Jersey passive margin (North America) was selected by the Ocean Drilling Program (ODP) as an ideal location to investigate the Cenozoic history of sea-level change because of its rapid sedimentation, tectonic stability, good chronostratigraphic control, and abundant seismic well log and borehole data. The 'New Jersey Sea-Level Transect' was designed as a series of boreholes from the onshore New Jersey Coastal Plain across the continental shelf to the slope and rise, an area sensitive to sea-level fluctuations. In the past decade,

extensive work on the Transect allowed improved sequence stratigraphic resolution. Particularly, the Miocene-Oligocene sequences were the subject of high-resolution studies because of their relatively continuous sedimentation and recovery, with excellent chronostratigraphy and paleo-environment constraints.

Through a comparison between Miocene-Oligocene New Jersey sequences and astronomical cycles, we demonstrate a close correspondance in number and timing between ~1.2-myr obliquity modulation cycles and third-order sequences, suggesting that there could be a causal link between the two. Constraints from oxygen-isotope records highlight the link between 'icehouse' sea-level lowerings, sequence boundaries, and ~1.2 myr obliquity nodes. We suggest that persistent large ice sheets associated with significant glacioeustasy (>>25 m up to 120 m changes) were mainly governed by obliquity induced insolation.

The Permian-Triassic transition and the beginning onset of the Mesozoic sedimentation at the Western peri-Tethyan domain scale

Sylvie Bourquin, Antoine Bercocivi, José Lopez-Gomez, José Bienvenido Diez, Jean Broutin, Ausonio Ronchi, Marc Durand, Alfredo Arche

The aim of this communication is from a review of the Upper Permian to Middle Triassic continental successions of the European basins to reconstruct palaeogeographic maps of the area and to discuss the impact of tectonics, climate and sediment supply on continental sediment preservation.

At the scale of the western European peri-Tethyan basins, the upper Permian is characterized by a general progradational pattern from playa-lake or floodplain environments to fluvial deposits, reflecting either an increase in sediment supply and/or decreased subsidence in the area. The palaeoflora and sedimentary environments suggest warm and semi-arid climate conditions. At the scale of the whole study area, an unconformity (more or less angular) is observed almost everywhere between the Permian and the Triassic deposits, except in the central part of the Germanic Basin. During the Induan, all the intra-belt basins were under erosion and the sediment supply was only preserved in the extra-belt domains: in the northern domain, *i.e.* the central part of the Germanic Basin, under the same climate conditions as during the latest Permian, and in the extreme southern domain, probably in the Tethys Ocean, implying a large amount of detritic components entering the marine waters. The Mesozoic sedimentation began in the early Olenekian; the ephemeral fluvial systems indicate arid climatic conditions during this period. At the top of the Early Triassic, another tectonically induced, more or less angular unconformity is observed (*i.e.* the Hardegsen unconformity, dated as intra-Spathian), especially in the North European basins. This tectonic activity induced new source areas and a new fluvial style with marine influences at the distal part of the systems. During the Anisian and Ladinian, the continental sedimentation was characterized by a retrogradational trend, *i.e* an evolution

from a fluvial system to fluvio-marine environments, attesting to a direct influence of the Tethys Ocean in the southern and northern domains. Both at the end of the Olenekian (Spathian) and during the Anisian, the presence of palaeosols, micro- and macrofloras indicate less arid conditions throughout this domain.

The PETM record in the terrestrial to shallow marine sediments of the Paris Basin: sedimentology and stratigraphy of the Paleocene-Eocene transition at Therdonne, Oise

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During the Paleogene, a brutal and global warming related to a massive release of greenhouse gases enriched in light 12C carbon in the atmosphere-ocean system is characterized by an abrupt negative carbon isotopic excursion (CIE) in the sediments, both marine and terrestrial. The beginning of this Paleocene-Eocene Thermal Maximum (PETM) event corresponds to the Paleocene-Eocene boundary at 55.8 Ma (Aubry *et al.*, 2007). Its first step (onset) occurred rapidly: 10 ka, and the recovery phase to the pre-excursion values was progressive: 150 to 200 ka (Röhl *et al.*, 2000; Sluijs, 2006; Westerhold *et al.*, 2007). In the Paris Basin, it is recorded within the Mortemer Fm of the Sparnacian facies (Aubry *et al.*, 2005); the duration of the latter may have been of 0.8 to 1 Ma and contemporaneous of a regression-transgression phase of the North Sea Basin (hypothetically between the Th5 and Yp3-4 T-R cycles of the Paleogene time scale, Ogg & Ogg compilation after Gradstein *et al.*, 2004).

The aim of this study is to elaborate the stratigraphic framework and to decipher the depositional environments evolution from the Late Paleocene to the Early Eocene in a terrestrial to shallow marine setting at Therdonne (near Beauvais, Oise), a key section from the northwestern part of the Paris Basin, previously known for its vertebrate content (Dutheil *et al.*, 2002).

We have investigated accurate sedimentological, grain size, mineralogical, palynofacies, Rock Eval, biostratigraphic and δ^{13}Corg chemostratigraphic analyses. For these methods, we used data from a 35m deep drilling and from a 20m deep quarry outcrop, both separated by 200m at the 'Butte de Bourguillemont'. Thirteen lithological units have been defined, and important lateral facies evolutions are observed in the basal part of the section, highlighting the complex geometry of the units deposited in littoral to fluvial environments.

On the outcrop, sedimentological observations highlight a succession of marine units, a channel filled by paleosol derived sands, then by coastal sands and

shelly sandstone, then fluvial sandy units, lacustrine limestone and clays with paleosols characterized by kaolinite-smectite mixed-layers previously described in Sparnacian units elsewhere in the Paris Basin (Thiry, 1981; Thiry *et al.*, 2006). Then swamp clays and silts with lignitic beds emphasize the transgression of the North Sea marked here by brackish environments. At the top, fine sands and clay units overlying a hiatus correspond to shallow marine environments and to the Lower Ypresian transgression.

The outcrop succession has been correlated to the drilling's one thanks to lithologic markers such as lignite, sand, clay or carbonate beds, mineralogy and grain size features, and chemostratigraphy. The same units are easily distinguished; the whole deposited in probably less than 1 Ma and contains 2 main hiatuses. A thickness variation is observed between both; it may result from subsidence differences close to the Bray fault and/or to recent weathering processes on the outcrop.

As Therdonne deposits are mainly of silicoclastic origin, with few calcareous beds, a carbon isotopic curve was established from the dispersed organic matter. Total organic content measurement, palynofacies and Rock Eval data help to precise the amount, nature and quality of the organic matter, and the validity of the carbon isotope analyses. The CIE has been clearly identified on more than 20m of the succession, although the onset and recovery phases of the CIE remain to improve. Palynologic analyses of the pollen, spores and dinocysts assemblages were performed in order to constrain the stratigraphic framework, the foraminifera being only reworked from the Upper Cretaceous chalk in few units of the succession. The Apectodinium acme, usually used to define the PETM event in marine settings, is present in the littoral and lagoonal units, and pollens and spore assemblages allow correlation with SP3 and SP4 units of the Cap d'Ailly reference section. Among the pollen, spores and dinocysts, Lower Ypresian markers are present above the upper hiatus of the section. Vegetal and vertebrates fossils among which Upper Thanetian elasmobranch taxa are present in the lower littoral unit of the section.

A correlation of the units defined at Therdonne has been tentatively established with the Cap d'Ailly reference section (Dupuis & Steurbaut, 1987; Dupuis *et al.*, 1998) and Sotteville-sur-Mer sections (Smith *et al.*, 2010). The same evolution is delineated after the Upper Thanetian marine sands, with terrestrial sediments or paleosols along a major hiatus related to a sea level fall. Then at Therdonne coastal sands (reworking a nearby paleosol) and shelly sands are correlated with lignitic lacustrine units at Cap d'Ailly and Sotteville-sur-Mer, those units recording the onset of the CIE. Afterwards the depositional environments are terrestrial at Therdonne and Sotteville-sur-Mer with fluvial and lacustrine sediments with paleosols, then palustrine units, while they become very quickly brackish and marine at Cap d'Ailly. Finally all the NW Paris Basin is lagoonal and records the Apectodinium acme. A fully marine glauconitic unit is deposited at Cap d'Ailly and Sotteville-sur-Mer but absent at Therdonne (gap or erosion?). Then the three successions record a hiatus overlain by the Lower Ypresian marine Sables Fauves Mb.

Further sedimentological investigations of additional sections and drillings should in the future help to refine the lithostratigraphy and paleogeographic evolution reconstruction of the Paleocene-Eocene transition in the Paris and adjacent basins. Constrained by high resolution chemostratigraphic and biostratigraphic data, they would allow deciphering the PETM record in the

Sparnacian facies and considering its impact on landscapes, sediments, soils, aquifers, flora and fauna.

Propriétés réservoirs du Dogger du Bassin de Paris: influence d'intrusions syn-sédimentaires de fluides météoriques, puis de circulations profondes durant l'enfouissement

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À l'Est du Bassin de Paris, les carbonates du Dogger présentent habituellement de faibles porosités et perméabilités, en relation notamment avec une intense cimentation sparitique et d'importants phénomènes de pression-solution (stylolitisation). Il existe néanmoins quelques exceptions à cette tendance : des niveaux réservoirs sont recensés au toit de séquences de dépôt réputées émersives. Pour comprendre ces exceptions, ce travail basé sur une étude pétrophysique, diagénétique et géochimique se propose d'examiner les influences de la diagenèse précoce puis de la diagenèse tardive sur les propriétés réservoirs dans ces carbonates.

Les analyses pétrophysiques ont confirmé les faibles porosités et perméabilités générales de l'Est du Bassin de Paris (f<5% and k<0.5mD). Toutefois, ces analyses pétrophysiques ont mis en exergue la présence de deux niveaux poreux (Niveau Poreux 1 et Niveau Poreux 2) situés dans la partie supérieure du Dogger calcaire. D'une dizaine de mètres d'épaisseur, ces niveaux poreux ont une porosité dépassant 15%. Leur perméabilité est variable, elle est élevée (k=100-700mD) lorsque les niveaux sont macroporeux et correspondent à des grainstones de *shoals* oolitiques, elle est faible (k=0,1-1mD) lorsque les faciès sont boueux (dépôts de lagon protégé) et dominés par de la microporosité inter-cristalline.

Les analyses géochimiques sur les ciments précoces de certaines limites de séquences émersives mettent en évidence une intrusion de fluides météoriques consécutive à des chutes eustatiques. Lors de ces émersions, les eaux météoriques ont été à l'origine d'une lithification et d'une stabilisation minéralogique précoce du sédiment carbonaté. Ces ciments ont probablement rigidifié précocement le contact entre les grains et ont ainsi contribué à limiter la compaction mécanique et la stylolitisation lors de l'enfouissement. De plus, le lessivage par des eaux météoriques sous-saturées en $CaCO_3$ d'un sédiment carbonaté marin en minéralogie instable (aragonaite et/ou HMC *High Magnesium Calcite*) sont souvent responsables de la disparition (ou de la diminution) de ces phases instables au profit de la LMC (*Low Magnesium Calcite*, phase stable). Ces phénomènes de transformations minéralogiques précoces lors des émersions bathoniennes ont probablement favorisé la préservation de la porosité dans ces niveaux durant l'enfouissement.

Par ailleurs, les analyses géochimiques réalisées sur les ciments de blocages formés lors de la diagenèse d'enfouissement montrent qu'ils ont probablement

précipité à partir d'eaux météoriques ayant circulé pendant le Crétacé inférieur, période marquée par d'intenses mouvements géodynamiques sur les bordures du Bassin de Paris. Ces recharges en eaux météoriques durant le Crétacé semblent être à l'origine du développement extensif des sparites de blocage dans l'Est du Bassin de Paris

L'architecture stratigraphique issue de l'étude sédimentologique permet de supposer que celle-ci a joué un rôle sur le positionnement des niveaux poreux au sommet du Dogger. En effet, le modèle stratigraphique montre la présence d'un écran imperméable marneux positionné latéralement aux calcaires du sommet du Dogger. Cet écran marneux a pu perturber ou empêcher les recharges en eaux météoriques, pouvant expliquer le sous-développement des ciments de blocage dans ces niveaux du sommet du Dogger.

L'étude intégrée sédimentologique et diagénétique montre que l'existence des niveaux poreux (NP1 et NP2) semble tributaire d'une histoire sédimento-diagénétique particulière qui peut être résumée en 3 actes :

(1) lithification et stabilisation minéralogique précoce sous des surfaces d'émersion (SB7 et SB8), rendant le sédiment résistant aux phénomènes de compaction et pression-solution ;

(2) faibles recharges météoriques au Crétacé en raison de l'écran latéral formé par les Marnes à Rhynchonelles (Bathonien), empêchant le développement de ciments de blocage dans le sommet du Dogger

(3) faibles recharges hydrothermales et cimentations associées durant l'Oligocène.

Ces 3 facteurs ne se sont conjugués qu'au niveau de NP1 et de NP2, sur une épaisseur cumulée de moins de 20 m, à comparer aux 210 m totalement compactés et/ou cimentés formant le reste du Dogger.

Barremian-Aptian carbonate systems of the eastern Arabian plate. A global sequence stratigraphic reference model

Frans van Buchem

Geological studies covering a wide range of disciplines and analytical tools have been carried out over the last 40 years on the Barremian-Aptian deposits in the Middle East which contain some of the most prolific carbonate reservoirs in the world. With reservoirs becoming more mature, it has become more important to further improve the understanding of their detailed architecture. One way to improve that knowledge is to integrate the existing data in a comprehensive, time-controlled stratigraphic framework. This framework will allow establishing basin-wide correlations, and thus the comparison between reservoirs of fields in different phases of development.

The time framework which is now being elaborated for this interval combines biostratigraphic and chemostratigraphic dating techniques, together with geometrical information from high-resolution 3-D seismic surveys and seismic-

scale outcrops. New data on ammonites and orbitolinids as well as on carbon- and strontium-isotopes from Iran, Oman, Saudi Arabia, the United Arab Emirates and Yemen, have greatly improved the time control and provide regionally consistent dating for the depositional sequences in the Barremian and Aptian. Three second-order sequences have been defined, each composed of third-order sequences. A robust facies pattern has been identified within this sequence stratigraphic framework, providing a predictive tool for the characterization of this reservoir-seal-source system. Basin-wide variations in accommodation and climatically controlled variables, such as wind and current directions, have locally shaped the specific expression of the sedimentary facies and the stratigraphic architecture.

The quality of the time control and the density of the data points make this Barremian-Aptian dataset one of the most detailed and best constrained worldwide. The sequence stratigraphic model and the resulting (relative) sea level curve can consequently be considered as good candidates for a global reference model.

Dinosaurs as biostratigraphic markers: the case of the ' Arkose du Val-de-Saire' (Cotentin, Normandy, France)

Eric Buffetaut

Silicified clastic deposits, including clays, sandstones and conglomerates, often referred to as the 'Arkose du Val-de-Saire', have been known since the 18th century in the northeastern part of the Cotentin peninsula (the area known as Val de Saire), in western Normandy. Because of the lack of fossils, the age of this formation has long been uncertain. During the 19th century, ages ranging from Cambrian (Dalimier, 1861; Bonissent, 1870) to Miocene (Dufrénoy & Elide de Beaumont, 1840) were suggested. Following an initial suggestion by Caumont (1835), Bigot, in 1890, suggested a Late Triassic age on the basis of a possible correlation with continental red clays and sandstones in the same area, which, however, were themselves at that time very poorly dated. This age assignment has been widely accepted, hitherto without any strong palaeontological support.

The recent discovery of dinosaur remains in the Arkose du Val-de-Saire at La Pernelle (Manche), confirming a previous brief report of a large bone from that locality (Graindor & Parent, 1971), provides the first direct biostratigraphic evidence about the age of these continental deposits. The material includes vertebrae, rib fragments and limb elements, among which an incomplete femur. Although fragmentary, this material can be identified as belonging to a large prosauropod-grade sauropodomorph. The straight, craniocaudally compressed femur is reminiscent of the melanorosaurid *Camelotia borealis*, from the Rhaetian of Britain.

Such large prosauropods are known from the Hettangian to the Sinemurian. However, the red beds (Eroudeville Formation) usually correlated with the Arkose du Val-de-Saire are overlain by the Airel Formation, which is considered as late Rhaetian to basal Hettangian on the basis of palynomorphs (and has

also yielded dinosaur remains, belonging to the theropod *Lophostropheus airelensis*). This implies that the dinosaur-bearing arkose cannot be later than Rhaetian. Therefore, the occurrence of a melanorosaurid sauropodomorph in the arkose of La Pernelle shows that this deposit is Late Triassic, probably late Norian to early Rhaetian, in age. This is in good agreement with palynological data (Taugourdeau-Lantz, unpublished) indicating a Late Triassic age for the Eroudeville Formation. These biostratigraphical data generally confirm Bigot's age assignment.

Although dinosaurs are usually not considered as very reliable biostratigraphic markers, the case of the prosauropod from La Pernelle shows that in some stratigraphic contexts they can be useful age indicators, especially in non-marine formations containing no other stratigraphically useful fossils.

Géomorphologie sismique 2D / 3D

Jacqueline Camy-Peyret, Jean-Loup Rubino

La mise à disposition de blocs de données sismiques 3D très haute résolution couvrant de vastes zones géographiques permet désormais de se focaliser sur les environnements de dépôts et d'analyser leur évolution stratigraphique.

C'est une opportunité fantastique dont les interprétateurs doivent à tout prix se saisir, pour enrichir la compréhension de leurs zones d'études quelles qu'elles soient.

Il existe ainsi un lien indissociable entre la géomorphologie sismique et la stratigraphie séquentielle.

Les environnements changent au cours des séquences de dépôts; on peut ainsi accéder aux rêves des géologues celui de visualiser en 3D l'évolution, au cours du temps, des environnements de dépôts. Il devient ainsi possible de caractériser les différences morphologiques des systèmes de dépôts entre les périodes transgressives et régressives aussi bien dans les carbonates que dans les silicoclastiques et surtout de visualiser toutes les structures associées aux périodes de bas niveaux marins, notamment celle des surfaces d'érosion aux caractères très diagnostiques.

La présentation est illustrée par des extraits de notre cours, basé sur l'étude des morphologies sismiques 2D/3D et de leurs analogues actuels.

Ostracods, microfacies and magnetic susceptibility of the lower part of the Givetian in the type-locality

Jean-Georges Casier, Xavier Devleeschouwer, Estelle Petitclerc, Alain Préat

For the study of the lower part of the Givetian in the type-locality at Givet, 292 samples were collected for the sedimentology and magnetic susceptibility (SM), and 90 other for the ostracod study, in the upper part of the Hanonet Fm, in the Trois-Fontaines Fm and in the base of the Terres d'Haurs Fm cropping out at the Mont d'Haurs. The investigated sections, and among them the old Rancennes quarry, are located along the western and southwestern ramparts of an entrenched camp built by Vauban during the XVIIth century.

The upper part of the Hanonet Fm records a mixed silico-carbonate ramp setting. Peloidal silty packstones rich in *Girvanella* and eopteropods are associated with crinoidal packstones-grainstones, and coral and stromatoporoid floatstones-rudstones suggesting mid- and inner ramp palaeoenvironments. These open marine environments were subjected to a high energy regime that destroyed the crinoidal meadows and the bioconstructions with deposition of numerous proximal and distal tempestites. The transition to the overlying lagoonal facies dominated by calcispheres, cyanobacteria and paleosiphonocladales is abrupt and the environment is now very shallow, restricted, intertidal to supratidal, with loferites in slightly evaporitive conditions. These typical microfacies of the Trois-Fontaines Fm characterize a very shallow restricted carbonate platform which will evolve to a mixed ramp with the overlying Terres d'Haurs Fm. In this case the transition is progressive and begins in the upper part of the Trois-Fontaines Fm despite the fact that a well developed shallowing-upward fifth-order cyclicity (three cycle types are recognized) persisted until the top of this formation. The cyclicity is lost in the Terres d'Haurs Fm and the driving parameter for sedimentation is the energy index which was not very high. Algal microflora, (micro)-fauna and sedimentary structures allow to follow the palaeoenvironmental variations. The 5th-order cyclicity in the Trois-Fontaines Fm records also the SM variations and can be used to infer the relative sea level fluctuations. Finally, the Hanonet and Terres d'Haurs formations do not display any organized cyclicity unlike the Trois-Fontaines Fm. The transition of the Hanonet Fm to the Trois-Fontaines Fm records a relative sea level fall (Préat *et al.*, 2007; Mamet & Préat, 2009) followed by an increase with the Terre d'Haurs Fm as suggested by the reappearance of the coral fauna and the echinoderms.

More than 2,000 ostracods were extracted by the hot acetolysis method and 69 species are recognized in the investigated sections. The abundance and diversity of ostracods are extremely variable, linked to the environmental conditions, and the monospecificity is frequent. Only 11 samples collected with one exception all in the Trois-Fontaines Fm, are barren of ostracods. Ostracods belong to the Eifelian Mega-Assemblage and are indicative of shallow marine, semi-restricted and lagoonal environments.

In the upper part of the Hanonet Fm, ostracods are indicative of a calm and well oxygenated environment below fair weather wave-base. Then the

abundance and diversity of ostracods decrease but the Podocopina increase in number of species and specimens. They are indicative of an increase of the water motion. So great is the energy of the environment at the Hanonet Fm / Trois-Fontaines Fm transition, that ostracods are broken or missing. After that the monospecificity prevails, at first during a short time with the genus *Coeloenellina* indicative of semi-restricted environmental conditions, and then in about 40 m with the genus *Herrmannina* (Leperditicopida) indicative of real lagoonal conditions. In this level the absence of ostracods in two series of samples demonstrates the existence of very stressful environments. In the base of the Terres d'Haurs Fm, environments are anew semi-restricted or more generally shallow marine but the water energy is never very high.

Three new species are proposed: the first one belongs to the genus *Cavellina*, the second one to the genus *Parabolbinella*, and the last one is brought closer the genus *Coryellina*.

The MS values range between -2.49×10^{-9} and 2.98×10^{-7} m^3/kg. The SM curve reported along the lithologic column shows 14 magnetic sequences characterized by increasing trends, decreasing trends or constant SM values. In the Hanonet Fm, the values range between 0.2 and 1×10^{-7} m^3/kg. In the base of the Trois-Fontaines Fm the MS value are constant and below 0.2×10^{-7} m^3/kg in massives limestone beds rich in corals and stromatoporoids. The remainig interval of the Trois-Fontaines Fm records a cyclicity of the magnetic signal with high fluctuations of SM values (mean value > 1.0×10^{-7} m^3/kg). A high decrease of the SM is observed at the Trois-Fontaines / Terres d'Haurs transition with mean values close to 0.5×10^{-7} m^3/kg.

A general good correlation is observed between the results obtained by the ostracod study, the sedimentlogical analysis and the SM. Especially, in the Trois-Fontaines Fm, there is a correspondence between the highest SM values, the restricted environments displayed by the sedimentological analysis and the presence of Leperditicopida.

The Rancennes quarry could usefully complete the stratotype of the Terres d'Haurs Fm located along the southwestern ramparts of the Mont d'Haurs entrenched camp because the base of the formation is not visible there.

[VF] Ostracodes, microfaciès et susceptibilité magnétique de la partie inférieure du Givétien dans la localité type

Pour l'étude de la partie inférieure du Givétien dans la localité type de Givet, 292 échantillons ont été récoltés pour la sédimentologique et la susceptibilité magnétique (SM), et 90 autres pour les ostracodes, au sommet de la Formation d'Hanonet, dans la Formation de Trois-Fontaines et à la base de la Formation des Terres d'Haurs exposées au Mont d'Haurs. Les coupes étudiées, dont l'ancienne carrière de Rancennes, sont situées le long des remparts ouest et sud-ouest du camp retranché construit par Vauban au XVIIème siècle.

La partie supérieure de la Fm d'Hanonet montre des faciès de rampe silico-carbonatée médiane et interne (packstones silteux à péloïdes, girvanelles et éoptéropodes) remaniant des bioconstructions à stromatopores et coraux (floatstones et rudstones) et des prairies à crinoïdes (packstones et grainstones). L'environnement est ouvert et soumis à de nombreuses

variations d'énergie à l'origine de la mise en place de tempestites. Le passage aux faciès lagunaires à calcisphères, cyanobactéries et paléosiphonocladales est brutal, et le milieu devient très peu profond, restreint, intertidal à supratidal, avec développement de loférites dans un contexte légèrement évaporant. Ces microfaciès typiques de la Fm de Trois-Fontaines appartiennent à une plate-forme carbonatée restreinte et passent ensuite à une rampe mixte ouverte dans la Fm des Terres d'Haurs. La transition est progressive et s'opère dans la partie supérieure de la Fm de Trois-Fontaines qui conserve néanmoins, jusqu'en son sommet une cyclicité de 5ème ordre de type 'shallowing-upward' (trois catégories de cycles sont identifiées) coiffés de faciès supratidaux et de calcrètes. Cette cyclicité est perdue dans la Fm des Terres d'Haurs, et le paramètre déterminant à l'origine de l'enregistrement de la sédimentation est à nouveau l'index énergétique. La microflore algaire, la microfaune et les structures sédimentaires soulignent les variations de milieux, les cycles de 5ème ordre de la Fm de Trois-Fontaines enregistrent également des variations de la SM qui peuvent être rattachées aux variations relatives du niveau marin. Les formations d'Hanonet et des Terres d'Haurs ne présentent donc pas de cyclicité organisée à la différence de la Fm de Trois-Fontaines. Le passage de la Fm d'Hanonet à celle de Trois-Fontaines enregistre une diminution relative du niveau marin (Préat *et al.*, 2007; Mamet & Préat, 2009) qui est ultérieurement suivie d'une augmentation lors du passage à la Fm des Terres d'Haurs, marquée par un retour des faunes coralliaires et des échinodermes.

Plus de 2.000 ostracodes ont été extraits par acétolyse à chaud, et 69 espèces sont reconnues. Leur abondance et diversité sont extrêmement variables en fonction des conditions environnementales, et la monospécificité prévaut fréquemment. Seuls 11 échantillons n'ont pas fourni d'ostracodes et ils proviennent, à une exception près, de la Fm de Trois-Fontaines. Ces ostracodes appartiennent exclusivement au Mega-Assemblage de l'Eifel, et indiquent des milieux marins peu profonds, semi-restreints et lagunaires.

Dans le sommet de la Fm d'Hanonet, les ostracodes sont représentatifs d'un environnement calme, bien oxygéné sous le niveau d'action des vagues de beau temps, puis leurs abondance et diversité diminuent et ils sont alors remplacés par les Podocopina qui témoignent d'une augmentation de l'agitation du milieu. Au passage des formations d'Hanonet et de Trois-Fontaines, l'énergie du milieu devient telle que les ostracodes sont absents ou brisés. Ensuite la monospécificité prévaut, d'abord un court moment avec le genre *Coeloenellina*, ce qui témoigne de conditions semi-restreintes, puis sur une quarantaine de mètres, avec le genre *Herrmannina* qui appartient aux Leperditicopida. Ces derniers indiquent un environnement franchement lagunaire. Au sein de ce niveau, deux épisodes sont stériles attestant de conditions très défavorables pour ces organismes. À la base de la Fm des Terres d'Haurs, les environnements sont à nouveau semi-restreints ou plus généralement marins francs peu profonds, mais en aucun cas fortement agités.

Trois espèces nouvelles sont instituées: l'une appartient au genre *Cavellina*, une autre au genre *Parabolbinella* et la troisième est rapprochée du genre *Coryellina*.

Les valeurs de SM obtenues évoluent entre $-2{,}49 \times 10^{-9}$ et $2{,}98 \times 10^{-7}$ m^3/kg. La courbe de SM reportée le long de la colonne lithologique indique 14 séquences magnétiques caractérisées par des évolutions croissantes,

décroissantes ou constantes des valeurs de SM. Dans la Fm d'Hanonet, les valeurs sont comprises entre 0,2 et 1 x 10^{-7} m^3/kg. La base de la Fm de Trois-Fontaines montre des valeurs constantes et < 0,2 x 10^{-7} m^3/kg dans les bancs massifs à stromatopores et coraux. Le reste de la Fm de Trois-Fontaines enregistre une cyclicité du signal magnétique avec de fortes fluctuations des valeurs de SM (en moyenne > 1,0 x 10v m^3/kg). Une forte décroissance de la SM est observée au passage à la Fm de Terres d'Haurs caractérisée par des valeurs moyennes proches de 0,5 x 10^{-7} m^3/kg.

Il existe une bonne corrélation entre les résultats obtenus par l'étude des ostracodes, l'analyse sédimentologique et la SM. En particulier, dans la Fm de Trois-Fontaines, il y a correspondance entre les valeurs les plus élevées de SM, les environnements restreints et l'abondance des Leperditicopida.

La carrière de Rancennes pourrait utilement compléter le stratotype de la Fm des Terres d'Haurs situé le long des remparts sud-est du camp retranché du Mont d'Haurs, et qui n'expose pas la base de cette formation.

Comments on Devonian GSSPs and on the Devonian / Carboniferous boundary

Jean-Georges Casier, Alain Préat

The Eifelian / Givetian GSSP is located in the Tafilalt (Morocco), at Djebel Mech Irdane (Morocco). The series composed of dark-gray decimetric limestone beds with numerous hard-grounds is interrupted 10 cm below the boundary by a 40 cm-thick level of grey silty-marl. In this bed, Ellwood *et al.* (2004) have found shocked quartz, Ni, Cr, As, V and Co anomalies, a large negative $\delta^{13}C$ shift and microspherules indicative of a bolid impact. The ostracod study has not demonstrated an abnormal biological extinction in this level (Casier *et al.*, 2010). On the contrary, the entry of several species in the upper part of this level is the outstanding fact. But the most important problem is the position of the base of the Givetian in the Givet type-locality. *Icriodus obliquimarginatus* defining a zone of the alternative conodont zonation based on *Icriodus* has been collected in the Hanonet Fm by P. Bultynck (1987), 4 m below the base of the Givet Group. But this author estimated that it is certainly not the earliest record for the type-region because at Wellin, 24 km east of Givet, *Icriodus obliquimarginatus* occurs 18 m below. Moreover in the La Couvinoise quarry at Couvin, 25 km west of Givet, the *hemiansatus* Zone defining the base of the Givetian in the standard zonation (SDS, Rennes, 1988) is recorded in the Hanonet Fm a few dozens of meters below the base of the Givet Group (Bultynck & Hollevoet, 1999).

The Givetian / Frasnian GSSP is located at Puech de la Suque (Montagne Noire, France). The ostracods, largely dominated by Podocopina instars, indicate that most of beds are related to storm deposition in this section. The sedimentological analysis specifies intermediate and distal storm deposits and reveals in addition the presence of numerous hardgrounds highlighting an important condensation of the sequence. The ostracod study and the sedimentological analysis document that the G/F boundary corresponds to the beginning of a sea-level rise. In the type-region for the Frasnian Stage, this

boundary should be close the Givet Group / Frasnes Group boundary, or even in the upper part of the former, and consequently well below the boundary designed at Nismes by the SDS (Casier & Préat, 2009). This section chosen in 1986 as an auxiliary stratotype for the G/F boundary in neritic facies is still in debate (Klapper, 2000).

The Frasnian/ Famennian GSSP is located in the upper Coumiac quarry (Montagne Noire, France). The section is highly condensed with numerous hardgrounds well visible from thin sections under the microscope and the F/F boundary has been even placed in a thin millimetric hardground which corresponds to an undetermined time gap! As a consequence the correlations with sections located in shallow setting are difficult. Where is located the Frasnian and Famennian boundary in the type-region (Southern border of the Dinant Synclinorium) for these two stages? Close to the first record of *Palmatolepis triangularis*? Below, where the macrofauna recover from the Late Frasnian Event (= historic boundary of Gosselet, 1877)? Or again below where the benthic ostracods recovered or even at a minimum 6 m below the first occurence of *Palmatolepis triangularis* where the Entomozoid ostracods recovered from the Late Frasnian Event? This point is fixed about 2.5 m above the last occurrence of *Palmatolepis linguiformis*. The F/ F GSSP is far from being ideal.

The Devonian / Carboniferous GSSP is located at La Serre (Montagne Noire, France). Recently Kaiser *et al.* (2007) have recorded *Siphonodella sulcata* defining the base of the Carboniferous, below this limit, and that requires a re-positioning of the GSSP. A working group has been constituted by the SDS in order to found a solution to this problem. The ostracod study and a sedimentological analysis (Casier & Préat, 2007) show the presence of a tectonic discontinuity very close to the bed where the first Siphonodella sulcata have been collected, and also an important reworking (numerous microbreccia) of the fauna. The choice of a new reference section should be more judicious.

In conclusion, despite important progress, the biostratigraphy can not fixed with enough precision the stage boundaries. Other disciplines are requisite (chemical indicators, magnetism, ...) in order to restrict especially the diachronism inherent in sedimentary series.

[VF] Commentaires à propos des GSSP dévoniens et de la limite Dévonien / Carbonifère

Le GSSP de la limite Eifélien/Givétien a été fixé dans le Tafilalt (Maroc), au Djebel Mech Irdane. La série constituée d'un ensemble de bancs décimétriques de calcaires gris-noir, présente de nombreux hardgrounds, et elle est interrompue, 10 cm sous la limite, par un niveau de marne silteuse grisâtre. C'est dans ce niveau qu'Ellwood *et al.* (2004) ont signalé des quartz choqués, de fortes anomalies en Ni, Cr, As, V et Co, une importante anomalie négative du $\delta^{13}C$ et la présence de microsphérules qu'ils ont attribués à l'impact d'une météorite. L'étude détaillée des ostracodes n'a pas permis de mettre en évidence un taux anormal d'extinction biologique à ce niveau (Casier *et al.*, 2010). Au contraire, c'est plutôt l'apparition de plusieurs espèces dans la partie supérieure du niveau qui est le fait marquant. Mais ce qui pose problème, c'est la fixation de la base du Givétien dans la localité-type de Givet. L'espèce de conodonte *Icriodus obliquimarginatus* qui caractérise une zone de la zonation

alternative basée sur les *Icriodus* y a été récoltée dans la Fm d'Hanonet par P. Bultynck (1987), 4 m sous la base du Groupe de Givet. Mais celui-ci estime que ce n'est certainement pas la première occurrence de cette espèce dans la région-type parce qu' à Wellin, 24 km à l'est de Givet, elle apparaît 18 m plus bas. À noter aussi que 25 km à l'ouest de Givet, dans la carrière La Couvinoise, à Couvin, la Zone à *hemansiatus* qui définit la base du Givétien dans la zonation standard (SDS meeting, Rennes, 1988) est reconnue dans la Fm d'Hanonet plusieurs dizaines de mètres sous la base du Groupe de Givet (Bultynck & Hollevoet, 1999).

Le GSSP de la limite Givétien/Frasnien est situé au Puech de la Suque (Montagne Noire, France). L'étude des ostracodes, représentés quasi exclusivement par des formes larvaires de Podocopina, montre que cette coupe est constituée principalement de tempestites. L'analyse sédimentologique précise qu'il s'agit de tempestites distales et intermédiaires et révèle en outre de nombreux hardgrounds soulignant une importante condensation des couches. L'étude des ostracodes et la sédimentologie montrent finalement que la limite G/F est située à la base d'un épisode transgressif. Dans la région-type de l'étage Frasnien, au bord sud du Synclinorium de Dinant, cette limite devrait donc être proche de la limite des Groupes de Givet et de Frasnes, voire même dans le sommet du premier, contrairement à ce que laisserait supposer la limite retenue à Nismes par la SDS, en 1986 (Casier & Préat, 2009a). Celle-ci choisie pour les milieux néritiques est actuellement controversée (Klapper, 2000).

Le GSSP de la limite Frasnien/Famennien est situé dans la carrière haute de Coumiac (Montagne Noire, France). La coupe y est très condensée, avec de nombreux hardgrounds (bien visibles en microscopie), et la limite F/F est même fixée au niveau d'un hardground correspondant à un arrêt de sédimentation dont on ne peut apprécier la durée. Les corrélations sont par conséquent difficiles à établir avec les milieux peu profonds. Ainsi, dans la région-type des étages Frasnien et Famennien (bord sud du Synclinorium de Dinant), faut-il placer la limite F/F à la première apparition de *Palmatolepis triangularis*? ou bien plus bas, là où s'opère le renouvellement de la macrofaune liée à l'extinction de la fin du Frasnien (limite de Gosselet, 1877)? Ou encore plus bas, là où réapparaissent les ostracodes benthiques?, ou même 6 m en-dessous, avec le renouvellement des ostracodes entomozoidés? Ce dernier niveau est situé environ 2,5 m au-dessus de la dernière occurrence connue de *Palmatolepis linguiformis*. Ce GSSP est donc loin d'être satisfaisant.

Le GSSP de la limite Dévonien / Carbonifère est situé à La Serre (Montagne Noire, France). Récemment Kaiser *et al.* (2007) ont signalé la présence de *Siphonodella sulcata* sous cette limite, et cela nécessite donc une révision de ce GSSP. Un groupe de travail a été constitué par la SDS pour régler ce problème. L'étude des ostracodes couplée à une analyse sédimentologique détaillée (Casier, J.-G. & Préat, A., 2007), montre la présence d'une discontinuité tectonique à proximité immédiate du banc dans lequel apparaît les premières *Siphonodella sulcata*, de même qu'un remaniement important (microbrèches abondantes) de toute la faune au niveau de la limite D/C. Le choix d'une nouvelle coupe de référence serait donc le plus judicieux.

En conclusion, malgré des progrès importants, la biostratigraphie ne suffit pas à fixer de manière suffisamment précise les limites d'étages. Il faudra y ajouter les données d'autres disciplines (marqueurs chimiques, magnétisme,

etc.) afin notamment de restreindre au maximum les diachronismes inhérents aux séries sédimentaires.

Permian and Triassic stratigraphy from selected continental regions of southwestern Europe, and geodynamic implications

Giuseppe Cassinis, Cesare Perotti, Ausonio Ronchi

Permian and Triassic continental deposits of SW Europe (Mediterranean domain) are representative of many geological events suitable for comparison and correlation. We emphasise herewith, region by region, the respective features drawn up from our investigations.

The Permian of the Southern Alps is characterised by two main and well differentiated tectonosedimentary cycles, separated by a regional unconformity which marks a gap of as-yet imprecise duration. The Lower Cycle, > 2 km thick, consists of calc-alkaline, acidic-to-intermediate volcanic products and alluvial-to-lacustrine sediments, both infilling fault-bounded intracontinental basins, mainly interpreted as strike-slip or pull-apart basins, affected by a transcurrent regime. From palaeontological evidence (macro-microfloral and tetrapod footprints) and isotopic research, this cycle ranges from the Middle Carboniferous (Moscovian) to the Early Permian (Kungurian).

It can be interpreted as a post-Hercynian transform tectonics phase, and was interrupted by a geological event (the so-called 'Mid-Permian Episode'; Deroin & Bonin 2006) which involved widespread areas, with specific tectonic, magmatic, thermal and basinal features, preluding a plate reorganization and opening of the Neotethys ocean.

The Upper Cycle, devoid of igneous rocks, is more widespread but less thick than the lower cycle, and is dominated by an extensional regime linked to crustal thinning. It predominantly consists of the Verrucano Lombardo/Val Gardena Sandstone fluvial red clastics (0–800m thick), in part laterally and upwardly replaced, east of Val d'Adige, by the evaporitic-marine Bellerophon Fm. From continental (macro-microfloras and tetrapod footprints) and marine (foraminifers, algae, brachiopods, etc.) fossils, this cycle is related to the Late Permian. This upper cycle heralds the onset of the Alpine evolution.

In Tuscany, the Mts. Pisani section shows, in ascending order, the alluvial-to-lacustrine S. Lorenzo Schists and the Asciano Breccia, which rests unconformably on the previous formation, of late ?Westphalian–Autunian age. The overlying presence of Permian volcanics has been argued from the discovery of rhyolitic phenoclasts at the base of the Triassic Verrucano. According to Rau *et al.* (1988), the fluvio-deltaic shelf complex of this Group, which also comprises the upper Mt. Serra Quartzites Fm., is dated as ?late Ladinian–Carnian, and is followed by carbonate deposits.

Southern Tuscany shows, in the Mt. Leoni–Farma area, Late Carboniferous and Late Permian/earliest Triassic marine successions, separated by a very

pronounced gap. Above, from ?late Olenekian/Anisian up to the Carnian, the fluvial Verrucano crops out unconformably, capped again by marine sediments.

In contrast with previous interpretations, the Permo–Carboniferous volcanic and sedimentary deposits of the Ligurian Briançonnais have been related only to Permian ages (Dallagiovanna *et al.*, 2009). This dating, based on radioisotopic research, confines the units to Asselian–?Artinskian times. Moreover, the overlying Melogno Porphyroids highlight two distinct dates, of 273 Ma (C lithozone, Kungurian) and 259 Ma (D, Wuchiapingian), both separated by a gap of about 14 Ma, affecting the Middle Permian. Then, through a Late Permian unconformity, occur the Verrucano conglomerates and the Early Triassic quartzites, followed by fine-grained clastic and carbonate deposits.

In Sardinia, the Permian of Nurra consists of few Autunian (pre-late Sakmarian) plant-bearing sediments and volcanics, discordantly overlain by a second sequence mainly of fluvial unfossiliferous red beds. However, the recent discovery at the top (Cala del Vino Fm.), below the Early Triassic 'Conglomerato del Porticciolo', of a large vertebrate-bearing body hypothetically related to an Early–Middle Permian transition, points to the presence of a Mid–Late Permian gap, thus in part coeval with the above-mentioned 'Episode'. The higher Buntsandstein marks the onset of the Alpine cycle, progressively drowned by the marine Muschelkalk.

In southern France, the Toulon-Cuers Basin of SW Provence shows similarities with the Nurra succession, for the Permian proximity of these regions (Cassinis *et al.*, 2003). The most distinct difference, at the top of Les Salettes Fm., is the Bau Rouge Mb., which is partly characterised by fluvio-lacustrine, macro-microfloral bearing sediments of as-yet-uncertain age. Eastwards, in the Bas-Argens and Estérel basins, intense acidic-mafic alkaline volcanism took place, which led to isotopic and geochemical data that are very useful for correlation (such as the attribution of the A7 Rhyolite to 272.5 Ma, *i.e.* to Kungurian). The discovery of abundant fossiliferous key-beds also led to the suggestion of some ages (*e.g.* reference of the Les Pradinaux Fm. to Middle Permian). Upwards follows unconformably the eo-Alpine Buntsandstein, yielding early Anisian palynomorphs.

Westwards, in Languedoc, the Lodève Basin shows a lower cycle, about 700 m thick, with fluvio-deltaic and lacustrine varicoloured formations (Usclas-St Privat, Tuillières-Loiras, Viala), known as the Autunian Group *sensu* Gand *et al.* (1997), which have been related to early Cisuralian (Asselian+Sakmarian) mainly based on macro-microfloras and ichnofaunas. Above, from the late Cisuralian (Artinskian) probably up to the late Guadalupian, lies a succession of ca. 2000 m, marked by a regional unconformity. The lower fluvial Rabejac Fm. evolves to the silty red mudstones and thin playa-lake dolomites of the Salagou Fm., which is topped by the La Lieude Fm. Above, a middle Anisian Buntsandstein, linked to the Alpine cycle, seals a gap possibly of ?Mid–Late Permian to Early Triassic and slightly younger age.

According to Arche and López-Gómez (2006), in the southwestern Iberian Ranges small Early Permian (Autunian) fluvio-lacustrine basins, bearing volcanic rocks, are followed by a second cycle bounded by two angular unconformities. It mainly consists of Late Permian (?late Guadalupian–Wuchiapingian *p.p*) basal conglomerates and red fine-grained clastics, which

announce the Alpine sedimentation. A third cycle includes the Hoz de Gallo Fm. (Changhsingian) and, after an Early Triassic hiatus, the fluvial Cañizar Fm.(?Olenekian–early Anisian), of which the lower part is named the Chequilla Conglomerate (Bourquin *et al.*, 2007), interpreted as a lateral equivalent of the 'Poudingue de Port-Issol' of Provence and Sardinia.

The ?Mid–Late Permian ('Thuringian') to Early Triassic sediments of the Balearic Islands, yielding palynomorph assemblages (Ramos & Doubinger, 1989; Broutin *et al.*, 1992), show quite similar features. As in the Iberian Ranges, the intermediate gap marks the beginning of the eo-Alpine history before the Muscelkalk transgression.

Testing the effectiveness of tetrapod ichnoassociations for the stratigraphy of the continental Permian

Giuseppe Cassinis, Paolo Citton, Umberto Nicosia, Marco Romano, Ausonio Ronchi, Eva Sacchi, Giuseppe Santi

Tetrapod footprints can represent, at least in some cases, useful biochronological tools for the description of the continental Permian sediments and their correlation, and to draw a consistent frame that allow the understanding of the geodynamic evolution at the regional scale. As a matter of fact, the ichnoassociations are frequently the only available stratigraphic tools for the temporal subdivision of the ancient continental sequences and, therefore, it is crucial to evaluate correctly their real value and reliability.

Several authors used Permian tetrapod tracks for stratigraphic purposes, but with different or questionable results (Andreas & Haubold, 1975; Gand, 1987; Boy & Fichter, 1988a; Ceoloni *et al.*, 1988; Conti *et al.*, 1997, 2000). Also, the stratigraphic value of the tetrapod ichnofossils was repeatedly questioned in the literature– *e.g.* on the basis of ecological considerations (Boy & Fichter, 1988b) – by reducing their stratigraphic resolution importance (Gand & Durand, 2006) or by directly denying any stratigraphic value for a resolution finer than half of the Permian (Lucas, 1998b).

Subsequently, the constant composition of some ichnoassociations and their homotaxy, along the sequences cropping out in some basins of the Central and Southern Alps (Avanzini *et al.*, 2001), suggested also the using of tetrapod ichnoassociations with a biochronological meaning, for assessing the stratigraphy of the ichnofaunal units and their ages (Conti *et al.*, 1997). This attempt has been criticized by Lucas (1998a) that considered such subdivision as the result of a casual 'local event'. Later on, the same Author proposed its own subdivision of the continental Permian based on ichnofaunochrons (Lucas, 2006), using in part the same data.

This frame led many authors to suggest different correlation charts of the Permian continental deposits. A simple examination of a number of these correlation schemes is sufficient to highlight the present difficulties. The different opinions were in no cases completely convincing and, thus, we tried to re-check the stratigraphic confidence of the tetrapod footprints, taking into account the main European Permian continental basins.

Methods

In order to obtain a reliable basis, we selected few key taxa and checked their stratigraphic value by a comparison with external calibration elements (isotopic ages and co-occurrence with body fossils), obtaining for each taxon a 'validated occurrence'. The validated occurrence was then compared with their previously assumed vertical distribution; the results were used for subdividing and correlating the rock units in which the footprints and the correlation elements occurred.

Results

The calibration of all these elements allowed to build a plot of indisputable data, some already available in literature, others completely new. Then, the rock units cropping out in many Permian continental basins, were plotted on this scheme using the calibrated taxa as references.

The resulting scheme, that has to be considered 'calibrated', suggests some modifications in the previous basin correlations; it also points out the presence of repeated problems in the consistency of the stratigraphy based on vertebrates in respect to the one based on plant remains.

Holocene and Late Pleistocene relative sea level fluctuations in Cabo Frio island, Rio de Janeiro State - Brazil

João Wagner Castro, Kenitiro Suguio

The small Cabo Frio island, Rio de Janeiro State, southeast Brazil show four bodies of beachrocks, emerged up to +1.5 m and submerged down to - 4.5 m. These bodies are constituted of discontinuous strips, parallel to the coastline. Beachrock is beach sediment that has been cemented within the intertidal zone. Like the beach itself, it represents a transition between the marine and meteoric environments, where it is commonly elected by processes from each. Because beachrock is lithified within the intertidal zone and because it commonly forms in a few years, its potential as an indicator of past sea level is important. 10 beachrocks samples were analyzed by polarizing microscope and SEM. This study indicated that carbonate elements that constitute most of the samples were at least partly incorporated within the intertidal zone. The adequate method for radiocarbon dating (total sample or cement) was decided according to these observations. The dates obtained from Cabo Frio island beachrocks indicate 4 separate sea level stands: the first one at about + 1.5 m around 13.000 BC, the second one at about 0.0 around 12.500 BC, the third at about - 3.0 m around 11.000 BC and finally the fourth sea level at about - 4.5 m around 10.000 BC. The results suggests that between 13.000 to 10.000 yr BP, a sea level fluctuation was around 5.5 m, corresponding probably to negative fluctuation of - 4.5 m and positive fluctuation of + 1.5 m. On the coast of Rio de Janeiro State, Brazil several relative sea level positions are recognized. The more important was the Malhada mash to the north area, a great marine transgression around 5000 BC. Our southern Brazil coastline observations reveal a dynamic tectonic regime, mainly subsidence to the west

and uplift to the east at the transition Holocene and Late Pleistocene. The comparison of the results obtained from Cabo Frio island indicates a tectonic subsidence between 13.000 to 10.000 years BC in the area this study.

Palynology and stratigraphy of Paris basin Stampian: correlation with Tongrian and Rupelian stages of Belgian and North Sea

Jean-Jacques Chateauneuf

The Paris basin Stampian as defined by A. d'Orbigny (1852) comprises epicontinental deposits which are rich in mollusks but generally exempt from planctonic faunas enabling accurate inter-basins correlations.

A preliminary zonation on the base of dinoflagellate cysts record (dinocysts) and pollen grains was carried out in the 1970s (Châteauneuf and Gruas-Cavagnetto 1978) and 1980s (Châteauneuf 1980) from quarries and boreholes sections spanning Sannoisian stage and Fontainebleau sands formation.

The Etampes limestone overlaying this last formation is up to now barren of palynomorphs.

From this time dinocysts stratigraphy has greatly progressed particularly in the North European basins. So we have decided to revisit and refine interpretations of the Stampian palynological content in the light of Tongrian and Rupelian biozonations whose mixed marine and epicontinental microfloras are calibrated on international chronozones.

Thus the Stampian Formations from the lowermost Argiles vertes de Romainville (Sannoisian) to the top of Fontainebleau Sands was divided into 7 dinocysts zones corresponding respectively to NSO2 to NSO4 zones (Van Simaeys *Et al.*2005) and D13 to D14na zones (A. Koethe 2005).

We consequently propose correlations of this Stampian interval with those coeval defined in Belgian stages.

So the Sannoisian formations are equated with Ruisbroek sands whereas Fontainebleau sands are equivalent to Berg-Walsele sands, Terhagen and early Putte members.

The position in the Paris Basin of the Eocene-Oligocene boundary as defined from Priabonian and Rupelian stages is debated in the light of these results.

[VF] Palynologie et stratigraphie du Stampien du bassin de Paris : corrélations avec les séries tongriennes et rupéliennes de Belgique et d'Europe du Nord

Le Stampien du Bassin de Paris, tel que défini par A. d'Orbigny en 1852 est formé de dépôts épicontinentaux qui sont riches en mollusques mais généralement dépourvus d'organismes planctoniques permettant des

corrélations interbassins fiables. La biostratigraphie de ces formations est basée, outre les mollusques, sur les characées, les ostracodes et sur quelques niveaux ayant livré des restes de mammifères. Une première zonation basée sur la répartition des kystes de dinoflagellés et des grains de pollen a été établie (Châteauneuf et Gruas-Cavagnetto 1978 ; Châteauneuf 1980) à partir de coupes de Carrières et de sondages dans la série allant de la base du Sannoisien au sommet des Sables de Fontainebleau. Le Calcaire d'Etampes quant à lui n'a pas fourni à ce jour d'horizon favorable à la conservation des palynomorphes.

Depuis cette époque, la stratigraphie à partir des dinokystes a fortement progressé, en particulier dans les bassins de l'Europe du Nord. Nous avons donc repris l'interprétation des associations présentes dans le Stampien à partir des découpages en biozones des étages Tongrien et Rupélien dont les microflores plus marines que celles du Stampien permettent un étalonnage sur les échelles chronostratigraphiques internationales.

Ainsi la série allant des Argiles vertes de Romainville(Sannoisien) au sommet des Sables de Fontainebleau a été découpée en 7 zones correspondant respectivement aux zones NSO2 à NSO4a (Van Simaeys *et al.*2005) et aux zones D13 à D14na (A. Koethe 2005), ce qui permet de proposer la corrélation entre cet intervalle de dépôt du Stampien et celui des séries belges correspondantes.

Le Sannoisien est corrélé avec les Ruisbroek Sands et les Sables de Fontainebleau avec les membres de Belsele- Waas, la série de Terhagen et la base du membre de Putte.

La position de la limite entre l'Eocène et l'Oligocène dans la Bassin de Paris, telle que définie à partir des étages Priabonien et Rupélien, est discutée en fonction de ces résultats.

Palynofloral contribution to the stratigraphy of the Oligocene-Miocene boundary in Marseille and Rouet basins (Provence): Climatic and environmental implications

Jean-Jacques Chateauneuf, Denise Nury

The macro- and palynofloras of southern Provence have for long time been investigated. Most of these studies are focused on inventories (De Saporta, 1863 to 1889), or climatic events (Bessedik, 1985; Sittler, 1984; Giménez-Moreno, 2005). Furthermore, the geological levels concerned were generally discontinuous and the stratigraphy items rarely approached.

New data have been gathered during the geological mapping of the last 1/50.000 Marseille sheet giving opportunity to complete and reinterpret the data from outcrops and boreholes previously studied (Châteauneuf & Nury, 1995), in particular at the presumed location of the Oligocene- Miocene boundary in the Rouet Basin on the southern edge of la Nerthe range.

Interpretations of the pollen grains and dinoflagellate cysts records allowed proposing to place this boundary at the base of the Corbula beds in the Carry-le-Rouet Bioclastic Formation corroborating the scarce dates formerly gathered from nannofossils and planctonic foraminifers.

Climatic events linked to this time span and deduced from the pollen grains are tentatively interpreted and compared with those of coeval formations in the Marseille and Aix-en-Provence Basins, in spite of great differences existing in the environmental deposits.

Indeed, in these two basins deposits are much more continental and confined, lacking consequently of marine dinocysts.

So after a relatively cool period in the Early Chattian (dated MP 30 by mammals) a rise of temperature and humidity takes place in the Rouet Basin at the top of the Chattian in the Rousset Formation and around the Oligocene-Miocene boundary at the base of the Carry-le-Rouet Bioclastic Formation. This event well marked in the Carry-le –Rouet area is much more difficult to identify in the Chattian discontinuous deposits of the Marseille Basin as well as those of Aix-en –Provence area where abundant alpine clastic and reworked elements are over-represented in the organic matter.

[VF] Apport de la microflore à l'etude stratigraphique de la limite Oligo-Miocène dans les bassins de Marseille et du Rouet : climats et milieux de dépôts associés

La flore de Provence méridionale a fait l'objet de nombreuses recherches qui ont porté pour l'essentiel sur des inventaires (De Saporta, 1863 à 1889) ou sur l'évolution des climats (Bessedik, 1985 ; Sittler, 1984 ; Giménez-Moreno, 2005) à partir des grains de pollen.

Les niveaux étudiés étaient souvent discontinus et l'aspect stratigraphique rarement abordé en particulier à la limite Oligocène-Miocène.

Dans le cadre des levés de la nouvelle carte géologique à 1/50 000 de Marseille, nous avons procédé à une réinterprétation des coupes et sondages dont les résultats avaient été publiés (Châteauneuf et Nury, 1995) et à un échantillonnage complémentaire de coupes dans le bassin du Rouet, sur le flanc sud de la chaîne de la Nerthe, au niveau de la zone présumée du passage Chattien-Aquitanien.

L'étude des grains de pollen et des kystes de dinoflagellés (dinokystes) nous permet de placer cette limite à la base du niveau de marnes à Corbules de la Formation Bioclastique de Carry-le-Rouet, ce qui confirme les rares éléments de datation antérieurs à partir des nannoflores et des foraminifères planctoniques.

Les événements climatiques associés à cette limite, interprétés à partir de la microflore sont comparés à ceux des formations contemporaines des Bassins de Marseille et d'Aix-en-Provence dont les environnements de dépôt sont nettement plus continentaux et confinés, ce qui est confirmé par la rareté ou l'absence des dinokystes.

Ainsi, après une période relativement fraîche au Chattien récent (MP 30), un réchauffement très net intervient au sommet de cet étage et au niveau de la

limite Oligocène-Miocène, telle qu'elle a été définie ci-dessus, dans la Formation Saumâtre du Rousset et à la base de la Formation Bioclastique de Carry-le-Rouet. Cet événement est plus difficile à mettre en évidence dans les formations chattiennes plus discontinues du Bassin de Marseille et du Bassin d'Aix-en-Provence où les apports détritiques alpins et les remaniements de matériel organique sont majoritaires.

Datation des niveaux marins pléistocènes à l'aide des échantillons de coraux fossiles sur la côte égyptienne de la Mer Rouge

Abdelmajid Choukri, Jean-Louis Reyss, Oum-Keltoum Hakam, Jean-Claude Plaziat

L'ère Quaternaire a été marquée par des changements climatiques importants qui sont caractérisés par une alternance de périodes froides (glaciaires) et chaudes (interglaciaires). Ces changements climatiques sont associés à des variations du niveau de la mer qui sont liées à plusieurs facteurs: variation du volume de l'océan due à la fonte des glaces, réajustement isostatique associé à la décharge des calottes de glace, tectonique et déformations locales de la terre. Ces variations du niveau de la mer ont laissé de nombreuses empreintes géologiques et géomorphologiques qui permettent de reconstituer l'histoire du climat et d'étudier les mécanismes de ses variations dans le passé. Plusieurs études ont été effectuées en différentes régions du globe pour étudier les niveaux marins fossiles en déterminant leur âge et leur position par rapport au niveau de la mer actuel. Une comparaison des altitudes des hauts niveaux marins dans des régions stables et dans des régions tectoniquement actives permet d'étudier aussi la tectonique des côtes instables et déterminer les déformations locales de certains sites.

Les coraux qui se développent près de la surface de l'eau de mer, constituent, à condition qu'ils n'aient pas subi de recristallisation, un bon matériel pour étudier les variations du niveau de la mer.

Dans ce travail, nous présenterons les résultats de datation radiochimique de plus de 120 échantillons de coraux non recristallisés et nous donnerons la carte des niveaux marins établie sur cette côte considérée relativement stable. Nous discuterons également les indices méthodologiques tirés de cette étude et qui permettront de juger la validité de l'âge mesuré avant de le confronter au contexte géologique et géomorphologique.

Difficultés de datation des niveaux marins pléistocènes à l'aide des coquilles de mollusques fossiles

Abdelmajid Choukri, Jean-Louis Reyss, Oum-Keltoum Hakam, Jean-Claude Plaziat

Les méthodes de datation par les déséquilibres radioactifs dans les familles de l'uranium ont été utilisées pour dater les variations du niveau marin dans le passé et, tout particulièrement, celles établies pendant la période du Quaternaire. Les travaux effectués jusqu'à présent ont permis de retracer la plupart des stades climatiques de cette période caractérisée par une alternance de périodes chaudes et de périodes froides. La durée de stagnation de l'eau de mer pendant un stade climatique chaud est suffisamment longue pour permettre une formation de dépôts sédimentaires contenant des fossiles ayant formé leur squelette à partir de l'eau de mer qui contient uniquement de l'uranium sans ses descendants. Si le système fossile a évolué en système fermé depuis sa formation jusqu'à présent, c'est à dire qu'il n'y avait pas eu d'échange de radioéléments pères ou fils entre le système et le milieu environnant, les rapports d'équilibres radioactifs $^{230}Th/^{234}U$ et $^{234}U/^{238}U$ peuvent être reliés au temps écoulé depuis le début de la fossilisation. La méthode de datation $^{230}Th/^{234}U$ couvre une période de 350 000 ans environ.

Depuis les premières mesures faites par Potratz *et al.* (1955) et Barnes *et al.*(1956) sur des échantillons coralliens et après la découverte du déséquilibre radioactif du rapport $^{234}U/^{238}U$ par Cherdynstyev (1955) et sa mesure dans l'eau des océans par Thurber *et al.* (1962), et après le progrès considérable des techniques de mesure par spectrométrie alpha et par spectrométrie de masse, plusieurs études paléo-climatiques, basées sur les datations radiochimiques par les méthodes de déséquilibre radioactif dans les familles de l'uranium, ont été menées à différents endroits du globe. En absence de coraux non recristallisés qui représentent un matériel de choix pour ces méthodes et, dont on peut contrôler le degré de recristallisation par mesure du taux de la calcite, les coquilles de mollusques fossiles ont été utilisées. Ces dernières sont connues pour leur capacité à absorber des radioéléments à partir des eaux météoriques lorsqu'elles sont exondées et par conséquent à subir des rajeunissements.

Les âges obtenus sur des échantillons de coquilles de mollusques ont été utilisés, malgré leur contestation par plusieurs auteurs, pour établir l'échelle stratigraphique de la variation du niveau marin dans le passé tel qu'au Maroc où on a trouvé des résultats parfois contradictoire avec ceux obtenus à l'aide de coraux dans d'autres régions à l'échelle internationale. Les incertitudes sur l'âge des niveaux marins, interprétés relativement à l'altitude, conduisaient à des hypothèses contradictoires sur l'amplitude des mouvements tectoniques de la côte.

Après une série de datations sur des récifs coralliens de la côte égyptienne de la Mer Rouge qui nous ont permis de mesurer les âges des hauts niveaux marins situés actuellement au dessus du niveau de l'eau de mer, nous avons mené une étude sur un grand nombre d'échantillons de coquilles de mollusques appartenant à plusieurs espèces et prélevées dans des coupes bien

étudiées géologiquement sur la côte atlantique du Haut Atlas au Nord de la ville d'Agadir dans le but de : (1) évaluer le degré de fiabilité des âges de ces échantillons en fonction de la stratigraphie du site, des conditions de conservation des fossiles et des différents résultats d'analyse radiochimique, (2) dater la même coupe ou des coupes similaires à partir des analyses multiples sur des échantillons appartenant à la même espèce ou à des espèces différentes, (3) essayer d'établir des indices méthodologiques à partir des résultats radiochimiques par comparaison à ceux données par les coraux sur la rive occidentale de la Mer Rouge en Egypte, ces indices permettront de juger la validité de l'âge avant de le confronter au contexte géomorphologique et géologique de la formation datée et, (4) évaluer la tectonique et les déformations locales par comparaison avec d'autres régions tectoniquement stables au moins depuis les périodes datées.

Dans ce travail, 120 analyses des échantillons de coquilles de mollusques fossiles sur la côte atlantique du Haut Atlas au Nord de la ville d'Agadir, ont permis de dater trois hauts niveaux marins: l'Holocène, le plus haut niveau marin 5e et un niveau plus ancien. Les résultats montrent que les coquilles de mollusques fossiles fournissent, souvent, des âges apparents plus jeunes que leurs âges réels à cause d'une incorporation postérieure d'uranium pendant la fossilisation. La fiabilité des âges dépend de la conservation des sites vis à vis de l'eau de mer et des eaux continentales. En absence de critères méthodologiques permettant de juger la fiabilité de la datation, l'âge doit être, même dans le cas de multiplication de mesures, confronté au contexte géologique du site. Un modèle basée sur des hypothèses mathématiques a permis de corriger partiellement les âges mesurés.

Updated Orbitolinid stratigraphy and its correlation with the standard Ammonite zones in Late Hauterivian-Early Aptian times

Bernard Clavel, Robert Busnardo, Jean Jacques Charollais, Marc André Conrad, Bruno Granier

The table presented here sumarizes the several findings of orbitolinids in beds providing significant ammonites or immediately underneath ammonite-bearing strata, allowing a direct calibration of the assemblages on the standard ammonite zones. It is supplemented by information on orbitolinid occurrences in levels without ammonites but correlated on the regional sequence stratigraphic framework. The first category (directly dated by ammonites) is given a higher hierarchical weight than the second (indirectly dated from the sequence stratigraphic interpretation).

Paleogeographic evolution of the Urgonian carbonate platforms (Switzerland - SE France)

Bernard Clavel, Robert Busnardo, Jean Jacques Charollais, Marc André Conrad, Bruno Granier

We present here a set of paleogeographical maps representing the discrete stages of the origin, development and decline of the Urgonian platforms in southeastern France and Switzerland. Each map illustrates the late HST (Highstand Systems Tract) of the several third order sequences identified in the Late Hauterivian - Early Aptian time interval.

Application of Orbitolinid biostratigraphy to the dating of platform facies: study of the Ligatus, Balearis and Ohmi ammonite zones (Late Hauterivian p.p.)

Bernard Clavel, Robert Busnardo, Jean Jacques Charollais, Marc André Conrad, Bruno Granier

This poster depicts a composite transect from the Vocontian through (Vergons -hypostratotypic section of the Hauterivian- and Angles -stratotypic section of the Barremian-) to the platform (Vivarais, Vercors, and Jura) during an interval of time spanning the Ligatus, Balearis and Ohmi zones (Late Hauterivian p.p.). It illustrates the procedure of using assemblages of orbitolinids to identify the position of intervals time-equivalent ammonite zones in platform settings where these macrofossils are either rare or absent.

Calibration of Orbitolinid zones with the Ammonite standard zones. Part I: the Pas de l'Essaure section, Glandasse Plateau, Vercors (France)

Bernard Clavel, Robert Busnardo, Jean Jacques Charollais, Marc André Conrad, Bruno Granier

The Pas de l'Essaure section is on the eastern border of the Glandasse Plateau (Vercors). There, bioclastic facies with orbitolinids interfingered in the hemipelagic deposits with ammonites are the first earliest indications. Orbitolinid assemblages therefore can be directly correlated with the ammonite standard zones and were found to span the Hugii Zone.

Calibration of Orbitolinid zones with the Ammonite standard zones. Part II: the Pont de Laval section, Vivarais (France)

Bernard Clavel, Robert Busnardo, Jean Jacques Charollais, Marc André Conrad, Bruno Granier

The Pont de Laval section is on the western side of the Rhône valley (Vivarais), near the Ardêche Gorges. In this area bioclastic facies, the forerunners of Urgonian platform development, are interfingered in the ammonite-bearing hemipelagic facies. Orbitolinid assemblages collected in these bioclastic facies are therefore directly correlatable with the ammonite standard zones and found to span the Hugii Zone. The underlying hemipelagic marls of the Ohmi Zone also contain numerous orbitolinids and ammonites.

Synonymy of the 'Calcaires de Glandasse' Formation and the 'Calcaires urgoniens' Formation *sensu* Arnaud *et al.* 1998

Bernard Clavel, Robert Busnardo, Jean Jacques Charollais, Marc André Conrad, Bruno Granier

The 'Calcaires urgoniens' Formation was redefined and a new formation, namely the 'Calcaires de Glandasse', was introduced by Arnaud *et al.* (1998) on the basis of the occurrence of an unconformity they identified and labelled 'SbB3'. These authors ascribe it a latest Barremian age (Sartousiana Zone). In one of the 'Calcaires urgoniens' reference sections at Col du Rousset the SbB3 is bracketed by Late Barremian ammonites above and a late Early Barremian - Early Aptian orbitolinid assemblage below, that is it is late Early or Late Barremian in age, which could agree with their interpretation. However, in the other reference section in the Gorges du Nant the SbB3 is dated Late Hauterivian on the basis of the orbitolinid assemblages (among which *Valserina primitiva* and *Paleodictyoconus beckerae*) spanning the so-called SbB3. The diachronicity in both reference sections is not compatible with either lithostratigraphic or sequence stratigraphic concepts; its identification in other sections is therefore highly debatable. Both the fossil assemblages (but only at a taxonomic level higher than the species or even the genus, for the designations ascribed to these lower taxonomic levels may give them ages) and the facies of the two formations are similar. In addition, the span of time each occupies is either identical or overlaps to such an extent that the assignment of a new designation to one of them is a misconstruction. So the creation of the 'Calcaires de Glandasse' leads to a misunderstanding of stratigraphic relationships and is unnecessary.

Evolution of Urgonian (Upper Hauterivian - Lower Aptian) carbonate platforms in Switzerland and SE France

Bernard Clavel, Robert Busnardo, Jean Jacques Charollais, Marc André Conrad, Bruno Granier

A study of the stratigraphy of the Urgonian carbonate platforms on NW/SE transects, from the Jura to the northern subalpine chains (Bornes-Aravis, Chartreuse, Vercors) and Vivarais, led to new conclusions regarding their origin, development, and decline.

The agenda can be summarized as follows:

- the platforms began to form in the northern Jura in the early Late Hauterivian;
- they prograded (basinward) during Late Hauterivian and Early Barremian times with a concurrent progressive subaerial exposure (landward);
- during the Late Barremian and the earliest Aptian (Early Bedoulian), they were aggrading. The rudistid limestones attained their maximun extent basinward, while as sea level rose peritidal deposits occupied part of the previously exposed area.
- aggradation ended during the Early Aptian (late Early Bedoulian) throughout the platform as the whole of the carbonate area was subject to exposure in a major 'forced regression' (followed by a major transgression).

This new interpretation of events was developed as the result of a precise calibration of orbitolinid zonation and ranges with the standard ammonite zones owing to the existence of sections in which marker species of both faunas occur. In addition, the study benefited from a better understanding of the evolutionary trends of these foraminifera, and, where such information is available, the integration of biostratigraphic data from other groups such as echinoids, dasycladaleans, dinokysts and nannofossils. This new rendering of events markedly contradicts interpretations made by other investigators.

We expect our findings with respect to the orbitolinid successions will be validated in other areas of the Tethyan realm, including the Pyrenees, the Betic Cordilleras, the Middle East, *etc*. If, as we anticipate, our biostratigraphic calibration and the resulting interpretation of events is confirmed regionally, documentation and understanding of the global tectono-sedimentary history of the Early Cretaceous Tethys will be greatly advanced.

U-Pb zircon (LA-MC-ICPMS) and Ar dating of phonolites from Marquesas Archipelago (French Polynesia): evidence of radiogenic Pb diffusion in U-enriched zircons

Alain Cocherie, Hervé Guillou, Sébastien Nomade, Philippe Rossi, Mark Fanning

It is now well established that isotopic closure temperature are different in the various minerals and radio-isotopic methods. For example the closure of U-Pb system in zircon is well above K/Ar system in amphibole or biotite. This allows geochronologists to highlight magmatic as well as tectonic processes by using various isotopic methods in the same sample. Unfortunately, until recently and because of the precision of U-Pb method limited by the amount of radiogenic Pb, precise combined U-Pb/zircon v.s K/Ar/amphibole-biotite studies were restricted to pre-quaternary periods. A new U-Pb technique was successfully developed using laser ablation technique (UV 213 nm) coupled with a field sector ICP-MS equipped with a multi-ion counting system allowing the isotopic ratios to be recorded in fully static mode. Thus, Quaternary zircons can now be dated at about 1% level (2s) on the $^{206}Pb^*/^{238}U$ age corrected for Th disequilibrium (Cocherie *et al.*, 2009). Two samples from the young intra oceanic volcanism from Marquesas Archipelago (French Polynesia) were investigated using this new technique and compare with age obtained using the K/Ar and Ar/Ar methods.

The first phonolite sample from Ua Pou Island (UP 301) was dated using $^{40}Ar/^{39}Ar$ method after total fusion of single mica grains. An isochron age of 3.562 ± 0.090 Ma was determined. Large euhedral zircon grains were also found in this lava flow. After Th disequilibrium correction, the SHRIMP technique led to an age of 3.26 ± 0.13 Ma (9 spot analyses), slightly younger then the Ar-Ar age. Other zircon grains from the same sample were recently dated using LA-MC-ICPMS. A precise age of 3.434 ± 0.036 Ma (16 spot analyses), similar to Ar-Ar age within the uncertainties was obtained. These ages are interpreted as the emplacement age of this lava. Using a larger beam and recording some additional spot analyses could have improved the precision on SHRIMP age. The lack of analytical blank remains the main advantage of the SHRIMP technique. On the other hand, LA-MC-ICPMS technique does not require high mass resolution and allows larger volume of zircon material to be analyzed in the mass spectrometer despite the same diameter of the laser beam compared to the primary ion beam of the SHRIMP (~20 µm). Thus, the peak/background ratio makes LA-MC-ICPMS technique especially convenient to date very young and well-crystallized zircon grains. Thus the emplacement age of the lava is rather well constrained about 3.4-3.5 Ma.

The second sample is also a phonolite, sampled in Fatu Hiva Island (FH 16). An age of 1.11 ± 0.03 Ma was determined on mesostase using K-Ar technique. Colourless to pink zircon grains were extracted and dated using LA-MC-ICPMS. These zircons can be complex and they display variable U contents. The colour was directly correlated to the amount of U ranging from 55 to 5788 ppm with a wide gap of data between 200 and 2000 ppm. The back-scattered electron

images show that some U-enriched grains are surrounded by U-depleted rim (mainly below 100 ppm). Despite this huge contrast in U contents, the two groups of data do not exhibit contrasting U-Pb ages. The U-enriched group led to an average $^{206}Pb^*/^{238}U$ age at 1.181 ± 0.009 Ma (15 spot analyses). Surprisingly, the U-depleted rims show older ages than the core of the same grain (~1.3, 1.4 Ma). By contrast, a group of U-depleted colourless grains (without U-enriched core) led to a slightly younger age of 1.142 ± 0.025 Ma (8 spot analyses). Taken into account the uncertainty due to the Th disequilibrium correction, the youngest colourless zircons are considered to date the emplacement of the phonolite similarly to the K-Ar age, close to 1.11 Ma. About 40 Kyr before the U-enriched grains crystallized probably during the first stage of the ascent of the magma until an intermediate magma chamber. The apparent older ages of the rim can be interpreted as a shift associated with an excess of radiogenic $^{206}Pb^*$ originated from the U-enriched core. In other words, a slight Pb-loss from the U-enriched core can induce a significant excess Pb on the U-depleted rim while the Pb-loss cannot be quantified on the age of the core.

Presence of the genus Frambocythere COLIN, 1980, Ostracoda (Limnocytheridae, Timiriaseviinae) in the Upper Maastrichtian of the Zagros Mountains, Iran, a new relay between southern Europe and the Far East

Jean-Paul Colin, Hossein Vaziri-Moghaddam, Amrollah Safari, Samira Shariari Graii

The limnic ostracode (Limnocytheridae, Timiriaseviinae, *Frambocythere* cf. *tumiensis* (Helmdach, 1978) has been found for the first time in Iran. The levels containing this species is in the lower part of the Tarbur Formation in the interior Fars of the Zagros mountain. The Upper Maastrichtian age is given by Rudist, larger foraminifera (*Omphalocyclus macroporus*, *Loftusia* spp.) and planktonic foraminifers, in overlying facies of the upper part of the Tarbur Formation. The Maastrichtian age is also confirmed by the occurrence in the same levels of the charophytes *Platychara shanii*, *Peckichara cristellata* and cf. *Stephanochara producta* (det. E. Musacchio).

In the Upper Cretaceous the genus *Frambocythere* Colin, 1980 (*in* Colin & Danielopol, 1980), which ranges from Albian to Early Tertiary, was until now known only from the Upper Maastrichtian of southern Europe (France, Spain; Babinot *et al.*, 1996), India (Bhandari & Colin, 1999; Whatley & Bajpaj, 2000), and China (Hou *et al.*, 1978).

The presence of *Frambocythere* cf. *tumiensis* in Iran is therefore a new relay between southern Europe and the Far East.

Check-list of Maastrichtian species of *Frambocythere*

- *Frambocythere tumiensis aepleri* (Helmdach, 1978): Upper Maastrichtian of N Spain.

- *Frambocythere tumiensis anjarensis* Bhandari & Colin, 1999: Upper Maastrichtian of India.
- *Frambocythere tumiensis ferreri* Colin, 1980 *in* Colin & Danielopol, 1980 : Upper Maastrichtian of Spain and SE France.
- *Frambocythere tumiensis lakshmiae* Whatley & Bajpai 2000: Upper Maastrichtian of India.
- *Frambocythere tumiensis tumiensis* (Helmdach, 1978) : Upper Maastrichtian of N Spain.
- *Frambocythere tumiensis fanghiaensis* (Ye, 1978) *in* Hou *et al.* 1978: Upper Maastrichtian of China.

Sequence Stratigraphy of the Miocene-Pleistocene of the transition area Onshore-Offshore, Eastern Venezuela Basin

Saileth Teresa Cortez, Nubia Santiago, Miller Del Carmen Zambrano

The study area includes the transition onshore-offshore between area of the Eastern Venezuela Basin, particularly the Orinoco Delta, which has an important hydrocarbon zone with a good number of field discoveries of gas, oil and condensate, in Venezuela and Trinidad.

The Orinoco Delta sediments of Plio-Pleistocene age have a thickness exceeding 20000 feet, deposited in a foreland basin, producted by South America lithosferic flexion in response to the Trinidad fold-belt formed by the oblique colission between the Southamerica and Caribe plates. This delta is dominated in the north by waves and rivers and in the south dominated by waves and tides.

The Stratigraphy of Miocene-Pleistocene sequences is dominated by successive growing of clinoforms at the platform edge. The established stratigraphic model includes five second order sequences (K, A, B, C and D), four third order sequences (C-1, C-2, D-1, D-2 and D-3) and eight fourth order sequences (D-1a, D-1b, D-1c, D-3a, D-3b, D-3c, D-3d and D-3e). In the Plio-Pleistocene interval predominate prograding sequences with thicknesses up to 6000 feet with facies varying from sandy to shaly lithologies towards the east of the delta.

The second order sequences are characterized by a fining up log pattern until reaching a maximum flooding surface. Later it progrades toward the top. The progradations are characterized mainly by sands. The sequence K (Early Cretaceous) is present only in offshore with 4500 feet of thickness. The Sequence A (Late Cretaceous) is more continental onshore with a thickness of 700 feet. It is marine offshore with a thickness of 2000 feet. The Sequence B (Paleocene-Eocene) is only present offshore and is very shaly with some intercalations of sand with occasionally glauconitic shales and some limestones possibly associated with a sea level rise.

The third order sequences are present between the Late Eocene and Late Miocene. Sequence C-1 (Late Eocene-Oligocene) with hundreds of feet with

coarsening up regressive pattern. The sequence C-2 (Early to Middle Miocene) has a thickness of 1000 to 3000 feet, fining upwards with thick sandstones present at the base. Two maximum transgressive pulses are present (Langhiense and Serravaliense) as evidenced by shaly materials and offshore limestones. The sequence D-2 (Late Miocene) has a thickness of 2000 to 4000 feet with a fining up pattern.

The fourth order sequences are present between Late Miocene to Recent. They contain the main hydrocarbon accumulation in the delta which are characterized by abundant clastic reservoirs deposited in both shallow and deep environments, with 100 to 300 feet of thickness and porosity values up to 30 percent.

Ostracoda (Crustacea) through the main Phanerozoic biocrisis: the Permian – Triassic boundary events

Sylvie Crasquin, Marie-Béatrice Forel

The Permian – Triassic boundary (252My) is characterized by the highest Phanerozoic drop of biodiversity. During the Late Permian and the earliest Triassic, in marine environment, 49 à 57% of families, 83% of genera and 96% of species disappeared. These extinctions could be progressive or sharp. A complex conjunction and accumulation of noxious causes destroyed the biotopes during 10My. The benthic life was the most affected.

The Permian – Triassic GSSP (Global Stratotype Section and Point) located in Meishan (Zhejiang Province, South China), as several other reference sections of the boundary (Dolomites, Italy, Western Taurus, Turkey; Bükk Mountains, Hungary) were sampled in detail for ostracod (benthic micro-crustacean) analysis.

We propose here a first evaluation of extinction and recovery rates in the ostracod group during the Permian – Triassic events.

A new vertebrate assemblage from the Tunisian Chotts

Gilles Cuny, Eric Buffetaut, Jean-Louis Latil, Etienne Jaillard

The Lower Cretaceous Douiret and Aïn Guettar formations in southern Tunisia can easily be characterized by their selachian fossils. The association of the hybodonts *Egertonodus* sp. and *Priohybodus arambourgi* with the ray '*Rhinobatos*' sp. is specific to the Douiret Formation, whereas the association of the hybodont *Tribodus tunisiensis* with various Lamniformes (*Eoptolamna eccentrolopha*, *Cretodus semiplicatus* and *Scapanorhynchus* sp.) and the sawfish *Onchopristis dunklei* is specific to the Chenini Member of the Aïn Guettar Formation. The Oum ed Diab Member of the same Formation is

dominated by hybodont sharks, such as *Diabodus tataouinensis*, whereas lamniform sharks are very rare. The Douiret Formation is supposed to be ante-Aptian in age, whereas the Aïn Guettar Formation is supposed to be Late Aptian-Albian in age.

Vertebrate remains have recently been collected from Bir Oum Ali and Foum el Argoub, West of Gabès in the Tunisian Chotts. At Bir Oum Ali, the assemblage is dominated by teeth of *Lepidotes*. Some actinopterygian teeth are similar to those of *Caturus* and some belong to pycnodonts. Shark teeth include teeth of *Cretodus semiplicatus*, *Onchopristis dunklei* and *Tribodus tunisiensis*. A single tooth of *Cretalamna appendiculata* and some fragments of hybodont fin spines have also been recovered. Finally, tiny crocodilian teeth were also found.

Teeth of *Lepidotes* are also very abundant at Foum el Argoub and the shark teeth include teeth of *Cretodus semiplicatus* and *Scapanorhynchus* sp. Several teeth of spinosaurid theropods as well as a tooth fragment of an indeterminate non-spinosaurid theropod were also recovered. The presence of spinosaurids in close proximity to stratigraphically useful marine fossils is important for a better understanding of the evolutionary history of this group of dinosaurs.

The association of *Cretodus semiplicatus*, *Onchopristis dunklei* and *Tribodus tunisiensis* is characteristic of the Chenini Member of the Aïn Guettar Formation, allowing the correlation of Bir Oum Ali with sites like Oued el Khil in the Tataouine area. The abundance of lamniform sharks at Foum el Argoub also confirms a correlation with the Chenini Member. As the genera Cretalamna and Cretodus are unknown before the Albian, a basal Albian age is suggested for these two sites, an age supported by the rare ammonites found in the neighbourhood. However, orbitolinid foraminifera rather suggest a Late Aptian age.

The stratigraphic and palaeontological record of Ordovician radiolaria and conodonts from the peri-Gondwanan Karatu-Naryn terrane (Sarydzhaz, eastern Kyrgyzstan)

Taniel Danelian

Our current understanding of Early Palaeozoic radiolarian diversity is very incomplete. Therefore, any new radiolarian-delivering locality has the potential to provide new morphological, biostratigraphic and palaeoenvironmental information, which may improve our understanding of the Cambrian-Ordovician radiolarian biodiversification.

Recent stratigraphic studies, undertaken in the context of new geological mapping in the area surrounding the river Sarydzhaz, in the eastern part of Kyrgyzstan, discovered a reasonably well preserved Ordovician radiolarian fauna in some thin chert beds. These are often situated at the top of distal turbiditic sequences of the Kokbel and Oldzhobai formations and they were processed with hydrofluoric acid etching. Some the investigated stratigraphic intervals that yielded radiolarians, contain also conodonts that were studied mainly in thin section preparations.

The studied area is a remote region of the Tien Shan Mountains, situated close to the Kyrgyz-Chinese border, with widespread outcrops of Lower Palaeozoic sedimentary sequences, composed essentially of fine siliciclastic lithofacies. The sedimentary sequences were deposited on a passive margin of the peri-Gondwanan Karatau-Naryn microplate in a basin to outer fan transitional palaeoenvironment. The palaeontological constraints for the age of these sequences are rare. The only noticeable exception is a monograph on Late Ordovician brachiopods. Occurrence of Early to Middle Ordovician conodonts in the region was previously reported, but this was not accompanied by any detailed taxonomic study. On the other hand, this is the first ever report of Ordovician Radiolaria from Kyrgyzstan. Co-occurrence of conodonts in some of the studied samples provides important age constraints for the newly discovered radiolarian fauna.

The Kokbel Formation is mainly composed of alternating beds of siliceous claystones, black shales, black cherts and dark-grey limestones. It lies conformably over Middle to Upper Cambrian black shales dated by trilobites. Its age is poorly constrained; it is tentatively considered as Tremadocian, based on its stratigraphic position. An almost monospecific radiolarian assemblage is discovered in two beds situated in its upper part. It comprises a new inaniguttid species (*Inanigutta* (?) *biporata*), characterised by a very distinctive pore pattern on the outer shell.

Moderately well-preserved radiolarians were recovered from a number of horizons situated in the middle and upper part of the Oldzhobai Formation, of possibly Tremadocian to Floian age, as suggested by co-occurring conodonts. The fauna is represented by a small number of conodont elements in each sample, half of which are juveniles. In some samples the assemblage is nearly monospecific, dominated by *Paracordylodus gracilis*, a fairly cosmopolitan taxon occurring in latest Tremadocian to early Floian peri-cratonic settings. The radiolarian assemblages of the Oldzhobai Formation are dominated by members of the family Inaniguttidae.

Benthonic foraminiferal events of the Qom Formation in north and northwest of central Iran

Jahanbakhsh Daneshian, Leila Ramezani Dana

In order to recognition of Oligocene - Miocene deposits and the Aquitanian - Burdigalian boundary, benthonic foraminifera from different localities of north and northwest of central Iran have been studied. In this region, benthonic foraminiferal events were extracted. These foraminifera are facies controlled and they are not as useful as planktonic foraminifera for biostratigraphic studies. But they can definitely be very helpful in the absent of planktonic foraminifera. Based on study of eleven stratigraphic sections and 1190 samples in north and west of central Iran, 12 datum levels of benthonic foraminifera such as *Borelis melo curdica*, *Peneroplis farsensis*, *Elphidium* sp. 14, *Meandropsina anahensis*, *Meandropsina iranica*, *Austrotrillina howchini*, were recognized. The boundary of Aquitanian and Burdigalian sediments in studied area is recognized by the first occurrence of Borelis melo curdica.

The latest Paleocene vertebrate site of Rivecourt (Oise, France) and its implications for the biochronological record of europe

Gaël De Plöeg, Thierry Smith, Grégoire Métais, Maud André, Julien Claude, Eric De Bast, Dario De Franceschi, Christian Dupuis, Annelise Folie, Cyril Gagnaison, Jeremy Martin, Judicaël Prieur, Florence Quesnel, Jean-Yves Storme, Haiyan Tong, Floréal Solé, Johan Yans, Eric Buffetaut

The Late Paleocene terrestrial vertebrates of Europe are mainly known from the rich Cernay-Berru channel deposits that overlie the marine Upper Thanetian Châlons-sur-Vesle sands in the eastern part of the Paris Basin (Reims area). The earliest Eocene terrestrial vertebrates of Europe are represented by the Dormaal fluviatile deposits of the Tienen Formation that overlie the marine Upper Thanetian Granglise sands in the nearby Belgium Basin. While both marine sands belong to the same NP8 biozone, the two continental deposits have yielded two totally different vertebrate faunas. The first one represents the MP6 reference-level that is characterized by archaic mammals including plesiadapiforms and several families of condylarths. The second represents the MP7 reference-level that correspond to the first occurrence of earliest modern mammals in Europe. The Dormaal deposits, that include the earliest European primates, artiodactyls, rodents and true carnivores, coincide with the Carbone Isotope Excursion (CIE) of the Paleocene Eocene Thermal Maximum (PETM) that starts at 55.8 Ma. But the time span between the MP6 fauna of Cernay and the MP7 fauna of Dormaal is not well constrained. Moreover, no terrestrial fauna from this time interval had hitherto been described.

Recently, the locality of Rivecourt (Oise) in the central part of the Paris Basin has yielded a small intriguing vertebrate fauna. Preliminary results indicated a late Paleocene age based on the occurrence of typical mammalian groups such as pleuraspidotheriid and lousinine condylarths, and plesiadapiforms including the well-known MP6 marker *Plesiadapis tricuspidens*. New material from Rivecourt and detailed comparisons indicate also the presence of mammals that compare better with the earliest Eocene MP7 of Dormaal. Among these, the louisinine *Microhyus musculus* which is also recorded from the latest Paleocene of the upper part of the Tremp Formation in the Spanish Pyrenees suggests a younger age (MP6b). But the interest is focused on dental remains of rodents and a miacid carnivoran close to the North American genus *Vassacyon* attesting for the first time the presence of modern mammal orders in the latest Paleocene of Europe.

The diversity of the terrestrial vertebrates is the result of a mix of typical land and fresh water vertebrates. However, marine vertebrates such as sharks, rays and marine actinopterygians are abundant, indicating a reworking from the underlying marine Upper Thanetian beds, as in Dormaal. Apart from mammals, small terrestrial vertebrates seem rare and at the moment only few jaws and

vertebrae of anguimorph, scincomorph and amphisbaenian lizards, a boid snake, and a possible proteoid urodele have been identified. Fresh water fish are abundant. Large non-mammalian tetrapods have also been discovered, such as trionychid, geoemydid, testudinid and (reworked) cheloniid turtles, various crocodilians including a gavial-like form, a diplocynodontid and a more robust form, champsosaurs and birds, including a large terrestrial form. Abundant botanical remains are present such as wood fragments, charcoals and seeds. A comparative study with the nearby MP7 flora of Le Quesnoy that is situated only three kilometres West of Rivecourt is in progress. Despite the geographical proximity, the floristic composition indicates significantly different environments at the two sites.

The sedimentological study of the very organic fluvial deposits of Rivecourt clearly indicates a complex hydrographic network with successive erosive channels fielded by meandering sandy deposits. Towards the top of the section very fine lignitic sediments end the succession. Carbon isotope analysis has been performed on the bulk organic matter from the sediments containing the vertebrates in order to complement the stratigraphical data and to situate the Rivecourt deposits with respect to the PETM.

The Rivecourt terrestrial vertebrate site corresponds to an intermediate age between the MP6 of Cernay and the MP7 of Dormaal, possibly indicating a correlation with the MP6b of the Upper part of the Tremp Formation in Spain.

Patrimoine géologique : de l'inventaire au géotoursime

Patrick De Wever, Annie Cornée, Grégoire Egoroff

Le patrimoine géologique recouvre des champs très variés : inventaire, protection, valorisation, diffusion, éducation, géotourisme ... Il convient de toujours associer l'objet *in situ* et les objets *ex situ*.

L'approche raisonnée commence par des inventaires qui permettent une identification des objets. Ensuite sont envisageables la protection raisonnée et la valorisation (scientifique, pédagogique ou géotouristique). Il permet aussi d'établir des catégories de sites, de déterminer leur importance (locale, régionale, nationale, internationale).

L'inventaire alimentera plusieurs bases de données:

- un site du Ministère de l'environnement, le SINP (Système d'Information sur la Nature et Paysages) à côté des ZNIEFF, etc...
- sur la base ' lithothèque nationale ' du Ministère de l'Education nationale, destinée aux enseignants du secondaire ;
- ces géosites seront versés dans une base de données européenne (avec ProGEO) et internationale via l'IUGS / UNESCO.

Magnetic susceptibility and microfacies compared in Proterozoic carbonate sequences (Kasai Province, Democratic Republic of Congo)

Franck Delpomdor, Xavier Devleeschouwer, Christian Blanpied, Stefan Schroeder, Alain Préat

The Mbuji-Mayi Supergroup is a NW-SE elongated basin covering a surface of 12,000 km^2, from Lubudi to Luembe rivers in the Kasai Province in Democratic Republic of Congo. The Mbuji-Mayi sedimentary series is weakly or not affected by the regional metamorphism. Lithostratigraphically, this Supergroup comprises, from base to top, a 550 m-thick siliciclastic succession (BI Group) and a 1 km-thick carbonate sequence with numerous stromatolithic buildups (BII Group). Radiometric ages on syngenetic galena for the BI Group (BIe_1 Formation) yielded 1,040 and 1,065 Ma (Cahen, 1954; Holmes and Cahen, 1955; Raucq, 1957). Overlying amygdaloidal basaltic pillow lavas from the Sankuru-Bushimay confluence have given K/Ar radiometric ages of 948 ± 20 Ma (Cahen *et al.*, 1974, 1984). In our study, two drill cores (Lubi and Kafuku) have been sampled in the BIe_2 Formation until the base of the BIIa Subgroup, for petrography and magnetic susceptibility analysis.

The petrography allows recognizing four microfacies (MF1-4) forming a standard sequence recording hypersaline low-energy subtidal environments colonized by non-branching and branching columnar stromatolites. The microfacies standard sequence shows the succession of homogeneous dolomudstones (MF1), flat laminated dolomudstones (MF2), wavy laminated dolomudstones (MF3) and columnar stromatolithic boundstones (MF4).

Rock magnetism analyses have been recently conducted on the same samples used for sedimentological purposes. Low-field magnetic susceptibility (X_{LF}) data were acquired on 64 samples with a Kappabridge MFK1-A.

Xsub>LF values range between 2.24 x 10^{-9} and 66.46 x 10^{-9} m^3/kg for the Lubi drill core. In details, X_{LF} and microfacies curves are anti-correlated. Low-field magnetic susceptibility values decrease progressively from homogeneous dolomudstones towards columnar stromatolithic boundstones as indicated by the two main 'shallowing-upward' evolutions. The interval between these two sequences records large X_{LF} fluctuations. The mean low-field magnetic susceptibility plotted for each microfacies along the standard sequence shows a strong linear correlation (R^2 = 0.83) implying that X_{LF} is clearly associated with the different microfacies. The anti-correlation trends observed between microfacies and XLF suggest a model of a carbonate ramp.

X_{LF} values range between 6.91 x 10^{-9} and 50.19 x 10^{-9} m^3/kg for the Kafuku drill core. More specifically, a first decrease of the X_{LF} values from 32.71 x 10^{-9} to 8.47 x 10^{-9} m^3/kg is observed on the first 12.4 meters (from the base). This first magnetic sequence is clearly anti-correlated with the microfacies evolution. A second interval characterized by successively globally increasing and decreasing trends corresponds to several microfacies fluctuations. A third interval, in the upper part of the drill core, shows an increasing trend, which is clearly correlated with a microfacies evolution from MF1 to MF4. In the Kafuku

drill core, a different behaviour of the X_{LF} data are highlighted even if similar microfacies are observed. By plotting the mean XLF of each microfacies along the standard sequence, there is no correlation (R^2 = 0.048).

These two different behaviours of the X_{LF} data could suggest that a diagenetic overprinting has affected the Kafuku sediments or that these stratigraphic intervals are not of equivalent ages.

Hysteresis measurements and thermomagnetic analyses are underway on selected samples to determine the magnetic minerals and their grain sizes in order to identify the magnetic mineralogy controlling the MS signal and their origin. Additional geochemical analyses are used to determine the detrital or diagenetic origin of the magnetic susceptibility signal.

Test microevolutions in planktonic foraminiferal index species in response to environmental changes during the OAE2 in the Western Interior Basin (USA) and their consequences for high resolution biostratigraphy

Delphine Desmares, Danièle Grosheny, Bernard Beaudoin

While ammonites are used to precisely define the position of the Cenomanian-Turonian boundary, changes in the planktonic foraminiferal assemblages are less indicative, diachronous and seem to occur over a broad interval of time coeval with the contemporary oceanic anoxic event (OAE2). This global expansion of the oxygen minimum zone led to the disappearance of rotaliporids, complex planktonic foraminifera which previously occupied deep oceanic waters and which are widely used as a stratigraphic index.

This planktonic foraminiferal turnover corresponds to the traditional 'zone à grosses globigérines', defined as the *Whiteinella archaeocretacea* Partial Range Zone. The base of this partial range zone overlays the last occurrence of *Rotalipora cushmani* (top of the *R. cushmani* total range zone) and its top underlies the first occurrence of *Helvetoglobotruncana helvetica* (base of the *H. helvetica* total range zone).

In the late Cenomanian strata of the Western Interior Seaway, two keeled species of rotaliporids are recorded: *R. cushmani* and *Thalmanninella greenhornensis*. Inflated forms - *Rotalipora planoconvexa* and *Thalmanninella multiloculata* - co-occur with these keeled morphotypes. If they preserve the same morphological features as the keeled forms (*e.g.* supplementary apertures, coiling ratio), the inflated morphotypes are characterised by the peripheral keel not being expressed on each chamber or even being totally absent. Indeed, *Th. multiloculata* and *R. planoconvexa* preserve juvenile characters (*i.e.* the development of the keel is suppressed). Such a shift in developmental rate represents an heterochrony (where there is change in the timing and/or rate of ontogenetic processes controlling the development of

morphological traits). Thus, *Th. multiloculata* and *R. planoconvexa* are respectively neotenous forms of *Th. greenhornensis* and of *R. cushmani*, such heterochrony reflecting adaptive strategy. With this test microevolution, the rotaliporids may have remained in shallower habitats, thereby escaping an expanding oxygen-minimum zone.

However, all morphological gradations have been observed between the keeled and the globular morphotypes. This wide variation in transitional forms in the assemblages containing *Th. greenhornensis/Th. multiloculata* and *R. cushmani/R. planoconvexa* reflects their responses to environmental pressures.

Ten outcrops, spanning the Cenomanian-Turonian boundary interval, were examined across the Western Interior Basin, following two transects from Arizona to Kansas and from South Dakota to Texas. High resolution correlation between these sections indicate that the last occurrence of *R. cushmani* and the first occurrence of the index species *H. helvetica* are diachronous at the basin scale. Thus, the first appearance of *H. helvetica* is a problematic biomarker horizon. Furthermore, forms transitional between *H. helvetica* and its ancestor *Whiteinella praehelvetica*, are commonly identified in the terminal Cenomanian, during the acme of oceanic anoxic event. *H. helvetica* differs from its ancestor *W. praehelvetica* in having a true keel throughout all chambers of the last whorl. The transitional forms are mostly globular but the last two or three chambers of the final whorl have a peripheral keel. In term of taxonomy, transitional forms are difficult to attribute to a particular species because there is a continuum between *W. praehelvetica* and *H. helvetica*.

As *R. cushmani* and *H. helvetica* are index species, the classification of intermediate morphotypes affects the biostratigraphic models of different authors. Indeed, such specimens are often classified according to criteria chosen by each individual micropalaeontologist, and this separation can be arbitrary.

Beyond resolving biostratigraphic uncertainty, the presence or absence of a keel could be a tool to constrain environmental changes in time and in space. Thus, microfacies analyses prove that globular morphotypes predominate in anoxic environments whereas the intermediate and keeled forms are associated with more favourable oxygenated environments.

New insights from rock magnetism, sedimentology, reefal and peri-reefal faunas in the Mont d'Haurs and Fromelennes formations (middle to late Givetian) at 'Cul d'Houille' section (Flohimont, France)

Xavier Devleeschouwer, Estelle Petitclerc, Benoit Hubert, Emilie Pinte, S. Maillet, Catherine Cronier, Arnaud Bignon, Simo Spassov, Alain Préat

The 'Cul d'Houille' section is located near Flohimont (France) on the western side of the Houille river in the southern part of the allochthonous Ardennes fold-and-thrust belt. The Mont d'Haurs and Fromelennes Formations are observed and have a thickness respectively of 87 and 148.5 meters. The boundary between the Mont d'Haurs and Fromelennes Formations corresponds to the transition from reefal limestones to argillaceous limestones and siltstones. The successive Flohimont, Moulin-Boreux and Fort Hulobiet Members (Fromelennes Formation) consist of discontinuous outcrops due to bad exposure conditions implying unclear limits between these different members. The section was investigated previously for conodonts (Bultynck, 1974), for stromatoporoids (Cornet, 1975) and for sedimentological and sequential analyses (Préat & Carliez, 1994) only in the Moulin-Boreux Member, and more recently for lithology and faunal occurrences on the entire section (Hubert & Pinte, 2009).

Rock magnetism analyses have been recently conducted on the same samples used for sedimentological purposes. Magnetic susceptibility (MS) data were acquired on 600 samples with a Kappabridge MFK1-A. MS values range between -4.17×10^{-9} and 1.48×10^{-7} m^3/kg for the whole section. The MS curve of the Mont d'Haurs Fm. shows the lowest MS value (-4.17×10^{-9} m^3/kg) in its upper part approximately 10 meters below the boundary with the Fromelennes Formation. The highest MS value (8.55×10^{-8} m^3/kg) is observed at the base of the Mont d'Haurs Fm. Most of this formation displays low MS values ($< 2 \times 10^{-8}$ m^3/kg) excepted in its basal part where high values (> 5.5 10^{-8} m^3/kg) are recorded in the first 80 cm. Many samples have also negative low-field magnetic susceptibilities indicating that diamagnetic minerals are carrying the signal. As a consequence several magnetic sequences are recognised. They record globally increasing MS values. The last magnetic sequence is straddling the Mont d'Haurs/Fromelennes boundary up to 1.5 m in the basal part of the Fromelennes Formation. The Flohimont Member (base of the Fromelennes Fm.) has low MS values ($< 2.0 \times 10^{-8}$ m^3/kg) only in the basal part on the first 4.5 meters. The discontinuous outcropping beds of the Flohimont Member are characterised by higher MS values ($> 5.0 \times 10^{-8}$ m^3/kg) and magnetic sequences are not easily detected due to missing intervals. The base of the Moulin-Boreux records a decrease of the MS values from 3.8×10^{-8} m^3/kg to 7.66×10^{-10} m^3/kg on the first 9 meters. Above this first magnetic sequence, Moulin-Boreux Member contains several magnetic sequences showing global MS increases like those observed in the Mont d'Haurs Fm. The low-field magnetic susceptibilities remain largely positive throughout the

Moulin-Boreux Member. Most of the samples presenting negative MS values are encountered in the lower part of the member as shown by the lowest MS value (-3.09 x 10^{-9} m^3/kg). The MS remain globally below 2.0 x 10^{-8} m^3/kg in the lower/middle part of the Member, increase above 2.0 x 10^{-8} m^3/kg in the middle/upper part of the Member before rapid increase close to the Moulin-Boreux/Fort Hulobiet Member limit. The MS values of the Fort Hulobiet Member are globally above 6 x 10^{-8} m^3/kg.

Hysteresis measurements and thermomagnetic analyses are in progress on selected samples to determine the magnetic minerals and their grain sizes in order to identify the magnetic mineralogy controlling the MS signal. Gamma-ray logging realised on the whole section will be compared to MS and microfacies data.

In addition to sedimentological and rock magnetism analyses, the peri- and reefal faunas (stromatoporoids, tabulate corals, trilobites and ostracods) are studied to estimate biodiversity and ecological trends.

Like to Givet section, the Mont d'Haurs Fm. shows a high diversity of stromatoporoids and tabulate corals (lamellar, branching and massive forms). The passage to the Flohimont Mb (Fromelennes Fm.) is marked by a decrease of the diversity (only some lamellar forms and branching like Alveolitids and Thamnoporids for tabulates and Clathrocoilona for stromatoporoids). The Moulin Boreux Mb. registered a low diversity but is also characterized by a large diversification (excepted tabulates, only scoloporids were found) in this upper part (biostromes composed by massive stromatoporoids). The Fort Hulobiet is marked by a renewal of tabulates (Alveolitids, Auloporids).

The distribution and the biodiversity of trilobite fauna have been analyzed for the first time in the Fromelennes Fm. The trilobite assemblage shows a low diversity and is represented only by the *Dechenella* genus (up to 50 specimens were analysed). They are all condensed on the middle part of the Flohimont Member.

Most of hundred species of ostracods are identified from the upper part of the Mont d'Haurs Fm. to the end of Fromelennes Fm., belonging to Erisdostraca, Palaeocopida and Podocopida orders. The Mont d'Haurs Formation show a low diversity (only about ten species) but the transition with the Fromelennes Fm. is marked by a high diversity (up to 40 species) with *Quasillites fromelennensis* as dominant species. The Flohimont, Moulin Boreux and basal part of Fort Hulobiet Members registered also a low diversity with some monospecific level (*i.e. Cryptophyllus* sp. G. Magne 1964). The end of the section is characterized by a diversification (up to 20 species, mainly Bairdiidae).

The Givetian-Frasnian boundary at Nismes parastratotype (Belgium): ferromagnetic minerals (magnetite and hematite) carrying the magnetic susceptibility signal

Xavier Devleeschouwer, Estelle Petitclerc, Simo Spassov, Alain Préat

The Nismes section is located in the southern part of the allochthonous Ardennes fold-and-thrust belt (southern Belgium) about 22 km SW of Givet. The Nismes section was adopted by the Subcommission on Devonian Stratigraphy as an auxiliary stratotype for the Givetian-Frasnian boundary in a neritic facies. It exposes 26 meters belonging to the upper part of the Fromelennes Formation (Late Givetian) and the stratotype for the base of the Nismes Formation (Late Givetian and Early Frasnian). In the Nismes section, the Fromelennes Formation consists of thin to medium bedded fine-grained homogeneous grayish limestones with abundant crinoids and brachiopods in its upper part. The second part of the section starts with the Pont d'Avignon Member consisting of 1.4 meter thick nodular limestones with very abundant brachiopods. The Pont d'Avignon Member is overlain by the Sourd d'Ave Member (the first 11 meters) showing brownish shales with numerous calcareous lenses in the upper part. 94 samples were collected every 15-30 cm for magnetic susceptibility measurements through all the lithologies. 16 samples were selected for detailed rock magnetic analyses.

The low-field magnetic susceptibility (X_{LF}) values of the Nismes section are relatively low (between 1.36 and 10.5 x 10^{-8} m^3/kg) as usually observed for most of the carbonate rocks. Despite low values, the MS signal fluctuates along the lithological column with several MS evolutions (MSE) reported as magnetic sequences. MSE 1 and 2 in the Fort Hulobiet Member record two successive decreasing MS trends. MSE 2, over nearly 10 m, displays the largest X_{LF} amplitude fluctuation of the series. The lowest X_{LF} value of the section is observed at the transition between MSE 2 and MSE 3. An increasing X_{LF} trend from 1.36 to 8.85 x 10^{-8} m^3/kg is observed during MSE 3. Finally, MSE 4 shows distinctly at the base a small decreasing trend that seems to continue upwards in the discontinuous outcropping Frasnian shales and limestones.

The majority of the samples have backfield curves, which are close to saturation at -300 mT, but show a small further decrease until -500 mT that makes up between 4 and 14 % of the IRM_{500mT}. However, for three of the sixteen samples this decrease is much stronger (*e.g.* Ni 80 in Fig. 5), the contribution to the IRM_{500mT} being above 19%. Apparently, high coercivity minerals are present with variable contributions to the IRM_{500mT}. It is assumed that hematite is responsible for the high field IRM contributions rather than goethite.

The decay of the IRM_{500mT} expressed as normalized values relative to the IRM at 0 s (IRM_0) is plotted against the time (s) on a logarithmic scale. In general, between 7 and 13 % of the IRM_{500mT} are lost within 100 s indicating the presence of superparamagnetic and/or viscous grains, which are generally

rather of diagenetic than of detrital origin. The Nismes samples contain thus a non-negligible amount of SP nanoparticles in the ferromagnetic *s.l.* fraction.

The IRM decrease was quantified by the magnetic viscosity coefficient $S_d = \partial M/\partial \lg(t)$, with M being the normalized magnetisation and t the time, which has been calculated for the analysed specimens. The normalised magnetic viscosity coefficients are significantly higher in the Givetian than in the Frasnian, which may indicate that the Givetian part underwent slightly stronger diagenetic processes forming more SP particles than the Fasnian part. Obvioulsy, there is also a clear correlation with the lithologies as the Givetian is mostly dominated by limestones and the Frasnian is characterized by a higher percentage of detrital rocks.

The nature of the ferromagnetic *s.l.* fraction has been investigated using measurements of the coercive force H_c and the coercivity of the remanence H_{cr}. The magnetic mineralogy is dominated by low coercive minerals in all samples. Consequently, also the remanence coercive forces are low (< 70 mT) regardless X_{LF} for most of the samples. H_{cr} values ranging between X_{Ferro} and X_{LF} is seen even if the concentration of the ferromagnetic minerals is weak; as a consequence these minerals probably control most of the MS signal fluctuations.

Microfacies are described from open-marine environments under the influence of storms to restricted environments with semi-evaporitic conditions. The microfacies curve reveals three shallowing-upward parasequences separated by sea level rises. Gradual transgressions are observed and have affected the carbonate platform during three pulses, the last one leaves the peri-reefal and restricted environments for the deepest open-marine environments. The MS profile presented here has an intermediate behaviour between carbonate platform and ramp environments corresponding to the transitional step during the drowning of the Givetian platform (final HST) and the onset of the Frasnian ramp. The drowning is associated to an increased terrigenous influx leading to higher X_{LF} values during the lower part of the Nismes Formation in the Frasnian.

Rock magnetism, sedimentology, gamma-ray logging, clay mineralogy and geochemistry at the Frasnian-Famennian GSSP (Coumiac, Montagne Noire, France): a synthesis

Xavier Devleeschouwer, Laurent Riquier, Olivier Averbuch, Alain Herbosch, Nicolas Tribovillard, Alain Préat

In 1993, Klapper *et al.* have selected the Coumiac section as a GSSP for the Frasnian-Famennian (F-F) boundary. This section is mostly composed of red, pink and grey limestones with a few shaly intervals at the base of the section. It also contains two thin black carbonate levels corresponding to the Lower and Upper Kellwasser (KW) Horizons. The stratigraphic series ranges from the *punctata* (early Frasnian) up to the upper *crepida* (early Famennian) conodont

Zones and is 30 m-thick. Around 123 samples were analysed for sedimentology and magnetic susceptibility (MS). Additional hysteresis measurements were performed on 20 samples and 51 samples were selected for geochemistry (major, minor and trace elements) by X-Ray Fluorescence (XRF). Moreover, 117 Gamma-Ray spectrometry (GRS) measurements were realised on the field using a handheld spectrometer. Measurements with a 2-min count time were performed with a 25-cm sampling step, perpendicular to the section wall and at full contact with rock. Lastly, clay mineralogy assemblages were identified on 44 samples by XRD.

Four microfacies were recognised in these hemipelagic red and grey argillaceous and micritic carbonates. The deepest microfacies MF1 corresponds to shales and argillaceous mudstones enriched in radiolarians. MF2 is a sponge wackestone/bafflestone with styliolines and tentaculitoids whereas MF3 is a laminated wackestone/packstone with styliolines, ammonoids and bivalves. The shallowest microfacies is a crinoidal packstone. More than 20 hardgrounds have been recognised throughout the section and are densely observed close to the F-F boundary. The environment of the Coumiac section corresponds to a distal carbonate ramp *sensu* Read (1985) with offshore hemipelagic sedimentation. Distal and proximal storm deposits are common in the shallowest microfacies. The deepness of the environment could be only roughly estimated in the absence of reliable paleobathymetric indicators.

MS curve presents a clear decreasing trend from the early Frasnian to the end of the Frasnian (*linguiformis* zone) with the lowest MS values being observed in the two Kellwasser horizons. Increasing low-field magnetic susceptibility values are reported during the Early Famennian. By comparing MS values with hysteresis parameters, it appears that the MS signal is primarily dominated by the ferromagnetic fraction (magnetite-type phase and hematite) and in a minor way by paramagnetic clay minerals.

The GRS logging reveals that the concentrations of the 3 measured elements (K, U and Th) display similar fluctuations: a long-term decrease during the Frasnian followed by a slight increase of the concentrations at the base of the Famennian. K and Th are well correlated (R^2 = 0,89) reflecting a fine-grained siliciclastic admixture in the carbonate rocks. In addition, high U/Th ratios (>1.25) were obtained twice around the Lower KW and close to the F-F boundary (Upper KW). This clearly indicates reducing conditions during the formation of the two black horizons. This observation is confirmed by geochemical analyses (Zn, Fe and S increase).

Clay minerals are dominated by illite (65-100%) and kaolinite (0-30%). Traces of interstratified Illite-smectite (up to 10%) and smectite (5 to10 %) are also present. Smectite has been detected in 7 samples between the two Kellwasser Horizons. The percentage of kaolinite starts increasing at the base of the early *rhenana* zone to reach higher values between the Kellwasser Horizons. The highest percentage (30 %) is reached at the base of the Famennian. Kaolinite percentages decrease during the base of the Famennian before reaching again higher values (up to 20 %) in the *crepida* zone. The mean value of the corrected illite cristallinity index (mean IC value = 0.79) corresponds to the higher part of the high diagenesis zone *sensu* Yang and Hesse (1991). Burial temperatures deduced from the IC values confirm the CAI values of 2-2.5 (Girard & Albarède, 1996) typical of a weak diagenesis. The origin of illite could be related to an authigenic phase evolved from smectite in a confined

environment on the platform during a warm and humid climate. These minerals have been therefore transported from protected areas to deeper environments by storms as indicated by the microfacies analysis.

Magnetic susceptibility evolutions and Corg isotopes in continental deposits at the Paleocene/Eocene boundary (Sotteville and Vasterival sections, France)

Xavier Devleeschouwer, Jean-Yves Storme, Christian Dupuis, Florence Quesnel, Johan Yans

The Paleocene/Eocene (PE) boundary is affected by a global, high-amplitude and rapid warming called the Paleocene-Eocene Thermal Maximum (PETM) associated with a negative Carbon Isotope Excursion (CIE). Some outcropping sections (Sotteville and Vasterival) scattered along the Upper Normandy coast (France) are located in the central part of sub-basins of the southern North Sea Basin.

PE deposits (7 m thick) of the Sotteville section overlie the Cretaceous chalk. Calcareous sands with some lacustrine limestones lenses and quartzite silcrete concretions characterise the base of the section (Pays de Caux Member). Three units are observed and each of them is capped with a bed of lignite. These three units compose the Calcaire d'Ailly Member. Several sandy units with cross-stratifications are sandwiched between clay layers present at the base and at the top of this new named Sotteville-sur-Mer Member. The top of the section is a pale green glauconitic level enriched in clays.

The Vasterival section encompasses the lignite complex (L1) of the Cap d'Ailly section. In the Cap d'Ailly area, the Mont Bernon Group (MBG) equals to the so-called Sparnacian (SP) (Magioncalda *et al.*, 2001; Aubry *et al.*, 2005). The lower part of the MBG is the Mortemer Formation, which comprises (base to top): sands and sandstones ('Sables et Grès du Pays de Caux', SP1) followed by sandy limestones, pyritic marls and paleosols, and ~1m-thick lignite complex ('Calcaire d'Ailly Member', SP2). This lignite complex (L1) contains a succession of five pluricentimetric-scale lignite beds (Lb1 to Lb5) interstratified with organic bearing silts and clays. The 'Sables et Argiles à Ostracodes et Mollusques' (SAOM) of the Ailly Member (SP3) overlies uncomformably this lignite complex (Magioncalda *et al.*, 2001; Aubry *et al.*, 2005).

59 and 30 samples respectively for Sotteville and the lignite complex L1 of Vasterival were analysed for Magnetic susceptibility (MS) data with a Kappabridge MFK1-A.

MS values for the Sotteville section range between 0.96×10^{-8} and 273.4×10^{-8} m^3/kg. The highest MS value has been found in the lacustine limestones of the first unit of the Calcaire d'Ailly Member. In details, MS curve is characterised by two horizons with high MS values (> $20\ 10^{-08}$ m^3/kg). The first horizon starts at 0.75 m from the base and has a thickness of 0.5 m. The second horizon starts at 2.47 m from the base with a peak at $116.7\ 10^{-08}$

m^3/kg and is 23-cm thick encompassing the end of the second unit of the Calcaire d'Ailly Member. Above this horizon, three magnetic sequences record MS fluctuations always below 20 x 10^{-08} m^3/kg.

A high-amplitude negative excursion of the C_{org} isotope curve (from –25.3 ‰ to –29.7 ‰) is observed at Sotteville and its onset corresponds to the PE boundary (at 1.02 m from the base) and the lower part of the CIE. The lower MS peak is located thus 12 cm before the beginning of the CIE and the PE boundary. However, the first horizon encompasses the PE boundary and contains a second smaller peak (71.62 10^{-08} m^3/kg) observed 5 cm after the PE boundary.

MS values of Vasterival range between 2.91 x 10^{-8} and 55.94 x 10^{-8} m^3/kg. The highest MS value (55.94 10^{-8} m^3/kg) corresponds to a lacustrine limestone at the base of the section (0.44 m from the base). The MS curve records a long-term MS decrease subdivided in several magnetic sequences. The highest MS values are observed at the top of each magnetic sequence and correspond to a lignite layer. At the base of the section, only the upper part of the first magnetic sequence has been sampled. The horizon with high MS values has a thickness of approximately 24 cm at the base of the section.

A high-amplitude negative excursion of the C_{org} isotope curve (between –26.1 ‰ and –28.8 ‰) is observed at Vasterival and its onset corresponds to the PE boundary (at 0.98 m from the base). The organic carbon isotope values return to 26.01 ‰ at 1.49 m from the base. This 0.51 m-thick horizon seems to correspond to the lower part of the CIE and the beginning of the PETM. The lower MS peak is thus located approximately 60 cm before the beginning of the CIE and the PE boundary.

Due to stratigraphic uncertainties in these continental deposits in both sections, the only reliable parameter used for high-resolution stratigraphic correlation seems to be, until now, the onset of the CIE, which marks the PE boundary. It's now tentatively proposed to make a correlation between these two sections using the highest MS value (peak) obtained at the base of each section below the PE boundary. It could be envisaged in both sections that a similar process or origin could explain these abnormal MS values in the lacustrine limestones. In the continental sections studied here, the classic interpretation of the MS signal (*i.e.* detrital input variations to the marine domain linked with sea-level fluctuations in relation to climatic or tectonic evolutions) cannot be used.

Cubic SD magnetites are commonly found in the CIE level sediments of the Wilson Lake and Ancora drill cores (New Jersey, USA) in the neritic inner to middle shelf environment on the North American continental margin. These cubic magnetites seem to be produced by magnetotactic bacteria and have thus a biogenic origin (Lippert *et al.*, 2007; Kopp *et al.*, 2007). These bacteria are common in freshwater and marine environments. Rock magnetic analyses (thermomagnetism and hysteresis measurements) are thus necessary to identify the minerals carrying the MS signal in Sotteville and Vasterival sections in order to try (1) to determine a detrital, authigenic (pedogenetic modifications) or biogenic origin (2) to specify the grain sizes of the magnetite crystals using the coercivity and magnetisation ratios.

U-Th dating using Inductively Coupled Plasma – Quadrupole Mass Spectrometry: A rapid and accurate chronological tool for the study of the past natural archives

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Until recently, U-Th dates were the most often obtained by using Alpha Spectroscopy or more advanced mass spectrometry (TIMS, MC-ICPMS). Here, the potential for rapid and accurate U-series dating of various natural materials (calcite, aragonite, and apatite) has been explored using inductively-coupled plasma-quadrupole mass spectrometry (ICP-QMS). The analytical procedure includes a largely simplified chemical separation technique for uranium (U) and thorium (Th) using UTEVA resin. The developed technique permits simultaneous quantification of uranium [^{238}U] and thorium [^{232}Th] concentrations and their respective isotopic composition, required for U-series disequilibrium dating. Up to 50 U-Th dates per day can be achieved through ICP-QMS with d^{234}U and d^{230}Th reproducibility (2s) of 3-4 ‰ and 1%, respectively. The high sensitivity (>3.0 x 10^5 cps/ppb) together with low background (<0.5 cps) on each mass between 228-236 amu allowed U-Th dating of ancient natural samples at precision levels of less than 2%. Consequently, the combination of simplified chemistry using UTEVA with state-of-the-art ICP-QMS isotopic measurements that do not require a U-Th separation step now provides an extremely rapid and low-cost U-series dating technology. The level of precision is most convenient for numerous geochronological applications in earth-environment-climate-human sciences. Here, examples of U-series dating of deep-sea corals, stalagmites or bones using ICP-QMS will be shown and discussed.

Some exceptional MP6 to MP16 estuarine channels at Palaeogene stage boundaries in the Paris Basin, E of the Pays de Bray anticline in Marne (Louvois MP6 to Monthelon MP10b) and Aisne (Condé-en-Brie MP9 to Chéry-Chartreuve / Rocourt-St-Martin MP15b)

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The Palaeogene of the Paris Basin includes stratotypes which are international references as well as localities that are important for marine biostratigraphic scales. Stage boundaries have been much discussed. Through the study of emerged areas and hiatuses intercalated at stage boundaries, we propose to

describe sedimentary bodies which have yielded abundant terrestrial bioclasts, in continuity or alternating with marine marker horizons, in order to improve the chronostratigraphy of the basin in the Palaeocene and Eocene.

On the basis of some synthetic sedimentological sections in départements Marne and Aisne and of associated diagraphic correlations we show that stage boundaries near emerged margins reveal deposits which have recorded interesting channels preserved in tectonic collapse areas, downstream from a large catchment area and upstream or on the border of an estuarine domain. These estuaries persisted throughout the period analysed here and provide new evidence on stage boundaries, such as the Sparnacian-Cuisian boundary, the Ypresian-Lutetian boundary within the Ypresian, or the Auversian-Marinesian boundary within the Bartonian.

These boundaries, hitherto based on marine biostratigraphy, will be discussed and a new correlation between the MP (Palaeogene Mammals) scale, molluscs from marker horizons, and the NP (Nannoplankton) scale will be proposed on the basis of faunal records, correlations and depositional models.

Integration within a palaeogeographical and tectono-sedimentary evolution - already discussed at the Arras Chalk Colloquium (SGN - Duprat, 1997), at BiochroM' 97 and at RST 2000 - allows to improve the sequential analysis model of Gély and Lorenz (1991) and to confirm some of the hypotheses put forward by Pomerol as early as 1965, concerning the tectonic influence of the Bray anticline upon the palaeogeography of the basin.

In a peri-estuarine domain permanently fed by freshwater from catchment areas, the synchronism between tectonic movements and periods of uplift of the Bray anticline can explain some relative sea level drops synchronous with groundwater rise. In particular, we observe marker horizons with evidence of synsedimentary tectonics (Montenat *et al.*, poster RST 2000 for the Auversian-Marinesian), which are characterised by a rapid and complex transition from marine clastic formations to continental carbonates with limneids and planorbids (Métais *et al.*, STRATI 2010). For the same assumed reasons the estuarine channel of Sables à Unios et Teredines (Grauves MP10) evolves vertically towards lacustrine limestones.

In a more subsident area, the mouth of the estuarine channel of Artonges (Broyes – Condé-en-Brie – Brales) contains a more complete Palaeogene section including a newly found mammal-rich site in the 'Brasles area' near or above the Lutetian base, arguing the sedimentological model presented at SGN and BiochroM in 1997.

Similarly during the Palaeocene, the vast emerged and karstified Chalk domain extending from Provins-Esternay-Sézanne in the West to Louvois in the East is cut by Palaeocene to Eocene channels at stage boundaries. This suggests a very promising prospection area in the Montagne de Reims, where a search for new vertebrate localities could complement the prospecting activities conducted for a long time by local naturalist associations (Louis, 1996). Also some ongoing studies in the 'Hermonville area', Montchenot and 'Châlons-sur-Vesle area' are currently yielding some vertebrate levels within or at the top of marine facies, confirming the estuarine hypothesis (BiochroM'97) of the north-eastern part of the Sezanne channel.

Finally, a better understanding of the tectono-sedimentary evolution of the Montagne de Reims area and new biochronological data about it may reveal new Palaeocene sites with for instance evidence of Gastornis at Louvois, MP6, and lead to a better definition of the international marker horizons MP8+9 ('Avenay') - MP10a/MP10b ('MP10 Grauves'), after the biochronology proposed by Lecomte 1994, Hooker 1996, Escarguel 1997 and Franzen 2005.

Mammal and Reptile sites:

- MP16: Grisolles.
- MP15b: *Rocourt-Saint-Martin* (levels II-9a to II-10d); Nogent l'Artaud; *Chéry-Chartreuve* (levels Au-3d to Au-4e).
- MP15x: Sergy, Latilly and Arcis le Ponsart (=MP15b? to be discussed: no sedimentary section).
- MP14: Le Guepelle. MP12-MP13: Jumencourt; Jaulgonne.
- MP10b-(?MP11): *Monthelon* (upper Unios & Teredina levels 7a to 11b); *Mancy*; *Cuis*; *Prémontré*; *Bouvancourt*; *Arty* (within and above C. giganteum levels); *Venteuil*; *Oeuilly*; new site '*Sables de Brasles - East*'.
- MP10a: *Monthelon* (lower Unios & Teredina levels 1b to 6a); *Mont-Bernon*; Saint-Agnan; *Broyes* (upper levels); Brasles (Feugueur 1963, Louis & Laurain 1983).
- MP9: *Condé-en-Brie*; *Pourcy* (upper levels); Broyes (lower levels, Louis 1970).
- MP8c: Avenay.
- MP8b: Mutigny.
- MP8a: Pourcy (lower levels).
- MP7: Try (upper levels); Soissons Grand Séminaire; Sinceny; Muirancourt.
- MP6c: *Berru*; *Montchenot*; *Louvois*; Rilly; Try (lower levels or reworked?).
- MP6b: La Fère (Arctocyon primaevus); Cernay; new site 'Châlons-sur-Vesle area'; new site 'Hermonville area'.

Vertebrate macro-remains as stratigraphic markers: the case of the 'Kujdanowiaspis assemblage' from the Lower Devonian of Podolia (Ukraine) and Celtiberia (Spain)

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The vertebrate fauna, including chondrichthyan microremains and osteostracan and placoderm macroremains encountered in the Lower Devonian (*i.e.* Lochkovian and Pragian) deposits from Podolia (Ukraine; see list in Voichyshyn, 2001) was considered as unique. Unfortunately, because of the Old Red Sandstone facies, the stratigraphic boundaries were very difficult to determine. Until recently, most of the units were lithologic. The occurrence of the arthrodire placoderm *Kujdanowiaspis buczacziensis* has since been proposed to mark the beginning of the Pragian, owing to a number of

correlations between fossil distributions (*i.e.* the pteraspidiform *Althaspis*) in Western Europe and Podolia (Dupret and Blieck, 2009).

Recently, the long time 'unique' placoderm and chondrichthyan faunal assemblage from Podolia has been found in Spain (Martinez-Pérez *et al.*, in press; Dupret *et al.*, submitted). The absence of *K. buczacziensis*, nevertheless, leads us to consider an age older than Pragian, *i.e.* late Lochkovian. This dating confirms previous works mainly based on invertebrates and conodonts. These 'double check' processes confirm the possibility of using macrovertebrate remains for stratigraphic purposes.

The occurence of the same fauna during the Late Lochkovian in Podolia (southern margin of Laurussia) and in Spain (Armorican 'block', part of northern margin of Gondwana or independant component), leads us to favour palaeogeographic reconstructions showing a proximity between both palaeo-provinces, allowing for the formation of, at least, punctual migratory paths. Moreover, the Old Red Sandstones have long been considered as non-marine deposits, especially in Podolia, despite the discovery of seldom brachiopod (lingulid) fragments. The similar faunal composition between Podolia and Celtiberia (the latter being clearly marine) challenges the non-marine status of the Podolian deposits.

Towards a detailed paleogeographic reconstruction of the Paris Basin during the Late Paleocene and the Early Eocene

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The Paris Basin is one of the famous historical sites from where the concept of the Paleocene-Eocene boundary originates (Aubry *et al.*, 2005). Today, it always preserves a huge potential in deciphering and understanding the climatic and geodynamic evolution of shallow marine to continental paleoenvironments during the Paleocene Eocene Thermal Maximum event.

We report on the construction of paleogeographic maps as critical tools highlighting the evolution of the landscapes. In order to reconstruct them, we are documenting a reference transect along the English Channel coast, from Upper Normandy to the North Sea Basin onshore (Northern France), crossing major outliers, old quarries and recent boreholes. Preliminary results allow distinguishing five main sedimentologically and biostratigraphically consistent regional sequences covering the NP Zone 7-8 to 11 interval, separated by three major hiatuses. The maps are based on these divisions. In addition, we try to correlate some of the prominent variations of the δ^{13}CCorg curve recorded across the Paris Basin (Sinha, 1997; Thiry & Dupuis, 1998;

Magioncalda, 2004; Breillat *et al.*, 2010; Quesnel *et al.*, 2010; Storme *et al.*, 2010; Smith *et al.*, 2010; Yans *et al.*, 2010). **Five maps** illustrating the main environmental events are presented.

A **first map** shows the development of continental paleoenvironments (extensive erosion, paleosols, karsts, fluvial deposits, etc.) between the two main pulses of the Thanetian transgression (often considered as unique) at the NP8-NP9a junction.

A **second map** exemplifies the sea level drop occurring just before the onset of the Carbon Isotope excursion (CIE) correlative of the PETM. It is represented by alluvial plains and fresh water swamps deposits (lacustrine limestone, peats, lignites...), sometimes rich in flora and/or fauna and in which the PETM began (Magioncalda, 2004; Garel *et al.*, 2010; Smith *et al.*, 2010; Storme *et al.*, 2010). Many units are diachronous in this Mortemer Fm mainly deposited in terrestrial (and locally coastal) environment (Breillat *et al.*, 2010).

The **third map** attempts to restore the paleosurface on which ground-water related silcretes and other oxided sandstones (laterally linked with upstream pedologic silcretes), formed. Those particular paleoweathering are probably one of the main effect of the PETM, although some may have formed locally earlier, during the latest Paleocene, and elsewhere later, during the Early Ypresian (Quesnel *et al.*, 2009).

The **fourth map** relates on the invasion of the Paris Basin by large tidal flats and lagoons (Woolwhich Shell Beds in England, Tienen Fm in Belgium, Soissonnais Mb in Paris Basin). This marine invasion culminated with the deposition of open marine glauconitic clay (~NP10?) preserved in few localities of the NW Paris Basin. This Craquelins unit is missing towards the centre of the basin (Breillat *et al.*, 2010) revealing major erosion and/or non deposition before the subsequent Ypresian transgression.

The very beginning of this latter is illustrated on the **fifth map** which points to the inner shore regressive sands and pebbles deposited mainly in the NW part of the studied area (Oldhaven Sands, Blackheath beds, St Saëns and Sinceny 'Galets avelannaires', Quesnel *et al.*, 2009; Quesnel *et al.*, 2010). The development of the Ypresian transgression (NP11) which spread offshore facies afterwards is not detailed here.

To conclude, shallow paleoenvironments of the Paris Basin acted as a very sensitive recorder of every small uplift movements and sea level changes. Paleogeographic maps help to decipher and differentiate these events in order to tentatively correlate them with other regional records such as the North Sea Basin or the North Atlantic Ocean.

Basal vertebrate diversity from the Mesozoic of Northern Libya

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Five horizons exposed in the Jabal Nafusah in Northern Libya have yielded articulated and disarticulated basal vertebrate assemblages. The sedimentological units belong to the Takbal Fm (Bathonian ?), the Cabao Fm (Lower Cretaceous, ante-Aptian), an undetermined formation (Green marls) similar to the Douiret Formation, described in Tunisia, the Kiklah Fm (Albian?), and an undetermined formation probably Albian in age.

The Tabkal Fm has yielded the following taxa: *Hybodus* sp., *Asteracanthus* sp. and, *Asiatoceratodus* aff. *tiguidensis*). The presence of marine and freshwater fauna suggests a thanathocoenosis. The Cabao Fm has provided *Hybodus* sp., *Priohybodus arambourgi*, Neopterygii indet., Mawsoniidae indet., Ceratodontidae indet.). The undetermined green marl horizon has provided very small teeth of *Priohybodus arambourgi* and *Hybodus* sp., and teeth and scales of Semionotiformes indet. The Kiklah Fm has yielded: *Tribodus* sp., *Protolamna* sp., *Onchopristis* cf. *dunklei*, Pycnodontiformes indet, Semionotiformes indet.). This faunal assemblage is very similar to those described in the Chenini Fm (Tunisia), considered as Albian in age. A siliclastic horizon of an undetermined formation has yielded two actinopterygian specimens, which belong to a Polypteriformes indet. and a Macrosemiidae indet. These fossils consist of prints but their articulated body is well marked. Articulated polypterids are scarce in the fossil record as well as the mention of a macrosemiid in Africa.

At least sixteen taxa, represented by elasmobranchs, actinopterygians, dipnoans, and coelacanths, have been found and their study increases significantly the current knowledge of basal vertebrates from the Mesozoic of North Africa.

Sedimentology and stratigraphy of the Dogger region Demnat - Central High Atlas Morocco -

Abdenbi El Aloui

The bowl Iouaridene lies in the western part of Central High Atlas-AtlasDemnat (Roch, 1939; Leveque, 1961). This is a series of silty-carbonate Dogger age.

The objective of this work will lead to a sedimentological study by defining and analyzing the different facies and sequences in various scales will help define the depositional environments and deduce the sequential evolution, and also propose an interpretation of sediment dynamics. Thus an analysis of diagenetic sedimentary facies has been discussed to identify and characterize the major changes that have affected (early cementation and dolomitization) over the

study of clay assemblage of different sedimentary sequences. In order to reconstruct the paleogeographic history of this region.

Relation entre substratum riche en matière organique et foraminifères planctoniques, Aptien de la Tunisie septentrionale

Abdallah Elkhazri, Saloua Razgallah, Hassen Abdallah

En Tunisie septentrionale le Barrémo-Aptien, 'Formation M'Cherga', révèle une sédimentation continue à divers faciès. Le Barrémien est caractérisé par l'individualisation de deux barres carbonatées d'épaisseurs variables, intercalées par une sédimentation marno-calcaires. L'Aptien inférieur (Bédoulien) comprend des alternances d'argiles grises, de marnes et de calcaires noirs. Dans la partie moyenne du Bédoulien supérieur les calcaires sont sous la forme de fines plaquettes noires feuilletées à microfaciès laminé riche en foraminifères planctoniques et en grains de phosphate et de glauconie. Ce faciès caractérise les niveaux 'Black shales' correspondant à l'événement anoxique 'OAE 1a'. Ces couches à matière organique sont associées à une décroissance brusque de la biodiversité (chute des foraminifères benthiques) avec un apport important de foraminifères planctoniques (80 à 90%) à loges radialement allongées (*Lilliputianella*, *Leupoldina*) permettant une meilleure adaptation à cette déficience en oxygène. Dans la partie moyenne du Bédoulien supérieur, l'espèce *Leupoldina cabri* apparait avec un nombre assez important (Gisement à *Leupoldina*).

La position stratigraphique de cet horizon déficient en oxygène demeure discutée au moins en Allemagne (Niveau Fischschiefer: Barrémien supérieur-Bédoulien inférieur), en Italie (Livello Selli: Bédoulien inférieur), en France (Black Shales: Bédoulien supérieur) et en Tunisie (Black Schales : Bédoulien supérieur en se référant à la première apparition de l'espèce *Leupoldina cabri*). Au-dessus, le Gargasien est caractérisé par des argiles verdâtres qui contiennent en abondance des foraminifères planctoniques à loges essentiellement globuleuses associés aux benthos témoignant de conditions favorables à la vie et à l'installation d'un milieu marin franc dans le nord de la Tunisie.

Ce travail met en évidence l'impact de cet événement sur la distribution des foraminifères planctoniques et sur leur stratégie adaptative à cette déficience en oxygène.

Palaeozoic stratigraphy in the Czech Republic

Oldřich Fatka

In Central Europe exposures of Lower and Middle Palaeozoic sediments are known in several more or less restricted regions. Quite extensive richly fossiliferous outcrops of unmetamorphosed Cambrian to Middle Devonian sedimentary sequences associated with subordinate volcanites occur in central part of the Bohemian Massif; in part which was designated as the Barrandian area, to commemorate the importance of palaeontological and stratigraphical research conducted by the French scientist Joachim Barrande. Cambrian rocks are established in two separate regions; in the large Příbram-Jince Basin and in the smaller Skryje-Týřovice Basin, while Lower Ordovician to Middle Devonian sequences belong to the Prague Basin.

In this region, Palaeozoic fossils have been collected since the second half of the 18th century and the first stratigraphical scheme was proposed more than 150 years ago by Barrande in 1846. Barrande published this first scheme in a preliminary report on the "*Système silurien*" and it was fully explained six years later in the first volume of the "*Système silurien du centre de la Bohême*" (Barrande, 1852). Because Barrande was strongly influenced by geological studies of Sir Roderick Murchinson in Britain, he adopted the designation *Système silurien* (= Silurian System) for all rocks in the studied area. Barrande distinguished three major divisions (called I. Division Inférieure, II. Division Moyenne and III. Division Supérieure); these three divisions were subdivided into seven levels, which were designated as *étage A* to *étage G*.

In Barrande's original concept, the lowermost levels - *étage A* (roches métamorphiques) and *étage B* (roches azoiques), both belonging to the Division Inférieure, were unfossiliferous and belong to the Proterozoic in the recent terminology. The oldest fossiliferous levels were designated as *étage C*; it contained his '*faune primordiale*' and corresponds to the Cambrian Series 3 in current terminology. The next *étage D* fits well with the Ordovician in the recent terminology. These two étages were classified as the Division Moyenne. The following *étage E*, *étage F* and *étage G*, are equal to our Silurian to Middle Devonian respectively; they were classified as the Division Supérieure. Cambrian age of the *étage C* was recognized by Marr in 1880 for the first time. However, Marr applied 'Cambrian' in the Sedgwick's extensive sense, embodying also the whole overlying *étage D* of Barrande (*i.e.* Ordovician in current terminology). Presence of Devonian was recognized to the end 19th century.

Intensive paleontological research resulted into continuous improvement of stratigraphical subdivision in the Barrandian area and provided also important arguments for development of the GSSP philosophy. This activity culminated in the second half of 20th century when several of the earliest GSSP were established in the Late Silurian to Lower Devonian of the Barrandian area. We can only regret that J. Barrande was so deeply impressed by results of Murchinson's studies that he accepted his subdivision and did not propose independent stratigraphy, including own designations. Stratigraphic schemes

proposed originally by Barrande and developed now for more than 150 years made possible to correlate Cambrian, Ordovician, Silurian and Devonian stratigraphic units of the Barrandian area with the official geologic time scale.

It should be stressed that since the Barrande's time, more or less intensive cooperation of Czech and French palaeontologists played an important role for understanding of palaeontology, palaeogeography, stratigraphy and correlation of the Barrandian area.

Palaeobathymetry and palaeoenvironments of Shiranish Formation (L- Maastrichian) - Sinjar mountain – NW Iraq

Abed Salih Fayyadh

The palaeobathymetry and palaeoenvironments of Shiranish Formation (Upper–Cretaceous) in Singar area revealed by using the fluctuations in the distribution of benthonic (B) and planktonic (P) foraminiferal fauna, represented by diversity, abundance and percentages of P/B.

The study shows that there are alternation of groups of benthonic species and genera with increasing depth, and that the individuals of planktonic foraminifera are more than benthonic, while the percentage of benthonic genera are more than of planktonic in studied section.

The benthonic foraminifera are more diverse and the percentages of calcareous ones exceed agglutinated species by 4:1, and the individuals of agglutinated species increased respectively to the top of studied section in addition to decrease of species that represent the families Nodosariidae and Dentalinidae in the same direction.

From these fluctuations we deduced that Shiranish formation were deposited in the marine environment of palaeodepth range from 500-1500m (middle bathyal of Tethys sea that covered the area during Early Maastrichtian).

The study also shows that there were a great influence of turbidity currents and slumping effected environment of deposition of the formation during that time.

Analysis of gravity-driven growth faults and syn-kinematic deposition, Niger Delta, Nigeria

Hamed Fazlikhani, Stefan Back

Syn-depositional faults above mobile shale were examined in the western Niger Delta offshore Nigeria by using the three-dimensional seismic data. Six large-scale regional and one counter-regional growth fault within the study area are used to analyze the influence of gravity-driven faults development on syn-kinematic deposition. The initiation, the lateral propagation and retreat,

periods of activity and quiescence, and the decay of faulting around these blocks can be monitored by analyzing series of time-structure and isochron-thickness maps. The syn-depositional activity of the studied growth faults was expressed in three ways: (1) by thickening of sediments on the hanging wall into the active fault plane, generating a sedimentary wedge; (2) by a significant difference of the sediment thickness of contemporaneous strata on the footwall and hanging wall of the active fault; and (3) by lateral changes of the length of the studied faults between successive horizon levels. Based on the above criteria, the study area can be subdivided into three structurally/sedimentary different zones: firstly a northwestern zone that is characterized by the presence of a major counter-regional growth fault in the deep subsurface associated with an immature rollover anticline generating the primarily 'depobelt' on the downdropped fault block; this deep structure is superseded by an array of younger, seaward-oriented growth faults strongly displacing the former footwall block. Secondly a central to eastern zone that seems largely unaffected by young deltaic faulting; this zone is characterized by the thinnest sedimentary record of the study area; and thirdly a southeastern zone dominated by a large, listric, regional master fault that is associated with a well-developed rollover anticline internally segmented by a complex crestal collapse. Combined structural and stratigraphic analyses document a strong interrelation between syn-depositional fault activity and syn-tectonic sedimentation in that phases of major depositional coincide with significant fault activity, lateral fault growth and fault migration; in turn, areas and intervals characterized by least sediment accumulation also record the lowest record of fault activity. Much of this tectonic-sedimentary relationship can be attributed to differential sedimentary loading of the underlying mobile-shale substratum.

Vitesses des processus sédimentaires érosifs au cours des cycles de variation du niveau de base

Serge Ferry

D'une façon générale, l'érosion procède de façon différente lors d'un abaissement du niveau de base (érosion linéaire par enfoncement du réseau hydrographique) ou lors d'une remontée (érosion aréolaire par effet de rabotage par les vagues).

En régime régressif, l'exemple ' pathologique ' de la crise messinienne méditerranéenne a montré que l'incision du réseau hydrographique périphérique accompagnant l'abaissement du niveau de base se produit à la même vitesse dans les roches dures du socle et dans les roches sédimentaires tendres. Il montre également que la rectification du profil en long des cours d'eau est un processus adaptatif non seulement impérieux mais rapide, si le débit du fleuve est suffisant : plus de 1000 m de surcreusement par le fleuve Rhin-Rhône sous la Camargue en moins de 300.000 ans, selon Clauzon et al (1996), soit plus de 30 cm d'abaissement par siècle. Inversement, les profils en long irréguliers de certains fleuves côtiers sont révélateurs d'une tectonique active récente, comme par exemple sur la marge angolaise (Guiraud *et al.* sous presse) où le soulèvement récent est estimé atteindre 17 cm/siècle, soit

presque le double de la vitesse des mouvements verticaux alpins actuels. La comparaison de ces deux exemples souligne indirectement l'influence du débit donc du climat sur le processus d'érosion, rapide pour le fleuve Rhin-Rhône, retardé pour les fleuves angolais soumis à un climat sec.

Les transgressions, quant à elles, procèdent souvent par la création de surfaces de ravinement (' wave-cut platforms '), illustrées par quelques cas spectaculaires (Nummulitique subalpin, Burdigalien provençal, Plio-Quaternaire de l'île de Rhodes). Là encore, peu importe la nature du substratum, dur ou tendre, seule compte la surface d'équilibre. Le processus est à l'œuvre sur les côtes de la Manche où, à chaque remontée glacio-eustatique du Quaternaire récent, les falaises reculent sous l'effet du rabot des vagues. La morphologie de la Manche actuelle, à fond plat et bordée de falaises, est d'ailleurs sans doute le résultat cumulé de l'effet érosif des surfaces de transgression des derniers cycles glaciaires où l'amplitude des variations du niveau marin a, neuf fois au moins, largement dépassé la centaine de mètres au cours du dernier million d'années.

En ce qui concerne les vitesses de déplacement de la ligne de rivage, en voici quelques exemples. Dans le bassin intérieur nord-américain (bassin flexural d'avant-chaîne), la vitesse de la transgression coniacienne (Niobrara Fm.), après la très forte régression forcée de la fin du Turonien, se serait produite à des vitesses allant de 50 à 150 m/siècle selon les endroits (Merewether *et al.* 2007). Dans le cas de l'Hauterivien supérieur de la marge atlantique marocaine (bordure cratonique passive), on dénombre une quarantaine de cycles à haute fréquence d'une épaisseur totale d'environ 250 m pour une durée de l'ordre de 2,5 Ma, soit une durée moyenne d'environ 600.000 ans/cycle. L'amplitude maximum des fluctuations amont-aval de la ligne de rivage sur ces cycles est de l'ordre de la centaine de kilomètres. Cela donne des vitesses de régression et de transgression de l'ordre de la trentaine de m/siècle, comparables à celles de la marge du bassin d'avant-chaine nord-américain. Dans le cas du ' Continental Intercalaire ' saharo-tunisien, réputé autrefois fluviatile mais découvert principalement constitué d'un grand nombre de séquences d'estran, les fluctuations de la ligne de rivage peuvent être de l'ordre du millier de km par cycle stratigraphique. Mais faute d'éléments de datation précis, les durées, et par conséquent les vitesses sont difficiles à évaluer ; elles sont sans doute au moins du même ordre de grandeur, sinon plus, que dans les cas précédents.

Il est difficile de comparer les situations anciennes du Mésozoïque à celles du Plio-Quaternaire qui est une période marquée par une amplification des reliefs et la superposition des cycles glacio-eustatiques responsables indirects de la genèse des plateaux continentaux. Notamment les vitesses de remontée du niveau marin glacio-eustatique sont beaucoup plus rapides, estimées par Flemming et al (1998) pour la dernière déglaciation entre 60 cm et un mètre/siècle, par Rohling et al (2008) pour l'avant-dernière déglaciation à 1,5 m/siècle. D'autres estimations (Sidall *et al.* 2003) font état de vitesses pouvant atteindre temporairement 2 m/siècle. Sur un plateau continental penté à 1 ‰, la vitesse de transgression peut alors atteindre 2 km/siècle soit environ 10 fois plus que pour les transgressions mésozoïques s'effectuant sur des basses plaines deltaïques ou des bordures cratoniques peu pentées.

Pulsations tectoniques à moyenne et haute fréquence - leur enregistrement sédimentaire

Serge Ferry, Daniele Grosheny

Les travaux sédimentologiques et stratigraphiques menés depuis presque dix ans sur le pourtour méditerranéen ainsi que dans d'autres bassins mondiaux dans l'intervalle Albien supérieur-Coniacien permettent de comparer les enregistrements séquentiels sur des segments de marges différents et donc de tester la notion d'eustatisme, notion toujours en vogue pour expliquer les cycles stratigraphiques de 3° ordre (1 à 2 MA).

La conclusion qui se dégage de ces études est que cet enregistrement séquentiel est la plupart du temps hétérogène. Il traduit par conséquent des gauchissements lithosphériques d'origine tectonique. Le détail stratigraphique obtenu sur les différents transects plate-forme/bassin permet par ailleurs de montrer que cette tectonique ne procède pas de façon régulière mais par pulsations brèves, dont la durée ne doit pas excéder quelques centaines de milliers d'années, soit sur une partie faible de la durée de ces cycles stratigraphiques. Pendant le reste de la durée du cycle, se produit probablement une relaxation des contraintes qui rend les corrélations à longue distance possibles, et donc semble valider un mécanisme eustatique. Au cours de la phase paroxysmale, les déformations ne sont pas de même sens partout. Au plan séquentiel, il en résulte que ces pulsations tectoniques, souvent quasi synchrones à grande échelle, engendrent des distorsions telles qu'une limite de séquence (discontinuité de chute du niveau marin relatif) peut se corréler avec une surface de transgression ailleurs. L'exemple détaillé de la limite Cénomanien-Turonien est particulièrement démonstratif de ce point de vue mais on retrouve un résultat semblable à d'autres limites stratigraphiques (Albien-Cénomanien, Turonien-Coniacien).

À plus haute fréquence, c'est à dire dans la bande de fréquence des cycles de Milankovitch, les comparaisons du nombre des cycles, dans les secteurs des bassins où la profondeur faible de dépôt devrait permettre de les enregistrer tous, montre que ce nombre varie grandement d'un bassin à l'autre. Ce fait ne peut s'expliquer non plus par un mécanisme eustatique à haute fréquence. Il s'agit plutôt du résultat du relâchement quasi périodique local des contraintes tectoniques interplaques qui induit des mouvements verticaux de faible ampleur sur les marges des différents bassins. Ces mouvements engendrent les cycles stratigraphiques à haute fréquence.

Nos travaux, comme ceux d'un nombre grandissant d'auteurs, mettent donc en doute la notion d'eustatisme pour les cycles du 3° ordre au quatrième ou cinquième ordre. Si nos conclusions sont valables, on ne doit pas oublier qu'elles concernent principalement les périodes non glaciaires. La réalité est sans doute plus complexe lorsque les glaciations surimposent leur effet au mécanisme précédent (cas du Cénozoïque). Il devient dès lors difficile de faire la part de ce qui revient à la tectonique et au glacioeustatisme dans la genèse des séquences de dépôt, en l'absence d'études stratigraphiques intégrées très précises et de corrélations de bassin à bassin à l'échelle mondiale.

The International Commission on Stratigraphy and GSSPs as Global Standards

Stanley (Stan) Finney

Since being established more than 40 years ago, the primary mission of the International Commission on Stratigraphy (ICS) of the International Union of Geological Sciences (IUGS) has been to establish an International Chronostratigraphic Chart with a single set of global units at the ranks of Stage, Series, and System with the lower boundary of each precisely defined by a Global Standard Boundary-Stratotype Section and Point or GSSP. These chronostratigraphic units are the basis for the geochronologic or time units of the Geologic Time Scale with the ranks of Age, Epoch and Period, and the GSSPs mark points in time that precisely define the beginnings of the time units. After 40 years of work, GSSPs have been selected for 61 of the 101 stages of the Phanerozoic, and a GSSP has been selected for the Ediacaran System of the Proterozoic. In addition, a single set of global units is being established to replace the multitude of different sets of chronostratigraphic/geochronologic units that were defined for regions with greatly different stratigraphic successions and with biostratigraphies that differed due to paleobiogeographic and paleoecologic differentiation.

Selection of even a single GSSP is a long-term endeavor. Historical revisions to a chronostratigraphic unit, differing concepts of it among specialists, and different units from different regions must be evaluated, and determination made for the single unit to be used as a global standard. In addition, gaps between or overlaps with underlying and overlying units must be considered. Stratigraphic signals at the preferred stratigraphic level must be evaluated in order to determine those that offer the greatest potential for reliable, precise correlation of the lower boundary of the unit into as many facies and as worldwide as possible. Then stratigraphic successions, possibly many worldwide, must be studied in order to determine which one best meets the criteria for a global stratotype section as listed in the *International Stratigraphic Guide*. These activities are carried out by members of a single Subcommission within the ICS, and possibly by a small task group within a Subcommission. For a stratigraphic horizon in a single stratographic section to be further considered as a GSSP, a formal proposal must be prepared and submitted to a vote; often more than one proposal is forthcoming for a single boundary. Voting may occur within a task group, but the most important decision is made by the full voting membership of the Subcommission. Approval requires a supermajority (>60%) of 'yes' votes for a single proposal, after competing proposals have been eliminated in earlier rounds of voting. Once approved by a Subcommission, the GSSP proposal is forwarded to the voting membership of ICS, which includes the three executive officers of ICS and chairs of all ICS Subcommissions. For approval by ICS, the proposal must again receive a supermajority of 'yes' votes. If approved by ICS, a recommendation for approval is forwarded to the IUGS Executive Committee, where a majority vote ratifies the ICS recommendation. Subsequently, the GSSP is marked by a plaque and an article on the GSSP is published in *Episodes*. Given the length of this process and the many levels of approval, as

well as the discussion and deliberation that occurs at each level, the GSSPs and the units they define truly warrant validity, legitimacy, and authority as global standards.

The process of selecting a single set of global standard chronostratigraphic/geochronologic units greatly benefits studies of Earth history. It provides a simple, single set of global units for communication that replaces a complexity of, often competing, regional sets of units. With exact boundaries defined by GSSPs, ambiguities regarding the extent of a chronostratigraphic unit are eliminated, and in many instances boundaries are defined by stratigraphic signals that offer the most reliable, precise, and highest resolution of worldwide correlation possible. Furthermore, boundary intervals are often characterized by a complexity of stratigraphic signals - different biostratigraphies, chemostratigraphy, magnetostratigraphy, sequence stratigraphy, and astronomically tuned cyclostratigraphy – that allow for precise correlation across a wide range of facies and, in some instances, for determination of precisely calibrated ages of GSSPs.

During the past 40 years, the work of the ICS Subcommissions has generated a huge volume of new information on stratigraphic successions worldwide. It has encouraged refined biostratigraphies for many fossil groups and modern revisions to their taxonomy. And it has stimulated the development and application of stratigraphic signals of globally instantaneous phenonema generated by the Earth's magnetic field, its stable-isotope geochemistry, and its solar insulation.

High resolution stratigraphy and paleoclimate records of OAE1a at Roquefort-La Bédoule (SE France)

Sascha Floegel, Ann Holbourn, Wolfgang Kuhnt, Janne Lorenzen, Michel Moullade, Guy Tronchetti

The chronology of the onset of the Selli Event (Cretaceous OAE 1a subevent) is still enigmatic due to deposition of incomplete or very condensed sedimentary records in most deep marine environments. As a consequence, little is known about the sequence and relative timing of events including atmospheric CO_2 changes, sea surface temperature and sea level variations, spreading rate of anoxia, organic carbon burial and relations to $\delta^{13}C$ fluctuations. Particularly oxygen isotope records spanning OAE1a are either of insufficient resolution to identify short-lived cooling events and/or show strong diagenetic overprint that renders oxygen isotope data unreliable. New continuously sampled outcrop and drill cores from the 'Lower Aptian' historical stratotype at Roquefort-La Bédoule provide continuous, high-resolution geochemical and isotope records that closely track the onset of OAE1a in a subtropical intra-shelf basin. This expanded, open marine shelf carbonate succession was never deeply buried, and its diagenetic overprint is minimal due to the relatively high clay content. The scientific drilling operation recovered a total of 180 m undisturbed core material which is currently analyzed in ultra-high resolution using micropaleontological and geochemical proxies. The new records reveal that the negative $\delta^{13}C$ excursion preceding OAE1a lasted at least 100 kyr, implying that

enhanced volcanic CO_2 emission was instrumental in triggering OAE1a. The main positive carbon isotope shift at the onset of OAE1a, previously regarded as abrupt, occurred stepwise over an extended period of >250 kyr. Transient climate cooling during the initial $\delta^{13}C$ increase probably reflect ephemeral high-latitude glaciations, triggered by changes in radiative forcing and drawdown of atmospheric CO_2.

Modélisation géologique 3D du Dogger du bassin de Paris, pour une approche plus réaliste des modèles d'écoulement pour le stockage géologique de CO2

Sunsearé Gabalda, Fabrice Gaumet, Anne Bialkowski, Christophe Rigollet, Pascal Audigane

Contexte et objectifs

La présente étude s'intègre dans le cadre du projet de recherche $SHPCO_2$ (Simulation Haute performance pour le stockage géologique de CO_2), financé par l'ANR(1) et en partenariat avec l'IFP, ENSMSE(2), LAGA(3), INRIA(4). Il est dédié au développement d'une plate-forme informatique haute performance pour la simulation numérique du stockage géologique de CO_2 avec la volonté de se confronter à des modèles géologiques ' réalistes ' (domaines faillés, géométries caractéristiques des bassins, variations latérales de faciès) et donc aux difficultés numériques de simulations des écoulements que ces contraintes impliquent.

Dans ce cadre, l'unité GBS (service GEO du BRGM) est chargée de réaliser des modèles géologiques 3D maillés de l'aquifère du Dogger du bassin parisien, à partir du logiciel de modélisation 3D Petrel.

Ces modèles doivent restituer d'une part, la géométrie 3D de la zone d'étude et d'autre part les propriétés pétrophysiques des roches (porosité, perméabilité) qui caractérisent cet aquifère.

Application d'une méthodologie intégrée

La zone d'étude est choisie en fonction du fort potentiel de stockage géologique du CO_2 (maximum d'épaisseur de l'aquifère, incluant des faciès sédimentaires poreux) et de la qualité des données de puits disponibles. Cette zone est localisée au sud-est de Paris sur une superficie de 100 km x 100 km.

Les modèles réalisés dans ce secteur bénéficient du programme de valorisation des données de subsurface du BRGM. Ils intègrent notamment des données de puits variés :

- les logs fondamentaux issus de la base BEPH(5),
- les logs diagraphiques digitalisés et les logs pétrophysiques calculés,
- des descriptions de carottes (3 puits de référence sur le secteur étudié),
- des contraintes biostratigraphiques (Garcia, 1993)

- mais aussi des travaux d'interprétations géologiques réalisés à l'échelle du bassin de Paris:
- des données sismiques (lignes retraitées de la non-exclusive du bassin parisien, BRGM),
- un schéma structural simplifié de la zone étudiée (failles de Bray, Malnoue, Vittel, Belou, Saint-Martin de Bossenay, Valpuiseaux) construit à partir de plusieurs horizons pointés sur les profils sismiques de l'étude non-exclusive (BRGM)
- des cartes paléogéographiques des séquences de dépôts du Bajocien Supérieur au Callovien Terminal (Gaumet, 1997)

Notre méthodologie est basée sur l'intégration de ces informations pour réaliser un modèle géologiquement cohérent et réaliste en se basant sur les principes de la stratigraphie séquentielle.

Depuis le toit de l'Aalénien jusqu'à l'Oxfordien Inférieur, dix lignes isochrones (' Maximum Flooding Surfaces ') sont corrélées sur 70 puits (corrélations modifiées d'après Gaumet F., 1997). Ces lignes sont ensuite interpolées en 3D, recalées selon une grille sismique de référence et confrontées au schéma de failles disponible. On obtient ainsi un modèle géométrique 3D dont les couches sédimentaires sont limitées par des surfaces isochrones.

Le modèle de faciès est construit en superposant les cartes paléogéographiques sur les surfaces de même âge et conditionnées par un paramétrage en électrofaciès aux puits (modifiées d'après Gaumet F., 1997). Cette méthode permet de visualiser la répartition des variations latérales et verticales de faciès, nous renseignant ainsi sur la connectivité (ou non) des réservoirs. Cette information est essentielle à la simulation des écoulements dans la zone considérée.

Le remplissage des mailles en propriétés pétrophysiques est simulé de manière stochastique dans le modèle géométrique 3D et permet de proposer un modèle statique du Dogger du bassin parisien. La variabilité de la porosité est simulée au sein de chaque faciès à partir de logs de porosité calculée, continue sur toute la profondeur étudiée (25 logs). La perméabilité est quant à elle déterminée à partir de lois Phi-K, recalculées pour chaque faciès selon des valeurs de couples porosité-perméabilité mesurées sur carottes et extraites des rapports de fin de sondages.

Valorisation scientifiques et techniques

Aujourd'hui, ces modèles permettent aux ingénieurs-réservoir du projet $SHPCO_2$ de tester concrètement leur capacité de calcul et de simulation d'injection et d'écoulement du CO_2. Plusieurs modèles volumiques, de tailles, de précisions géologiques variées qui intègrent des failles majeures sont réalisés :

- un modèle de la zone d'injection (20 x 20 km) qui contient 2 millions de mailles (500 x 500 m),
- 2 modèles de 700 000 et 10 millions de mailles (500 x 500 m) sur la totalité de la zone d'étude (100 x 100 km).

Ces modèles rentrent dans le cadre de la valorisation des travaux de recherche, de mise à jour et du développement des connaissances géologiques du bassin de Paris. Ils permettent de proposer une visualisation 3D de la répartition spatio-temporelle des faciès réservoirs (barrière oolithique et/ou bioclastique et shoals granulaires) et des niveaux potentiellement

imperméables qu'ils renferment (faciès de plate-forme externe/bassin profond), tout en intégrant les zones de couverture au toit et au mur des réservoirs.

Perspectives

Ce type de modèle, réalisé ici dans le cadre d'une étude liée au stockage géologique de CO_2, pourrait également être utile pour la compréhension géologique du bassin (paléogéographique et géodynamique) et constitue un outil précieux pour l'aide à la décision dans différents domaines appliqués tels que l'exploration pétrolière, la gestion des aquifères, l'évaluation du potentiel géothermique, aussi bien à l'échelle du réservoir qu'à l'échelle du bassin et pourquoi pas jusqu'aux affleurements.

Enfin, pour répondre à des objectifs d'exploration, on pourrait envisager d'intégrer des paramètres traduisant les phénomènes de diagénèse et de fracturation. Ces paramètres pourraient s'intégrer dans le cadre d'une étude géostatistique plus poussée, afin de traduire plus précisément la variabilité spatiale des faciès carbonatés en termes de porosité et perméabilité.

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(3) Laboratoire Analyse, Géométrie et Application (Université Paris 13, CNRS)

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(5) Le Bureau Exploration-Production des Hydrocarbures

La cyclostratigraphie, outil pour estimer la fréquence d'anciens événements séismo-tectoniques : le cas de la faille d'Ormon (Zone Dauphinoise, Alpes) au cours de l'extension liasique

Bruno Galbrun, Françoise Bergerat, Slah Boulila, François Baudin, Pierre-Yves Collin, Pierre-Yves Collin, Isabelle Rouget, Johann Schnyder

Les mouvements discontinus des failles séismiques actives sont bien caractérisés par le biais des enregistrements séismiques, l'étude des traces de surface ou, pour les plus anciennes, les documents écrits. Les dates des séismes et leur temps de récurrence sont ainsi connus pour la plupart des grandes failles actives. Cependant on constate qu'une faille active peut montrer tantôt une déformation lente, continue (aséismique) et tantôt des ruptures instantanées liées à des événements séismiques. Ceci a été clairement établi, tant à partir des données d'extensométrie, de GPS et d'INSAR, que par des modélisations.

Les séismes historiques ou préhistoriques importants peuvent également être bien caractérisés par l'analyse de profils sismiques haute-résolution, de carottes de sondage dans les sédiments holocènes, de décalages de terrasses

fluviatiles ou de traces encore visibles à l'affleurement dans les dépôts récents. De plus, certaines de ces failles séismiques majeures ont été étudiées de manière approfondie au moyen de tranchées. Leurs mouvements successifs ont, dans les cas favorables, été datés par radiochonologie (cosmonucléides 36Cl ou 10Be) ou luminescence infrarouge stimulée (pour les derniers 100 ka).

Plus les failles sont anciennes, plus il est difficile de déterminer si le déplacement observé est dû à un glissement lent (asismique), ou au cumul de mouvements brusques qui se sont succédé. On considère souvent la croissance des failles anciennes comme un phénomène continu sur un long intervalle de temps, mais cette mésestimation des mouvements discontinus peut être, en grande partie, attribuée à la faible résolution des datations. Il est probable qu'au moins une partie des mouvements anciens sur les failles majeures est due à la séismicité. Les résultats de cette activité séismique passée sont parfois reconnus au moyen de critères sédimentologiques indirects interprétés comme séismites.

De tels témoins de paléoséismes ont été reconnus dans la série carixienne (Jurassique inférieur) de Saint-Michel-en-Beaumont (Zone Dauphinoise, Alpes), à proximité d'une des failles majeures de l'extension liasique : la faille d'Ornon. La série étudiée, épaisse de 75 mètres, montre une alternance de marnes et calcaires, entrecoupée de nombreuses passées turbiditiques, qui peuvent correspondre à des séismites. La présence de trois grandes structures d'instabilités d'origine tectonique, associées à des failles 'molles' synsédimentaires, démontre aussi l'occurrence d'une activité sismique importante. Ainsi l'ensemble de ces structures peut être interprété comme résultant de pulsations séismo-tectoniques, dans l'ambiance extensive générale téthysienne au Lias.

L'approche cyclostratigraphique, entendue comme la reconnaissance dans l'enregistrement sédimentaire des paramètres de l'orbite terrestre, de durées connues, est devenue un outil particulièrement performant pour estimer le temps correspondant au dépôt d'une série. Les séries d'alternances marno-calcaires se prêtent particulièrement à une telle approche. La coupe de Saint Michel-en-Beaumont a ainsi été analysée à haute résolution par des mesures, tous les 10 cm, sur le terrain, de susceptibilité magnétique et de gamma-ray. Les analyses spectrales des variations de ces paramètres montrent que la sédimentation a été régie par les paramètres de l'orbite terrestre : précession, obliquité, excentricité à 100 et 400 ka. En considérant la période d'excentricité de 400 ka, une durée totale de la série analysée peut-être estimée à environ 2 Ma. La périodicité des turbidites peut également être appréciée: elle est hautement variable sur l'intervalle analysé : durant les premiers 800 ka cette périodicité est d'environ 20 ka, la fréquence augmente à environ 6 ka pour les 350 ka suivants, enfin elle baisse sensiblement vers le sommet de la série, devenant de 40 à 60 ka. Il est aussi possible d'estimer le temps écoulé entre les trois principales structures d'instabilité situées vers le milieu de la série : 200 ka entre les deux premières, 300 ka entre la deuxième et la troisième.

Cet exemple d'analyse des témoins sédimentaires de l'activité sismique de la faille d'Ornon montre que l'approche cyclostratigraphique est non seulement un outil puissant pour établir le cadre temporel précis d'une succession sédimentaire cyclique, mais aussi pour analyser des événements non-cycliques ou dont le cycle est difficilement estimable. Elle permet (i) de préciser le comportement des grandes failles anciennes et (ii) d'accéder à une échelle de

temps intermédiaire entre celle des failles sismiques récentes et actuelles (<100 ka) et celle des failles 'géologiques' (plusieurs Ma).

Quantitative approach to biochronology. CONOP and Unitary Associations, a comparison between two deterministic methods

Federico Andrea Galster, Jean Guex

Biochronological correlation is an indispensable tool for basin analysis and geological studies in sedimentary terranes. In some cases the zonations on which correlations are based are precise and correct enough to permit well-constrained results. But in many cases the results are poorly constrained and produced by an ill-defined zonation with poor resolution. This is generally caused by discontinuous fossil record and contradictory identifications resulting in cyclic relationships between taxa.

A quantitative approach to biochronological correlation can improve the resolution. Some recently published examples (Cody *et al.*, 2008; Sadler *et al.*, 2009) can reach a very high and amazing level of resolution. Cody *et al.* (loc.cit.) for example calculated a biochronological scale for the Neogene based on Antarctic diatoms (including paleomagnetic data), which reaches a resolution level that is more than one order of magnitude greater than empirical zonations previously established. These results were based on the method known as 'constrained optimization' (Kemple *et al.*, 1995) and obtained using the program CONOP (Sadler 2006).

We tested the reliability of the results proposed by Cody *et al.* using an alternative quantitative method known as Unitary Associations (Guex 1991) and the software UAgraph (Hammer *et al.*, 2009, available at http://folk.uio.no/ohammer/uagraph).

From one point of view, the two methods are similar because both are deterministic quantitative tools. They differ in the sense that CONOP produces sequences of events and is based on an heuristic-like search for solutions which are closest to the best one (simulated annealing), whereas Unitary Associations constructs discrete sequences of coexistence intervals of species and is based on graph theoretical algorithms.

Both methods must deal with cyclic relationships between taxa. In CONOP's philosophy, the stratigraphic problem is considered as NP-complete and for this reason an heuristic-like approach is needed. On the other hand, the Unitary Associations philosophy considers that the number of computing operations necessary to obtain a result is linearly proportional to the number of samples and to that of the taxa involved (see Galster *et al.*, 2010 for a comparison between the two methods).

Our comparative results show that CONOP's solutions have a level of resolution comparable to UA's results if we restrict the analysis to the maximal intersections of the resulting ranges and the level of resolution is slightly higher than the ones produced by empirical approaches.

The scaled sequence of first and last occurrences (FO and LO) given by CONOP is essentially based on an algorithm which does not allow treatment of the inter FO's and LO's cyclic relationships. A consequence of this is that the outputs do not precisely match the local sequences observed in the input. In other words, this program produces best-fit interval values that are not univocally related to the amount of implications of the events (FO/LO) within cyclic relationships.

The Cody *et al.* (2008) data have been analysed with the UAgraph software, producing a first solution with a resolution comparable to that of an empirical approach or to CONOP solution reduced to its maximal intersections. In a second run, we have selected some non-diachronous first and last occurrences of taxa together with some paleomagnetic and radiochronologically dated events. This allowed us to increase dramatically the stratigraphic resolution of the final output.

Our main conclusion is that the use of first and last occurrences should only be done after an analysis of the diachroneity of the datums, *i.e.* events occurrences that are located above some maximal intersections in some localities and below the same intersections in other localities. Detection of cyclic relationship is essential for estimating the quality of the record and the reliability of the resulting zonation. UAgraph is a unique tool, for dealing with this kind of problem.

Paleocene-Eocene Thermal Maximum consequences on terrestrial environments. Insights from the evolution of organic matter in the Vasterival section (Paris Basin, France)

Sylvain Garel, Johann Schnyder, Jeremy Jacob, Mohammed Boussafir, Christian Dupuis, Jean-Yves Storme, Johan Yans, Claude Le Milbeau, Florence Quesnel

The Paleocene-Eocene Thermal Maximum (PTEM) is often proposed as an analogue of future climatic conditions expected in the screenplays provided by the International Panel on Climate Change (IPCC). The PETM is characterized by a 3°C estimated rise of global temperature and is recorded in marine and terrestrial deposits by a carbon isotopic excursion (CIE). Most of published works related to this paleoclimatic crisis focus on marine sediments. This presently limits our regional- and global-scale understanding of the impact of such a climate change in terrestrial environments and the deciphering of the ecosystems response.

This study focuses on the Vasterival section (Seine-Maritime, Upper Normandy, France) located in the NW of the Paris Basin, and in which the PETM is recorded in the organic matter (OM) by the $\delta^{13}C$ negative shift of the CIE. The 2m thick section is mainly constituted by terrestrial sediments deposited in fluvial and lacustrine to coastal swamp environments and in which OM-poor shales are followed by OM-rich shales, centimetric lignite beds, paleosols, and

two beds containing carbonate nodules. The uppermost part of the section is constituted by a 50cm thick shale with shell debris that attests to a lagoonal influence. This section is constantly refreshed by a little stream, thus facilitating the sampling of fresh material, notably a well preserved OM.

Global geochemical, palynofacies and isotopic analyses focused on thirty samples, and seventeen lipid extracts were analyzed by gas chromatography-mass spectrometry. The association of these methods allows us to characterize the OM of the different deposits encountered. Sulfur contents are particularly high (up to 15% of S), thus indicating an euxinic depositional environment. Total Organic Carbon (TOC) varies from 1% for OM-poor shales and paleosols up to 45% for lignite levels. From Hydrogen Index (from 6 to 210 mg HC/g TOC), Oxygen Index (from 80 to 630 mgCO2/g TOC) and Tmax values (from 410 to 430°C) we can show that the OM is of Type III (terrestrial higher plants), and immature. These results are reinforced by palynofacies observations, as a large amount of ligno-cellulosic phytoclastes is present in most of the samples. In the uppermost shale the continuity of the PETM in marine deposits can be inferred by the presence of many Apectodinium species. Thus, the terrestrial deposits would represent a time interval that includes the uppermost Paleocene and the basal part of the PETM.

Molecular analyses underline the contribution of terrestrial higher plants by the presence of long chain n-alcanes with odd-over-even predominance, and Onocerane I, a compound rarely detected in sediments, attests to a contribution of lycopods or plants affiliated to the genus Pseudofagus. A notable bacterial contribution is also inferred by the presence of hopanoids in the extracts. This is confirmed by organic petrography results that reveal alginites laminae, often interpreted as a witness of well-preserved bacterial and/or algal mats. From our early results we show that significant environmental changes are recorded during the CIE.

High resolution analyses and complementary analyses (X-ray tomography, isotopic, thin section petrography…) are currently in progress. This approach is complemented by a sedimentological study and they both will be extended to other sites along a transect crossing the terrestrial to lagoonal paleoenvironments of the Paleocene-Eocene transition in the Paris Basin. They aim at defining possible spatial heterogeneities in the PETM's impact on terrestrial environments and ecosystems, at a regional scale. To the west of the transect, the Cap d'Ailly sections and core will be first studied, because of their position very close to the Vasterival site, the relative richness in outcrops and the continuation of the PETM recorded in around 10m of lagoonal deposits, comprising various facies often OM rich: tidal fine sand, silt and clay, shell beds, and few cemented carbonate beds.

Mesozoic-Cenozoic anoxic basins and anoxic events of northeastern Peri-Tethys: different patterns of TOC accumulation

Yuri Gavrilov, Ekaterina Shcherbinina

The problem of anoxia occurrence in the sediments and water column of marine basins is exceptionally interesting and important because oxygen depletion environment strongly affected the main basin features leading to changes in the communities of marine organisms, water and sediment geochemistry, occurrence of some mineral resources. Synchronous development of anoxic environment in different areas of the World ocean caused large-scale ecological crises, which became actual biospheric catastrophes in isolated time slices.

Mesozoic-Cenozoic sedimentary record of northeastern Peri-Tethys contains multiple manifestations of occurrence of anoxic/disoxic environments featured by different nature, duration and degree of oxygen depletion. Sedimentary basins of different types are more clearly defined in Caucasian sector of this large epeiric basin which displays the most complete and contrasting sedimentary successions.

Long-lived and short-lived anoxic basins should be distinguished in Cretaceous to Tertiary sedimentary record. Oligocene-early Miocene Maikop basin and late middle Eocene Kuma basin were the most long-lived basins characterized by variations from anoxic to disocxic environment in bottom water. Maikop basin existed for more than 17 mln years, but the anoxia degree changed through time and space and sometimes became interrupted for relatively short time. Origination of this long-lived anoxia was evidently caused by drastic global tectonic and climatic perturbations at the Eocene/Oligocene boundary. Siliciclastic sedimentation replaced mostly biogenic calcareous sediments accumulated during Cretaceous to early Paleogene leading to accumulation of more than 1000 meters thick clayey sequence. Late middle Eocene Kuma basin existed for much shorter time (about 2 mln years) and was featured by mostly calcareous sediments (~ 40 m) and strong anoxic conditions, especially in the later stages. During both these time intervals, anoxic environment appeared as a result of partial basin isolation from the main Tethyan basin and increased fresh water input resulted in the enhanced water stratification. There is some similarity of these basins to modern Black Sea environment. In both cases, occurrence of anoxic condition had regional character although it seems to be related to globally intensified tectonic activity and climatic cooling. In the basins of such type, anoxic conditions prevented organic matter oxygenation, but did not provided its high concentration (TOC content usually does not exceed 2-4 %). Maikop and Kuma basins are the examples of anoxia occurrence evolved from the specific basin evolution.

Short-lived anoxic basins represent quite different type which sporadically appeared within normally aerated basins as result of dramatic productivity increase, especially of organic-walled plankton bloom. In this case, anoxic conditions only persisted while factors maintaining high productivity have been

existed. Mid-Cretaceous to early Cenozoic anoxic basins in Caucasian area just belong to this type of oxygen depleted basins.

One of the most impressive examples of short-lived anoxia development throughout the wide northeastern Peritethyan basin from Crimea to Central Asia arose with the onset of global biospheric crisis named Paleocene/Eocene Thermal Maximum (PETM) documented by dramatic negative carbon and oxygen isotope excursions in the marine and continental sedimentary record. In the northeastern Peri-Tethys, sediments rich in TOC up to 20-30% accumulated during about 40 k.y. Thin lamination of sediments, lack of benthic fauna, significantly increased redox-element content (Mo, Se, Re, Zn, Ni a.o.), and the presence of isorenieratene biomarkers evidence anoxic environment occurrence throughout wide epeiric basin (Gavrilov, Shcherbinina, Oberhänsli, 2003). This event was preceded by short but very large by magnitude regression. Wide wetlands were formed at the newly emerged areas where organic matter of terrestrial plants and biophile elements intensively accumulated. This landscape was responsible for release of great methane amounts supplying into the atmosphere and largely contributed the greenhouse effect and negative oxygen and carbon isotope excursions. When regression gave the way to rapid transgression, the land-sea interaction caused massive nutrient input into the basin resulting in the bacteria- and phytoplankton bloom and accumulation of TOC-rich sediments. In addition, phytoplankton bloom was largely supported by biofile element recycling. Organic matter oxygenation and intensive oxygen fixation occurred at the basin floor concurrently with diagenetic hydrogen sulfide diffusive penetration from sediments into the water column. These processes caused anoxic environment occurrence. Possibly, thermohaline water stratification also contributed the anoxia appearance in some parts of the basin. After transgression termination and interruption of enhanced nutrient supply, the phytoplanktom bloom weakened and gradually stopped, hydrogen sulfide was oxygenated in the water column, anoxia gradually dissipated, and environment recovered to the pre-transgression state.

Basically, mid-Cretaceous anoxic events detected in the northeastern Peri-Tethys have very similar scenario. At the same time, some of them were really characterized by anoxic environment occurrence in the water column, while others were only featured by accumulation of sediments more or less enriched in organic matter and anoxia/disoxia, if any, sporadically appeared at the very bottom water layer.

Among the mid-Cretaceous events detected in the Caucasus, the late Cenomanian OAE2 reflects most adequately actual anoxic environment. These sediments are featured by high values of TOC, finest lamination, high concentrations of some trace elements. Contrary to PETM, it shows positive carbon isotope excursion for about 2.5-3‰. It might be related to diagenetic processes within sediments. Hauterivian to late Albian events display more likely disoxic/suboxic environments in the Caucasus. TOC content and composition as well as trace element concentrations and other characteristics largely vary in sediments corresponded to individual events.

A comparison between anoxic basins of NE Peri-Tethys leads to the conclusion of complementarity of two potential causes of organic carbon preservation at the sea floor. Both occurrence of anoxic environment and increased bioproductivity can contribute TOC accumulation but these factors play part in

different types of basins and cause concentrations of significantly different values of TOC.

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Biodiversité observée au sein de Rhynchonelles asymétriques (Brachiopodes) du Coniacien-Santonien des plates-formes carbonatées: Nord Castillane (N. Espagne), Mouthoumet et Provence (SE. France)

Danièle Gaspard

Après une révision du genre *Cyclothyris*, Owen (1962) décida d'inclure les spécimens asymétriques du Cénomanien d'Europe dans l'espèce *Cyclothyris difformis* (Val. in Lamarck). Le problème n'est pourtant pas entièrement résolu puisque de tels représentants asymétriques existent tout au long du Crétacé. Notre attention se porte principalement ici sur des représentants de formations du Coniacien-Santonien de la plate-forme du massif du Mouthoumet (Bilotte, 2007) comparés à ceux de la plateforme Castillane (Floquet, 1991), eux-mêmes, considérés en parallèle avec des représentants localisés en Provence (S.E. France). Cette comparaison entraînera de facto des remarques concernant '*Rh*.' *globata* Arnaud du Campanien Gaspard & Odin, 2001).

La stratigraphie régionale et l'évolution paléogéographique sont prises en compte en se basant sur des travaux anciens et plus récents, en ne citant que quelques auteurs, parmi d'autres, dont : Babinot *et al.* (1984), Kennedy *et al.* (1995), Olivet *et al.* (1996), Grosheny (1986), Floquet (1991), Philip (2005), Vasseur (1894), Hennuy & Floquet (2006), Skelton (2006) pour restituer ses rhynchonelles par rapport aux différentes plateformes.

Ces rhynchonelles asymétriques ont été étudiées en fonction de leurs caractéristiques morphologiques, externes, internes, ... il en résulte une très grande diversité au sein de ces rhynchonelles dont la commissure frontale est par ailleurs déviée, tantôt à gauche tantôt à droite, dans une proportion avoisinant 50%. Ces observations entraînent de nouvelles attributions au niveau générique et spécifique.

La diversité observée, parmi ces brachiopodes, révèle des taxa vivants de préférence en situation externe de plateformes carbonatées. Ces brachiopodes sont des animaux invertébrés marins benthiques fixés sur des supports de nature variée. Les relations de ces organismes filtreurs avec le milieu et avec le substrat sont prises en ligne de compte. De façon générale, les brachiopodes actuels sont connus pour préférer les eaux claires et les milieux plutôt calme, mais cela n'a pas toujours été le cas. En comparant les populations de Rennes-les-Bains (Marnes à Micraster par exemple à ceux de Villamartin (Nidaguila formation) en situation infra à circalittorale avec une ornementation à côtes fines, à ceux de Provence avec une ornementation (côtes) très forte, on peut conclure dans le dernier cas à un plus fort hydrodynamisme, ...

Ainsi, les rhynchonelles observées dans le présent contexte en plus d'une grande diversité de morphologie globale externe et interne montrent une ornementation qui peut fournir des caractères discriminants mais aussi d'autres en relation avec le milieu environnant. Ils peuvent permettre d'approcher ou d'apprécier une profondeur de milieu, un niveau d'énergie et, sans doute aussi, servir d'élément complémentaire d'appréciation de proximité de rebord externe de plate-forme.

Recognition of ice-front occurrences from ice-marginal sedimentary successions: the Late Ordovician case study

Flavia Girard, Jean-François Ghienne, Xavier Du Bernard, Blanpied Christian, Jean-François Buoncristiani, Gilles Noual, Jean-Loup Rubino

The Palaeozoic is characterized by recurrent glacial events, the Hirnantian and the Permo-Carboniferous being the best known. However, a number of other glacial events are suspected from the forced regressions in the stratigraphic record, especially during the pre-Hirnantian Ordovician, but also possibly in the Late Cambrian. Localization of a palaeo-ice-front is not straightforward if typical indicators such as striated surfaces or glaciotectonic belt have not been preserved. Based on the well documented Hirnantian case study, this talk aims to list several criteria that can be used to locate spatially and temporally an ice front from the sedimentary record of ice-proximal environments, and then to recognize the presence of an ice-sheet, *i.e.* a glacial period.

The Tihemboka area in the western Murzuq Basin (SW Libya) preserved an outstanding Late Ordovician glacial succession comprising a great number of depositional facies and deformation structures. We will present unusual structures preserved either in proglacial or at the margin of the ice sheet, such as:

- *Proglacial facies* : climbing-dune cross stratification (CDCS), large subhorizontal bedsets typifying upper-flow regime conditions, kettle holes, large-scale rip-up clasts. These facies are associated with ice-contact sedimentary environments related to glacial meltwater outbursts.
- *Structures at the ice-sheet margin* : sandstone dykes, inverted flutes, tunnel conduits (from small-scale pseudo-dykes to large-scale channels); glaciotectonic fold-and-thrust belts, deformation structures linked with intraformational subglacial shear zones (striae, grooves, sheath folds, extensional fractures, ….). The first set of structures is related to overpressured subglacial meltwater flows, while the second set records ice flows.

Taken separately, one of the aforementioned structures is not sufficient to deduce an ice front. However, their association, even in the absence of direct ice-flow indicators, is thought to be sufficient to at least suspect an ice-front zone.

Stratigraphic position of such structures can be used to detect a previously unknown glacial event, or to precise advance/retreat glacial cycles in a sedimentary record and then to allow understanding of climate fluctuation like cooling-off and warmer periods. For instance, in the Murzuq Basin, high-frequency ice-front advance and retreat cycles resulted in up to five erosion-based, vertically superimposed and laterally juxtaposed, glacial depositional sequences. The whole set of 'glacial' structures described above is preserved in an ice-proximal fluvio-glacial outwash systems built during the later ice advance.

Ooid fabrics, a tool for high-resolution stratigraphy. Example: Upper Bathonian - Lower Callovian of the Paris basin

Bruno Granier

Petrographical studies (Granier, 1993, et seq.) of the 'Dalle Nacrée' Formation (Upper Bathonian - Lower Callovian oolitic limestones) in the subsuface of the Paris basin have resulted in notable advances in our knowledge of the architecture of oolitic deposits and as a consequence the geometry of the associated reservoirs. Four key criteria have been found useful in building sedimentologic and reservoir models:

- *ooid fabrics:* after the publication of an article by A. Strasser (1986), my former colleague, Robert Boichard (TOTAL), focused his attention on ooid microstructures. He found that at the base of the 'Dalle Nacrée' the ooids are radial, grade upward to concentric in the middle and are micritic at the top. This demonstrates a gradual change in the bio-physico-chemical conditions under which they were formed.
- *early lithification:* at that time I was interested in early lithification that enabled me to identify sedimentary discontinuities, that is the bored and encrusted surfaces capping 'sequences' (actually pseudo-parasequences sensu Granier, 1993) of which the top was subjected to early diagenetic lithification, and to recognize reactivated surfaces caused by submarine erosion. These in most cases are followed by beds containing perforated or encrusted pebbles derived from the erosion of the pre-existing early lithified seafloor.
- *hierarchy of the types of discontinuities:* then I found that the evolution of the ooid fabrics was not as gradual as construed previously but that transitions between the three types were abrupt. Each of the sudden changes is at a discontinuity representing a stratigraphic gap which gives rise to a saltatory evolution to the generation and deposition of ooids. There are two categories of discontinuities – bored/encrusted surfaces and erosional surfaces:
    - those of the first order of magnitude are regional in extent and bound genetic depositional units, that is the large units defined by the discrete ooid fabrics that characterize them;
    - the others, of a second order, are local and the ooids immediately above and below them are similar.

This concept of a hierarchy among discontinuities has as a practical consequence the introduction of a new tool for correlation (time-line) based on the 'broken' gradient / saltatory evolution seen in the ooid fabrics, that is the distinction of three stratigraphic levels: a lower unit of radial ooids, a median unit with concentric ooids and an upper unit with micritic ooids. Studies in Burgundy of analogous terrains (outcrops and quarries) confirm the validity of these hypotheses. These sedimentary discontinuities are generally well-marked on well logs (GR, RHOB, NPHI). Their first role as barriers - to mineralizing fluids and later to the migration of oil and gas - has been clearly established.

- *porosity distribution:* In these reservoirs there are essentially two types of porosity:
    - an effective porosity, essentially primary intergranular, that might be named more precisely 'residual primary'. It is the porosity that remains because cementation of the pore space was incomplete. It is not a 'secondary porosity' caused by dissolution: cathodoluminescence studies support this distinction;
    - an intragranular microporosity, its amount related to the type of ooid present (from bottom to top: radial concentric, micritic) which brings us back to our starting point. This microporosity in which connate water is trapped increases from bottom to top of the 'Dalle Nacrée' depending on the type of ooid: micritic ooids are more microporous than concentric ones and they in turn are more microporous than the radial ones. This determines a sliding scale of porosity cutoff ranging from about 4% at the base to ~8% at the top of the formation.

The key logs ('logs fondamentaux') of most exploration wells in the Paris basin are now in the public domain. From these logs it is quite easy to pick the several discontinuities and in any one set of wells to identify the first order discontinuities using a simple rule: pseudoparasequences thin sequentially upward from bottom to top of the parasequence to which they belong. As these first order discontinuities bound the discrete ooid units we do not need to confirm their category by thin section to identify the three main stratigraphic units that forms the 'Dalle Nacrée' Formation. Within one unit significant variations in thickness are common in adjacent wells of any one field. Some transects are similar to that of the modern Lily Bank oolitic shoals presented by A.C. Hine (1977). Thicker zones represent the crest of large amalgamated sandwaves that migrated in space and in time on a wide ramp. These changes of thickness are accompanied by lateral change in facies. Good correlation exists beween the occurrence of certain facies (clean oolite) and the best reservoir properties, the reverse is also true: echinoid-rich facies are commonly tight, strongly bound by syntaxial rim cements. So the qualities of a flow unit may be predicted from the sedimentological model. The hydrocarbon trapping is commonly a combination of stratigraphy (trap at a disconformity) and structural geology (anticlinal trap), but it may also involve sedimentological parameters, such as facies distribution (for instance the relative amount of echinoid remains and their genetically related early diagenesis) as for example in the 'Villeperdue nose'.

Are the GSSP concept and sequence stratigraphy antagonistic in their approach?

Bruno Granier

GSSP's are usually chosen in basinal settings where the sedimentary record is regarded as continuous, unaffected by sedimentary hiatuses. The marker is commonly a bio-signal (the FO or LO of a taxon), but sometimes it is another kind of signal (geochemical, palaeomagnetic, *etc.*). Ideally, this primary marker can be used to correlate the boundary established at the GSSP site with those determined at other localities worldwide. However the primary GSSP marker(s) may be absent elsewhere so a discrete set of secondary markers should have been specified so a correlation is still feasible.

Some GSSP's were fixed at lithostratigraphic (formation, group) boundaries (many Devonian examples) --an approach approximating that of the founders of stratigraphy when they defined stages, series and systems-- but other GSSP's have been introduced by 'blinker wearers' whose interests are confined to pelagic strata and who ignore or are not concerned with the succession of events in time-equivalent strata on adjacent platforms/ramps. On the other hand, engineers and geologists in the industry rarely make reference to the standard stages, but instead use regional stages, *i.e.* sequence-based 'operational units' (see Granier *et al.*, 2009-2010). Consequently, the academics concerned with establishing GSSP's find it difficult to communicate with problem-solving practical geologists who use sequence stratigraphy as an exploratory tool (and vice versa).

However some more GSSP's could be defined at surfaces that have a significance in term of sequence stratigraphy, that is they could be chosen at lithostratigraphic boundaries. Then global stages in platform settings could be identified, even if far removed from the GSSP locality. The effects of variations in water depth, *i.e.* in relative sea level, that control changes in the milieu of sedimentation decrease markedly seaward to become almost negligible in the deep basin: A sequence boundary is said to pass gradually into a continuity in the basin, so its location there would be the ideal site for a GSSP. The starting point would be the identification of a major discontinuity on plaforms/ramps worldwide. Tracked into the basins where it passes into a continuity, together with the identification of a number of candidates for the best site of a GSSP, the final step would be to identify a set of signals permitting long-distance correlation.

Since 1963 (the date of a vote that a 'majority' approved for a Tithonian-Berriasian boundary), the boundary between the Jurassic and Cretaceous systems moved up and down several times in accordance with the several shifts of the stage boundaries involved (base of the Grandis Subzone in Lyon 1963, base of the Jacobi Subzone in Neuchâtel 1973, base of Calpionellid B zone, base of M18r, base of the Ryazanian, etc.). These changes which are more or less acceptable for stage limits should not be tolerated for system limits that ought to be obvious/natural, so fixed and stable. These facts demonstrate that by ignoring more than a century of stratigraphic

investigations in making its recommendation the 1963 vote was premature, probably erroneous, and in any case should be reconsidered.

Are there better candidates for the location of the boundary between the Jurassic and Cretaceous systems? We all know the first example of an SB1 (type 1 sequence boundary) recognized by P. Vail in a seismic section off Morocco, on the eastern side of the Atlantic Ocean. We also all know the first example of a drowning illustrated by Schlager on a seismic section (Wilmington platform) on the western side of the Atlantic Ocean. Both record a major transgressive surface, a unique major natural feature that can be traced in basinal and platform settings from the eastern coast of the USA to the northwestern coast of Africa, in southern Europe and in the Middle East. It is located 'near' the base of the Valanginian. If the global importance of this event is generally accepted, the Berriasian should be placed in as the terminal stage of the Jurassic system:

1. it was not a division of the original Neocomian stage sensu d'Orbigny;
2. in the Boreal realm the current boundary is intra-Volgian, thus hindering or limiting correlations with the Tethyan realm;
3. in platform and bassinal settings Tithonian deposits grade upward to Berriasian strata without appreciable lithologic change at the currently accepted stage boundary;

there are no geochemical changes either at or near the stage boundary; *etc.*

So maintaining the Berriasian stage in the Cretaceous system against incontrovertible evidence of a major worldwide break just above it demands reconsideration of the criteria currently invoked for its placement. In the mean time I propose reversion to the pre-1963 status quo, that is the Berriasian stage be again ascribed to the Jurassic system. Consequently, the Tithonian-Berriasian stage boundary would be easier to define for it would not be hampered by the weighty shade/ghost of its base delimiting the boundary between the Jurassic and Cretaceous systems.

New stratigraphic data on the Lekhwair and Hawar regional stages of the Lower Cretaceous in Oman

Bruno Granier, Bernard Pittet

Although the type sections of most stages of the Kahmah series (or of the 'Thamama', almost a time-equivalent) of the Middle-East regional succession were recently revised and the definitions of their upper and lower boundaries were either definitively legitimized or slightly emended (Granier, 2000, *et seq.*), some authors continue to use incorrect information and to make interpretations therefrom that are in conflict with the valid data now to hand. So we post new stratigraphic findings concerning the Lekhwair(-ian) and Hawar(-ian) regional stages of the Lower Cretaceous in (the U.A.E. and) Oman:

- in Oman oolitic facies referred to as the 'Habshan Formation' are interfingered in the outer platform to slope facies of the Salil Formation. These shoal facies are diachronous for they record the seaward shift of successive progradational wedges, a migration caused by regular or forced regressions (see Lebec, 2004, for instance). This so-called 'Habshan Formation' in Oman was mistakenly correlated with the type Habshan of Abu Dhabi (Hassan *et al.*, 1975; ...) as briefly explained below:
    - in its type locality, well Zakum-1 of the Abu Dhabi offshore, oolitic (grain-supported) facies are rare in the predominantly mud-supported microfacies (characteristic of the innermost parts of the platform), and
    - microfossil (calcareous algae and foraminifers) assemblages are either of Tithonian and Berriasian age in the Habshan as defined by Hassan *et al.* (1975) or they are restricted to the Tithonian alone in the Habshan as emended by Granier (2000). In Oman microfossil assemblages of the so-called 'Habshan' are of Hauterivian and Early Barremian age. Therefore, in Oman the time-span of the so-called 'Habshan' is actually within that of the Lekhwair regional stage.
- in the ADMA offshore field 'A' (Granier *et al.*, 2003), the Hawar is a 25' thick depositional sequence: most of it was laid down as a transgressive systems tract, but the uppermost 2.5, a thin shaly interval was deposited during a highstand systems tract. As stated by Granier (2008): '*The upper limit of the Hawar Formation is coincident with an abrupt change in sedimentation from the uppermost shale* (...) *to very shallow-water carbonates* (...). *As does the lower boundary*, *the upper one records a forced regression: the fall in sea level can be estimated to have been 40 meters or more*'. To date most authors have overlooked this major sequence boundary. But they also did not recognize other key markers. For instance, the occurrence of the foraminifer *Choffatella* in the upper half of the TST support its use as an index characterizing relatively deeper-water environments. In Oman, at Wadi Bani Kharus, the Hawar interval attains a thickness of 25 meters (van Buchem *et al.*, 2002), more than three times that of the time-equivalent section in the Emirian offshore field. However *Choffatella* is restricted to the first five meters of this onland unit. This fact contradicts sequential interpretations of authors who consider the Hawar to be either the TST of a higher scale sequence extending into the Shu'aiba or the lower part of this TST. Granier *et al.* (2010) defined the maximum flooding surface of the Hawar sequence to be near the 5 meter mark. With respect to stratonomy, the Hawar sequence is highly asymetrical in Oman. Its pattern is reversed from that of field 'A' (thick TST and thin HST): at Wadi Bani Kharus the TST is thin and the HST is thick.

These new biostratigraphic data document explicitly the geometries observed in the Lekhwair (*i.e.*, the diachronism of the prograding clinoforms) and that of the Hawar (*i.e.*, one third-order depositional sequence) thus permitting recognition of the significance of these relationships for petroleum geology.

Stratigraphic architecture and facies distribution within the Early Aptian - Early Cenomanian carbonate platform of the Coahuila Block (NE Mexico)

Benjamin Gréselle, Pierre Callot, Carine Grélaud, Philippe Razin, Jean-Christophe Embry, David William Hunt

The Northwestern part of the Gulf of Mexico was a passive margin formed by several carbonate platforms and epireic basins in the Middle Cretaceous. The Coahuila Platform (NE Mexico) was a narrow and long isolated platform that developed basinward on the Coahuila block, a paleohigh limited by major faults. Whereas the Aptian is characterized by the flooding of the exposed Coahuila Block and a major transgression, the Albian is marked by a long-term phase of progradation. The transition from the Coahuila Block to the Sabinas Basin was studied in detail in order to better constrain environmental and relative sea-level changes in the Aptian-Albian. In the Sierra de la Paila, Albian formations can be followed laterally from the inner platform to the margin on more than 45 km. The inner platform extends westward over hundreds of kilometres and is dominated by evaporitic sedimentation. North-eastwards, *i.e.* basinward, Albian and Cenomanian hemipelagic wackestones and argillaceous mudstones lie over the black marls of the La Peña Formation (Upper Aptian).

Approximately 7000 metres were logged in 23 detailed sections to determine depositional geometries and to follow lateral and vertical facies changes. These data have been interpreted to propose a sedimentary and stratigraphic evolution from the Early Aptian to the Early Cenomanian:

- the Coahuila Block, exposed since the Permian, was flooded during the Early Aptian as illustrated by the transition from fluvio-deltaic sandstones to inner lagoon packstones;
- a major transgression near the Lower/Upper Aptian boundary is marked by the sharp change to laminated dark mudstones of the La Peña Formation in the basin and to coarser wackestone of the Paila Member of the Acatita Formation on the Platform;
- subsequent progradation is illustrated by a very progressive transition to shallower slope facies on the Coahuila Block;
- a relative sea-level fall is marked by a rapid change to rudist shoal facies overlain by a subaerial exposure surface;
- Middle Albian to lowest Cenomanian platform sedimentation is characterized by the aggradation of the platform: a rudist margin isolates a protected to restricted lagoon from the open-sea. As evaporite-dolomite alternations represent most of the Acatita Formation deposits, facies of the overlying Treviño Formation dominated by dolomites and algal mats testify for a widespread flat restricted lagoon ;
- a progressive opening is illustrated by the transition to fine-grained grainstones rich in calcispheres and both planktic and benthic foraminifera;
- the sharp vertical change to dark thin-laminated spiculites of the Cuesta del Cura may suggest a regional event.

The mid-Valanginian isotope event: A complex suite of palaeoenvironmental perturbations

Benjamin Gréselle, Bernard Pittet, Emanuela Mattioli, Michael Joachimski, Nicolas Barbarin, Laurent Riquier, Stéphane Reboulet, Emmanuelle Pucéat

The Mid Valanginian is characterized by a positive $\delta^{13}C$ excursion, a eustatic lowstand and a crisis of most carbonate platforms worldwide. This study focuses on the response of both platform and basinal environments to these global palaeoenvironmental perturbations. In the Vocontian Basin (SE France), accumulation rates of pelagic carbonates, platform-derived carbonates and clays were calculated on the basis of nannofossil absolute abundance combined to high-resolution correlations with the adjacent Jura-Dauphinois Platform. After a decrease in *Nannoconus* abundance in the basin, an increase in nannofossil abundance, higher clay accumulation rate, the onset of the positive $\delta^{13}C$ excursion and the demise of the platforms testify for a synchronous response of the two carbonate systems to an increase in nutrient discharge in marine waters. This triggered the replacement of autotrophic by heterotrophic platform carbonate producers and a severe drop in the carbonate mud production and subsequent export basinwards. Conversely, basinal primary productivity was stimulated and the peaks in nannofossil abundance and in clay accumulation rate are synchronous with a first maximum of $\delta^{13}C$. As the carbonate production by nannofossils decreased during the Late Valanginian, high productivity by non-calcifying organisms is proposed to explain a second maximum in $\delta^{13}C$ recorded in the Upper Valanginian, during a cooling of marine waters. We propose that the intensification of continental weathering responsible for increased clay and nutrient influx in the basin and the following cooling are related to the latitudinal migration of climatic belts linked to the development of high-latitudinal ice caps during the Late Valanginian.

The Global chronostratigraphy of the Ordovician System and the regional Ibero-Bohemian (Mediterranean) scale: application to France and other peri-Gondwanan areas

Juan Carlos Gutiérrez-Marco

The new chronostratigraphic classification of the Ordovician System was completed in 2007 and developed as a tripartite division into Lower, Middle and Upper Series, which include a total of seven global stages. Their respective GSSPs are located in western Newfoundland, Canada (base of the Ordovician and of Tremadocian Stage, ratified in 2000 by the IUGS); Västergötland, southern Sweden (base of Floian Stage, ratified in 2002); Yichang-Hubei, China (base of Middle Ordovician Series and Dapingian Stage, ratified in 2007); Changshan-Zhejiang, southeast China (base of Darriwilian Stage, ratified in 1997); Scania, southern Sweden (base of Upper Ordovician Series

and Sandbian Stage, ratified in 2002); south Oklahoma, USA (base of Katian Stage, ratified in 2006), and Yichang-west Hubei, China (base of Hirnantian Stage, ratified in 2006). The top of the Ordovician System (= base of the Silurian), defined in 1984, was recently revised without introducing a change of the GSSP. Some of these new Global Stages adapted names from the historical British classification (Tremadocian, after the Tremadoc series; Hirnantian, after the eponymous stage of the Ashgill series), or from the Australian regional scheme (Darriwilian), but with a clear change of its pre-existing regional usage, boundaries and signification.

In parallel with the establishment of the Ordovician standard, efforts of some researches led to subdivide the emerging global stages into smaller units with best possibilities of international detailed correlation. Thus, two different schemes were published simultaneously in 2004: a first which recognized six primary (labeled 1-6) and 19 secondary (labeled 1a to 6c) Ordovician units referred as “time slices', and a second of 21 consecutive “time units'. The first group of units were based on a combination of biostratigraphic and biochronologic data provided by graptolites, conodonts and chitinozoans, and the “time units' were exclusively based on graptolite biochronology. To solve the uncertainty merged in the definition and correlation of some of these previous, but not entirely clear geochronologic units, a new and refined scheme of 20 alternative chronostratigraphic units was introduced in 2009. This proposed subdivisions of the global stages referred to as *stage slices* which are informal, but defined, chronostratigraphic units, most of which are based on geographically widespread graptolite or conodont zones. Each of the global stages is subdivided into 2-4 *stage slices* that for clarity are designated by an abbreviation of the stage name followed by a figure indicating the general position of the unit within the stage (Tr1-3, Fl1-3, Dp1-3, Dw1-3, Sa1-2, Ka1-4, Hi1-2). Some of the *stage slices* have a similar range as former “time slices' but others are different in scope.

In France, as it occur in other peri-Gondwanan areas of the Mediterranean palaeobiogeographical province (lying in high paleolatitudes close to the Ordovícian South Pole), the general scarcity of graptolites and conodonts in the Lower and Middle Ordovician, and the largely endemic shelly faunas, impose serious difficulties to correlate the successions in this region with the new global chronostratigraphy. The latter is illustrated by the fact that only two of the taxa used for the definition of the global stages and series have been recorded in this region (*Undulograptus austrodentatus* from Turkey and *Normalograptus extraordinarius* from Bohemia) and none of them near formal stage boundaries. The situation is similar with the taxa defining the base of the *stage slices*, and only Dw2 (*Didymograptus artus*), Ka3 (*Amorphognathus ordovicicus*) and Ka4 (*Dicellograptus complanatus*) are recognizable if particular litho- and biofacies are wide to locally developed.

The difficulties to find a direct correlation with the historical British Ordovician stratotypes, after the separation of Avalonia from Gondwana by Arenig times, are found also with regard to the Global standard scale, and led to use the Ibero-Bohemian regional scale more easily and with a higher precision within the southern (paleogeographically) peri-Gondwanan and Gondwanan regions. These include southwestern and central Europe (Ibero-Armorica, Sardinia, Bohemia) to the Balkan and the vast area from Maghreb in northern Africa to Saudi Arabia and part of the Middle East. The Mediterranean regional scheme is largely based on endemic shelly fossils combined with some graptolites and

a good palynological record. The regional chitinozoan zonation is also useful for correlation, and sporadic occurrences of graptolites and shelly faunas of Baltic or Avalonian affinities allow for indirect correlation with some global stage levels. However, French authors have so far neglected the advantages of the regional Mediterranean scheme and favoured, after the long usage of an always changing British scheme, the direct adoption of the Global Ordovician scale, assuming problematic interpretations and often contradictory assessments related with the correlations provided by chitinozoan regional biostratigraphy.

Lower Cretaceous environmental interpretation based on presence of foraminifera in the Tirgan Formation, Northeastern Iran

Agha Hesam Haeri

Paleontological studies on the Tirgan Formation in the west Kopeh-Dagh region, Northeastern Iran, indicate a different environmental conditions in these areas. The Tirgan Formation with the Late Barremian-Early Aptian age in the Messinow (N56°37'43' & E37°24'34') and Jozak (N56°24'25' & E37°24'55') outcrops contains shallow marine benthic foraminifera such as orbitolinidea and so on, while sponge spicules and radiolaria show a deep marine for this rock unit in the Qezell Tappeh well#2 (N54°59'44.2' & E37°24'34.7'). As a result , the environment has been changed from a deep marine condition in the Qezell Tappeh well#2 into the shallow marine in the Messinow and Jozak outcrops in western and eastern part of this region respectively.

Recherche d'indices méthodologiques pour valider un âge 230Th /234U et possibilités de correction

Oum-Keltoum Hakam, Abdelmajid Choukri, Jean-Louis Reyss, Jean-Claude Plaziat

En absence de coraux non recristallisés, considérés comme matériel de choix pour la datation par la méthode $^{230}Th/^{234}U$, les coquilles de mollusques ont été utilisées par plusieurs auteurs pour étudier la variation du niveau de l'eau de mer dans le passé sur les côtes marocaines. Contrairement aux coraux, les coquilles de mollusques contiennent peu d'uranium authigène; elles acquièrent la majeure partie de leur uranium durant la période de fossilisation. La fiabilité de datation $^{230}Th /^{234}U$ des coquilles de mollusques a été déjà mise en cause par plusieurs auteurs qui l'avaient attribuée aux processus d'échange d'uranium et/ou de ses descendants avec le milieu environnant durant la période d'enterrement. Contrairement aux coraux, qui sont aragonitiques à l'origine, et dont la recristallisation peut être contrôlée par la mesure du taux de calcite, l'ouverture du système d'une coquille de mollusque ne peut pas être

décelée par une étude minéralogique du fait que les coquilles de mollusques vivantes peuvent présenter des structures en calcite, en aragonite ou les deux à la fois. Donc, en absence d'un moyen pour contrôler l'ouverture du système cristallin des coquilles, les âges obtenus sont, dans la plupart des cas, sélectionnés après confrontation au contexte stratigraphique et géomorphologique des sites étudiés.

Dans le but d'établir des indices méthodologiques à partir de l'ensemble des résultats de l'analyse radiochimique permettant de juger la validité d'un âge ^{230}Th /^{234}U pour tous les hauts niveaux marins datés jusqu'à présent, nous avons essayé, dans ce travail, de déceler d'éventuelles relations entre la concentration en ^{238}U, le rapport d'activités $^{234}U/^{238}U$ et l'âge non uniquement pour les âges retenus, mais également pour les âges rejetés.

Pour les coraux, la tache s'avère facile du fait que la minéralogie permet d'éliminer les échantillons recristallisés. Pour les coquilles de mollusques, la situation est compliquée du fait que la minéralogie des différentes espèces n'est pas encore bien étudiée.

Dans un premier lieu, nous avons essayé de confronter, pour les mêmes sites, les résultats obtenus à l'aide de coraux non recristallisés et des coquilles de mollusques sur la côte égyptienne de la Mer Rouge.

Dans un deuxième temps, et en absence de coraux, nous avons multiplié les analyses sur des échantillons de coquilles de mollusques appartenant à plusieurs espèces et prélevés aux mêmes endroits dans le but de pouvoir étudier la variation de l'âge apparent mesuré en fonction de la concentration en ^{238}U et en ^{232}Th, du rapport d'activités $^{234}U/^{238}U$, de la teneur en calcite en plus des conditions de conservation des sites.

La plupart des mesures indiquent que les coquilles de mollusques fournissent des âges rajeunis et ce rajeunissement ne peut être expliqué que par une incorporation postérieure d'uranium dans le squelette de ces échantillons. Des scénarios d'influence d'incorporation d'uranium sur le rajeunissement de l'âge ont été imaginés et des tentatives de correction de ces âges ont été proposées.

[EV]

U-series measurements of reef corals and fossil mollusk shells by a-particle counting and thermal ionization mass spectrometry have been used to unravel the time scale and regional specificity of sea level changes during the last 350 000 years. In contrast to corals, mollusk shells contain little authigenic U: their bulk U content represents essentially early diagenetic uptake. Several authors concluded that the $^{230}Th/^{234}U$ ages are generally unreliable compared to those of unrecrystallized coral samples. Kaufman *et al.* ascribed this failure to the post-mortem migration of U into mollusk shells. The U concentrations of fossil shells are usually higher than in living shells and the $^{234}U/^{238}U$ ratios are, in most cases, higher than would be possible if their U were incorporated from seawater.

A number of models based on certain geochemical assumptions have been used to correct rejuvenated fossil mollusk shell or fossil bone and teeth ages, but the results obtained showed that these models can not be applied to samples taken from the same site

In this work, our principal aim isto establish methodological indications from all radiochemical results allowing to judge the validity of Th/U age for all the high marine level. For this, We have tried to reveal possible relations between the concentration ^{238}U, the ^{234}U / ^{238}U activity ratio and the age not only for the retained ages, but also for the rejected ages.

Datation Th/U des dépôts quaternaires au moyen de carbonates impurs

Oum Keltoum Hakam, Abdelmajid Choukri, Jean-Louis Reyss, Jean-Claude Plaziat

L'étude de l'évolution du climat dans le passé est l'unique moyen de comprendre les mécanismes qui régissent à long terme les interactions entre les diverses composantes de l'environnement: atmosphère, océans, glaces et continents. Cette étude est donc essentielle pour l'évaluation de l'impact anthropique et pour la modélisation et la prévision climatique. La validité du cadre chronologique en est la clé majeure en raison de la discontinuité des enregistrements quaternaires. Ces derniers renferment des empreintes qui détiennent un registre d'une tranche de temps suffisamment longue et une gamme de variabilité suffisamment large pour analyser l'amplitude, le mode et le temps de réponse des milieux aux variations. Ces empreintes peuvent être datées par les méthodes de déséquilibres radioactifs dans les familles de l'uranium à condition qu'elles ne dépassent pas 350 000 ans. Les méthodes de datations par les séries de l'uranium permettent de dater avec précision les coraux non recristallisés, les spéléothemes et certaines coquilles de mollusques fossiles bien conservées qui sont essentiellement des carbonates purs. Malheureusement, ces matériaux sont rares autour de la plupart des côtes et des marges continentales du Maroc ce qui pousse à tenter d'utiliser d'autres matériaux qui sont dans la plupart des cas des carbonates impurs, tels que les concrétions calcaires, les caliches, les travertins, les marelles lacustres, les tufs lacustres etc...

La formation des dépôts calcaires est surtout accélérée pendant les périodes chaudes et humides. En conséquence, le nombre élevé de résultats pendant certaines périodes indique des événements chauds et humides. Par contre l'absence de dates durant un certain temps reflète des climats froids ou secs. Réciproquement, la corrélation des datations avec le paléoclimat est souvent citée dans les discussions concernant la fiabilité des résultats.

Dans ce travail, nous avons entrepris une série de mesures uranium, thorium par spectrométrie alpha sur des dépôts carbonatés dans le but de déterminer les spécificités régionales du Quaternaire marocain des régions étudiées, et bien documenter le comportement du système Th/U des fossiles étudiés.

Les données isotopiques obtenues au moyen de la Méthode de Dissolution Totale (TSD), sur plusieurs échantillons fossiles de carbonates impurs, ont permis de calculer respectivement l'âge apparent $^{230}Th/^{234}U$ et l'âge corrigé au moyen des techniques isochrones U-Th .

Couplage des données sismiques, gravimétriques et de géologie de surface, un élément de réévaluation pétrolière d'un bassin mature (application à la craie du bassin de Paris)

Franck Hanot, Joséphine Vicelli, Florian Miquelis

Les variations importantes de vitesse donc de lithologie dans la Craie ont été mises en évidence très tôt, dès le début de l'exploration dans le bassin de Paris. Elles sont depuis 50 ans, un obstacle sérieux causant l'implantation de forages sur de fausses structures en temps. Visbles sur la sismique moderne et les diagraphies des forages pétroliers, leur identification géologique n'a été réellement effective qu'à partir de 1999 avec la réalisation de deux forages entièrement carottés distants de 2 kilomètres et reconnaissant la craie sur une épaisseur de 700 mètres (programme Craie 700).

La relation étroite qui existe entre la topographie au toit de la craie sous couverture tertaire et les zones de craie recristallisée, ainsi que la présence de chenaux sableux d'âge Eocène inférieur à l'aplomb des dépressions du toit de la craie combinée à la présence d'une craie décalcifiée sur une épaisseur importante de plusieurs dizaines de mètres, conduisent à évoquer un phénomène de dissolution/migration/précipitation sous couverture tertiaire.

L'identification d'anomalies de vitesse et de géologie de la craie du Bassin parisien est donc rendue possible grâce à la combinaison :

- d'arguments sismiques : déformations des réflecteurs, faciès sismique particulier, corrections statiques résiduelles,
- d'arguments géologiques : topographie du toit de la Craie et lithologie du remplissage tertiaire,
- d'autres arguments géophysiques tels que la gravimétrie révélatrice des zones rapides donc denses de la craie.

L'utilisation des observations géologiques couplées aux données géophysiques (sismiques et gravimétriques) permettent aujourd'hui de corriger les profils sismiques des déformations liées aux variations de vitesse dans la craie. Elle est acceptée par les opérateurs pétroliers qui procèdent maintenant aux acquisitions de deonnées nécessaires.

Dinoflagellate stratigraphy of the Cretaceous/Paleogene boundary, Stevns Klint, Denmark

Malcolm Barrie Hart, David Forber, Meriel E.J. Fitzpatrick, Andrew Leighton

The Stevns Klint section in Denmark remains a key location for studies of the Cretaceous/Paleogene boundary, despite the recognition of the GSSP in Tunisia. In recent years the lithostratigraphy of this section has been re-defined and there is now a more complete understanding of the sedimentary succession exposed along the 14 km section. There has been some doubt cast upon the representativeness of dinoflagellate studies previously undertaken at Stevns Klint. Samples collected for micropalaeontological and stable isotope analysis have been prepared for palynological research, particularly from an expanded section through the Fish Clay (Fiskeler Member).

A re-examination of the Upper Maastrichtian chalks and an expanded section of the Fish Clay (Fiskeler Member) have shown discrepancies between our findings and earlier work. The white coccolith chalk of the uppermost part of the Sigerslev Member records the *Palynodinium grallator* Zone and culminates in a major sea level fall. The overlying 'Grey Chalk' (Højerup Member) also records open marine conditions, but the sediments were deposited in a series of low carbonate mounds. The last occurrence of *P.grallator* occurs at the top of the Højerup Member, indicating that this zone is typically latest Maastrichtian in age. Within the Fiskeler Member itself, *Danea californica* - a key taxon - was only intermittently present, necessitating the use of two (local?) subzones: *Carpatella cornuta* Subzone (lower) and *Xenicodinium reticulatum* Subzone (upper). *D. californica* and *C. cornuta* are relatively well-known in lowermost Danian successions elsewhere (Brazos River,Texas and marine successions in the Tasman Sea). Environmental conditions within the lower part of the Fiskeler Member appear to be relatively stable, if slightly more neritic than the uppermost Maastrichtian. The younger samples within the Fiskeler Member indicate a progressive transition towards more proximal environments. In the upper levels of the Fiskeler Member and the Cerithium Limestone Member no dinocysts are recorded; the sample only contain pollen grains.

New work on the fine fraction (45–125 µm) of the micropalaeontological samples has recorded a large number of calcareous dinoflagellates, including *Orthopithonella colaris* Wendler *et al.* (2001). The distribution of this taxon is much more extensive than initially described but its stratigraphical distribution does appear to indicate that this is a genuine 'disaster' taxon.

Origin and early evolution of Jurassic planktic foraminifera

Malcolm Barrie Hart, Wendy Hudson, Christopher W. Smart

Following extensive studies of the Oberhauser (1960) and Fuchs (1967) collections of Triassic foraminifera in Vienna, it is concluded that none of these taxa exhibited a planktic mode of life. In the basal Hettangian of the Karwendel Syncline (Austria) and in the Hettangian clays exposed at Hernstein (Austria) only species of *Oberhauserella* and *Praegubkinella* are recorded with no record of planktic morphotypes. This means that the earliest *Conoglobigerina* are derived from the *Oberhauserella* - *Praegubkinella* lineage in the mid-Toarcian, in association with the post-extinction event recovery. Diversity remains low in the Aalenian, although there are only a few recorded localities at which one can study the planktic assemblage. In the Bajocian there is evidence (from the Carpathians in Poland and the Bakony Mountains in Hungary) of the first 'foraminiferal ooze' in red limestone facies. In these successions there is a 99:1 planktic:benthic ratio and the rocks can be foraminiferal packstones (Hudson *et al.*, 2005). Many of these assemblages appear almost mono–specific, although there is some variation in spire height and rate of expansion of the chambers. As much of this work has been done on thin-sections, the aperture is rarely (if ever) visible and it is impossible to determine these as *Conoglobigerina* or *Globuligerina*. In some exceptionally preserved material from the Bathonian of Southern Poland (Pazdrowa, 1969) it is noted that there is a great deal of variation in spire height (though the majority are high–spired and quite 'pointed') but only rare specimens exhibit the loop-shaped aperture required for the determination of *Globuligerina*. All other characters appear to be identical.

Arising in the Aragonite II Ocean, these early planktic foraminifera had aragonite tests and their distribution informs us about the Aragonite Compensation Depth (ACD) but not the Calcite Compensation Depth (CCD), which must have been created by the (also) developing calcareous nannoflora. There is a significant expansion of numbers, diversity and the palaeobiogeographical distribution of planktic foraminifera in the Callovian-Oxfordian (Hudson *et al.*, 2009). At this time species of *Conoglobigerina* or *Globuligerina* are recorded in the North Atlantic Ocean as far south as the Gulf of Mexico. In glauconitic mudstones of latest Callovian and earliest Oxfordian age at Ogrodzieniec (Poland) large numbers of glauconitic steinkerns are found which represent an abundant assemblage of planktic foraminifera. Fuchs (1973) used material from this locality to generate a complete range of new genera and species, all of which have been studied in the collections of the Geologisches Bundesanstalt in Vienna. Several of these new species are mineral artefacts, while others are benthic foraminifera. There are, however, many high-spired specimens of *Conoglobigerina* in the assemblage. The abundance of planktic foraminifera in the latest Callovian and earliest Oxfordian may be indicative of a 'cool' phase (associated with southward ammonite migrations) in which the aragonite assemblage is preferentially preserved. There is evidence for a reduction in both numbers and diversity of

planktic foraminifera in the latest Jurassic and across the Jurassic-Cretaceous boundary. At this time there was a change in the calcification of the tests from aragonite in the Jurassic to calcite in the Cretaceous. After remaining a low diversity assemblage in the earliest Cretaceous, there is an expansion in numbers, diversity and palaeobiogeographical distribution as the continents fragmented in the post-Barremian and Aptian. With the temperature increases in the mid-Cretaceous (especially Cenomanian and Turonian) there was a cross-latitude migration and warm-water assemblages are known from many, relatively high latitude locations (*e.g.*, North Sea Basin, Western Interior Seaway). Fluctuations in distribution occurred throughout the Late Cretaceous until a final warming pulse in the latest Maastrichtian was followed by evidence of cooling immediately before the K/Pg boundary.

Modélisation des accumulations de la matière organique à la limite Cénomanien-Turonien dans la région de Gafsa, Tunisie centrale

Abdallah Hassen, Belayouni Habib, Sassi Sassi, Saïdi Moncef

À la limite Cénomanien-Turonien le secteur de Gafsa, partie méridionale de la Tunisie centrale, est fragmenté en petits bassins séparés par des zones hautes relativement étroites orientées en général Est-Ouest ou localement NW-SE. Ces hauts-fonds contrôlent étroitement les échanges entre les divers bassins de la région. Ceux-ci peuvent être également séparés localement par des seuils de directions diverses qui peuvent prolonger les hauts-fonds vers l'Ouest, au niveau des blocs basculés. À travers ces seuils se font les échanges les plus significatifs entre les bassins eux-mêmes et avec la Téthys, du coté Est.

Les séries de la limite C/T dans la région de Gafsa fossilisent de la matière organique dont l'abondance ainsi que la répartition géographique sont variables et dépendent étroitement de l'architecture paléogéographique de cette région. La matière organique est inféodée aux secteurs bas où elle s'étale sur les séries de l'intervalle transgressif, et exceptionnellement déborde sur le haut niveau marin de la séquence de dépôt ; alors que les secteurs hauts en sont presque complètement dépourvus et au contraire ceux-ci abritent les plates-formes carbonatées du Gattar au Turonien inférieur *pp.* (série de haut niveau marin). Ainsi le haut niveau marin correspond à des dépôts riches en matière organique au milieu du bassin et à des dépôts de plate-forme sur les hauts-fonds (lithosomes à rudistes, dépôts bioclastiques). Par contre au niveau des marges des bassins, la matière organique est fossilisée uniquement dans les dépôts de l'intervalle transgressif de la séquence de dépôt de la limite C/T.

La MO est étudiée en surface et en subsurface sur des cuttings. En forage la série traversée est de 80 m, alors que celle en affleurement elle totalise 62,5 m (25,5 m d'intervalle transgressif ; 37 m de dépôts de haut niveau marin). La fossilisation et la richesse en MO dépendent, entre autres au sein des bassins, du battement de la déficience en oxygène par rapport à l'interface eau/sédiment.

Les échantillons de forage analysés sont dans l'ensemble riches à très riches en matière organique. Les teneurs en COT varient entre 0,05 et 32,31%. La moyenne est de 5,45% (n=31). Alors que les potentiels pétroliers sont également variables et peuvent atteindre 221,88 kg d'hydrocarbure/tonne de roche ; néanmoins certains échantillons se caractérisent par des potentiels faibles n'excédant pas 2 kg d'HC/t de roche.

Les échantillons d'affleurements analysés sont également riches en matière organique. Les teneurs en COT, néanmoins moindres, sont comprises entre 0,75 et 12,05% avec une moyenne de 4,55% (n=25). La différence de 0,9% est surement due à l'altération de la matière organique en affleurement.

Du point de vue évolution thermique de la matière organique, les échantillons (affleurement et subsurface) n'ont pas atteint le stade de la fenêtre à huile et sont immatures (Tmax < 435°C). D'après les diagrammes IH/IO et IH/Tmax, il apparaît que la matière organique est planctonique algaire (de type I).

On the prospects of 14C

Christine Hatté, Nadine Tisnérat-Laborde, Eric Douville, Michel Fontugne, Norbert Frank, Caroline Gauthier, Evelyne Kaltnecker, Mercedes Mendez-Millan, Claude Noury, Martine Paterne, Jean-François Tannau, Hélène Valladas

In 1946, Libby proposed a dating method based on the natural ^{14}C... a lot has changed since that time when several tens of grams of carbon were required to measure radioactivity. From technological and conceptual revolutions to human impact, ^{14}C geochemistry allowed to place events in time and to specify past and present carbon cycle.

Beta counters have become small accelerators allowing on-line CO_2 measurements, kilograms of carbon are restricted to a few micrograms of carbon, bulk of different origin is replaced by specific molecules. The scientific questioning around ^{14}C geochemistry changes.

Our aim is to introduce technological advances of the past 10 years, to place them in the evolution of the basic concepts of ^{14}C geochemistry/geochronology and to present the prospects that this new ^{14}C geochemistry offers.

Halang Formation from Stratigraphy and Micropaleontology (case study in Darmaji section, Banyumas Area, Indonesia: a Preliminary Study)

Marfasran Hendrizan, Rubiyanto Kapid, Haryadi Permana, Purna Sulastya Putra

Halang Formation have very large distribution from Majalengka to Banyumas, Indonesia, deposited in turbidite system by containing of volcaniclastic sediments. Objective of the research is to identify relationships of Halang Formation with other formation that overlied and overlain by Halang Formation. Previous researches have a differences in stratigraphic position, Halang Formation overlied Pemali Formation. the others, Pemali Formation was overlain by Halang Formation. Intensive study from micropaleontology for Halang Formation has done in some areas in Banyumas, Kuningan, Kebumen, and Majenang in Central Java, Indonesia. Index species of foraminifers were *Globorotalia plesiotumida*, *Globorotalia tumida*, *Globorotalia siakensis/Globorotalia mayeri*, *Neogloboquadrina acostaensis*, *Neogloboquadrina humerosa*, and they were used for marker in Halang Formation.

Preliminary results of Darmaji river, Karangpucung, South of Central Java were consisted of siltstone dominated, and intercalated of limestone in small amount. Foraminifers were very abundant in this section, especially planktonic foraminifers with very well preservation. *Globorotalia plesiotumida* and *Globorotalia tumida* were bioevents for this section, stated that Late Miocene to Pliocene. The paleobathimetry of this section showed that lower bathyal based on the assemblage of benthic foraminifers *i.e. Globobulimina* sp., *Melonis* sp, and *Cibicides* sp.

Évolution sédimentaire et climatique de la série aptienne de Bir Oum Ali (chaîne des chotts, Sud tunisien)

Rabaa Hfaiedh, Ihsen Zghal, Annie Arnaud Vanneau, Alexis Godet, Jamel Ouali, Hubert Arnaud

Cette série aptienne déposée au nord du bouclier saharien correspond au premier retour à de vraies conditions marines au-dessus des dépôts argilo-clastiques du néocomien (faciès wealdien).

On peut la subdiviser en cinq parties.

- La première partie est représentée par le membre Berrani qui forme une petite falaise de calcaires à rudistes et orbitolines renfermant

Palorbitolina lenticularis. Elle est probablement d'âge aptien inférieur (Bédoulien inférieur).

- La seconde partie est représentée par une succession d'alternances de calcaires bioclastiques et de marnes dans laquelle peuvent s'insérer quelques bancs de calcaires plus détritiques. On y rencontre *Palorbitolina lenticularis*, *Praeorbitolina lotzei*, *Voloshinoides murgensis* et *Choffatella decipiens*. Cet assemblage est caractéristique du Bédoulien supérieur
- La troisième partie est représentée par un dépôt de gypse pouvant atteindre jusqu'à 30m d'épaisseur. Cette série épaisse est surtout visible dans le flanc sud, alors que dans le flanc nord, ce gypse est de moins en moins épais et peut même disparaître localement
- La quatrième partie correspond à un retour massif des apports détritiques avec des dépôts argilo-sableux importants. Cet ensemble ne referme pas de faune indicative d'un âge précis car on y observe soit des crinoïdes à la base, soit des débris d'os, de dents et de plantes au sommet.
- La cinquième partie est représentée par deux barres calcaires faisant falaise interrompue par un niveau un peu plus tendre. La première falaise renferme *Paracoskinolina tunesiana* et *Mesorbitolina pervia*, association indiquant le Gargasien, la seconde *Mesorbitolina parva et Mersorbitolina texana* qui sont présents aussi bien dans l'Aptien supérieur que dans l'Albien basal.

Au-dessus, les marnes et bancs calcaires de l'Albo-Cénomanien renferment des ammonites, des oursins et des orbitolines.

La transgression débute essentiellement à l'Aptien inférieur avec les premiers sédiments marins du membre Berrani. Elle correspond à des environnements de dépôt de plate-forme tropicale peu profonde, protégée des apports détritiques massifs. Cette phase de dépôt de plate-forme est interrompue par une émersion généralisée suivie par une érosion et une karstification importante. Notons que c'est au même moment que les dépôts carbonatés de plate-forme sont interrompus sur la marge nord-téthysienne (sommet des calcaires urgoniens du SE de la France).

La seconde partie montre une évolution vers des dépôts marins de plus en plus francs, même si, au début, les premières paraséquences calcaires présentent des traces d'émersion et de paléosols. L'élévation de la tranche d'eau favorise l'augmentation des faciès à oolites et à orbitolines, puis l'abondance des algues vertes et des débris de crinoïdes. Le maximum d'approfondissement correspond à un calcaire blanc particulier renfermant une faune circalittorale à *Marssonella* sp. et *Nezzazata* sp.. Au-dessus de ce banc, une ammonite de la famille des Deshayesitidae a été trouvée.

La troisième partie correspond à des accumulations de gypse, témoignage d'un probable changement climatique permettant un plus grand confinement au moins local et coïncidant avec une période d'aridité.

La quatrième partie est caractérisée par l'arrivée de dépôts fluviaux deltaïques, traduisant le retour à un climat plus humide et à une période d'érosion plus intense. Elle débute à la base par des dépôts marins à crinoïdes passant vers le haut à des dépôts moins profonds à gastéropodes (Nérinées) dans des sables verts et à des niveaux à Huîtres. La diminution de la tranche d'eau est attestée par l'apparition d'épikarsts au sommet de certains bancs (banc à accumulation de Nérinées).

La cinquième partie correspond au retour de faciès de plate-forme carbonatée tropicale, mais cette fois ci beaucoup plus riches en apports détritiques. Là encore la profondeur ne semble pas avoir été importante puisque des épikarsts peuvent apparaître au moins au sommet du premier gros banc métrique calcaire.

En conclusion, nous retrouvons dans cette région des événements déjà connus sur la marge nord téthysienne comme les phases transgressives de l'Aptien inférieur et l'émersion et la fin provisoire des plates-formes carbonatées à la limite Bédoulien inférieur/Bédoulien supérieur.

Par contre, nous avons la preuve qu'une période d'aridité suivie d'une période humide s'est développée à la limite Aptien inférieur/Aptien supérieur et au cours de l'Aptien supérieur.

Evaluation of the astronomical time scale for the Paleocene and earliest Eocene

Fritz Hilgen, Klaudia Kuiper, Lucas Lourens

The astronomical-tuned time scale is rapidly extended into the Paleogene but, due to the existence of an Eocene gap, different tuning options had to be presented for the Paleocene. These options differ both in number and tuning of ~405-kyr eccentricity related cycles and are only partially consistent with recalculated 40Ar/39Ar constraints for the Cretaceous/Paleogene (K/Pg) and Paleocene/Eocene (P/E) boundaries. In this paper, we evaluate the cyclostratigraphic interpretation of records from ODP Leg 198 and 208 sites, and the Zumaia section to eliminate differences between tuning options.We found that the interval between the K/Pg boundary and the early Late Paleocene biotic event (ELPE) comprises 17 instead of 16 x ~405-kyr eccentricity related cycles as previously proposed, while the entire Paleocene contains 25 x ~405-kyr cycles. This interpretation solves problems in the tuning of ODP leg 198 and 208 sites and eliminates large and abrupt changes in seafloor spreading rate. Using 40Ar/39Ar age constraints for the K/Pg boundary, a tuning to 405-kyr eccentricity is proposed for the Paleocene and earliest Eocene. This tuning results in ages of ~66.0 and ~56.0 Ma for the K/Pg and P/E boundary and seems consistent with recalculated 40Ar/39Ar ages for ash layer -17 of early Eocene age. However, despite this apparent consistency with radio-isotopic constraints, an alternative 405-kyr younger or, less likely, older tuning can not be excluded at this stage.

Dating and delineating the boundary between the Fahliyan and Gadvan Formations through some parts of the Zagros fold-belt

Seyed Abolfazl Hosseini, Marc A. Conrad, Bernard Clavel, Danielle Decrouez

The Fahliyan Formation is an important hydrocarbon reservoir in the Zagros fold-belt. Facies analysis and regional correlations are carried out, principally based on benthic foraminifera and dasycladalean algae, on six outcrop sections in some parts of the Zagros fold-belt. Results let us revise the precise age and lithological boundary between the Fahliyan and Gadvan formations. In most cases, the Fahliyan Formation ranges from the Berriasian to as high as the Late Hauterivian, however always with an intraformational discontinuity interpreted as corresponding to a late Valanginian and early Hauterivian stratigraphical gap. Toward the eastern part of the Zagros fold-belt, in the shallow carbonate platform of the Fars area, the upper part of the Fahliyan Formation is replaced by the Gadvan Formation which starts with the Late Hauterivian stage. This means that these two formations should be revised both for their chronostratigraphical age and lithostratigraphical boundary, which pretty differ in previous reports. These two formations are time equivalents of the Yamama, Lekhwair and Kharaib formations in the eastern part of the Arabian Plate, in Qatar, Oman and Abu Dhabi. The regional correlation proves the presence of paleo-highs at top of the Fahliyan Formation as the main cause for different thickness and facies changes of the Gadvan Formation in these parts of the Zagros fold-belt.

Effects of the subaerial exposure on reservoir quality in South Pars gas field, offshore Iran

Gholamreza Hosseinyar

Subaerial exposure and meteoric diagenesis are critical in the development and preservation of porosity in many limestone reservoirs; however, the effect of subaerial exposure on porosity in limestones is variable.

Upper Permian and Lower Triassic carbonates in the subsurface of South Pars (offshore Iran) were studied to determine how subaerial exposure and freshwater diagenesis effected porosity distribution. The Upper Dalan (upper Permian) Member and Kangan (lower Triassic) Formation, the reservoir intervals at South Pars, are predominantly composed of carbonate strata (dolomites with some grain-rich limestone intervals) with anhydrite intervals.

Results of this study indicate that, subaerial exposure and meteoric diagenetic process caused to dissolution of unstable components (such as ooides, peloides and bioclasts) of the facies in the South Pars. So, pores space disturbed and moldic and vuggy pores have created. Dissolution and creating of secondary

pores is prevalent in grain-dominated facies, mostly. Furthermore, precipitation of calcite cements filled the primary (depositional) pores that this cement diffuses in limestone parts of the reservoir.

Subaerial exposure of South Pars reservoir strata caused to filling of the primary pore spaces and creating secondary pores such as oomolds as moldic pores are frequent pore types in the reservoir. Throughout this process, the permeability of reservoir was decreased however, porosity not decreased approximately and only the type of pores were changed.

Calibration astronomique du Maastrichtien

Dorothée Husson, Bruno Galbrun, Jacques Laskar, Linda Alide Hinnov

L'échelle des temps du Crétacé est la combinaison de données biostratigraphiques, magnétostratigraphiques, et de l'échelle des inversions de polarité du champ magnétique basée sur les séquences d'anomalies magnétiques océaniques. La datation des limites des magnétochrones à l'aide de modèles d'accrétion océanique a beaucoup contribué à l'établissement de cette échelle, mais seules de rares datations absolues permettent de contraindre ces modèles. L'échelle des temps Crétacé nécessite ainsi de constantes révisions.

Durant les dernières décennies, le développement de la cyclostratigraphie et de la calibration astronomique a permis d'atteindre un haut degré de précision dans l'estimation des durées et des âges au Cénozoïque. Cette discipline est basée sur l'analyse des cyclicités sédimentaires, et la mise en évidence de leur lien avec les évolutions des paramètres orbitaux de la Terre, de périodes connues. La cyclostratigraphie a ainsi permis d'élever la résolution de l'échelle des temps Néogène à moins 0.01 Ma.

De nombreux sites ont été étudiés ici, afin de couvrir l'ensemble du Maastrichtien et de disposer d'un cadre bio et magnétostratigraphique solide. Les séries sédimentaires proviennent de forages ODP des legs 122 (marge Nord ouest australienne), 207 (Atlantique équatorial), et 208 (Atlantique sud), du leg DSDP 74X et de coupes à terre situées à Gubbio (Ombrie Marche, Italie) et Bidart (sud ouest de la France). Les analyses cyclostratigraphiques ont portées sur les variations de la susceptibilité magnétique, marqueur du détritisme (coupes de Bidart, de la Contessa et site ODP), et de la réflectance (sites ODP), permettant de caractériser les évolutions de la couleur des sédiments.

L'utilisation de techniques de traitement du signal a permis de mettre en évidence un contrôle orbital de la sédimentation sur l'ensemble des sites, et d'identifier des cyclicités correspondant aux évolutions de la précession, de l'obliquité, et de l'excentricité à 100 et à 405 ka. Ces analyses ont également permis de caractériser les variations et perturbations de la sédimentation affectant les sites au cours du

Les durées de l'ensemble des séries sédimentaires étudiées, des magnétochrones C32n2n à C29r, et des biozones reconnues ont été estimées

par comptage des cycles d'excentricité à 100 et 405ka, et de précession. Un cadre cyclostratigraphique composite, s'étendant sur plus de 8 Ma, avec une précision atteignant parfois 0.02 Ma a été créé grâce au transfert des signaux sédimentaires dans le domaine temporel, sur la base de la reconnaissance des cycles à 405 ka (orbital tuning). Le calage de l'évolution de l'excentricité à 405 ka extraite par filtrage des enregistrements sédimentaires sur les solutions astronomiques développées récemment (La04 et La10) permet de proposer une échelle des temps Maastrichtien astronomiquement calibré. En raison de l'augmentation de l'incertitude des solutions astronomiques au cours du temps, liée au caractère chaotique du mouvement dans le système solaire, deux calages sont proposés, qui fournissent deux échelles de temps. Par exemple, l'âge de la limite Crétacé-Paléogène notamment évalué à 65.6 +/-0.02 Ma ou 66.1+/-0.02 Ma.

Paleoenvironmental and paleoclimatic reconstructions in the Paris Basin during the Lutetian

Damien Huyghe, Didier Merle, Franck Lartaud, Laurent Emmanuel

Paleoclimatic data available for the first part of the Cenozoic often come from the stable isotopic analysis of pelagic benthic foraminifers. Those works represent only a mean global vision of the paleoclimatic context. On the contrary, the paleoclimatic evolution is less documented in shallow water environments.

We chose the example of Grignon, located on the south-western part of the Paris Basin, to try to reconstruct the paleoenvironmental and paleoclimatic evolution. Carbonate fossils profuse in the sediments of this section and are well preserved. The area of Grignon corresponded, during the Lutetian, to near-shore environment. Many biostratigraphic data are available for this section and its age corresponds to the Middle Lutetian (NP15). Four groups of molluscs were selected for this study, using stable isotopic geochemistry ($\delta^{18}O$ and $\delta^{13}C$): two groups of bivalves (*Ostreidae* and *Venericardia*) and two groups of gastropods (*Sigmesalia* and *Turritella*).

The comparison of the mean $\delta^{18}O$ values of all samples indicate that the *Venericardia* and the *Sigmesalia* are two groups that mineralised their shells only during the warm months of the year and allow the reconstitutions of summer paleotemperatures. On the contrary, *Ostreidae* and *Turritella* build their shells during the whole year and $\delta^{18}O$ isotopic measurements can be interpreted as mean annual temperatures for the whole fossil, or seasonal variations of temperatures when high resolution measurements are performed. Considering true marine conditions, with a salinity of 35‰, we document variations of mean annual temperatures between 17°C and 27°C during the Middle Lutetian, in the Paris Basin. According to the *Sigmesalia*, the *Venericardia*, and the *Turritella*, summer temperatures could have reached 30°C, with a seasonal gradient of temperatures of 12°C.

The comparison of the $\delta^{13}C$ values of the fossils illustrate that this parameter was firstly influenced by the ecology of each group. *Venericardia*, that lived

into the sediment, *i.e.* where the degradation of organic matter is the most important, have the lighter isotopic values, whereas *Ostreidae*, that lived on the sediment are characterised by the most positive $\delta^{13}C$. The *Sigmesalia*, which could move from the surface to the sediment, have an intermediary $\delta^{13}C$.

[VF] Apport de la géochimie isotopique ($\delta^{18}O$ et $\delta^{13}C$) aux reconstitutions paléoenvironnementales au Lutétien dans le bassin de Paris

Les données paléoclimatiques disponibles pour la première partie du Cénozoïque proviennent essentiellement de l'analyse géochimique de foraminifères benthiques ou planctoniques, et l'évolution des paléotempératures reste peu documentée en domaine littoral. Les séries marines d'âge Cénozoïque du bassin de Paris présentent l'avantage d'avoir un contenu en fossiles extrêmement riche avec une très bonne qualité de préservation, ce qui permet de tester si ces environnements sont des bons témoins de l'évolution des conditions paléoclimatiques.

Nous nous sommes intéressés dans cette étude à l'exemple de la falunière de Grignon dont les sédiments datent du Lutétien. Trois groupes de fossiles ont été étudiés sur l'ensemble de la coupe, les *Ostreidae*, les *Sigmesalia* et les *Venericardia*. Les fossiles d'*Ostreidae* présentent l'avantage d'avoir une croissance continue sur plusieurs années et informent donc sur l'évolution des températures moyennes annuelles. Quant aux *Venericardia* et aux *Sigmesalia*, ces fossiles ne minéralisent leurs coquilles que durant l'été, et permettent ainsi de documenter l'évolution des températures d'été. Les résultats montrent que les températures moyennes annuelles ont dû varier entre 17 et 27°C au Lutétien dans le bassin de Paris, avec des températures maximales atteignant 30°C. De plus, l'analyse à très haute résolution de fossiles de turritelles montre que le gradient saisonnier de températures devait être élevé, de l'ordre de 12°C.

Ces résultats montrent donc qu'il peut être intéressant de multiplier les reconstitutions paléoclimatiques en domaine littoral, afin de caractériser notamment le gradient saisonnier de températures, ce qui n'est pas réalisable en domaine océanique.

Palynological reconstruction of the Eocene paleoenvironments in south of Western Siberia

Alina Igorevna Iakovleva

Analysis of quantitative distribution of the aquatic and continental palynomorphs from a marginal marine Eocene section drilled by the borehole No.011-BP (south-western Siberia) allows the reconstruction of the early through latest Eocene paleoenvironmental settings of the West Siberian marine basin. Successive palynomorph assemblages allow the recognition of 12 depositional cycles, attributed to third-order sea-level fluctuations. The

palynological data indicate significant palaeoclimatological and broad environmental changes characterizing the West Siberian Eocene:

1) the absolute dominance of cosmopolitan dinocysts in the Middle Ypresian assemblages suggests a shallow water West Siberian marine basin in constant connection with northern and southern seas, with warm climate;

2) a Late Ypresian regressive phase culminates in the temporary cessation of marine sedimentation spanning the Early Lutetian;

3) from latest Lutetian times onwards the south-east of the West Siberian marine basin became significantly shallower, indicating the development of brackish settings;

4) a strong influx of endemic taxa, combined with a high dominance of terrestrial palynomorphs suggest a shallow connection with adjacent basins during the Bartonian;

5) the Early Priabonian is characterized by the influx of freshwater in the southern part of the West Siberian Sea;

6) a final transgression occurred in southern West Siberian Basin by the Middle-Late Priabonian (~35.5-34.8 Ma).

Ammonite criteria for the Jurassic-Cretaceous boundary in Bulgaria – a review and new data

Marin Ivanov Ivanov, Vyara Idakieva Stoyanova

The Jurassic-Cretaceous boundary interval in Bulgaria passes through sediment sequences of different facieses: carbonate platform sediments (Kaspichan, Brestnitsa, Slivnitsa Formation etc.); hemipelagic, predominantly carbonate sediments (Glozhene, Ticha Formations); siliciclastic slope and basin deepwater successions (Zlatharitsa, Kostel, Cherni Osam Formations).

In the shallow water sediments occur benthic faunas – forams, bivalves, corals etc., while ammonites are completely missing. Among the hemipelagic sequences mainly presented by micritic limestones ammonite findings are relatively rare. In these sediments the Jurassic-Cretaceous boundary is precisely fixed on the basis of calpionellids, calcareous nannoplankton and calcareous dinocysts. A rich Upper Tithonian-Berriasian ammonite in Bulgaria fauna comes from the siliciclastic sediments in which are divided ammonite zones.

A special international symposium on the Jurassic-Cretaceous boundary was hold in 1977 in Bulgaria (Nikolov, Sapunov, 1977). The proposed criteria in this forum had been used in Bulgaria during the period 1977-2007. In the upper parts of the Upper Tithonian was recognized Paraulacosphinctes transitorius Zone with Micracanthoceras microcantum and Malbosiceras chaperi Subzones and at the base of the Berriasian Stage - Pseudosubplanites grandis Zone. In this way the boundary Tithonian-Berriasian was fixed between Malbosiceras chaperi Subzone and Pseudosubplanites grandis Zone (Nikolov,

Sapunov, 1977; Sapunov, 1979; Nikolov, 1982, 1987; Nikolov *et al.*, 2007). A different position of the boundary is set up by microfossils (calpionellids, calcareous nannoplankton and calcareous dinocysts – Lakova *et al.*, 1999).

New investigations on the ammonite successions in SW Bulgaria have provoked a correction of the criteria and a revision of the position of the Jurassic-Cretaceous boundary in Bulgaria (Ivanov *et al.*, in press).

For the last three years in sections of the Kostel Formation (Gorochevo Member) in Krayshte zone (SW Bulgaria) we have identified ammonite zones in the Upper Tithonian and at the base of the Berriasian. In the section between the villages Kosacha and Kopanitsa (Radomir District) in a continuous succession were determined Micracanthoceras microcanthum Zone (with Paraulacosphinctes transitorius Subzone in upper parts), Durangites spp. Zone in the Upper Tithonian and Berriasella jacobi Zone at the base of the Berriasian (Ivanov *et al.*, in press).

The Durangites spp. Zone in the Upper Tithonian is proved by the presence of *Durangites singularis*, *Durangites* cf. *vulgaris*, *Durangites* aff. *astillerensis*, *Protacanthodiscus* cf. *andreaei*, *Protacanthodiscus* sp. The ammonite association includes numerous phylloceratids and lytoceratids.

The Berriasella jacobi Zone is determined by the species *Berriasella jacobi*, *Subapinites* aff. *aristidis*, *Delphinella janus*, *Fauriella shipkovensis*, *Berriasella* sp.

The ammonite findings of hemipelagic sediments in the Jurassic-Cretaceous boundary interval in the West Balkanides (section near Komshtitsa and Barlya, Glozhene Formation) indicate the presence of Durangites spp. Zone and Berriasella jacobi Zone. Here were found out *Protacanthodiscus* cf. *andreaei* in Durangites Zone and Malbosiceras chaperi and the index species in Berriasella jacobi Zone.

Inspection observations has been carried out in the known siliciclastic sequences in the Central Fore-Balkan (Elena District), from which derived the published by Nikolov (1992) representatives of Berriasellidae.

At the base of the sections along the Zlatarishka and Miikovska rivers are found abundant ammonite faunas belonging to Berriasella jacobi Zone. It is characterized by *Malbosiceras shaperi*, *Pseudosubplanites (P.) euxinus*, *Tirnovella allobrogensis*, *Delphinella janus*, *Subalpinites aristidis* etc. Our investigation doesn't confirm the presence of representatives of *Paraulacosphinctes* in these intervals. The sediment successions start in both sections from the cores of the anticline structures, which doesn't allow the investigation of the lower boundary of the ammonite zone. Nevertheless, in the area of Central Fore-Balkan (Troyan and Elena District) there are sections with potential for fixing the Jurassic-Cretaceous boundary.

In the region of Eastern Fore-Balkan the Jurassic-Cretaceous boundary interval passes through hemipelagic sediments – micritic and clayey limestones of the Ticha Formation. It contain relatively well-preserved ammonites (Nikolov, 1982), as well as calpionellids and calcareous nannoplankton. In the Upper Tithonian here are found representatives of *Paraulacosphinctes*, *Aulacosphinctes* etc. (Micracanthoceras microcanthum Zone) and at the base of the Berriasian - *Berriasella*, *Tirnovella* and *Substeuroceras* (Berriasella jacobi Zone). In this region the boundary position among the comparatively thick

sediment sequences is not exactly fixed. In the sections of the Ticha Formation in the area of Targovishte and Preslav (section Ticha, Strazha etc.) there is a great opportunity for new parallel investigations on macrofauna and microfossils of the Jurassic-Cretaceous boundary interval.

In conclusion, we propose to put the Jurassic-Cretaceous boundary on ammonites in Bulgaria at the base of Berriasella jacobi Zone. There are a good potential for characterizing and specifying of the position of this boundary in the hemipelagic, as well as in the siliciclastic successions. Parallel investigations on ammonites and microfossils in unexamined so far sections are possible. The direct calibration of the biomarkers on ammonites and microfossils could be used in transregional correlations.

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Ammonite biostratigraphy of Lower Aptian and potential for finding out OAE 1a in Bulgaria

Marin Ivanov Ivanov, Vyara Idakieva Stoyanova

The Lower Aptian in Bulgaria includes sediment sequences from several lithostratigraphic units belonging to different facies: carbonate platform (Urgonian complex – Lovech and Vratsa Urgonian Group); clayey-carbonate (Razgrad Formation); dominant clayey (Trambesh, Gorna Oryahovitsa and Mramoren Formation); relatively shallow-water siliciclastic (Roman and Svishtov Formation) and flischoid siliciclastic (Damyanovo Formation) sediments. The sediments of the Razgrad and Trambesh formations contain an abundant cephalopod fauna with good ammonite successions compared to the other units, where the ammonite findings are rare.

By the beginning of 80s of the last century in the Lower Aptian was identified only one zone – Deshayesites deshayesi (Nikolov, 1965-1969; Dimitrova, 1967-1972). More detailed division of this interval was made by K. Stoykova (1982-1990). Some new biostratigraphic data on the substage were published by M. Ivanov (1992-2001).

Recently intensive investigations have been carried out on the Barremian and partially on the Aptian Stage (Ivanov, Idakieva, 2008-2009). The results presented here are based on new field observations and revision of the old ammonite collections.

In the most upper parts of the Barremian Stage in NE Bulgaria has been established a Martelites sarasini Zone with its index species as well as with *Martelites ellipticus*, *M. ratshensis*, *M. aff. rionense.* The species belonging to genus *Pseudocrioceras* occur in the most upper parts of the zone, which proves the presence of Pseudocrioceras waagenoides Subzone. In the deeper water sediments analogous to this subzone is horizon with *Turkmeniceras* (*T. turkmenikum*, *T. rarecostatus*, *T.* sp.), which previously had been assigned to the base of Lower Aptian.

The Barremian-Aptian boundary in Bulgaria now is fixed by the appearance of the early Deshayesitidae (*Paradeshayesites olganensis*, *P. tuarkyricus*, *Deshayesites luppovi* etc.) and by the disappearance of the representatives of *Pseudocrioceras*. It is set up at the lower parts of Trambesh Formation, upper parts of Roman and Mramoren Formation and at the most upper parts of the Urgonian complex.

The Lower Aptian Substage in Bulgaria is divided into four zones: Paradeshayesites oglanensis Zone, Paradeshayesites weissi Zone, Deshayesites deshayesi Zone, Dufrenoya furcata Zone.

Paradeshayesites oglanensis Zone is characterized by the presence of the earliest Deshayesitidae - *Paradeshayesites olganensis*, *P. tuarkyricus*, *P. weissiformis*, *P. laeviusculus*, *Deshayesites luppovi* etc. from the Razgrad and Trambesh Formation. Within the framework of Razgrad Formation in the ammonite association are included also species of *Prochelonicera*s, *Kutatissites*, *Audouliceras*, *Ancyloceras*, *Pseudohaploceras*, etc.

Paradeshayesites weissi Zone is identified for the first time in Bulgaria. Up to now this interval had been included in a Prochelonicera pachystephanum Zone or in the Deshayesites deshayesi Zone. It is distinguished by the presence of *Paradeshayesites* aff. *weissi*, *Deshayesites forbesi*, *D. euglyphus*, *D. dechyi*, *D. ex. gr. spathi/normani*, rare *Prochelonicera*s *pachystephanum*.

Among the marls of the Trambesh Formation, as well as in the fine-laminated silty or silicified sediments in the upper parts of the Gorna Oryahovitsa Formation or at the base of the Kovachevets Formation has been found a specific ammonite fauna. This association comprises representatives of *Pseudohaploceras*, which dominated, Roloboceratinae (*Roloboceras* aff. *hambrovi*, *R. transiens*, *R.* sp., *Megatyloceras ricordianum*, *M. bontchevi*), rare *Prochelonicera*s and numerous *Volgoceratoides* (*V. schilovkensis*, *V.* sp.), *Koeneniceras (K. tenuiplicatum*, *K. rareplicatum*, *K.* sp.) and *Aconeceras*. Up to now in this association Deshayesitidae are not found. It could be correlated to Roloboceras hambrovi Subzone in France and Spain and to Volgoceratoides schilovkensis Subzone in Russia. The presence of *Volgoceratoides*, *Koeneniceras* and *Prochelonicera*s is the reason for putting this interval conditionally into the Paradeshayesites weissi Zone.

The Deshayesites deshayesi Zone is considered here in a revised content in correspondence with the scope adopted by many authors and the Kilian Group. It is recognized by the presence of the index species, as well as the characteristic species *Paradeshayesites grandis*, *Cheloniceras cornuelianum*, *Ch. crassum*, *Ch. kiliani*. There also found *Paradeshayesites callidiscus*, *Deshayesites dechyi*, *D. planus*, *Toxoceratoides royerianus* and rare Ancyloceratidae and Desmoceratidae.

Dufrenoya furcata Zone has a restricted distribution in Bulgaria. It was indicated by several findings of *Dufrenoya praedufrenoyi* and some early representatives of *Tropeum* in the upper parts of Kovachevets and Russe Formation, but this interval is poorly studied.

The Lower-Middle Aptian boundary has been fixed by the appearance of the species belonging to *Epicheloniceras* and *Colombiceras*. It is set up within the Trambesh, Mramoren and Svishtov Formation or coincides with the boundary between Russe-Kovachevets and Trambesh formations.

The analysis of the ammonite successions as well as some sedimentological characteristics enable us to conclude that in the marls and clayey limestones Lower Aptian sequences there are indications for the presence of the anoxic event OAE 1a.

In the lower-middle parts of the Trambesh Formation (quarry Butovo) has been observed an interval with thin-laminated marls to limy clays rich in organic matter. Immediately above this interval follows the level containing *Roloboceras*, *Megatyloceras*, *Koeneniceras ? Vologoceratoides.* It consists of an alternation of limy clays and marls with 'red beds' (? siderite beds and concretions probably with increased manganese content).

A marker of thin-bedded siltstones and marls with abundant organic matter is distinguishable in the most upper parts of Gorna Oryahovitsa Formation (section Kovachevets). Here once again was found a level with *Koeneniceras* and *Volgoceratoides* among the thin-bedded laminated limestone with siliciclastic intercalations. The stratigraphic position of these bed sets is not already precised, but for the present we assume that they could be inserted into Paradeshayesites weissi Zone. A similar level is recognized in the most upper parts of Kovachevec Formation (section Byala-Strarmen) within the Dufrenoya furcata Zone. In all these intervals there is a total lack of benthic fauna. A poly scenario effect of origin and expression for the anoxic event OAE 1a is possible.

The presented data for possible expression of OAE 1a in the Lower Aptian in Bulgaria should be proved by a complex of methods.

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Le passage Cénomanien-Turonien sur la marge Sud-téthysienne : géochimie isotopique et stratigraphie séquentielle

Mohamed Jati, Danièle Grosheny, Serge Ferry, Moussa Masrour, Mohamed Aoutem, Nourrisaid Içame, François Gauthier-Lafaye, Delphine Desmares

Le passage Cénomanien-Turonien, caractérisé par le développement de l'événement anoxique global OAE2, est associée à une triple crise : lithologique avec des dépôts riches en matière organique (Black-shales), géochimique avec une anomalie en $\delta^{13}C$ enregistrée dans les carbonates et la matière organique, et paléontologique notamment chez les foraminifères planctoniques.

Pour expliquer la mise en place de l'événement anoxique la majorité des auteurs avancent une transgression majeure associée au passage Cénomanien-turonien. Cette explication est souvent basée sur des interprétations des cortèges sédimentaires du bassin profond où les variations du niveau marin sont difficiles à distinguer. Afin d'approcher réellement les fluctuations du niveau marin est d'étudier des transversales plates-formes/bassin.

Sur la marge atlantique (bassin d'Agadir-Essaouira), les résultats de l'analyse séquentielle (faciès et surfaces stratigraphiques remarquables) combinés à ceux de la géochimie isotopique et complétés par les données fauniques permettent de proposer un schéma de corrélation qui insiste sur la présence d'une lacune plus ou moins importante au moment de la mise en place de l'événement anoxique. L'anomalie géochimique caractéristique du passage Cénomanien-Turonien ne situe pas dans les black shales, qui sont ici tardifs et transgressifs, mais dans des faciès côtiers à huîtres qui sont contemporains des premiers black shales observés dans d'autres bassins où l'anomalie en $\delta^{13}C$ débute avec eux. La crise biologique est marquée pour les foraminifères comme ailleurs par la disparition de R. cushmani et l'apparition de H. helvetica mais la lacune de sédimentation présente sur cette transversale ainsi que dans les faciès peu profonds dans lesquels se manifeste l'anomalie géochimique, empêche d'en apprécier les modalités avec précision.

Dans l'Atlas saharien, le passage Cénomanien-Turonien est marqué par l'accentuation du différentiel de subsidence qui aboutit à une paléogéographie différenciée de plates-formes carbonatées à rudistes séparées par des couloirs de faciès fins à ammonites. Il en résulte que, dans l'Atlas saharien, les couloirs à dépôts micritiques bioturbés du Cénomanien supérieur terminal sont suivis, vers la limite d'étage, par des dépôts laminés anoxiques qui débordent largement dans le Turonien inférieur. L'anomalie en $\delta^{13}C$ débute dans les faciès oxygénés bioturbés sous les faciès anoxiques et se termine avant la fin du dépôt des black shales.

Le contexte régressif du passage Cénomanien-Turonien sur la marge atlantique marocaine met en évidence que l'installation de l'événement anoxique n'est pas due à un contexte transgressif, comme il habituellement avancé par les auteurs mais plutôt conditionnée en premier lieu par les conditions locales du bassin.

The Upper Cretaceous calciturbidites of the southwest of Albania: Facies and Geometry, Tectonic impacts

Mohamed Jati, Yolaine Rubert, Corinne Loisy, Adrian Cerepi, Gjergi Foto

[VF] Les calciturbidites du Crétacé supérieur de Sud-Ouest de l'Albanie, Faciès et géométrie : Impact de la tectonique

L'analyse des dépôts gravitaires dans des conditions d'affleurement idéales et de continuité dans l'espace et dans le temps, n'est pas toujours facile à réaliser. Souvent ces systèmes sont étudiés dans des contextes eustatiques et géodynamiques mal connus. Le bassin Ionien au Sud-Ouest de l'Albanie offre des bons exemples des systèmes gravitaires turbiditiques calcaires du crétacé supérieur (Campanian-Maastrichtien). Le bassin s'est ouvert au cours du rifting intracontinental triasique et atteint son maximum d'enfouissement au Crétacé

supérieur. Il est délimité de part et d'autre par deux plate-formes: Adriatique dans la partie orientale (zone de Kruja) et Apulienne côté occidental (zone de Sazani). Il et bordé dans ca partie orientale par des failles de détachements orientés NNW-SSE résultent de la collision entre les plaques Apulienne et européenne durant l'intervalle Crétacé-Eocène.

Sur une transversale NW-SE, plusieurs coupes ont été levées dans le Crétacé Supérieur (Campanien-Maastrichtien) depuis la zone de Muzina en position paléogéographique plus distale jusqu'à la zone de Piluri en position plus proximale. L'étude minutieuse des faciès et de leur organisation de l'échelle du banc à l'échelle de l'affleurement et de la région, couplée aux ichnofaciès, ont permis de comprendre la dynamique et les mécanismes de la mise en place de ces dépôts gravitaires. Des corrélations proximal-distal ont été proposées et sont validées par les données de foraminifères benthiques et planctoniques. Ces corrélations ont permis de proposer une géométrie des systèmes gravitaires dans l'espace et leur évolution dans le temps.

Dans les deux secteurs étudiés plusieurs types de dépôts gravitaires ont été observés depuis les slumps, débris flows jusqu'aux calciturbidites. Trois importants niveaux déformés sont identifiés et s'étendent sur de grandes distances. La présence de slumps et de failles synsédimentaires observés dans la région témoignent de phases d'instabilités tectoniques Post-Santonniene (Crétacé supérieur - Eocène) sur la marge passive Apulienne. Ces phases tectoniques, marquées par des émersions sur les deux plate-formes, peuvent être à l'origine de déclenchement des systèmes gravitaires observés dans le bassin ionien. Les faciès évoluaient depuis les Debris flows jusqu'aux calciturbidites de hautes densité puis de faible densité qui traduisent une évolution de mode de transport depuis un écoulement hyper-concentré jusqu'aux courant de turbidité de haute puis de faible densité.

Au sein des calciturbidites, Les séquences peuvent être soit complète (a-e de la subdivision de Bouma) ou incomplète. En général, elles sont granoclassées et présentent rarement un granoclassement inverse. Les calciturbidites à éléments grossiers (turbidité de haute-densité), souvent à base érosive, sont formées par du matériel (calcirudites à calcilutites) essentiellement transporté depuis la plate-forme interne comme en témoigne la faune et les lithoclastes et se dépose dans un environnement de pente-bassin comme en temoigne la faune présente dans partie sommitale de chaque cycle. Les calciturbidites à éléments fins (turbidite de faible-densité) dont le matériel (wackestone à mudstones) provient essentiellement de la plate-forme externe ont subi un transport sur une grande distance et dont la partie supérieur présente une faune essentiellement pélagique. Ces cycles de calciturbidites sont intercalés par des dépôts hémipelagiques riche en foraminifères planctoniques qui témoignent des périodes de stabilité.

Les corrélations cycle par cycle calciturbiditiques effectuées dans la région et confirmées pas les données biologiques montrent sans ambiguïté qu'il s'agit d'un système gravitaire qui s'étend depuis le secteur de Piluri jusqu'à la région de Muzina. Trois importants périodes de flux gravitaires ont été identifiés et sont interrompues par des phases de déformation (slumps). Ces périodes sont fortement associées à des phases d'émersions observées sur la plate-forme Apulienne qui traduisent une instabilité tectonique. Il est donc fort probable que ces dépôts gravitaires soient liés à la tectonique locale.

Néanmoins, comme il s'agit ici des résultats préliminaires, une analyse fine des cortèges sédimentaires ainsi que les principales surfaces d'émersions observées sur la plate-forme est nécessaire afin de consolider cette interprétation.

Palaeozoic palaeoclimate: insights from oxygen isotope proxies

Michael M. Joachimski

Oxygen isotopes have been successfully applied to studies on Cenozoic climate and ice volume history (Zachos *et al.* 2001). The use of oxygen isotopes in older time periods is hampered by potential diagenetic resetting of the oxygen isotope signals. Brachiopod shells have been preferentially used in the Palaeozic due to their low-magnesium calcitic shell mineralogy that is assumed to be relatively resistant to diagenetic recrystallisation. In comparison to biogenic calcite, apatite represents an alternative mineralogical phase for oxygen isotope analysis since apatite is very resistant to diagenetic exchange of phosphate-bound oxygen. Conodonts, microfossils composed of carbonate–fluor apatite and abundant in Palaeozoic-Triassic sediments, were studied for oxygen isotopes. Short-term as well as long-term changes in the oxygen isotope ratios of Ordovician to Carboniferous conodont apatite are interpreted to reflect climatic changes and the waning and waxing of high-latitude continental ice sheets. In comparison to oxygen isotope values measured on brachiopod calcite, conodont apatite shows a minor variation in the oxygen isotope ratios and in part higher values.

Palaeotemperatures reconstructed from oxygen isotopes of Devonian conodonts do not support earlier views suggesting the Middle Devonian was a supergreenhouse interval, an interpretation based partly on the development of extensive tropical coral–stromatoporoid communities during the Middle Devonian. Instead, the Devonian palaeotemperature record suggests that Middle Devonian coral–stromatoporoid reefs flourished during cooler time intervals whereas microbial reefs dominated during the warm to very warm Early and Late Devonian (Joachimski *et al.* 2009).

The oxygen isotope record of Carboniferous conodonts suggest that a first major cooling and potential glaciation event occurred in the Tournaisian with ice masses persisting into the Visean. The second glaciation event occurred in the Serpukhovian and culminated in the first glacial maximum of the Late Palaeozoic Glaciation (Buggisch *et al.* 2008).

Oxygen isotopes measured on latest Permian and Early Triaassic apatite indicate significant climatic warming across the Permian-Triassic boundary representing the largest mass extinction event in the Phanerozoic. Warming of low latitudinal surface waters up to 8° C is seen in context with increasing atmospheric greenhouse gas contents as consequence of Sibirian trap volcanism and thermal decompositon of organic carbon rich sediments and methane hydrates. However, climatic warming occurred shortly after the main extinction and thus cannot be seen as the ultimate trigger of the Permian-Triassic mass extinction

A preliminary study of Pinaceae cone, *Keteleeria ezoana* from the Miocene Pohang Basin of Korea

Seung-Ho Jung, Seong-Joo Lee

The Pohang Basin, Korea is the most representative Cenozoic sedimentary sequences for plant fossils. In particular two formations, Duho Formation and Hagjeon Formation yield diverse plant fossils including gymnosperm, angiosperm and marine algal fossils. Pinaceae female cone is one of the beautifully preserved gymnosperm plants, and a total of about 50 cones were collected from both the Duho and the Hagjeon Formation. In this paper we report large fossil female cones identified as genus *Keteleeria* of the family Pinaceae. These findings are unusual because cone size is large (15 cm in length and 6 cm in width) and detail structures of the cone with winged seeds, cone scale, and leaves are 3-dimensionally preserved. This fossil cone is comparable with *Keteleeria shanwangensis* recently reported from Mid-Miocene (17.5~15Ma) Shanwang Formation of eastern China on the basis of the gross morphology, arrangement and surface structure of cone scale. Korean specimens, however, slightly differ from Chinese ones by the fact that the cone scales of our specimens are subcordate shape, widest below the middle, while those of *K. shanwangensis* are subcordate-orbicular, widest above the middle. The winged seeds of Korean specimens are identical to those of *Keteleeria ezoana* which is abundantly found from the Cenozoic strata in Japan and China. The scale of Korean specimens is characterized by reflexed margin, a typical character of extent *K. davidiana*. So, this is the first report of female cone fossils attached by scale described as *Keteleeria ezoana*. This is also the first discovery from the Cenozoic strata in Korea.

Aquitanian, Burdigalian larger foraminifera (specially Miogypsinoidae) from the Qom Formation, southeast of Maragheh (NW Iran)

Mojtaba Kalantari

The marine strata of the Qom Formation in southeast of Maragheh (NW Iran) has a moderately diverse larger benthic foraminiferal fauna resembling to the fauna already described from European marine sequences. The fauna allowed the author to correlate the larger foraminiferal assemblage of northwestern Iran to standard shallow benthic zonation scheme of Cahuzac and Poignant (1997). The identified taxa are dominated by hyaline and porcellaneous forms including *Operculina*, *Neorotalia*, *Peneroplis*, *Amphistegina*, *Planorbulina*, *Borelis*, *Lepidocyclina* and *Miogypsina*. This faunal assemblage is also accompanied with coral, melobsoid algae. The presence of Miogypsina globulina and Miogypsina intermedia in absence of Miogypsinoides allows the foraminiferal fauna of the studied stratigraphic section to be correlated with shallow benthic zone SB 25 indicating the Burdigalian age.

Les dépôts paléocènes en Tunisie : paléogéographie et relations avec les dépôts sous-jacents

Narjess Karoui-Yaakoub

Le Paléocène en Tunisie est représenté par des marnes grises avec de rares et minces bancs de calcaire argileux. Il est rarement complet et il correspond à la partie supérieure de la formation El Haria qui se trouve en continuité de sédimentation entre le Maastrichtien et l'Éocène.

En particulier concernant le passage Crétacé-Tertiaire, les coupes qui présentent un passage K / T complet sont: la coupe d'Oued El Melah (zone de Sejnen) dans le Nord, les coupes d'El Kef, d'Ellès, de Tejerouine et d'Aïn Settara situées plus à l'Ouest de la Tunisie. Dans toutes ces coupes, on note la présence d'*Abathomphalus mayaroensis* marqueur de la dernière biozone du Maastrichtien.

Le Paléocène inférieur débute par des argiles gris-sombres, riches en matières organiques et contient les zones : P0 (*Globoconusa conusa*) et la zone P1 (P1a : sous-zone à *Parvularugoglobigerina eugubina*, P1B : sous-zone à *Parasubbotina pseudobulloides* et P1c : sous-zone à *Praemurica trinidadensis*).

Ainsi, dans ces coupes le passage K / T est sans lacune biostratigraphique, mais cependant on note une variation des épaisseurs des zones P0 et P1.

Ailleurs et surtout au milieu de nombreux bassins subsidents caractérisés par leur faible extension ou, dans certains blocs d'effondrement, le Paléocène commence par la sous-zone à *P. pseudobulloides* (Jebel Garci, Rhouhia). Alors qu'il pourrait être partiellement conservé ou absent autour des bassins ou sur les hauts-fonds

Par conséquent et autour de certaines structures tectoniques, la partie inférieure du Paléocène fait défaut et il ne peut être représenté que par le Thanétien terminal ou il peut être, même totalement absent (Jebel Bargou, Jebel Nassir, Région d'Enfidha et de Bir M'chergua).

Dans le centre et Le Nord-Est de la Tunisie, la paléogéographie du Paléocène est complexe, là où certaines structures tectoniques du Crétacé limitent des zones de subsidence (région de Ousselat-Bou Dabbous) des zones de soulèvement avec des dépôts paléocènes de faibles épaisseurs (zone de Serj-Bargou). Les hiatus sont donc liés à la paléotopographie préexistante et à la tectonique synsédimentaire.

Pendant le Paléocène deux zones émergées existaient: l'île de 'Kasserine' située dans le centre-ouest de la Tunisie et l'île de 'Jeffara' vers le sud.

Ces deux îles étaient séparées par le bassin intracratonique de Gafsa, où la base du Danien pourrait être conservée dans son dépocentre (exemple dans la coupe de Selja, la sous-zone P1A est conservée).

Dans ce bassin intracratonique à faible dépôt, la vitesse de sédimentation serait favorable pour les dépôts de phosphate. Ces dépôts ont été associés à des lacunes sédimentaires pendant des temps plus ou moins longs.

Autour de l'île de Kasserine des dépôts de phosphorite ont été accumulés au cours du Thanétien terminal.

Nouvelles données biostratigraphiques et paléoenvironnementales sur le Cénomanien-Turonien de la région de Berrouaghia (Algérie)

Fatiha Kechid-Benkherouf

La région de Berrouaghia fait partie du Tell méridional (bassin tellien) et représente la terminaison occidentale de la chaine des Biban. Au niveau de la localité de Sidi Nadji, les affleurements cénomano-turoniens représentent une série marine continue et bien développée, sur environ 500 m d'épaisseur. Cette série débute à la base par des alternances monotones de calcaires et de marnes, puis se termine par des calcaires en plaquettes noirs et calcaires à silex, à faciès pélagiques et de milieu profond. Hormis quelques résultats obtenus sur une microfaune attribuée au Crétacé (Macoin, 1963), aucune analyse biostratigraphique détaillée ni aucune analyse paléoenvironnementale n'ont été entreprises dans ce secteur. L'étude micropaléontologique présentée ici, confortée par des observations effectuées dans d'autres secteurs, notamment à Sor El Ghozlane et à Maalag Rassou, montre que cette série est très riche en foraminifères. C'est ainsi qu'au niveau de la seule coupe de Sidi Nadji une centaine de taxa ont été reconnus. Des données biostratigraphiques et paléoenvironnementales nouvelles permettent d'identifier cinq zones successives de foraminifères planctoniques caractérisant les différentes entités lithostratigraphiques au cours du Cénomano-Turonien (zone à *Rotalipora globotruncanoides*, zone à *R. reicheli*, zone à *R. cushmani*, zone à *Whiteinella archaeocretacea* et zone à *Helvetoglobotruncana helvetica*). Les limites stratigraphiques, dont celle du Cénomanien-Turonien, caractéristique de l'événement anoxique global OAE2, ont également été fixées; ces zones ont servi aussi à dater et placer les sédiments de cette région dans le cadre biostratigraphique établi pour le domaine téthysien. L'analyse qualitative et quantitative des assemblages de foraminifères benthiques a fourni des précisions sur les conditions paléobathymétriques (milieu bathyal : 200 à 1000 m), les biotopes (substrats vaseux développés sur le talus continental) et la crise anoxique ; cette dernière apparaît marquée par des modifications conséquentes du taux d'oxygène dissous au moment des dépôts, l'hypoxie au passage Cénomanien-Turonien et le retour progressif à des conditions d'oxygénation normale au Turonien inférieur analogues à celle du Cénomanien.

Palynostratigraphy and paleoenvironment of Siyahou Formation in the Samand well # 2

Mohammadreza Tayefeh Khabbazi

The palynological study on the lower Paleozoic sequence in the Samand well # 2 is applied for age determination, paleoenvironmental and paleogeographical interpretations. In order to study of palynomorphs, 52 cutting samples were prepared from lower Paleozoic strata of the Samand well # 2. These samples contain abundant, diverse and well-preserved palynomorphs such as acritarch, chitinozoans and scolecodonts, which suggest a Late Ordovician (Katian stage in global or Ashgill in British scale time units) age for the drilled sequence below the Dalan Formation. Therefore, this rock unit can be assigned to the Siyahou Formation in the Zagros basin with a huge hiatus which encompasses the uppermost Ordovician to lower Permian strata. Based on the presence of marine elements mentioned above, this sediments have been settled in a marine environment.

The Paleocene-Eocene Thermal Maximum (PETM) in Egypt: new insights from the Wadi Nukhul section (Sinai), correlation with the Dababiya Global Boundary Stratotype Section and Point (GSSP)

Hassan Khozyem, Thierry Adatte, Abdel Aziz Tantawy, Jorge Spangenberg, Gerta Keller, Karl Föllmi

The Paleocene-Eocene Thermal Maximum (PETM) represents one of the more prominent and abrupt climate anomalies in Earth history with sea surface temperatures (SSTs) increasing by as much as 5°C in the tropics and 8°C in the high latitudes (Thomas *et al.*, 2002; Zachos *et al.*, 2003; Zachos *et al.*, 2006; Weijers *et al.*, 2007; Handley *et al.*, 2008)). The peak warmth remained elevated for several tens of thousands of years before gradually returning to pre-event levels. In both high latitudes, the warm pulse coincide with a pronounced short-term negative excursion in both $\delta^{13}C_{car}$ and $\delta^{13}C_{org}$ (CIE) which is associated with a widespread dissolution of seafloor carbonate, the extinction of 35-50% of deep-sea-sea benthic foraminifera (Thomas 1990), the radiation and proliferation of planktic foraminifera (Lu and Keller, 1993, 1995) and terrestrial vertebrates and plants (Gingerich, 1980,; Axelrod, 1984). Coeval abundant kaolinite reflects high rainfall with enhanced chemical weathering in Antarctic (Robert and Kennet, 1994), North Atlantic (Gibson *et al.*, 1993) and in the northern Tethys margin (Bolle and Adatte 2001). In contrast, the southern Tethys margin was arid as indicated by the co-occurrence of palygorskite and sepiolite (Bolle et al, 1999). Several lines of evidence indicate that a rise in greenhouse carbon levels (CH_4 and/or CO_2) was

responsible for this global warming (*e.g.*, Dickens *et al.*, 1997; Bowen *et al.*, 2004).

The Wadi Nukhul section (SE Sinai, Egypt) consists of a 38 m thick continuous succession of late Maastrichtian to early Eocene pelagic sediments. Lithologically, the base of the section is formed of chalk alternating with marly limestone of late Maastrichtian age (uppermost part of the Sudr Formation), conformably overlain by approximately 18.5 m of marls, marly shale and shales of the Paleocene Dakhla Formation. Its topmost part gradually changes to a bioturbated chalk with flint layers coinciding with the base of the Paleocene Tarawan Formation followed upward by the late Paleocene - early Eocene Esna Formation, characterized by alternating shaly marls, shales and silty shales. The Paleocene-Eocene boundary (PE) was observed about 5 m over the top of the Chalk Tarawan within the Esna Shale and consists of a 90 cm thick black clayey interval enriched in organic matter and small phosphatic pebbles and corresponds biostratigraphically to the NP9a/Np9b nannofossil subzonal boundary.

The P/E interval have been subjected to an extensive geochemical study, including bulk and clay mineralogy, major, trace elements, total P, TOC, and TON contents, and stable isotopes ($\delta^{13}C_{car}$, $\delta^{18}O_{car}$, $\delta^{13}C_{org}$, $\delta^{15}N_{org}$).

The P/E boundary of Wadi Nukhul section exhibits: (1) an abrupt negative shift of both $\delta^{13}C_{car}$ and $\delta^{13}C_{org}$ values (–6 ‰ and –2 ‰ from the background value before the boundary, respectively), (2) a severe and persistent decrease in $\delta^{15}N_{org}$ to ~0 ‰, (3) a significant increase in TOC, TON and P contents just above the negative isotope excursion with coeval increase in Cu/Al, Ni/Al and Zn/Al (4) The onset of CIE is marked by a major turnover across the CIE-PETM interval of genus *Fasciculithus*, very common in the tropical Paleocene with sharp decrease of *Toweius spp*. concomitant with increase of warm-water *Coccolithus pelagicus/Ericsonia subpertusa*, and first appearance of the short-lived *Rhomboaster spp.-Discoaster araneus (RD)* assemblage. (5) a decrease in carbonate content due to dissolution and/or dilution by enhanced detrital (quartz) input with coeval increase of Zr/Al and Ti/Al ratios (6) A peak in V/Al ratio just above CIE, followed by a long term increase in Mn/Al ratio.(7) appearance of kaolinite coinciding with the CIE to the detriment of sepiolite, palygorskite and at lesser extent smectite

The lag observed between the $\delta^{13}C_{car}$ and $\delta^{13}C_{org}$ excursions and the decrease in carbonate contents could be explained by oxidation of the released methane in the water column, providing isotopically light dissolved inorganic carbon. The short lived increased in the redox sensitive V/Al ratio may indicate a brief period of low oxygen environment followed by more oxic conditions as reflected by enhanced Mn/Al ratio. Increased detrital input and kaolinite contents reflect a change from arid seasonal (palygorstkite, sepiolite and smectite) to more humid conditions through the PETM and may explain the coeval increase in nutrients (*e.g.* P, N) leading to high productivity as indicated by high TOC and TON contents, increased productivity sensitive elements (Cu, Ni and Zn) and . The $\delta^{15}N$ ~0 ‰ values above the boundary and persisting along the interval suggests a bloom and high production of atmospheric N_2-fixers, as cyanobacteria. Similar high phosphorus contents have been observed just above the P/E boundary in several sections located in Sinai (Abou Zenima, Gebel Mutalla) and south-central Egypt (Dababiya, Duwi).

Preliminary fieldwork, sedimentological and stable isotopes data suggest that the Dababiya GSSP section is an infilled channel deposit which spans over about 200m, with the basal units a and b (Aubry *et al.*, 2005) thinning towards the edges of the outcrop and finally disappearing. The Paleocene-Eocene GSSP is consequently only complete over a 2-3 meters width, in the center of the outcrop and therefore not really the best choice, if we follow the ICS requirements for establishing a GSSP.

Paleobiological diversity from the Cenozoic Pohang Basin, Korea

Dal-Yong Kong, Seung-Ho Jung, Bong-Jin Lee, Duck-Hwan Kim, Seong-Joo Lee

The Pohang Basin, Korea is one of the best fossiliferous sedimentary sequences for the Cenozoic, which is also characterized by high paleo-biological diversity. Particularly two formations, Duho Formation and Hagjeon Formation composed mainly of mudstones, contain various fossils including plant and animals fossils. Animal fossils contain both invertebrate and vertebrate animals, while plant fossils include angiosperm, gymnosperm, and even marine algal fossils. The biological diversity is highlighted by animal fossils, which have been found in one place containing several groups such as phylum Echinodermata (*e.g.*, echinoidea and ophiuroidea), phylum Mollusca (*e.g.*, pelecypoda, gastropoda, and scaphopoda), phylum Arthropoda and Crustacea, and vertebrate animals (*e.g.*, turtles, sharks, whales, and other small fishes). Plant fossils also show high biological diversity, including leaves, woods, diverse reproductive organs (*e.g.*, samara, cone, flowers and so on). Despite of the such a biological diversity of the formations, however, many problems regarding stratigraphic age and depositional conditions of the Cenozoic Pohang Basin remain still unsolved. In this paper, we try to understand stratigraphic relationships between the Duho Formation and the Hagjeon Formation by biologically diverse fossils collected for about five years by Paleontology Lab of Kyungpook National University, Korea and National Research Institute of Cultural Heritage.

Les événements stratigraphiques, sédimentologiques et géochimiques de la limite Paléocène - Eocène en domaine marin et continental : exemple de la marge sud-téthysienne (Tunisie-Maroc)

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À partir d'une analyse pluridisciplinaire, il s'agit de comprendre l'impact du climat sur les grandes perturbations du cycle du carbone à l'échelle globale et

géochimique dans le domaine océanique téthysien. L'intervalle Paléocène et principalement la transition Paléocène/Eocène ont été privilégiés parce qu'ils représentent un des meilleurs exemples géologiques pour comprendre cette relation.

Les sédiments du Paléocène et de l'Eocène ont en effet enregistré des changements majeurs à différentes échelles de temps qui s'imbriquent les uns dans les autres :

- deux importantes crises biologiques,
- des accidents géochimiques, dont le plus connu est le pic négatif du $\delta^{13}C$ de la limite Paléocène-Eocène,
- une déstabilisation d'hydrate de méthane (à $\delta^{13}C$ moyen de -60 ‰),
- un réchauffement climatique à long terme dès la base du Paléocène supérieur et jusqu'à l'Eocène inférieur, ainsi que des événements beaucoup plus chauds et brefs (PETM, ELMO, X event) avec une gradient latitudinal thermique,
- des changements paléo-océanographiques et entre autres un renversement du mode de circulation océanique avec production, supposée au niveau de la Téthys, de masses d'eau profondes chaudes et salées.

Plusieurs profils 'plate-forme / bassin' ont été sélectionnés en Tunisie centrale et centre-nord dans les régions de Kasserine pour le domaine continental, d'Elles pour le domaine néritique, de Sidi Ali pour le domaine pélagique et au Maroc dans le domaine atlaso-mésétien.

Les principales formations géologiques ont été calées grâce à l'analyse biostratigraphique, telles la Formation Souar qui débute dès l'Yprésien terminal en Tunisie centre-nord. La lacune du Paléocène inférieur (zones P2 et P3) a également été mise en évidence.

Grâce à l'analyse sédimentologique, nous avons également pu montrer que les dépôts marneux paléocènes sont généralement transgressifs en Tunisie. Ceux de l'Eocène sont plus différenciés et se répartissent sur une rampe carbonatée limitée par l'île de Kasserine au SW et plus profonde vers le NE. Au Maroc, le système inférieur Maastrichtien est interprété comme une phase régressive d'un cycle transgressif/régressif de second ordre (Régression eustatique fini crétacée), la discontinuité D1 constitue sa limite supérieure en relation avec une phase d'émersion généralisée (signature de l'inversion tectonique fini crétacée). Les dépôts paléogènes correspondent à un cycle transgressif/régressif de second ordre. Le maximum de transgression se situe à la limite Yprésien-Lutétien et pourrait être en relation avec l'évènement compressif atlasique de l'Yprésien terminal.

L'excursion négative du carbone et de l'oxygène à la base de l'Eocène inférieur a été retrouvée dans la totalité des coupes analysées -en Tunisie et au Maroc-, à la fois en domaine continental et marin néritique et pélagique. D'autres événements climatiques brefs ont également été enregistrés à la base de l'Eocène.

L'analyse des éléments traces des carbonates nous permet de conclure que cet outil est beaucoup plus sensible aux environnements de dépôt et aux processus diagénétiques.

Status of the astronomical solutions for paleoclimate computations

Jacques Laskar

Paris Observatory has a long tradition for long time computations of the orbital evolution of the planetary orbits in the Solar System, starting with the work of Le Verrier (1856) that was used by Croll (1890) in his theory of paleoclimates based on the change in time of the Earth eccentricity over three millions of years as computed by Le Verrier. Later on, after the development of Milankovitch therory (1941) and the landmark work of Hays *et al.* (1976), a new orbital solution based on perturbation methods was elaborated at Paris Observatory by Bretagnon (1974). Following Pilgrim (1904) and Milankovitch, Berger (1978) combined this former solution to the precession equations of the spin of the Earth in order to obtain a solution for the computation of the past insolation on the surface of the Earth.

The next improvement on orbital solutions came again from Paris Observatory, with the publication of a solution that mixed perturbation methods and numerical integration (Laskar, 1988) and its associated rotational and insolation quantities (Laskar et al, 1993). This solution (La93) practically extended the time of validity of past computations of the Earth orbital and rotational elements from about 1 Myr (million of years) to 10 to 20 Myr. Soon after, the first long time orbital solution obtained with the direct integration of the gravitational equations of motion by Quinn *et al.*, 1991, allowed to confirm the precision of the La93 solution that has been widely used for paleoclimate computations.

But at the same time, Laskar (1989, 1990) demonstrated that the Solar system motion is chaotic. As a result, the error on the computation of the orbit of the Earth is multiplied by 10 every 10 Myr, which strongly limits the possibility to obtain a precise reconstruction of the Earth's orbit over more than a few Myr.

At present, the most advanced Earth orbital and rotational solution has been obtained by a direct numercial integration (Laskar et al, 2004) of the planet orbits and the precession of the Earth spin axis. This solution has been used for the astronomical calibration of the Neogene(Lourens *et al.*, 2004) in the GTS2004 geological time scale. The time of validity of this solution is estimated to be of about 40 Myr.

At present, there is a large international effort towards the construction of a complete astronomically calibrated geological time scale over the full Cenozoic era. This will require the obtention of an orbital solution for the Earth motion over 65 Myr. But extending the La2004 solution from 40 to 65 Myr is not an easy task, as due to the chaotic motion of the system, it is equivalent to an improvement of the full gravitational model of more than 2 orders of magnitude.

Since more than 5 years, we have undertaken such a task in Paris Observatory. I will review the current status of these new solutions that will be

released soon, as well as the limitations that we are now facing in this fight against the exponential divergence of these chaotic solutions.

New Early Cretaceous fossil vertebrates from NW Libya and the stratigraphical distribution of African spinosaurids

Jean Le Loeuff, Eddy Métais

Many Lower Cretaceous continental formations of Africa have yielded fossil vertebrates only and are thus rather difficult to date. Marine incursions on the margins of the African craton can help, however, to date some localities in North Africa (*e.g.* in Tunisia and Libya). The discovery of different vertebrate assemblages in Libya may help to build a stratigraphy of the African Continental Intercalaire based on fossil vertebrates. Early Cretaceous vertebrates from Libya have been reported by various authors since Lapparent (1960). A history of these discoveries was recently published as well as a new stratigraphical framework and a preliminary report on the vertebrates from the Cabao Formation, a continental unit with marine influences (Le Loeuff *et al.*, 2010). On the basis of its palaeontological content (including the shark *Priohybodus*, a baryonychine spinosaurid, a possible camarasaurid, etc.), it was suggested that the Cabao Formation is probably Neocomian or Barremian in age. The overlying Kiklah Formation is also a sandy unit with strong marine influences which has yielded a shark assemblage. A single dinosaur tooth was discovered in the course of sedimentological exploration for Total Libya. This spinosaurid tooth belongs to a spinosaurine close to *Spinosaurus*, similar to what is known in the Tunisian Ain Guettar Formation (Aptian-Albian), the dinosaur assemblage of which is very different from that of the Cabao Formation.

At the scale of the Continental intercalaire and neighboring formations of North Africa it seems that early baryonychine spinosaurids (now known from Libya, Niger, Cameroon) were replaced by spinosaurine spinosaurids (known from Algeria, Morocco, Egypt, Tunisia: see Cavin *et al.* 2010), possibly after the Early Aptian and before the Cenomanian.

New reports of fossil vertebrates from Libya confirms that important changes among African vertebrate assemblages took place during the mid-early Cretaceous, possibly in the Late Barremian or Early Aptian including the disappearance of the hybodont *Priohybodus* and the replacement of early baryonychine spinosaurids by spinosaurine spinosaurids. Contrary to what was initially suggested by Lapparent (1960) who envisioned a rather uniform fauna throughout these deposits, it is now widely recognized that important changes occurred in the vertebrate assemblages between the earliest Cretaceous and the Cenomanian. Although not enough assemblages have been described in detail, it seems that fossil vertebrates may be useful to establish the stratigraphical framework of the Continental intercalaire and its equivalents in central, eastern and northern African Cretaceous basins.

Integrated Upper Devonian marine-terrestrial palynomorph biostratigraphy and chemostratigraphy in the Caima Ph-2 borehole, Amazonas Basin, northern Brazil

Alain Le Hérissé, Jose Henrique Goncalves de Melo, Yngve Grahn

In the Tapajós River area of the Amazonas Basin, northern Brazil, a continuously cored section of the Caima PH-2 borehole has been analyzed successively for miospores, chitinozoans, and marine organic-walled microphytoplankton, and was then subjected to organic geochemistry studies. In ascending stratigraphic order, the section comprises the uppermost Ereré Formation, the type Barreirinha Formation, and the lower part of the Curiri Formation (the latter two included in the Curuá Group). A major, well-defined transgressive-regressive sedimentary cycle is recognizable within the Late Devonian part of the Curuá Group, including a long-lasting anoxic event related to the transgressive maximum close to the unit's base. The palynological investigation, based on 375 core samples collected along a 137 m thick shaly-silty section, reveals a rich and highly diversified assemblage of marine and terrestrial palynomorphs. Late Devonian palynomorphs are represented locally by miospores, terrestrial plant debris, and marine elements such as chitinozoans and organic-walled microphytoplankton, including acritarchs and prasinophycean phycomata. Organic-walled microphytoplankton have been extracted from the same set of samples previously studied for chitinozoans and miospores. Due to sustained marine conditions in a continuously subsiding basin, the organic-walled microphytoplankton are exceptionally well represented, with more than 200 species identified. These allowed the subdivision of the investigated interval into 10 microphytoplanktonic biozones and subzones. The combined use of selected Euramerican and Western Gondwanan miospore taxa has permitted the accurate dating and biostratigraphic subdivision of the studied sequence in terms of the coeval miospore zones of the Old Red Sandstone continent and Western Europe. Moreover, eight chitinozoan zones are also locally identified in the PH-2 borehole. The Late Devonian microphytoplankton biostratigraphy is compared and correlated with the existing miospore and chitinozoan zonations. Palynology constitutes a particularly reliable tool for subsurface correlations, and is therefore of paramount importance to the hydrocarbon exploration of South American Devonian sequences. Examples from the subsurface and outcrop analogues of Devonian source rocks and reservoirs indicate that palynostratigraphy can provide detailed correlation of intervals of exploratory interest. Ecological signatures and ecophenotypic responses of selected microphytoplankton groups are integrated with organic geochemical data in order to evaluate the magnitude of the anoxic event recorded in the lower part of the Barreirinha Formation.

Dinoflagellate cysts of Aquitanian stratotype and paleoenvironmental approach of the Oligocene-Miocene boundary in Aquitaine (France)

Laurent Londeix, Jean-Jacques Châteauneuf, Sureje Lopes

The three main historical sites exposing Aquitanian stratotype sections between La Brède and Saucats (Gironde) were surveyed in details by one of us emphasizing particularly on inter-sections connections and relationship between respectively Oligocene and Burdigalian contacts with Aquitanian séquence. A composite section of about 35 m depth was set up. Accurate sampling of these sections was carried out in order to investigate dinoflagellate cysts (dinocysts) and pollen contents.

Rich palynomorphs assemblages were recorded.

Burdigalian dinocysts having previously been studied (Londeix & Jan du Chêne, 1998); we have proceeded to the revision of palynological record of Chattian from the Escornebéou area (Saint-Geours-de-Maremne, Pyrénées Atlantiques) in order to check dinocysts ranges beneath and above Aquitanian stage.

Dinocyst zonation

At Escornébéou a set of 30 species was identified some of them being restricted to late Oligocene, such as: *Achilleodinium latispinosum*, *Nematospheropsis reticulensis*, *Distatodinium biffii* and *Glaphyrocysta* cf. *semitecta sensu* Van Simaeys *et al.*, 2005.

Aquitanian stratotype has yielded 60 dinocysts taxa from which 20 were previously mentioned in the Aquitaine Chattian and 47 are lasting in the Burdigalian of the same area.

From this assemblage, *Glaphyrocysta circularis*, *Pentadinium laticinctum granulatum* and the genus *Chiropteridium* have their last occurrence at 15 meters above the base of the stratotype. This event is correlated with the top of DN1 (de Verteuil & Norris, 1996) or D15 (Köthe 2005) dinozones, both defined by the *Chiropteridium* complex disappearance. It is calibrated by magnostratigraphic scales and dated between 22, 2 and 22, 4 Ma (*op. cit.*; Williams *et al.*, 2004).

At the same level occurs a set of new forms such as *Hystrichokolpoma ellipticum* and *H. pacificum* and *Lithospheridium* sp. A which unfortunately are not reported from the above mentioned zonations.

A second event fitting with the topmost Aquitanian deposits is characterized by the last occurrence of the following forms: *Areoligera* spp., *Glaphyrocysta* spp. (except for *G. texta*) and *Cordospheridium gracile*, often typical of Paleogene assemblages which are not as yet reported from the published charts of coeval age.

Microfloral contribution

The spore and pollen contents of samples set were analyzed in parallel to dinocysts studies;

Coniferous trees are the most abundant component of microfloras. Coastal swamp vegetation is as well represented. Amongst this vegetation, *Avicennia* occurrence (around 14 meters level) testifies a mangrove settlement.

Herbaceous and halophylous community is very poor whereas forests are largely spread and develop successive belts of evergreen, mixed deciduous-evergreen and temperate strata including large Mediterranean taxa for the later (Oleaceae and Vitaceae).

The striking homogeneity of the microfloral assemblages along the Aquitanian section suggests a relative stability of climate in this area during this time space.

The Mediterranean component recorded in the Aquitanian is much less important in Chattian sediments. This can be interpreted as a growing seasonality from the Aquitanian onwards.

Finally the abundance of altitudinal taxa coupled with scarcity of herbs and shrubs gives to aquitanian floras an Atlantic specificity, most wet and so relatively different from those described by (Bessedik, 1985; Giménez-Moreno, 2005) along the French and Spanish Mediterranean coast.

[VF] Dinozonation de l'Aquitanien stratotypique et considérations paléoenvironnementales du passage Oligocène–Miocène en Aquitaine (France)

Une coupe détaillée de l'Aquitanien stratotypique a été levée par l'un d'entre-nous entre La Brède et Saucats, au sud de Bordeaux (Gironde) en mettant l'accent, d'une part sur les raccords entre les trois sites historiques, d'autre part sur les contacts avec l'Oligocène supérieur et la base du Burdigalien dans la région ; une coupe d'environ 35 m a ainsi pu être établie. Un échantillonnage détaillé de ces sédiments a été réalisé en vue d'une étude des kystes de dinoflagellés (dinokystes) et du pollen qu'ils contiennent. L'étude des dinokystes du Burdigalien stratotypique ayant fait déjà l'objet d'une publication (Londeix & Jan du Chêne, 1998), nous avons revu le contenu du Chattien des coupes d'Escornebéou (Saint-Geours-de-Maremne, Pyrénées Atlantiques) pour le comparer à celui de la base de l'Aquitanien.

Dinozonation

À Escornebéou, une trentaine de taxons ont été identifiés ; les espèces restreintes à l'Oligocène supérieur sont : *Achilleodinium latispinosum*, *Nematosphaeropsis reticulensis*, *Distatidinium biffii et Glaphyrocysta* cf. *semitecta sensu* Van Simaeys *et al.*, 2005.

L'Aquitanien stratotypique a livré 60 formes de dinokystes, dont une vingtaine sont présentes dans le Chattien d'Aquitaine méridionale et 47 sont présentes dans le Burdigalien stratotypique (de la même région). Nous constatons la dernière extension de plusieurs formes ; ainsi, *Glaphyrocysta circularis*, *Pentadinium laticinctum granulatum* et surtout le genre *Chiropteridium*

s'éteignent à 15 mètres de la base du stratotype. Cet horizon est corrélable avec le sommet de la dinozone DN1 (de Verteuil & Norris, 1996) ou D15 (Köthe, 2003) toutes deux marquées par l'extinction du genre *Chiropteridium*. Les corrélations de ce niveau avec les échelles magnétostratigraphiques le situent entre 22,2 et 22,4 Ma (*op. cit.* ; Williams *et al.*, 2004).

Au même niveau, apparaissent : *Hystrichokolpoma ellipticum* et *H. pacificum* et *Lithospheridium* sp. A qui ne sont pas signalées dans les niveaux équivalents des zonations miocènes précédentes.

Préfigurant la fin de l'Aquitanien, un second seuil apparaît vers le sommet de la séquence stratotypique, marqué par l'extinction de formes à caractère paléogène telles que *Areoligera* spp., *Glaphyrocysta* spp. (à l'exception de *G. texta*) et Cordosphaeridium gracile.

Ce seuil ne présente pas d'équivalent dans les zonations de dinokystes, mais semble correspondre à la fin de l'Aquitanien.

Apport de la microflore

Quelques échantillons du stratotype aquitanien ont été analysés du point de vue de la microflore. Ils sont riches en pollen et en spores. Les conifères y sont majoritaires avec des pourcentages des formes d'altitude variant entre 15 et 30%.

La végétation marécageuse abondante contient vers la cote 14 m quelques grains de pollen de mangrove du genre *Avicennia*, ce qui confirme le caractère épicontinental et littoral de ces dépôts. La strate herbacée et halophile est peu abondante tandis que la zone forestière, située en arrière du littoral et le long des cours d'eau est représentée par une forêt pluviale tropicale à laquelle fait suite une forêt mixte puis une forêt tempérée à nombreux éléments méditerranéens (Oleaceae et Vitaceae). Une relative stabilité du climat, aquitanien se dégage ainsi à travers le caractère remarquablement homogène des associations analysées.

Cette végétation est très similaire à celle des niveaux chattiens sous-jacents avec cependant un développement moindre de la composante méditerranéenne dans l'Oligocène. L'abondance des formes d'altitude et la rareté des plantes herbacées confèrent à la flore aquitanienne un cachet nettement atlantique et plus humide par rapport aux associations décrites sur le littoral méditerranéen français ou espagnol (Bessedik, 1985 ; Giménez-Moreno, 2005).

Dinoflagellate cysts of the Cretaceous/Paleogene boundary at Ellès, Central Tunisia

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A palynological analysis of the Cretaceous/Palaeogene transition at Ellès, central Tunisia, based on dinoflagellate cyst events, allowed the recognition of the boundary between Maastrichtian and Danian deposits and suggests a continuous deposition in the studied interval. The Maastrichtian/Danian boundary is here recognized, based on global dinoflagellate cyst events, including the first occurrences of the earliest Danian markers *Damassadinium californicum* and *Membranillarnacia tenella*. The quantitative analysis within the dinoflagellate cyst assemblage revealed 8 groups of morphologically related species, with important changes in their relative abundance. Among these groups, *Manumiella seelandica* dominates the assemblage in the Maastrichtian strata just below the Maastrichtian/Danian boundary and may indicate nearshore and regressive marine environments. However, the relative abundance of the *Spiniferites* and *Senegalinium* groups increases considerably within the Early Danian strata in comparison to the low relative abundance of the other groups, indicating more open marine conditions with higher productivity. These changes are controlled by climatic and eustatic changes.

[VF] Les kystes de dinoflagellés de la limite Crétacé/Paléogène à Ellès, Tunisie centrale

Une analyse palynologique de la transition Crétacé/Paléogène à Ellès, Tunisie centrale, basée sur des événements de kystes de dinoflagellés, a permis la reconnaissance de la limite entre les dépôts du Maastrichtien et ceux du Danien et suggère une sédimentation continue dans l'intervalle étudié. La limite Maastrichtien/Danien est ici reconnue grâce à des événements globaux de kystes de dinoflagellés, y compris la première apparition des marqueurs du Danien basal *Damassadinium californicum* et *Membranillarnacia tenella*. L'analyse quantitative au sein de l'assemblage de kystes de dinoflagellés de l'intervalle étudié a révélé 8 groupes d'espèces morphologiquement proches, montrant des changements importants dans leur abondance relative. Parmi ces groupes, l'espèce *Manumiella seelandica* domine l'association dans les sédiments maastrichtiens juste en dessous de la limite Maastrichtien/Danien et peut correspondre des milieux marins littoraux et régressifs. Toutefois, l'abondance relative des groupes de *Spiniferites* et *Senegalinium* augmente considérablement dans les dépôts du Danien inférieur par rapport à l'abondance relative des autres groupes, les conditions marines sont donc plus ouvertes avec une productivité plus élevée. Ces changements sont contrôlés par des changements climatiques et eustatiques.

Paramètres diagénétiques de la formation de l'Oolithe Blanche (Bathonien, bassin de Paris). Influences sur les caractéristiques pétrophysiques

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Contexte et objectifs

La présente étude s'intègre dans le cadre du projet de recherche SHPCO$_2$ (Simulation Haute performance pour le stockage géologique de CO$_2$), financé par l'ANR[(1)] et en partenariat avec l'IFP, ENSMSE[(2)], LAGA[(3)], INRIA[(4)]. Il est dédié au développement d'une plate-forme informatique haute performance pour la simulation numérique du stockage géologique de CO$_2$ avec la volonté de se confronter à des modèles géologiques ' réalistes ' (domaines faillés, géométries caractéristiques des bassins, variations latérales de faciès) et donc aux difficultés numériques de simulations des écoulements que ces contraintes impliquent.

Dans ce cadre, l'unité GBS (service GEO du BRGM) est chargée de réaliser des modèles géologiques 3D maillés de l'aquifère du Dogger du bassin parisien, à partir du logiciel de modélisation 3D Petrel.

Ces modèles doivent restituer d'une part, la géométrie 3D de la zone d'étude et d'autre part les propriétés pétrophysiques des roches (porosité, perméabilité) qui caractérisent cet aquifère.

Application d'une méthodologie intégrée

La zone d'étude est choisie en fonction du fort potentiel de stockage géologique du CO$_2$ (maximum d'épaisseur de l'aquifère, incluant des faciès sédimentaires poreux) et de la qualité des données de puits disponibles. Cette zone est localisée au sud-est de Paris sur une superficie de 100 km x 100 km.

Les modèles réalisés dans ce secteur bénéficient du programme de valorisation des données de subsurface du BRGM. Ils intègrent notamment des données de puits variés :

- les logs fondamentaux issus de la base BEPH[(5)],
- les logs diagraphiques digitalisés et les logs pétrophysiques calculés,
- des descriptions de carottes (3 puits de référence sur le secteur étudié),
- des contraintes biostratigraphiques (Garcia, 1993)
- mais aussi des travaux d'interprétations géologiques réalisés à l'échelle du bassin de Paris:
- des données sismiques (lignes retraitées de la non-exclusive du bassin parisien, BRGM),
- un schéma structural simplifié de la zone étudiée (failles de Bray, Malnoue, Vittel, Belou, Saint-Martin de Bossenay, Valpuiseaux) construit à

partir de plusieurs horizons pointés sur les profils sismiques de l'étude non-exclusive (BRGM)

- des cartes paléogéographiques des séquences de dépôts du Bajocien Supérieur au Callovien Terminal (Gaumet, 1997)

Notre méthodologie est basée sur l'intégration de ces informations pour réaliser un modèle géologiquement cohérent et réaliste en se basant sur les principes de la stratigraphie séquentielle.

Depuis le toit de l'Aalénien jusqu'à l'Oxfordien Inférieur, dix lignes isochrones (' Maximum Flooding Surfaces ') sont corrélées sur 70 puits (corrélations modifiées d'après Gaumet F., 1997). Ces lignes sont ensuite interpolées en 3D, recalées selon une grille sismique de référence et confrontées au schéma de failles disponible. On obtient ainsi un modèle géométrique 3D dont les couches sédimentaires sont limitées par des surfaces isochrones.

Le modèle de faciès est construit en superposant les cartes paléogéographiques sur les surfaces de même âge et conditionnées par un paramétrage en électrofaciès aux puits (modifiées d'après Gaumet F., 1997). Cette méthode permet de visualiser la répartition des variations latérales et verticales de faciès, nous renseignant ainsi sur la connectivité (ou non) des réservoirs. Cette information est essentielle à la simulation des écoulements dans la zone considérée.

Le remplissage des mailles en propriétés pétrophysiques est simulé de manière stochastique dans le modèle géométrique 3D et permet de proposer un modèle statique du Dogger du bassin parisien. La variabilité de la porosité est simulée au sein de chaque faciès à partir de logs de porosité calculée, continue sur toute la profondeur étudiée (25 logs). La perméabilité est quant à elle déterminée à partir de lois Phi-K, recalculées pour chaque faciès selon des valeurs de couples porosité-perméabilité mesurées sur carottes et extraites des rapports de fin de sondages.

Valorisation scientifiques et techniques

Aujourd'hui, ces modèles permettent aux ingénieurs-réservoir du projet $SHPCO_2$ de tester concrètement leur capacité de calcul et de simulation d'injection et d'écoulement du CO_2. Plusieurs modèles volumiques, de tailles, de précisions géologiques variées qui intègrent des failles majeures sont réalisés :

- un modèle de la zone d'injection (20 x 20 km) qui contient 2 millions de mailles (500 x 500 m),
- 2 modèles de 700 000 et 10 millions de mailles (500 x 500 m) sur la totalité de la zone d'étude (100 x 100 km).

Ces modèles rentrent dans le cadre de la valorisation des travaux de recherche, de mise à jour et du développement des connaissances géologiques du bassin de Paris. Ils permettent de proposer une visualisation 3D de la répartition spatio-temporelle des faciès réservoirs (barrière oolithique et/ou bioclastique et shoals granulaires) et des niveaux potentiellement imperméables qu'ils renferment (faciès de plate-forme externe/bassin profond), tout en intégrant les zones de couverture au toit et au mur des réservoirs.

Perspectives

Ce type de modèle, réalisé ici dans le cadre d'une étude liée au stockage géologique de CO_2, pourrait également être utile pour la compréhension géologique du bassin (paléogéographique et géodynamique) et constitue un outil précieux pour l'aide à la décision dans différents domaines appliqués tels que l'exploration pétrolière, la gestion des aquifères, l'évaluation du potentiel géothermique, aussi bien à l'échelle du réservoir qu'à l'échelle du bassin et pourquoi pas jusqu'aux affleurements.

Enfin, pour répondre à des objectifs d'exploration, on pourrait envisager d'intégrer des paramètres traduisant les phénomènes de diagénèse et de fracturation. Ces paramètres pourraient s'intégrer dans le cadre d'une étude géostatistique plus poussée, afin de traduire plus précisément la variabilité spatiale des faciès carbonatés en termes de porosité et perméabilité.

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(3) Laboratoire Analyse, Géométrie et Application (Université Paris 13, CNRS)

(4) Institut National de Recherche en Informatique et en Automatique

(5) Le Bureau Exploration-Production des Hydrocarbures

Biostratigraphie du passage tortono-messinien de la coupe du Douar Mehalif fondée sur le nannoplancton calcaire (bassin du chélif, Algérie nord-occidentale)

Mohamed El Habib Mansouri, Luc Beaufort, Marie-Pierre Aubry, Mostefa Bessedik

La coupe du Douar Mehalif, située dans la bordure sud-occidentale du massif du Dahra (bassin du Chélif), est constituée de deux formations géologiques reposant en discordance par ravinement sur des argiles rouges conglomératiques. Ces formations sont composées par des marnes bleues à niveaux cinéritiques et une alternance de marnes, diatomites blanches et diatomites argileuses.

Cette série a fait pour la première fois l'objet de calages biostratigraphiques à partir de l'analyse du nannoplancton calcaire. En effet, cette étude nous a permis d'identifier 10 familles de nannofossiles calcaires réparties en 14 genres et 52 espèces. La présence de certaines d'entre elles (Discoaster quinqueramus, D. neohamatus, D. surculus, Amaurolithus primus et A. amplificus) ont permis de mettre en évidence quatre biozones et sous-biozones (NN10, NN11a, NN11b et NN11c) attribuées aux Tortonien et Messinien. Les premières occurrences de Amaurolithus delicatus et de Reticulofenestra rotaria, marquent la base du Messinien.

Ces attributions biostratigraphiques sont confortées par les mêmes prélèvements ayant livré la succession des biozones de foraminifères Neogloboquadrina acostaensis, Nq. humerosa-Nq. dutertrei et Globorotalia mediterranea.

Cette étude stratigraphique intégrée nous a permis d'avoir une meilleure résolution chronologique de la période tortono-messinienne qui se corrèle bien avec celles d'autres coupes du bassin du Chélif et de la Méditerranée.

Sedimentary characters of platform-basin transitional Early Eocene facies in Tunisia

Besma Mardassi, Hédi M. Negra

Early Eocene carbonatic series which exhibit several facies and which are deposited in varied environments, constitute in Tunisia interesting targets for hydrocarbon (Bishop, 1988; Ben Ferjani *et al.*, 1990; Loucks *et al.*, 1996; Fakhfakh-Ben Jemia, 1996; Zaier *et al.*, 1998; Negra *et al.*, 2000). Shallow marine facies which are mainly expressed by massively-bedded carbonates, rich in nummulites (El Garia Formation) constitute good reservoir rocks oil bearing in several areas (Ashtart field, Sidi Litayem etc). Deeper marine facies (Mardassi, 1998) mainly expressed by well-bedded carbonates rich in planktonic microfauna (Bou Dabbous Formation; Fournié, 1978; Ben Ismaïl-Lattrache *et al.*, 1996) and locally characterised by a high content in organic matter, constitute a source rock for many oil fields. The organic-rich pelagic carbonates also constitute, at least locally, fractured reservoir rocks producing oil in some fields (Belli, El Menzah, etc.).Transitional 'platform – basin' facies which were not studied in detail, in terms of facies and deposition environment changes, could associate, at least locally, reservoir and source rocks. The present paper will focus more on the main sedimentary characters identified within transitional facies. In fact, the studied examples show that most changes in facies and thickness which are progressive, suggest a low angle deeping from 'platforms' to 'basins' such as in ramps. Transitional facies are mainly expressed by massively-bedded bioclastic facies interbedded by well-bedded pelagic carbonates (Mardassi-Hafsia, 2004). Bioclastic intercalations which frequently fossilise current structures, consist of turbidites (Eberli, 1987; 1988) and / or tempestites (Dott etal., 1982; Duke, 1985; Tucker, 1992; Negra *et al.*, 2007). On the other hand, reservoir properties of carbonates are in intimate relation with diagenesis which, itself, is linked to the initial sedimentary characters, especially composition and textures.

In terms of carbonates composition, radiolarians were identified both in 'shallow marine' and 'deep-marine' facies. In fact, to the North, in a 'basinal' setting, radiolarians are commonly associated to planktonic foraminifera. However, the proportions of radiolarians in limestones change from the base to the top of the Ypresian Bou Dabbous Formation. Within the upper part of the Bou Dabbous limestones, the proportion of radiolarians could rich 80%, comparatively to the underlying beds in which Globigerinids constitute the main allochems (80% of the whole components). Accessory components

mainly consist of bioclasts and benthonic foraminifera represented by Nodosaria, Lenticulina and Textularia. The deposition of radiolarian-rich facies could be related to paleoenvironmental changes (Danelian *et al.*, 2008; Turpin *et al.*, 2008). Also, radiolarians and sponge spines were identified as accessory components in shallower facies deposited to the South. According to all these facts, it appears that the radiolarian-rich facies deposition could be in relation with paleoclimatic changes (De Wever *et al.* 1994), since radiolarians occur both in a 'deep-marine' and in a shallower environment.

SEM analyses show that the Bou Dabbous micrites are mainly constituted of nanofossils essentially represented by coccoliths associated to anhedral to subhedral (Loreau, 1972) micritic grains and microspar crystals. However, coccoliths are frequent and relatively well preserved to the North, particularly within the middle and upper part of the Bou Dabbous limestones.

Diagenesis is acting in relation with the initial sedimentary composition and textures. The silicification process is interpreted as an early diagenetic stage and related to the remobilisation of biogenic silica contained within microfauna particularly in radiolarians and sponge spines. Silicification processes are identified both in shallow-marine and deeper facies. They appear more represented to the South in a proximal setting in which 'silicified beds' are intercalated within nummulithocalst-rich limestones. In contrast, solution and dolomitisation processes which preferentially occur in bioclastic calciturbidites and near elevated areas (Negra & Mardassi, 2000), clearly enhance the reservoir potential of the Early Eocene carbonates.

Cyclostratigraphy reloaded: the case of Sierra de Fontcalent 20 years later

Tania Marsset, Bruno Granier

The Sierra de Fontcalent is located 10 km West of Alicante (SE Spain). In the 1980's it was investigated by a French team which eventually published an integrated stratigraphic study of this basinal section (Rasplus, Fourcade, *et al.* 1987). At that time, the first author (T.M., as T. Clerc-Renaud) was interested in the identification of Milankovic cycles in the marl-limestone alternations of the Kimmeridgian-Valanginian interval spanning the Jurassic-Cretaceous boundary. Among other finds she identified a periodicity of approximately 21,000 years for a marl-limestone couplet that might be related to the precession index signal.

Today, considering recent developments in cyclostratigraphy, and a better knowledge of the stratigraphic and tectonic framework of the area (Granier *et al.*, 1995; et seq.) we propose a review of this key section. The revised computer-aided calculation of the data was not made on intervals based on biostratigraphy or lithostratigraphy, but on 3 intervals identified on the basis of sedimentological (clay minerals, major elements of the carbonate phase) variations and to their discrete rates of sedimentation. The evolution of the periodicities of the entire section and the transition between major sedimentological changes were given special attention.

As the Tithonian-Berriasian boundary was identified in the section and the location of the Berriasian-Valanginian boundary approximated (Fourcade, Rasplus *et al.*, 1989), we used cyclostratigraphy to assess the duration of the Berriasian stage and we compared it with previous time scales (van Hinte, 1976; Odin, 1994; Gradstein *et al.*, 2004). Our results agree better with those of the older authors. Accordingly, we retain their durations to approximate the Kimmeridgian-Tithonian boundary as well as those of the 3 key intervals, allowing a dating of these main sedimentary events.

Orbital calibration of the Hauterivian-Barremian boundary: new duration of ohmi and hugii biozones

Mathieu Martinez, Pierre Pellenard, Jean-François Deconinck, Laurent Riquier, Fabrice Monna, Miguel Company, Slah Boulila

The Hauterivian and Barremian stages (Early Cretaceous) are still presenting large uncertainties in their durations (Hinnov & Ogg, 2007), especially the ohmi ammonite biozone at the end of the Hauterivian whose duration varies from 1.9 Myr (Gradstein *et al.*, 2004) to 0.2 Myr (Ogg *et al.*, 2008). Sediments exposed in the Río Argos section (Subbetic domain, Southeastern Spain) are composed of marl-limestone alternations attributed to rhythmic climatic changes in the Milankovitch frequency band (Sprenger & Ten Kate, 1993). This section provides a detailed biostratigraphic and sequence stratigraphic framework correlated with other basins in the western Tethyan domains (Hoedemaker & Leereveld, 1995; Company *et al.*, 2003; Hoedemaeker & Herngreen, 2003). The section is proposed as a GSSP candidate for the Hauterivian-Barremian boundary (Ogg *et al.*, 2008). To have a better estimation of the ammonite zone duration, we performed an orbital calibration based on field spectral gamma ray (SGR) measurements that encompass the ohmi (uppermost Hauterivian) and the hugii (lowermost Barremian) ammonite biozones.

SGR measurements are taken every 20 cm, aiming at a detailed cyclostratigraphic study. SGR values are higher in marls (9.5 ppm eU on average) and weaker in limestones and (7.7 ppm eU on average) defining well the lithologic alternation (high frequency cycles). Lower frequency cycles are also well expressed. A wavelet analysis is first applied to detect changes in sedimentary cycles that may correspond to variations of the sedimentation rate (*e.g.*, Prokoph and Agterberg, 1999). The multi-taper method (MTM) is used per intervals of constant sedimentation rates. By comparing frequency ratios of sedimentary cycles and La2004 astronomical cycles of Laskar *et al.* (2004), we pointed out precession (18.1 and 21.7 kyr, obliquity (46.2, 36.6 and 27 kyr) and 95-kyr eccentricity cycles. The latter is used to orbitally calibrate the section. The durations of the ohmi and hugii ammonite zones are thus assessed at 0.67 Myr and 0.65 Myr respectively.

These durations are in agreement with those proposed by Bodin *et al.* (2006) using a cyclostratigraphic approach in sections exposed in the Vocontian basin

(SE, France). However, they differ significantly from estimates in the GTS 2008, which are based on the duration of the whole Hauterivian (Mc Arthur *et al.*, 2007). We therefore suggest that the duration of the Hauterivian is likely underestimated. As durations of the Berriasian to Barremian stages are mainly based on the magnetostratigraphy (Gradstein *et al.*, 2004), an orbital calibration of this period could greatly improve the temporal accuracy of magnetostratigraphy.

Emsian (Lower Devonian) conodont biostratigraphy of the Compte subfacies-area of the Spanish central Pyrenees

Carlos Martinez Perez, José Ignacio Valenzuela-Ríos, Héctor Botella

Emsian outcrops are relatively abundant in the Spanish Central Pyrenees (SCP), but detailed studies are rare so far. The better-known Emsian areas are included in the so-called Baliera and Compte subfacies belonging to the large Southern Facies-area. In recent years, we have started a comprehensive research of these Emsian strata from the SCP that have yielded an important conodont fauna of a late Pragian to late Emsian age. This fauna contain a significant polygnathid and icriodid assemblage with biostratigraphical relevance which is characterized by the joint occurrence of taxa considered as endemic of shallow-waters facies (rhenish facies) with those considered as cosmopolitan (frequent in deeper waters of the hercynian facies). This fact has the importance of a direct comparation and control conodont records of both biofacies, and therefore allows better correlations across different regions. Therefore, the main purposes of this work are to discuss this polygnathid assemblage together with other findings, and propose, for first time, a local biozonation for the Emsian stage of the SCP, comparing these biozonation with other classical regions.

All the condonts studied have been retrieved after the dissolution, with 7-10% formic acid, of 197 samples of carbonate rocks from nine geological sections: Compte-I top section (CP-I top); La Guardia d'Àres sections (LGA, LGA-X and LGA-XI); and the Villech sections (Vi-IA, IB, IC, ID and IE). All these sections have been described exclusively in the Compte subfacies-area of the larger Southern facies-area and expose strata from the top of the Castanesa Fm. to the top of the Villech Fm. (including their basal unit Castells Bed Mbr.), with a late Pragian to late Emsian in age.

From the nine sections studied, seven have yielded important conodonts of biostratigraphical relevance (CP-I top, LGA, LGA-X, LGA-XI, Vi-IA, Vi-IB and Vi-IE sections). These conodonts have allowed the recognition, for first time, of a local conodont biozonation with the *kitabicus*, *excavatus*, *nothoperbonus*, *laticostatus* and *serotinus* Zones, which are briefly discussed below.

The '*kitabicus* boundary' and hence the lower Emsian boundary has been identified only in the section Vi-IA with the first occurrence of *Polygnathus kitabicus*. The Lower *excavatus* Zone, in the same section, has been

recognized few meters above, with the first record of *Polygnathus excavatus excavatus*. On the other hand, the Middle *excavatus* Subzone has been identified in the sections LGA-X, LGA-XI, CP-I top and Vi-IA. In the LGA-X, LGA-XI and Vi-IA sections, its lower boundary has been approximated using other conodonts such as *Icriodus gracilis*, *Icriodus bilatericrescens* or *Icriodus sigmoidalis*, taxa that appear close to the base of this Subzone in other regions (see, *e.g.* Iberian Chains). The index conodont taxa of this Subzone, has also been recognized in LGA-X and LGA-XI, but within the zone.

Regarding the next conodont-zone, the *nothoperbonus* Zone, it has been identified at the base of the CP-I top section and at the top of LGA-XI section, both with the first occurrence of the index taxa, *Polygnathus nothoperbonus*. On the other hand, the *nothoperbonus* Zone has been recognized at the base of LGA, and at the Vi-IB section, age assigned by the conodont assemblage found. This Zone, following other authors, is used in the Pyrenees as equivalent to the *perbonus* (or Upper *excavatus* Subzone) and *gronbergi* Zones. In addition, within this zone we can point out the occurrence of *Polygnathus mashkovae* in CP-I top, LGA and Vi-IB sections.

The base of the *laticostatus* Zone has been identified only in the section LGA with the first record of *Polygnathus laticostatus*. Slightly above in the same section, we can point out the first mention in the Pyrenees of *Polygnathus vigierei* and *Polygnathus gilberti*, two important conodont markers. The last Emsian biozone recognized is the *serotinus* Zone. This Zone has been identified in the LGA and Vi-IE sections. In both sections its lower boundary has been approximated with the first record of *Icriodus corniger*, taxon that in other regions always appears at the base of the *serotinus* Zone. Together with *Icriodus corniger*, within the *serotinus* Zone, we have recorded *Polygnathus* cf. *serotinus* in the Vi-IE section, and *Polygnathus linguiformis bultyncki* in several levels of LGA and Vi-IE sections.

The analysis of the Emsian conodont sequence obtained from the seven sections of the Compte subfacies-area have allowed us, for first time, the establishment of a local biozonation, identifying the *kitabicus*, *excavatus*, *nothoperbonus*, *laticostatus* and *serotinus* Zones. The exposed data show that exist some difference between this local zonation and the conodont zonation described in other regions. Although, the presence of cosmopolite conodont taxa in the Emsian rocks of the Pyrenees have let us a precise correlation with other classical region such us Nevada (USA), the Armorican Massif (France), Bohemia (Czech Republic) or Central Asia (Zinzilban). In addition, this work shows the relevance of the SCP Emsian sections for further discussions on, for example, the Emsian zonal scheme, the subdivision of the Emsian stage or the redefinition of their lower boundary, subjects that are currently under discussion.

This work is a contribution to the 499 IGCP 'Devonian land-sea interaction: evolution of ecosystems and climate'.

Late Barremian-Bedoulian platform development and demise: a four steps history controlled by drowning events, their timing and key factor

Jean-Pierre Masse, Mukerrem Fenerci-Masse

There is a lively and strong debate between workers dealing with the timing of the demise of the Bedoulian platform carbonates from the Mediterranean domain , and their prominent controlling factors, especially concerning their relationships with the so-called OAE1a event and a biocalcification crisis. Controversy is rooted in the calibration of events to index ammonites and/ or the hypothesis of a single or multiple events .

Data from the late Barremian-Bedoulian of SE France document the existence of four successive drowning events, involved in the stepwise demise of the Urgonian platform, and having each a specific age refered to ammonite zones or subzones:

- the late Barremian drowning at the Sartousiana-Giraudi transition, coeval of the '*Heteroceras* marls' episode of basinal settings, is associated with the development of *Palorbitolina-Heteraster* marls (lower orbitolina beds),this drowning marks the onset of the Bedoulian palaeogeography,
- the Middle Bedoulian drowning at the Weissi-Deshayesi transition, tends to follow a significant exposure and is also marked by the wide subsequent extent of Palorbitolina facies (upper orbitolina facies),
- the Mid late Bedoulian drowning in correspondance with the 'Hambrovi' subzone, is coeval with the OAE 1a event and is usually associated with a hiatus, whereas its basinal expression are the black-shales of the Selli-Goguel event,
- the late Bedoulian drowning at the Grandis-Furcata transition, marks the onset of the 'Gargas marls' .

The existence of 4 successive drowning events allows us to recognize 4 successive steps in platform development and demise. The late Barremian age, step 1, starts with a drastic reduction of shallow platform settings with rudists, usually replaced by *Palorbitolina* facies or a drowning sequence leading to ammonite bearing deposits. The ensuing recovery of rudist facies and step 2 mark the developmental phase of the platform system whereas steps 3 and 4 are associated with its demise, that is the burial of the shallow carbonates below deep water sediments . Step 1 is actually the major spreading phase of Urgonian type facies spectrum including: bioclastics, coral and rudist facies groups. Step 2 sees the quasi disappearance of rudist facies and a spatial reduction of both coral and bioclastic facies. The termination of step 1 is marked by the emergence of the antecedent platform margin, whereas in areas with a continuous marine sedimentation the Middle Bedoulian event is less marked and the subsequent deepening (drowning 2) is expressed by a drowning sequence including both coral and *Palorbitolina* facies.

Step 2 starts with the flooding of the antecedent platform and the development of *Palorbitolina* and cherty limestones. Shallow water bioclastics recover rapidly ontop of the pre-existing emerged areas and are locally associated with coral facies, rudist fragments being punctually found. Shallow

water bioclastics recovered erratically in conjunction with the spatial migration of bioclastic shoals.

Drowning events appear not only critical for the demise of shallow carbonates through deepening but also because the associated sediments document a change from platform type to a transient state, ramp type morphology. The 'Urgonian facies' are therefore essentially present in the Lower Bedoulian. Assuming that the 'Hambrovi' subzone is represented by a sedimentary hiatus and that the Grandis subzone and the Furcata zone correspond to circalittoral deposits, shallow water carbonates appear to have a limited record in the Upper Bedoulian, and are restricted to the lowermost part of the Deshayesi zone.

The early Toarcian anoxic event: what is the beginning of the story?

Emanuela Mattioli

The early Toarcian anoxic event (T-OAE) and the associated biotic crisis have received much attention in the last decade. However, the events forewarning the crisis as well as its aftermath are still poorly known. The T-OAE coincides with a prominent carbon isotope negative excursion (T-CIE) that is preceded by an excursion of similar intensity at the Pliensbachian-Toarcian boundary (Hesselbo *et al.*, 2007). The onset of T-CIE occurred some 700 kyr later than the end of the Boundary-CIE (Suan *et al.*, 2008a). This succession of events demonstrates that the T-OAE was a complex suite of environmental perturbations.

In this work, we focused on calcareous nannofossil assemblages occurring in the Peniche section (Portugal) during the Boundary-CIE with the aim to understand if calcifying plankton reacted in a similar/different way to the two CIEs.

The production by nannoplankton collapsed during the T-CIE, as demonstrated by the lowest absolute abundance of nannofossils measured in Peniche and other studied sites (Mattioli *et al.*, 2008). Besides this nannofossil abundance decrease, also the size of the *incertae sedis Schizosphaerella* test was drastically reduced (Suan *et al.*, 2008b). If a similar size decrease is also recorded during the Boundary-CIE, calcareous nannofossil abundances are very high, and assemblages seem not to record an environmental stress.

This set of data indicates that environmental deterioration was recurrent until it reached its acme during the T-OAE. Our scenario implies an intrinsically long-lasting suite of events and argues in favour of long-lasting CO_2 degassing, most likely related to the emplacement of the large igneous province of Karoo-Ferrar as the main cause of the Toarcian environmental perturbations.

Les Calcaires à Bryozoaires de l'Ordovicien supérieur de l'Anti-Atlas oriental (Maroc) : Environnement de dépôt et analyse stratigraphique

Amira Meddour, Philippe Razin, Mohamed Jati, Jean-Loup Rubino

L'étude sédimentologique et stratigraphique de l'Ordovicien supérieur de l'Anti-Atlas marocain s'inscrit dans un programme de recherche qui porte sur les séries paléozoïques nord-gondwaniennes. Les principaux objectifs de ce travail sont de caractériser les systèmes de dépôts et leur extension latérale, de définir les différents cycles stratigraphiques aux différents ordres ainsi que de comprendre l'organisation stratigraphique à l'échelle des plates formes paléozoïques nord-gondwaniennes.

Le bassin anti-atlasique (Maroc) se situe sur la bordure nord du bouclier Ouest-Africain. Durant l'Ordovicien, il s'y développe une très vaste plate-forme silicoclastique dominée par la houle et les tempêtes. Les dépôts sont à dominante argilo-gréseuse, les seuls niveaux ' carbonatés ' observés correspondant à des accumulations bioclastiques lors des tempêtes (lags de tempêtes) intercalés dans des niveaux silteux-gréseux. Cependant, dans le secteur Erfoud (Anti-Atlas oriental) affleure une série mixte gréso-carbonatée bioclastique, où deux niveaux carbonatés riches en Bryozoaires ' Biostromes à Bryozoaires ' ont été reconnus et attribués respectivement au Caradoc moyen – supérieur et à l'Ashgill supérieur (J.Destombe 2004). Par comparaison avec ces carbonates, des calcaires à Echinodermes de l'Ashgill moyen à supérieur de la chaîne ibérique se seraient déposés dans une mer peu profonde relativement chaude avant la glaciation fini-ordovicienne (Vennin *et al.*, 1998)

L'analyse sédimentologique et stratigraphique des dépôts ordoviciens supérieurs de la région d'Erfoud permet d'interpréter les conditions de dépôts de ces intervalles carbonatés et d'en reconnaitre la disposition géométrique et stratigraphique. Les deux niveaux carbonatés s'organisent en deux séquences de dépôts d'une centaine de mètres d'épaisseur limités à leur base par une surface d'érosion majeure.

La première séquence vient tronquer une barre de grès pluri-décamétrique à mégarides tidales pour reposer le plus souvent sur une épaisse série hétérolitique de plate-forme silico-clastique dominée par l'action des vagues. La deuxième séquence est surmontée en discordance par la série argilo-gréseuse du Silurien. Chacune des deux séquences débutant par une unité de grès massif à litage plan ou de rares mégarides présentant parfois des lits bioclastiques à débris de bryozoaires. Ces corps gréseux sont lenticulaires et se biseautent sur la bordure des incisions qui correspondent aux limites de séquences. Ces unités gréseuses massives sont surmontées par une association de faciès hétérolitiques mixtes formés de couches gréso-carbonatées à débris de bryozoaires et d'échinodermes séparés par des interlits plus silteux. Ces faciès biodétritiques de granulométrie relativement grossière (sable grossier) se caractérisent par l'association d'un litage ondulé et d'un litage à mégarides 2D ou 3D. Ces dépôts sont recouverts, parfois par l'intermédiaire d'une surface de ravinement, de barres carbonatées constituées

principalement de Rudstone ou Grainstone grossier à débris de bryozoaires et échinodermes à litage oblique et/ou ondulé très bien développé. Dans la deuxième séquence, une unité d'argiles vertes à bioconstructions stratiformes à bryozoaires s'intercale entre deux unités carbonatées bioclastiques, l'une rétrogradante, l'autre progradante.

Les corrélations régionales tendent à montrer que la série hétérolitique sous-jacente des calcaires à Bryozoaires correspond à la formation des Ktaoua supérieurs, et la série gréseuse à mégarides appartient au groupe du 2°Bani. La préservation de ces deux séquences très localisées dans la région d'Erfoud serait liée d'une part à la présence d'incisions majeures à la base de ces séquences et surtout à un faible taux d'érosion par les dépôts glaciaires, précisément absents dans ce secteur.

L'analyse de cette succession de faciès conduit à interpréter les dépôts carbonatés à bryozoaires du secteur d'Erfoud comme des dépôts biodétritiques littoraux édifiés par l'action des vagues et remaniant des édifices bioconstruits se développant en domaine offshore au seins des faciès argileux. Ces systèmes biodétritiques littoraux se développent en contexte transgressif après des phases d'incisions majeures probablement liées à des phases de chute du niveau relatif de la mer importante. Les faciès argileux rétrogradant à bioconstructions marquent les périodes de maximum de transgression avant la progradation de nouveau prisme bio-détritique en période de haut niveau marin.

D'un point de vue environnemental, le développement de tels systèmes carbonatés, à l'Ordovicien supérieur, soulignerait des périodes relativement chaudes coïncidant avec des périodes de remontée importante du niveau marin relatif. Ces deux séquences de dépôts qui enregistrent les cycles de variation du niveau marin de grande amplitude semble précéder la phase de glaciation majeure de l'Hirnantien (Loi et al 2010).

Des travaux sont en cours pour étayer ces interprétations stratigraphiques, d'affiner les corrélations régionales et tenter de dater les intervalles argileux intercalés dans les dépôts carbonatés.

Could the predators have controlled the abundance of the Cenomanian oysters and led to their extinction?

Manal Sayed Mekawy

A possible answer for this question may come from the Cenomanian oysters (*Ceratostreon flabellatum*, *Rhynchostreon suborbiculatum* and *Costagyra olisiponensis*) of Gebel Yelleg, North Sinai, Egypt. Predators play an important role in the distribution and abundance of species in ecological communities. The diversity of predators remained at a nearly constant proportion from the Late Triassic to mid-Cretaceous. During Late Cretaceous-Neogene, predators diversified faster than the rest of the fauna (Bambach and Kowalewski, 1999). Trace fossils left on the skeletons of the oysters of Gebel Yelleg provide strong evidence that predators increasingly flourished from the Middle to Upper

Cenomanian and that may have had brought Cenomanian oysters to extinction.

The different steps of the muricids radiation

Didier Merle

Among the molluscs, the Muricidae (Gastropoda, clade Neogastropoda) represents one of the richest families of macro-gastropods with around 1500 recent species and around 1100 of fossil species (Vokes 1971, 1996). This high richness is the result of a strong diversification during the Cenozoic. On ecological point of view the muricids are active predators that have progressively colonized a large set of benthic environments from deep water to the intertidal zone. They live on various bottoms (sand, mud, rocks) and a subfamily, the Coralliophilidae, displays a parasitic adaptation depending on the corals. The specific richness culminates now in intertropical biota. On paleontological point of view, this spectacular adaptive radiation raises the problem of the knowledge of the different phases of the muricid diversification along the Cenozoic.

A database made by the author and including the FAD (First Appearance Data) and the LAD (Last Appearance Data) of around 700 valid fossil species allows delineating five phases in the muricid diversification.

1. Appearance of the family. The oldest and single undisputable Cretaceous muricid is *Paziella* (*Flexopteron*) *cretaceus* (Garvie, 1991) from the Late Cretaceous of Texas, USA (Kemp clay Formation). Other reports of Cretaceous muricids are considered as doubtful (Bandel, 1993; Merle 1999; Merle & Pacaud 2002).

2. The Danian explosion. The Danian explosion is marked by the appearance of species belonging to the genera *Paziella* and *Poirieria* in different parts of the Atlantic Ocean (Nigeria, Brazil, North America, Western Europe and Eastern Europe). There is no record of the muricids in the Pacific. The early appearance of *Paziella* confirms the anatomical hypothesis suggesting that the genus represents a very primitive muricid (Harasewych, 1984).

3. The basal diversification. This period extends from the Early Paleocene to the end of the Middle Eocene and corresponds to the appearance of the oldest members of all subfamilies (except Haustrinae). The oldest Pacific species are recorded from Indian Late Eocene (Vredenburg, 1929) and the Early Eocene from New Zealand. During the Middle Eocene, the muricids have been found anywhere and the range of the family can be regarded as worldwide, but the major muricid records come from the Atlantic Ocean and the western Tethys. Another aspect of the basal diversification is that the muricids assemblages in shallow waters are dominated by the genera *Timbellus* and *Paziella* (*Flexopteron*) in marine environments and by 'pre-ocenebrines' as *Nucellopsis*, *Jsowerbya* (Merle, 2005a-b) and trophonines in paralic environments.

4. The switch phase. This period extends from the Late Eocene to the Early Oligocene. It corresponds to the rarefaction and the disappearance of the dominant taxa of the precedent period and to the appearance of the modern

ocenebrines in paralic environments. But the major feature is that the maximum of richness is not more observed in the Atlantic Ocean nor in the western Tethys, but in the Pacific Ocean, especially in Indonesia, South Australia and New-Zealand. It is the main reason for calling that period the switch phase.

5. The modern diversification. The period extends from the Late Oligocene to Recent. It corresponds to a FAD increase in the Indo-Pacific region and a FAD decrease in the Atlantic Ocean. The modern diversification displays a structural change in the muricid assemblage. The genera *Timbellus* and *Paziella* (*Flexopteron*) disappear from shallow waters and are relayed by other genera such as *Chicoreus*, *Hexaplex* and by the members of the Rapanine clade.

Although many species have been described through the Cenozoic and in the recent, the spectacular radiation of the Muricidae remains widely misunderstood. Its phylogeny is still poorly explored (Barco *et al.*, in press) and moreover, there is no work attempting to delineate and to date the major events of its radiation during the Cenozoic. This first attempt to identify its different diversification phases is a preliminary step to better document that strong radiation of gastropods.

Biostratigraphy and tectono-sedimentary context of the Bartonian deposits of the Tardenois (Aisne, France)

Eddy Métais, Grégoire Métais, Marc Duprat

The sedimentary dynamics and the paleobiodiversity of mammals during the end of the Middle Eocene remain poorly known in the Paris Basin.

The scarcity of the fossil mammal discoveries and the important lateral facies variations within the formations make the regional correlations difficult.

Prospecting and screenwashing work performed for more than 10 years in the Tardenois has yielded exceptional unpublished fossil vertebrate remains (mainly large mammals, associated with small mammals, amphibians, reptiles, and fish) which were found in 5 new loci inside one of the Tardenois localities already mentioned by one of us (MD) during BiochroM'97 and RST 2000.

The detailed study of the tectono-sedimentary context has allowed to specify the stratigraphic position of these fossil-bearing deposits (scattered fragments and bonebeds) located in sandy fluvio-estuarine channels nearly contemporaneous with the level of mollusks of Mortefontaine, recognized as being of Marinesian age. The preliminary study of the mammal assemblages shows that these faunas are close to the fauna of Robiac (MP16 Reference Level) although some suggest an older age, but posterior to MP14. These faunas, although still incomplete, could document a very poorly known interval in Europe corresponding to the MP15 Level.

The logged sedimentological sections have allowed to better understand the strong facies variations commonly observed in the deposits of the Auversian-Marinesian transition and clearly illustrate the diachronism that can affect

formations defined on lithological criteria only ('Sables de Beauchamp' for example). Finally, these new discoveries are compared and correlated with the sub-contemporary faunas already described in the area, such as those found at Sergy (Thomas, 1906), Nogent l'Artaud (Morellet, 1948), Latilly and Grisolles (Louis, 1976), thus suggesting that they may all correspond to the same reference level.

The preliminary list of the mammal assemblage includes the following:

MAMMALIA Linné, *1758*

Perissodactyla

- Palaeotheriidae:
  - ? *Pachynolophus*
  - *Palaeotherium siderolithicum* Pictet & Humbert, 1869
  - *Palaeotherium* cf. *castrense* Noulet, 1863
  - *Anchilophus* cf *gaudini* Pictet & Humbert, 1869
  - *Plagiolophus* sp.
  - *Lophiotherium* sp.
- Lophiodontidae:
  - *Lophiodon* cf. *lautricense* Noulet, 1851
- Helaletidae:
  - *Chasmotherium* cf. *cartieri* Rütimeyer, 1862

Artiodactyla

- Cebochoeridae:
  - *Cebochoerus robiacensis* Deperet, 1917
- Xiphodontidae indet.

Carnivora

- Miacidae indet.
- Amphycionidae indet.

Rodentia

- Theridomyidae:
  - *Paradelomys* sp.

Integrating radioisotopic and astrochronologic methods for improvement of time scale reconstructions

Stephen R. Meyers, Bradley B. Sageman, Bradley S. Singer

In recent years, the resolution of deep-time paleoclimate studies has been steadily increasing. This is a consequence of improvements in microstratigraphic techniques, radioisotopic dating methods, astrochronologic analyses, paleomagnetic studies, and other innovations. Yet the ultimate objective of obtaining multiple geographically distributed localities that are correlative within a common high-resolution time scale remains rare. In most cases, all available sites do not preserve the same suite of geochronologic tools. Astrochronology has great potential to assist in the development of such

common time scales because the orbital signal for a given paleo-time interval has consistent attributes whose variations across latitude are predictable. Unfortunately, the development of astrochronologies for strata that preserve signals of orbitally-forced climatic variation has been dependent on some degree of in situ time control in order to constrain the possible solutions for matching spectral signals to orbital periods. In this study we demonstrate how the Average Spectral Misfit (ASM) method offers a means to reconstruct orbital time scales for stratal successions that preserve orbital variance, but lack in situ time control at a resolution sufficient to constrain the orbital signal (ASM is a technique that matches predicted orbital periods for a time interval to the spectral record of a data series and outputs the average sedimentation rate that produces the best fit to the prediction). Using the Cenomanian-Turonian (C-T) GSSP as a starting point, we will show how new Ar-Ar data confirm the ASM reconstruction for an interval with in situ dates. Then we will apply the ASM method to other C-T sites where in situ dates are not possible and the potential error on biostratigraphic correlation of ages precludes accurate testing of time models. Lastly, we will explore the implications of multiple, meridionally distributed astrochronologic reconstructions for the interpretation of paleoenvironmental changes in the C-T interval.

Micropaleontological investigations on the Permo-Triassic boundary based on the surface samples of the Kuh-e Surmeh in subcoastal Fars Province, Southwestern Iran

Abdolreza Moghaddasi

One stratigraphic column of the Permo-Triassic boundary has been measured and sampled from Tang-e Choob-Bandi in Kuh-e Surmeh in subcoastal Fars province in southwestern Iran by the author on March 2009.

A total of 31 thin-sections with interval of 50cm were prepared from the surface samples and studied for micropaleontological purposes in order to distinguish the Permian and Triassic boundary. The samplings were from upper part of upper Dalan Member of the Dalan Formation and base of the Kangan Formation.

Based on micropaleontological and field geology studies the Permo-Triassic boundary in Kuh-e surmeh is disconformable and the Permo-Triassic boundary locates just below the thrombolites in base of the Kangan Formation. The hiatus between the Dalan and Kangan formations encompasses the Dorashamian stage.

All samples contain the diagnostic microfossils and these microfossils (Foraminifera, Algae, Microgastropods, Ostracoda) have been photographed and illustrated on plates 1 – 7 and their stratigraphical distributions have shown on the enclosed relevant range chart.

Acknowledgements

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High-resolution clay mineralogy for orbital tuning of the Hauterivian-Barremian transition in the Betic Cordillera (SE Spain)

Mathieu Moiroud

In the Subbetic Domain of the Betic Cordillera (SE Spain), undisturbed hemipelagic marl-limestone alternations attributed to rhythmic climatic changes from orbital parameters are well-exposed on the Río Argos section (Sprenger & Ten Kate, 1993). Because of a detailed and robust biostratigraphic framework, this section is proposed as a GSSP candidate for the Hauterivian-Barremian boundary (Hoedemaeker & Leereveld, 1995; Company *et al.,* 2003; Ogg *et al.*, 2008). Our study encompasses the *Ps. ohmi* and *S. hugii* ammonite zones, at the Hauterivian-Barremian transition (Early Cretaceous), including the Faraoni oceanic anoxic event recorded at the base of the *Ps. ohmi* zone (Bodin *et al.*, 2006). A cyclostratigraphic approach using spectral gamma-ray (SGR) and magnetic susceptibility (MS) was previously carried out to better constraint biozones durations (Martinez, 2009). In order to test the ability of clay minerals in recording astroclimatic forcing, a high resolution mineralogical study (*i.e.* 20 cm-spaced hand specimens over 41 m) was performed.

The composition of the clay fraction is determined by X-ray diffraction on oriented mounts, and the total carbonate content measured. Special attention is given concerning burial diagenesis evaluation. In order to establish the smectite content of the mixed-layer clay minerals, the 'saddle index' technique is used (Inoue *et al.*, 1989), and the illite crystallinity index is calculated (Kübler & Jaboyedoff, 2000). To detect and quantify orbital cycles in the sedimentary series, Morlet Wavelet analysis is selected for its conspicuous representation of sedimentation rate changes, as well as Maximum Entropy Method for its spectral resolution and Multi-Taper Method its robustness.

The clay fraction is mainly composed of random illite/smectite mixed-layers rich in smectite sheets (I/S R0) and illite, and small amounts of kaolinite and chlorite. The high I/S R0 content, the saddle index and illite crystallinity suggest a very limited influence of burial diagenesis and the occurrence of dominant inherited clay materials. Carbonate contents point out slight diagenetic artifacts through the presence of several non-indurated limestone layers. The variation domain of clay mineral contents between marl and limestone is restricted but their ratios are consistent with the lithology, as clay mineral ratios signature in marly layers and calcareous layers are significantly different according to a Wilcoxon statistical test. Kaolinite/chlorite, illite/(I/S R0), kaolinite/illite, kaolinite/(I/S R0) ratios, as well as calcium carbonate and illite crystallinity, were tested as climatic variables using spectral analysis.

Wavelet analyses display rather poorly-constrained and decreasing period bands, common to all the climatic proxies, which also reveal similar frequencies on their respective power spectra. The identification of orbital cycles is provided by comparing frequency ratios of sedimentary cycles and La2004 astronomical cycles (Laskar *et al.*, 2004) extended to the Hauterivian (Martinez, 2009), leading to the identification of eccentricity (E, e1, e2), obliquity (O2, O1, O3) and precession (P1, P2) components. Both wavelet and spectral analyses display strong amplitude modulation in short astronomic periods (*i.e.* precession cycles) and 100 kyr-eccentricity by the long eccentricity.

Spectral filtering of frequencies attributed to the short eccentricity, which duration is stable until 100 Ma, and the long eccentricity, stable over the geological times (Laskar *et al.*, 2004), supply orbital calibration of the studied section. The redimensioned section provides estimations of sedimentation rate which vary approximately from 4 to 2 cm/kyr with a slight decreasing trend. The values of the various mineralogical proxies give durations of the ammonite zones ranging from 626 to 768 kyr and from 476 to 595 kyr for the *Ps. ohmi* and *S. hugii* ammonite zones, respectively, and a total duration from 1201 to 1273 kyr. These values are in good agreement with the cyclostratigraphic studies based on SRG and MS (Martinez, 2009), but strongly differ from the durations previously proposed by the GTS 2008 (Ogg *et al.*, 2008).

Taux d'accumulation sédimentaire sur les plates-formes carbonatées: le Quaternaire est–il une référence pour le Crétacé?

Lucien François Montaggioni, François Fournier, Jean-Pierre Masse, Jean Borgomano, Marc Floquet, Guy Cabioch

Nombre de travaux suggèrent que les taux d'accumulation décroissent régulièrement en fonction du temps au cours du Phanérozoique. Un certain nombre de facteurs géologiques et/ou de biais méthodologiques sont invoqués pour expliquer cette tendance (Sadler, 1981, 1999; Wilkinson *et al.*, 1991 ; Schlager, 1999, 2000; Strasser et Samankassou, 2003). Notre propos est de présenter ici une analyse comparative des vitesses de sédimentation en milieu carbonaté tropical peu profond au Quaternaire et au Crétacé.

Des modèles numériques de développement de plates-formes récifales, utilisant les courbes eustatiques dérivées des enregistrements isotopiques de l'oxygène pour les derniers 1.8 Ma, montrent que la sédimentation carbonatée peu profonde est fortement discontinue au cours du temps. L'accumulation sédimentaire exprime moins de 10% de la durée totale du Quaternaire. Les vitesses d'accumulation moyennes estimées sur une durée de 1.8 Ma restent inférieures à 1 m/ka. En revanche, en ne tenant compte que des intervalles pendant lesquels la sédimentation a été manifeste, les taux d'accumulation s'établissent à 10 m/ ka environ. Les derniers cycles transgressifs, et en particulier, la dernière remontée eustatique (de 19 ka à l'Actuel), présentent deux phases distinctes. Lors de la première phase, de 19 ka à 6 ka, la vitesse

moyenne de création d'espace a été de l'ordre de 10 m/ka. Le taux d'accumulation a été très variable (0 – 10 m/ka). Au cours de la deuxième phase, entre 6 ka et le présent, la vitesse de création d'espace est inférieure à 1 m/ka. Au cours de l'Holocène terminal (derniers 3 ka), la vitesse de création d'espace a brutalement chuté (< 0,5 m/ka) et, par suite, le taux de sédimentation a été ralenti (0,2 m/ka, en moyenne).

Les valeurs estimées pour la sédimentation de la plate-forme urgonienne du Barrémien de Provence, sont comparables à celles calculées pour l'intervalle entre 3 ka et le présent, avec une valeur moyenne de l'ordre de 0,1 m/ka, et des estimations entre 0,10 et 0,40 m/ka pour certains facies à rudistes. Des dépôts de même nature, étudiés dans le Crétacé supérieur d'Italie, présentent également des taux moyens compris entre 0,02 et 0,2 m/ka. Ces valeurs, relativement faibles, s'apparentent donc à celles de la période de relative stabilité de l'Holocène terminal. Une alternative serait d'admettre que des taux supérieurs de sédimentation existent au Crétacé à l'échelle de paraséquences mais que la faible résolution chronostratigraphique permet pas de les détecter. Notre analyse montre que la décroissance apparente des taux d'accumulation des carbonates au cours du Phanérozoique pourrait être, pour une grande part, le résultat d'une appréciation erronée des durées effectives de la sédimentation et/ou d'une application incorrecte des enseignements du 'Quaternaire'.

Cretaceous geological stages: Should we erase everything and restart from scratch? - The Aptian case

Michel Moullade, Guy Tronchetti, Bruno Granier

If the rule of priority had been applied for the stratigraphic nomenclature as strictly as it have been for paleontological denominations, and if the initial intentions of some authors like d'Orbigny (1847), Renevier (1854) or Coquand (1871) had been better understood and/or respected, the Lower Cretaceous would now comprise the following succession of stages: Berriasian, Valanginian, Hauterivian, Urgonian, Rhodanian, Aptian, Albian.

Compared to current usage, this original sequence lists two intruders (Urgonian, Rhodanian) and one accepted stage is missing (Barremian).

In addition, the Aptian is now given a length of time which does not correspond to its original definition.

Taking into account the practice which has prevailed, while deploring that it often resulted from misinterpretations, disrespect of the rules and/or the dogmatism of certain great figures in geology, it does not appear realistic to return to the origins in regard to the Urgonian or the Rhodanian. But on the basis of our recent work on the stratotypes (Moullade *et al.*, 2009), we suggest an approach to a redefinition of the Aptian which should somewhat simplify resolution of the current imbroglio. This proposal is as follows:

1. restrict the Aptian to the initial concept of d'ORBIGNY (1840), *i.e.* that of the 'Aptian Marls Formation' (cf. Renevier, 1854), which would remove from this stage the 'La Bédoule Formation' and the 'Clansayes Level',

2. delete the term Gargasian, a de facto junior synonym of the Aptian thus redefined,

3. restore to the Albian the 'Clansayes Level' (either recognized as a substage – the Clansayesian - or not),

4. erect the Bedoulian as a stage. Initially conceived as a substage (which would have been named Rhodanian if the rule of priority had been correctly applied) this Bedoulian stage takes its place between the Barremian and the Aptian s.s.

Our proposal includes also redefinitions of the Barremian-Bedoulian, Bedoulian-Aptian (*s.s.*) and Aptian (*s.s.*)-Albian boundaries, by taking better into account historical lithostratigraphic and paleontological criteria. We also offer suggestions about potential G.S.S.P. (Global Boundary Stratotype Sections and Points).

[VF] Les étages géologiques du Crétacé : devrions-nous tout effacer et repartir à zéro ? – le cas de l'Aptien

Si la règle de priorité avait été strictement appliquée pour la nomenclature stratigraphique, à l'exemple de ce qui se fait pour la nomenclature paléontologique, et si les intentions initiales de certains auteurs comme d'Orbigny (1847), Renevier (1854) ou Coquand (1871) avaient été mieux comprises et/ou respectées, le Crétacé inférieur devrait comporter de nos jours la succession d'étages suivante : Berriasien, Valanginien, Hauterivien, Urgonien, Rhodanien, Aptien, Albien.

Par rapport à celle qui est d'usage de nos jours, cette séquence comporte deux intrus (Urgonien, Rhodanien) et un absent (Barrémien).

D'autre part, l'extension temporelle qui est aujourd'hui donnée à l'Aptien ne correspond pas à son acception originelle.

Compte tenu de l'usage qui a prévalu, et tout en déplorant qu'il ait souvent résulté d'erreurs d'interprétation, du non respect des règles et/ou du dogmatisme de certaines grandes figures de la géologie, il ne paraît pas réaliste de demander aujourd'hui de revenir aux origines pour ce qui est de l'Urgonien et du Rhodanien. Mais pour ce qui est de l'Aptien, en fonction de nos travaux récents sur les stratotypes (Moullade *et al.*, 2009), nous suggérons une démarche qui devrait simplifier quelque peu l'imbroglio actuel et qui comporte les propositions suivantes :

1. restreindre l'acception de l'Aptien à la conception originelle de d'Orbigny (1840), soit la formation des 'Marnes d'Apt' (cf. Renevier, 1854), ce qui revient à en éliminer la 'formation de La Bédoule' et le 'niveau de Clansayes',

2. supprimer le vocable de Gargasien, devenu *de facto* synonyme plus récent de l'Aptien ainsi redéfini,

3. replacer dans l'Albien le 'niveau de Clansayes' (qu'il soit reconnu ou non comme un sous-étage à part entière - le Clansayesien),

4. ériger au rang d'étage le Bédoulien. Initialement conçu comme un sous-étage (qui aurait du en fait laisser la place au Rhodanien si la règle de priorité avait été appliquée), cet étage Bédoulien prend place entre le Barrémien et l'Aptien *s.s.*

Notre proposition s'assortit enfin de définitions des limites Barrémien-Bédoulien, Bédoulien-Aptien (*s.s.*) et Aptien (*s.s.*)-Albien qui prennent mieux en compte les critères litho-stratigraphiques et paléontologiques historiques, et de suggestions concernant des G.S.S.P. (Global Boundary Stratotype Sections and Points) potentiels.

Review and Modifying of Previous Microfossils Studies in Mobarak Formation, Alborz Basin, North of Iran

Hossein Mosaddegh, Mehrdad Sardarabadi, Ali Kashfi

Precise microfossils studies are carried out in Carboniferous succession in Alborz Basin (Mobarak Formation), North of Iran. In this study have been studied Foraminifera, Calcareous Algae and Conodonts in central and eastern Alborz Basin. The age range obtained in central Alborz Basin (Aru, Jaban ...) is coincide with Middle Tournaisian to Early Visean (MFZ1? to MFZ9). Toward to northeast of Alborz Basin(Gaduk section), the Mobarak Formation has been dated as Tournaisian to Early Visean (MFZ1 to MFZ10) by means of foraminifera (*e.g.* Uralodiscus sp.). Whereas, in the eastern Alborz (Balast,Kiasar,Touyeh-Rudbar,Nowdeh,...) based on conodonts (*e.g.* Gnathodus bilineatus, Mestognathodus beckmanni) and foraminifera (*e.g.* Howchinia sp.) studies the recorded age is Tournaisian to Middle/Late? Visean (MFZ1 to MFZ11?). In contrary of recent published report (Brenckle, et al, 2009) that indicated that the top of Mobarak Formation becomes increasingly older across the Alborz to the southeast, this study clearly shows that the top of the Mobarak Formation becomes younger in an easterly direction across the Alborz Mountains in opposition with dominant background. Generally, this study provided a better understanding of Chronostratigraphy in Carboniferous strata of Alborz Basin.

Using Geochronological Tools to Unravel the Timing of Three Extinctions: Examples from the Permian and Triassic

Roland Mundil

Severe mass extinctions occurred several times during the Phanerozoic. High-resolution geochronology with an age resolution at the permil level showed that the extinction pulses were geologically short (100 ka or shorter) and suggest that, in some cases, there is a causal link between continental-scale, short-term volcanic events (Large Igneous Provinces – LIPs) and global environmental crises (1, 2). Synchroneity with LIPs has been shown for three of the 'big five' extinctions (3), namely the end-Permian extinction coinciding with Siberian Trap volcanism, the end-Triassic extinction with Central Atlantic Magmatic Province volcanism and the end-Cretaceous with Deccan Trap volcanism (4). The end-Guadalupian (end Middle Permian, ca 260 Ma) biotic crisis has traditionally not been included in the 'big five' mass extinctions, possibly because of its close proximity in time to the end-Permian event, although its magnitude (in terms of the total extinction rate) is comparable to the three most severe extinctions (end-Ordovician, end-Permian, end-Cretaceous) (3, 5). As a result, research of the end-Guadalupian event has so far been neglected and its timing as well as the temporal relation to the Emeishan LIP in western China is as yet poorly studied. Geochronological data are so far mostly based on ambiguous 40Ar/39Ar analyses of commonly altered basaltic products (6, 7) and U-Pb zircon analyses on felsic products (volcanic intercalations, intrusions, dykes) using micro-beam techniques that typically result in radio-isotopic ages with percent-level uncertainty, and thus insufficient for high-resolution correlations of events (8, 9). No precise and accurate radio-isotopic data exist from this time period so that evolutionary events (extinction and recovery) on land and in the ocean are notoriously difficult to correlate though biostratigraphic records are available from numerous sedimentary archives. In addition to volcanic ashes within marine deposits in the tethyan realm, the Bowen and Sydney Basins in eastern Australia, filled with terrestrial sediments of late Paleozoic to early Mesozoic age are intercalated with numerous volcaniclastic beds (10). New U-Pb (CA-TIMS) zircon ages for several tuffs interbedded within the sediments allows correlations with different parts of the world. Currently, these correlations mostly depend on carbon-isotope records as well as biostratigraphy and lithostratigraphy that are deemed unsuitable for constructing high-resolution chronostratigraphic framework in absence of robust and precise radio-isotopic ages. The new precise and accurate data presented here are aimed at integrating calibrated records from different parts of the world in order to establish the timing and mode of extinction events and recovery.

Recently, geochronological studies where instrumental in constraining the age and timing of the Permian-Triassic extinction which is considered the most severe extinction in Phanerozoic times (11). These studies also suggest a causal link between the Siberian Trap volcanism and the mass extinction and illustrate the challenge of integrating geochronological data obtained from different isotopic systems. The lack of U bearing phases in most of the rocks

erupted and intruded during LIP events makes the application of K-Ar (40Ar/39Ar) analyses the obvious choice and most of the high-precision ages on the Siberian Trap volcanism are from that system (2, 12, 13). On the other hand, most radio-isotopic ages constraining the age and tempo of the mass extinction in marine sediments are on felsic airborne tuffs that contain accessory zircon – and thus the U-Pb has traditionally been the method of choice. Although both methods are essentially capable of achieving 0.1% level analytical precision, integrating ages from the 40Ar/39Ar system has proven difficult because of the relatively large uncertainty that is associated with the 40K decay constant and complications obtaining accurate ages of the natural standards that are used as fluence monitors for 40Ar/39Ar geochronology (partly because of the poorly constrained 40K decay constant). Recent advances in crosscalibrating these two major geochronometric clocks, however, now allow testing the synchroneity of events much significantly enhanced confidence (14-16). It is now clear, that the main pulse of the extinction at the end of the Permian essentially coincides with the main activity of the Siberian trap volcanism at ca 252 Ma. Recent high-resolution U-Pb zircon analyses on ashes within Early Triassic marine deposits constrain the perturbations in ocean chemistry and restrict large excursion recorded by $\delta^{13}C$ to a surprisingly short time scale (17, 18). New 40Ar/39Ar analyses on late products of the Siberian Trap volcanism that document Early Triassic activity may potentially be linked to the changes in ocean chemistry. To test this hypothesis, Ca isotope analyses have. Recent work also strongly suggests that there is a causal link between the CAMP (Central Atlantic Magmatic Province) LIP and the Tr-J extinction, mainly based on U-Pb zircon ages of ca 201 Ma from volcanic ashes within marine sediments and 40Ar/39Ar ages (bias corrected to 201 Ma) and recently also U-Pb ages from CAMP products (19-22).

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The Danian-Selandian boundary in the Pricaspian region from nannoplankton and dinocysts

Vladimir Musatov, Olga Vasilyeva

The Zumaia section in Spain was accepted as a new stratotype of the Selandian, the Danian/Zelandian type boundary (Proposed Global Stratotype…, 2007). The Danian/Selandian boundary turned out to occur stratigraphically higher than the conventionally specified one by ~ 774 thousand years (relative to the top of the magnetochrone 27n); that has called for the necessity of its substantiation in Russia's sections.

The Zumaia section in Spain penetrates bathyal sediments; it has been described from plankton carbonate groups. O. Varol's (1989) zonal chart based on nannoplankton proves to be the best tool for dividing that interval. The base of the red marls in the Zumaia section lies close to the base of the NTp8b zone from O.Varol's scale (the top of the NP4 zone) and practically coincides with the second radiation of the Fasciculithus genus (25cm below the boundary). The authors conclude that the Danian/Selandian boundary in the Zumaia is associated with completion of the Danian sedimentation cycle (limestones of the Aitzgori Fm.), drastic fall of the sea level, extensive depositional break. Lithologically, the boundary coincides with the rock composition changes both, in Spain and in the historical stratotype. However, there are no direct paleontological markers for correlating the Danian/Selandian boundary in the Spanish Zumaia section and in the Danish historical stratotype. At the same time, stratotype sections of the Danian and the Selandian from Denmark have been described from the dinocysts (Hansen, 1977; Heilmann-Clausen, 1985).

The Pricaspian region used to be a major Paleogene epicontinental marine basin in the Peri-Thetys northern margin; both, organic-walled and carbonate plankton associations used to form there during the Cenozoic. Therefore, the Paleogene sections from the Pricaspian might prove to be critical for correlating sections from Northern Europe and Tethys.

The Lower Danian (Algai Fm) in the Pricaspian region is composed of marls, limestones and carbonate clays (35m). The section is described from nannoplankton complexes from the zones NP2 *Cruciplacolithus tenuis* and NP3

Chiasmoilthus danicus. The upper Danian (Tsyganovka Fm) is composed of highly calcareous, glauconite-saturated sequence of mixed sand-clay-calcareous composition (36m). The Selandian (Syzran Fm) is subdivided into two subsuites: the Lower Syzran Subfm is composed of dark gray siliceous (gaize-like) low-calcareous clays (80m). The Upper Syzran Subfm is composed of siliceous sandy and low-calcareous clays with aleurolite and sandstone intercalations (70m).

The top of the Cyganovka Fm is described from the dinocyst D3a *Alterbidinium circulum* zone. The Lower Syzran Subfm is represented by the D3b *Cerodinium depressum* zone. This interval belongs to the nannoplankton NP4 *Ellipsolithus macellus* (*Coccolithus robustus*) zone. The Upper Syzran Subformation is referred to the *Cerodinium depressum* zone and the nannoplankton NP5 *Fasciculithus tympaniformis* zone. In the nannoplankton and dinocyst complexes within the boundary Danian/Selandian interval, substantial changes take place; those are shown as a sequence of biotic events.

Dinocysts. (1) FO *Spinidinium densispinatum* (abundance) in the upper part of the Cyganovka Fm. (2) LO *Alterbidinium circulum* in the top of the Cyganovka Fm. (3) FO *Cerodinium depressum* in the middle part of the Lower Syzran Subfm. (4) LO *Spinidinium densispinatum* (abundance) in the lower half of the Lower Syzran Subfm. (5) LO *Spinidinium densispinatum*, FO *Impagidinium* sp.1 Heilm.-Claus. in the top of the Lower Syzran Subfm. (6) FO *Isabelidinium*? *viborgense* in the upper part of the Upper Syzran Subfm.

Nannoplankton. (1) FRO *Neochiastizygus perfectus* (first rare occurrences) in the base of the Cyganovka subfm. (2) FO *Sphenolitus primus* in the middle part of the Cyganovka Fm. (3) FO *Chiasmolithus edentulus* in the upper part of the Cyganovka Fm. (4) FCO of *Neochiastozygus perfectus* (common/frequent occurrences) in the base of the Lower Syzran subfm. (5) FO *Fasciculithus magnus*, *F. ulii* (rare occurrences) in the upper part of the Lower Syzran subfm. (6) FO of *Fasciculithus billii*, (7) FO of *Fasciculithus tympaniformis* in the base of the Upper Syzran subfm.

The sequence of events from dinocysts makes it possible to correlate the Pricaspian sections with the boundary Danian/Selandian interval from Denmark. The last appearance (LO) of *Alterbidinium circulum* is known from the top of the Danian limestones in the stratotype of the Danian stage (Heilmann-Clausen C., 1985), which allows to correlate this event with the top of the Cyganovka Fm from the Pricaspian region. Sequential appearance of the species *Cerodinium depressum*, *Impagidinium* sp. 1 Heilm.-Claus., *Isabelidinium*? *viborgense* occurs in the base of the Kerteminde Fm. in Denmark (Heilmann-Clausen C., 1985). The LAD *Spinidinium densispinatum* event is recorded in the Lellinge Greensand sequence. In accord with those biomarkers, the Syzrank Fm from the North Pricaspian region correlates with the Selandian from Denmark.

The first common appearance of nannoplankton of the species *Neochiastozygus perfectus* in the base of the Lower Syzran subfm indicates affiliation of that interval to a part of the NTp7B zone in O.Varol's scale. Coccolithophore appearance of the *Fasciculithus* (*F. billii*, *F. tympaniformis*) genus in the base of the Upper Syzran subfm in the Pricaspian region corresponds to the beginning of the fasciculite second radiation and the NTp9 zone in O. Varol's scale (1989). That stratigraphic level is very close to the

Danian/Selandian boundary accepted in the new stratotype section of Zumaia in Spain (Proposed Global Stratotype…, 2007).

Thus, changes in the compositions of microplankton communities in the Pricaspian region and correlation of bioevents from dinocysts and nannoplankton make it possible to state that with the new Selandian stratotype acceptance, the boundary between the Danian and the Selandian stages is placed substantially higher than the end of the Danian carbonate sedimentation cycle in its historical stratotype. Upon comparison with the Zumaia section, the position of the Danian/Selandian boundary in the Pricaspian might be specified close to the base of the Upper Syzran subfm, *i.e.* in the middle of the siliceous-terrigenous sedimentation cycle. At the same time, correlation with the historical stratotype from Denmark is suggestive of marking the Danian/Selandian boundary considerably below – in the base of the Lower Syzran subfm. We believe such position of the boundary reflects the natural-historic stages and the sedimentation cycles changes of the large epicontinental Pricaspian basin from northern Peri-Tethys.

A high precision 40Ar/39Ar tephrochronology for the Sancy volcano (French Massif Central): implications for the Middle Pleistocene volcanic markers in South-East Europe

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The Sancy stratovolcano lies on the south-eastern flank of the Mont-Dore stratovolcano just north of the Mio-Pleistocene Cézallier volcanic area in the central part of the French Massif Central (FMC). These two stratovolcanoes constitute the 'Mont-Dore Massif ' which covers 500km^2 and produced a volume of volcanic products exceeding 70km^3 between 3 Ma and 300 ka. The Mont–Dore stopped is activity about 1.6 Ma ago. After a 500 ka long quiet period the Sancy *s.s.* became the most active French volcano during the late Early and Middle Pleistocene. The Sancy activity ceased around 200 ka (Cantagrel et Baubron, 1983) just before the beginning of the Chaîne des Puys volcanic activity.

Tephras originating from the Mont-Dore massif and the Sancy, in particular, are recognized in several middle Pleistocene maars sedimentary fillings in the Velay region (*e.g.* Bouchet, Alleret maar, Roger *et al.*, 2000; Nomade *et al.*, 2010) and even in Northern Italy (Pianico paleolake; Brauer *et al.*, 2007, Roulleau *et al.*, 2009). These ash layers constitute valuable chronological markers if they can be precisely dated or correlated to well-dated proximal Pyroclastic Ash flows (PA). Unfortunately, available geochronological studies, mainly K/Ar (*e.g.* Cantagrel and Baubron, 1983) and the three ^{40}Ar/^{39}Ar ages published 20 years ago (*e.g.* Féraud *et al.*, 1990) limits any precise correlation of these distal ash deposits with the numerous pyroclasticdeposits recognized in the Sancy volcanic pile. In order to improve our knowledge of this stratovolcano and build the first tephrochronological temporal framework of its

explosive activity we collected in July 2008, thirteen PA covering the entire proximal volcanic pile.

We will present in this contribution the $^{40}Ar/^{39}Ar$ single grain laser dating of these samples. Depending on the xenocrystic contamination, between 9 to 23 single sanidine grain were analyzed using a CO_2 laserprobe. Argon isotopes were measured using a VG 5400 mass spectrometer equipped with a single ion counter (LSCE $^{40}Ar/^{39}Ar$ laboratory in Gif-sur-Yvette). Ages we obtained are relative to the ACS-2 standard with an age of 1.193 Ma (Nomade *et al.*, 2004) and all uncertainties are reported below at 95% confidence. $^{40}Ar/^{39}Ar$ ages obtained for the 13 PA range from 1101 ± 6 ka (2s level, internal uncertainty) (PA Vendeix haut) to 393 ± 8 ka (2s level, internal uncertainty) (PA Barbier). The effects of xenocrystic contamination is mainly found in the oldest samples and manifested by complex age distributions. Four main periods of explosive activity, lasting about 90 to 140 ka each, are recognized and named Sancy 1 (*S.1*) to Sancy 4 (*S.4*). *S.1* corresponds to the beginning of the explosive activity between 1101 ka and 1010 ka; *S.2*, from 818 to 685 ka and *S.3*, ranging from 640 to 540 ka. The youngest pyroclastic episode, *S.4* around 390 ka is only represented by one PA in the proximal volcanic pile. We did not find any PA that could correspond to the ash layer found in the Bouchet and Praclaux maars and dated at 281 ± 10 ka (Roger *et al.*, (1999)). However, we associate this ash to the youngest *S.4* episode. Based on the mineralogy and $^{40}Ar/^{39}Ar$ ages we obtained in several tephra layers found in the Alleret Maar we can now with confidence say that this 40.6 m thick Middle Pleistocene lacustrine sequence (60km south east of the Sancy) records numerous PA that belong to the *S.2* episode (c.a. 720 to 685 ka) and at least one ash layer that belongs to the *S.3* episode (ca. 575 ± 12ka).

This radio-isotopic study of 13 PA combined with the one in the Alleret maars (Nomade *et al.*, 2010) are the first steps toward a late Early to Middle Pleistocene chronological framework based on the Sancy stratovolcano's PA.

Stratigraphical and sedimentological synthesis of the southern subalpine red molassic series

Fabien Pellen, Serge Ferry

The Tertiary molassic basin of southeast France contains two molassic series. This study aims to better understand the relations between these two series and their deposition mechanisms in order to redraw the river system from the Rupelian to the Oligocene/Miocene boundary. Field observations allowed the following interpretations:

The two molassic series work as two different systems separated by a tectonic event linked to the Alpine orogeny. The first red molasse fills the valleys created by regional tectonics and then spreads on the South-East of France as fluvio-lacustrine systems. The lower part of this first series develops in two disconnected collectors. This study shows that the main collector called the 'Sillon de Barrême' (South-East of France), is characterised by a northward flow. This basin looks like a 'piggy-back' basin transported by the 'Nappe de Digne' overlapping. The secondary collector follows the 'Nappe de Digne'

overlapping and turns off southwestward before pouring into the Manosque-Forcalquier basin. The second red molasse works as a huge alluvial cone with a westward development. A release, which could be the main one, is preserved in the north of the 'Front Ventoux-Lure'. It spreads in the Manosque basin as fluvio-lacustrine facies.

[VF] Synthèse stratigraphique et sédimentologique des Molasses Rouges subalpines méridionales

Le bassin molassique Tertiaire du Sud-Est de la France comporte deux séries molassiques. Cette étude a pour but d'expliquer les relations entres ces deux séries ainsi que leurs modes de fonctionnement afin de mieux comprendre et de retracer le réseau hydrographique du Rupélien à la limite Oligocène/Miocène. L'étude est basée sur de nombreuses observations de terrain.

Ces observations de terrain montrent que les deux séries molassiques fonctionnent comme deux systèmes différents et sont séparées par un épisode tectonique. La molasse rouge 1 remplit les vallées créées par la tectonique régionale dans un premier temps, et, dans un deuxième temps, se répand sur le Sud-Est de la France sous la forme d'un réseau fluvio-lacustre. La partie basale de cette première série se développe en deux collecteurs déconnectés l'un de l'autre. Cette étude montre que le collecteur principal, le sillon de Barrême (Sud-Est de la France), présente un écoulement nord et semble fonctionner comme un bassin transporté (piggy-back) par le chevauchement de la nappe de Digne. Par ailleurs, on constate que le collecteur secondaire suit le chevauchement de la Nappe de Digne et bifurque pour se jeter dans le bassin de Manosque-Forcalquier.

La molasse rouge 2 fonctionne comme un cône alluvial géant avec un développement vers l'Ouest. Un exutoire, pouvant être l'exutoire principal est conservé au nord du front Ventoux-Lure. La seconde molasse rouge se répand dans le bassin de Manosque sous faciès fluvio-lacustre.

The use of 'European' ostracode faunas in testing Silurian stratigraphy and palaeogeography

Vincent Perrier, David J. Siveter, Tonu Meidla

The study of the stratigraphic and palaeogeographic distribution of different Silurian ostracodes species indicates that they may be of considerable interest to the Palaeozoic stratigraphy. This work, which focuses on the material of the 'European' province in the Upper Silurian, shows strong disparities in the distribution of different groups of ostracods depending on their lifestyle. The interpretation of the lifestyle of the Silurian forms is mainly based on the carapace morphology, the associated faunas and the depositional environments. Palaeocopid and 'podocopid' ostracods, considered as benthic, allow to establish a precise biostratigraphy for shallow marine environments and regions close to each other (*e.g.* plates Baltica, Avalonia, Acadia). On the other side, myodocopid ostracods, considered as pelagic, are excellent

biostratigraphic markers on a large scale and mostly in outer shelf environments. The distribution results obtained for the upper Silurian are comparable to the distributional data of recent benthic and pelagic ostracods faunas. These data also show that during the upper Silurian the plates Baltica, Avalonia and Acadia were probably very close to each other and that the Rheic Ocean was a major oceanic barrier for the benthic faunas.

[VF]

L'étude de la distribution stratigraphique et paléogéographique de différentes espèces d'ostracodes siluriens révèle que ces derniers peuvent être d'un intérêt considérable pour la stratigraphie du Paléozoïque. Ce travail, centré sur le matériel de la province 'Européenne' durant le Silurien supérieur, montre de grandes disparités dans la distribution des différents groupes d'ostracodes en fonction de leur mode de vie. L'interprétation du mode de vie des formes siluriennes est principalement basée sur la morphologie des carapaces, les faunes associées et les environnements de dépôts. Les ostracodes palaeocopes et 'podocopes', considérés comme benthiques, permettent d'établir une biostratigraphie précise pour des environnements peu profonds et des régions assez proches les unes des autres (ex. plaques Baltica, Avalonia, Acadia). Quant à eux, les ostracodes myodocopes, considérés comme pélagiques, sont de très bons marqueurs biostratigraphiques à grande échelle et principalement dans les environnements hors plateau continental. Les résultats de distribution obtenus pour le Silurien supérieur sont comparables aux données de distribution des faunes d'ostracodes benthiques et pélagiques actuels. Ces données montrent aussi, que durant le Silurien supérieur, les plaques Baltica, Avalonia et Acadia étaient probablement très proches les unes des autres et que l'Océan Rheic était une barrière océanique majeure pour les faunes benthiques.

Silurian pelagic ostracods as a biostratigraphic tool

Vincent Perrier, Jean Vannier, David J. Siveter

The Silurian myodocopes (bolbozoids, cypridinids and entomozoids) are atypical and poorly documented ostracods, usually much larger (up to 2 cm long) than the average Lower Palaeozoic ostracods. They are present in many European localities during the Late Silurian and show a great numerical abundance and a relatively high diversity. We present here a revision of the different groups.

Some species such as *Parabolbozoe bohemica* or *Richteria migrans* (Perrier *et al.* 2007) have a wide palaeogeographic distribution (transoceanic distribution). This widespread distribution added to the facies where they were deposited (black shales), their recurrent pelagic faunal associates, and several morphological features of functional significance (rostrum and caudal process) led us to envisage a pelagic lifestyle for these faunas, an assumption formulated in the 1980's (*e.g.* Siveter, 1984; Siveter *et al.* 1991; Vannier and Abe, 1992) which we are testing here.

The abundant 3D-preserved material shows that the anterodorsal bulb of bolbozoids was an unornamented and virtually hemispherical structure. The bulb seems to have housed the lateral eyes as well as a part of the swimming antenna (*i.e.* A2 protopod). An unornamented area is present in cypridinids and *R. migrans*, these groups probably also possessed a lateral eye. The rostral complex (*e.g.* rostrum, rostral incisure) of bolbozoids and cypridinids is identical to that of recent swimming myodocopes. The strengthening of the rostrum and the rounded shape of the notch led us to think that the Silurian myodocopes were swimmers using their second antennae (A2) in the same way as their recent representatives. In conclusion, our data provide precise details on the possible lifestyle of Silurian myodocopes, interpreted here as swimmers (powerful antennae), living above the dysoxic bottom (hyperbenthic niches), having scavenging habits (assemblages in nodules) and possibly visually adapted to dim-light environments (eye hypertrophy, bioluminescence). Environmental changes (oxygenation) probably played a key role in the Myodocopes ecological shift of during the Silurian.

The palaeogeographic distribution and stratigraphic range of several species show that Silurian myodocopes can be used as marker fossil for different levels of the Late Silurian of Europe and Central Asia.

[VF] Les ostracodes pélagiques siluriens, un outil biostratigraphique

Les myodocopes siluriens (bolbozoïdés, cypridinidés et entomozoïdés) sont des ostracodes atypiques et peu connus, généralement beaucoup plus grands (jusqu'à 2 cm) que la moyenne des formes paléozoïques. Durant le Silurien supérieur, ils sont présents dans de nombreuses localités d'Europe où ils sont très abondants et diversifiés. Nous présentons ici une révision des différents groupes.

Certaines espèces tels que *Parabolbozoe bohemica* ou *Richteria migrans* (Perrier *et al.* 2007) ont une distribution paléogéographique étendue (transocéanique). Ce mode de distribution ajouté au milieu de dépôt (black shales), aux faunes associés (principalement pélagiques) et à plusieurs caractéristiques morphologiques (ex : rostre et processus caudal) nous a conduit à envisager un mode de vie pélagique pour ces faunes. Nous testons ici cette hypothèse formulée dans les années 1980 (ex : Siveter, 1984; Siveter *et al.* 1991).

L'abondant matériel conservé en 3D montre que le bulbe des bolbozoïdés était une structure hémisphérique dépourvue d'ornementation. Ce bulbe semble avoir abrité les yeux latéraux ainsi que d'une partie de l'antenne natatoire (protopode de A2). Une zone sans ornementation est aussi présente chez les cypridinidés et *R. migrans*, ces groupes possédaient aussi probablement un œil latéral. Le complexe rostral (rostre, incision rostrale) des bolbozoïdés et des cypridinidés est identique à celui des myodocopes nageurs actuels. Cela nous a conduits à penser que les myodocopes siluriens sont des formes nageuses utilisant leur seconde antenne (A2) de la même façon que leurs représentants actuels.

En conclusion, nos données fournissent des détails précis sur le mode de vie possible des myodocopes siluriens, interprété ici comme des formes nageuses (puissantes antennes), vivant au-dessus du fond dysoxique (niches

hyperbenthiques), ayant des habitudes de nécrophages (assemblages *in situ*) et peut-être visuellement adapté à de faible conditions lumineuses (hypertrophie de l'œil, bioluminescence). Les changements environnementaux (oxygénation) ont probablement joué un rôle clé dans le changement de milieu des Myodocopes au Silurien.

La distribution paléogéographique et l'extension stratigraphique de plusieurs espèces montrent que les myodocopes siluriens peuvent être utilisés comme marqueurs fossiles pour différents niveaux du Silurien supérieur d'Europe et d'Asie centrale.

Variations in calcareous nannofossil productivity between the southern and northern Tethyan margins during the mid Aptian-Early Albian interval: discrepancies between fluxes and relative abundance data

Camille Peybernes, Fabienne Giraud, Etienne Jaillard, Emmanuel Robert

In terms of global change, the mid Aptian to Early Albian interval has been identified as a period of 1) eustatic sea-level rise, 2) oceanic accretion with the opening of the Western Mediterranean sea and the rifting of the Central Atlantic Ocean, 3) substantial climatic changes, and 4) major changes in the carbonate production. In particular, a warming episode was recognized between the mid-Late Aptian and is associated with increased water cycling, terrigenous influx and eutrophication on the sub-tropical/tropical shelves, leading to major platform demise (Föllmi *et al.*, 1994; Weissert *et al.*, 1998). However, Heldt *et al.* (2009), focusing on the Tunisian carbonate platform show the absence of widespread platform drowning during this time possibly linked to non eutrophication of this platform located within the broad arid climate belt of Chumakov *et al.* (1995).

In the pelagic realm, the trophic conditions prevailing in sea surface can be depicted by the quantification of calcareous nannofossil fluxes and assemblages. Actually, nannofossil quantitative studies including absolute abundance and assemblages have been performed in the northern Tethyan margin (Vocontian basin sections) on the Kilian (Late Aptian) and the Paquier (OAE 1b, Early Albian) levels, respectively, and in the southern Tethyan margin (DSDP site 545, Mazagan Plateau) on the OAE 1b (Herrle, 2002).

In the southern Tethyan margin, the Agadir basin (south of Morocco) is characterized by continuous and well-dated sections for the Aptian-Early Albian interval. This basin opened on Atlantic to the west presents a proximal to distal transect of different paleoenvironments for this interval. During Aptian to Albian times, the Agadir Basin was in the tropical-equatorial hot arid belt of Chumakov *et al.* (1995). A quantitative study of calcareous nannofossil assemblages based on three sections of this basin was performed. A comparison of mean calcareous nannofossil fluxes and mean relative abundances of meso-eutrophic taxa between the Agadir basin, Mazagan

Plateau and the Vocontian basin shows that the nannofossils fluxes and the relative abundance of meso-eutrophic taxa are not correlated. During the Early Albian, the northern Tethyan margin is characterized by nannofossil fluxes four times higher than the upwelling-submitted Mazagan Plateau, and height times higher than the Agadir basin. However, considering the mean relative abundance of the meso-eutrophic taxa, they are in the same range for the Mazagan plateau and the Vocontian basin. For the Late Aptian-Early Albian interval, the nannofossil fluxes of the Northern Tethyan margin are around seven times higher than those of the Agadir basin. Thus, the southern Tethyan margin is characterized by a lower nannofossil primary productivity with respect to the northern Tethyan margin. These data seem corroborate the results of Heldt *et al.* (2009) showing that trophic conditions in sea surface of the southern Tethyan margin were lower probably due to the presence of an arid climatic belt.

Preliminary biostratigraphical data from Mississippian calcareous microorganisms (foraminifers and calcareous algae) of the Derbyshire platform (United Kingdom)

Lucie Pille, Markus Aretz, Daniel Vachard

The Derbyshire platform (Central England) formed along the northern border of the London-Brabant Massif (LMB) is bordered by the Edale Basin in the North and the Widmerpool Gulf in the South and West. In Derbyshire, the represented stratigraphical interval goes from Courceyan to Arnsbergian. The maximum thickness of layers dated from Dinantian is 1900 meters in Eyam. The oldest rocks of the platform are then Courceyan in age and known from boreholes but only Holkerian to Brigantian carbonates are well exposed in numerous valleys and quarries in the Bakewell-Castelton region.

The classical outcrops of Southern Belgium for which detailed data and biozonations on carbonate microorganisms are available (Conil *et al.* 1991, Poty *et al.* 2006) are situated on the opposite side of the LMB. Carbonate deposition continued on the Derbyshire platform longer than in Southern Belgium and thus this region may be used to complement the biostratigraphic scheme of Western-Central Europe and to evaluate the importance of the LMB as palaeobiogeographic barrier.

Because of the well-established lithostratigraphic correlations (Cossey *et al.* 2004), the important thickness and the continuity of the strata, especially in the upper Brigantian, which is lacking in many sections in the UK, a detailed study of the carbonate microfossils from these outcrops is of high interest for high-resolution biostratigraphy and palaeobiogeographic relations of this part of the Palaeo-Tethys.

In England, the lower Asbian (Cf6α=MFZ13) is characterized by the appearance of *Asperodiscus* and *Nodasperodiscus*, *Vissariotaxis compressa* and *Endothyra spira*. Archaediscus stage angulatus prevail increasingly and the large species appear. The biozone Cf6β (MFZ13) characterized by

Neoarchaediscus incertus is not known in England. According to Strank (1981), in England, the upper Asbian starts with an increasing abundance of several taxa (Cribrostomum, Koskinobigenerina, Endostaffella, Pseudoendothyra, 'Millerella', Endothyranopsis, Plectogyranopsis). It is characterized by the appearance of Euxinita, Asteroarchaediscus, Howchinia bradyana, Biseriella, Climacammina, Cribrospira panderi, Sacamminopsis and Bibradya. There is also a development of large Archaediscus. Brigantian is characterized by the increasing abundance of Asteroarchaediscus and the appearance of Janischewskina, Loeblichia parammonoides and Warnantella.

Here we present results from two studied areas: the Millers Dale Station Quarry as part of the transect Wye Valley-Cressbrook Dale and the Horseshoe quarry. The transect Wye Valley-Cressbrook Dale is located in a national park, the 'Peak District National Park', the outcrops are mainly along a touristic trail, 'the longstone biodiversity Trail'. The interest of this succession of outcrops is an almost continuous nine kilometer long section showing beds dated from Lower Carboniferous. In the Millers Dale Station Quarry the Asbian-Brigantian boundary is placed between pale, thick-bedded carbonates of the Bee Low Limestones and the dark, thin-bededed carbonates of the 'Station Quarry beds'. The biodiversity of Millers Dale Station Quarry is made of an association including foraminifers such as Bibradya, Archaediscus karreri, A. moelleri, Bradyina, Cribrospira, Globoendothyra, Tetrataxis, Forschia, Endothyranopsis and Eostaffella and algae sensu lato such as Ungdarella, Stacheoides, Fourstonella and some undetermined Dasycladales.

The Horseshoe Quarry, also called 'Furness Quarry', is situated south of Eyam. It exposes more than 150 meters of Brigantian strata. At the base of the section, beds are massive to metre thick (lower section). Bed thickness decreases up-section, and grades into thin- to medium-bedded limestones to argillaceous limestones alternating with shales (upper section). Cherts occur in the upper part. Microfacies analyses reveal a dominance of bioclastic wackestones.

Foraminifers and calcareous algae have been observed throughout the succession. However, the base of the lower section shows a low diversity among the foraminifers and calcareous algae, but higher up the diversity increases. Overall, the organisms indicate the lower euphotic zone.

Archaediscidae and Eostaffellidae are the most represented families with the genera Archaediscus and Eostaffella. The most frequent taxa are then Archaediscus karreri and Eostaffella spp. but also Endothyra ex gr. similis, Endostaffella spp., and Endothyranopsis crassa.

Foraminifers as Howchinia, Endothyranopsis crassa, Archaediscus karreri and very advanced Eostaffella as well as the calcareous algae such as Frostereyella indicate for the upper section a Brigantian age. Some specimens of Eostaffella seem to be similar to Eostaffellina and Plectostaffella, which both are more common in the Serpukhovian. However, these Serpukhovian-like taxa have already been found in the Visean of England by Strank (1981) with Eostaffella ovoidea and Plectostaffella? spp. In the case of the Horseshoe Quarry, they confirm the close position of the Brigantian-Serpukhovian boundary, which is located not far above the top of the succession exposed in the quarry (Cossey *et al.* 2004).

Thus the preliminary data of these two sections confirm the key position of the Derbyshire platform for the biostratigraphic subdivision at least of the latest Viséan based on the bad record of this time slice in Southern Belgium and also by the observed transitional character of the faunas, with the appearance of Serpukhovian-stylised forms in the Viséan.

Early Ypresian microfossils, nannoplankton and stable isotopes in the Corbières (Aude, France) continental margin record

Claudius Pirkenseer, Etienne Steurbaut, Chris King, Robert Speijer

The Corbières Foreland Basin represents the southeastern-most extension of the Aquitanian Basin and is thus palaeogeographically related to the West-European Cenozoic Basin. During the Ypresian a succession of marine carbonates, marine marls, brackish marls to sandstones and subsequent fluvio-lacustrine sediments were deposited in the Corbières (Aude, France) area in several sequences.

The present study focuses on the middle and upper part of the neritic „Blue Marls' and overlying sandy marls and sandstones close to the village Pradelles-en-Val. 128 samples were collected in 1m intervals in order to document the early Eocene paleoenvironmental evolution of this succession through a quantitative analysis of the microfossil assemblages. Furthermore, we aim at identifying anomalous environmental conditions that might be associated with Early Eocene hyperthermals (Elmo- / ETM2- and X- / ETM3-event). In contrast to the Paleocene-Eocene thermal maximum, which has been recorded in deep-sea to non-marine depositional settings the ETM2 and ETM3, however, have until now only been demonstrated in deep-sea sequences, not in shelf deposits.

On the basis of the relative abundance of bioklasts (bryozoa, echinodermata) and characteristic Foraminifera groups larger than 250µm 12 faunal zones (FZ1-12) can be established. The lower half of the section is characterized by a strongly variable (1-70% plankton), but overall decreasing plankton/benthos-ratio. A last pronounced peak in plankton occurrence in association with the near disappearance of all larger faunal elements (except pteropods) and a change in the ostracod assemblage (*e.g.*, LO *Echinocythereis isabenana*, FO *Hermanites* cf. *paijenborchiana*) defines FZ5 ('Depleted-Zone').

The ostracod assemblages contain common shelf-dwelling genera, such as *Bairdoppilata*, *Echinocythereis*, *Hermanites*, *Horrificiella*, *Loxoconcha* and *Pterygocythereis* throughout the section in variable numbers. The speciation event within the Echinocythereis isabenana-aragonensis lineage is documented for the middle part of the section, thus taking place in the calcareous nannoplankton zone NP11. In total 24 ostracod taxa are recorded. The small species *Eopaijenborchella lomata*, *Eucytherura hyonensis*, *Krithe angusta*, *Loxoconcha subovata* and *L. tenuis* were not registered quantitatively.

Ostracod abundance is generally low during intervals with high ratio of planktonic foraminifera.

Based on characteristic species three ostracod assemblage zones can be separated. The top of the lowermost Zone (OZ-A) is defined by the last occurrence of Echinocythereis isabenana in sample CN25. Following the hiatus of FZ5 the *Grinioneis paijenborchiana*-Zone (OZ-B) ranges from sample CN31 to CN113b. Its uppermost part is subdivided into subzone OZ-B1, which is distinguished by the acme of the taxa *Krithe* aff. *londinensis* and *Echinocythereis aragonensis* and the highest diversity of the section (15 taxa). *Dameriacella sigillata* occurs only in the upper part of this subzone. The uppermost OZ-C shows a strong assemblage shift with the appearance of 5 previously not recorded taxa. *Horrificiella* aff. *lichenophora*, *Paracypris* sp. 2 and *Cytheridea* cf. *newburyensis* represent the most prominent species.

The most common species *Horrificiella aculeata* and *Bairdoppilata crebra*, range throughout the zone OZ-A to top OZ-B. Further long-ranging species include *Paracypris contracta*, *Loxococoncha subovata*, *Cytherella gamardensis*, *Pterygocythereis cornuta* and *Eucytherura hyonensis*. The latter two taxa display a more scattered distribution. *Krithe angusta* occurs last in FZ6 at the base of OZ-B. *Eopaijenborchella lomata* and *Eucytherura hyonensis* are both absent from FZ2. *Pterygocythereis cornuta* is not recorded from FZ10-11a.

The Pradelles section is marked by poorly preserved, low-diversity calcareous nannofossil associations, dominated by small Prinsiaceae (essentially *Toweius*) and *Coccolithus pelagicus*. The number of specimens fluctuates throughout the section, although remains always low (less than 15 specimens/field of view), pointing to a paleoenvironment, which was not very suitable for nannoplankton productivity and/or selective dissolution of coccoliths on the seafloor. Based on the co-occurrence of *Tribrachiatus orthostylus*, *Ellipsolithus macellus* and *Neochiastozygus rozenkrantzii*, in combination with the absence of *Discoaster lodoensis*, indicate calcareous nannofossil zone NP 11. *Blackites truncatus*, which is also recognized throughout the section, allows a more precise biostratigraphic positioning, within the upper part of NP 11. The occurrences of planktonic foraminifera *Morozovella subbotinae* and several *Acarinina* taxa (lower part of the section) are in agreement with this biostratigraphic position (E4), as are the larger foraminifera *Nummulites globulus* and *Assilina leymeriei* (SBZ8; uppermost part of the section).

Towards the top of the section, an upward-shallowing trend is recorded by the increase in clastic input and macrofossils such as larger foraminifera, cerithid gastropoda and bryozoa as well as the near disappearance of planktonic foraminifera. The species record of calacareous nannoplankton refers to fully marine paleoenvironments with normal salinity as shown by the low % of Braarudosphaera bigelowii, although in the vicinity of the coast. This is evidenced by the relatively high frequency of Pontosphaera spp and reworked Cretaceous material (10-60%).

Bulk sediment isotopic values for $<\delta^{13}C$ and $\delta^{18}O$ were obtained for the whole section. Values alternate between -1.98 to -0.45 ‰ $\delta^{13}C$ and -7.22 to< -5.15 ‰ $\delta^{18}O$ V-PDB. Clean specimens of the ostracod species Horrificiella aculeata provided values between -5.88 to -3.76 ‰ $\delta^{13}C$ and -3.89 to -2.35 ‰ $\delta^{18}O$ V-PDB.

^{13}C values are recorded in mid FZ2, FZ5, FZ8 and FZ12-13. Lower $\delta^{18}O$ are registered in FZ1-3, FZ5, FZ9 and FZ12-13. From FZ7 onwards the variability of values in the normal and 3-averaged curve increases.

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Stratigraphic distribution of chondrichthyans and conodonts from the Middle Triassic of the Iberian ranges (Spain)

Cristina Pla, Pablo Plasencia, Ana Marquez-Aliaga, Hector Botella

The Triassic epicontinental shallow marine sediments of the Iberian Peninsula form part of the westernmost area of the Tethys margin. These sediments consist of three carbonate units separated by two mudstone-evaporite and represent three transgressive-regressive main cycles than onlapped the western margins of the Paleozoic Iberian Massif. The two lower carbonate units correspond to the Muschelkalk facies and have been dated as Anisian and Ladinian based on ammonoids, bivalves, foraminifera, conodonts and pollen/spore associations. Nevertheless, the Triassic fossil record of Spain area is considered scarce.

Recently, large collections of vertebrate microremains (mainly isolated teeth and scales) and conodonts have been retrieved during the dissolution, with 10 per cent acetic acid, of 45 fossiliferous samples from carbonate levels of eight geological sections (Calanda, Libros, Henarejos, Moya, Jarafuel, Macastre, Bugarra and Montserrat) located at the meridional area of the Iberian Range (Teruel, Cuenca and Valencia provinces, Spain). The materials studied belong to the Muschelkalk facies and are represented by the upper one dolomite unit, the Cañete Formation. The faunal succession of bivalves and ammonoids of these sections has been extensively studied during last decades, providing solid information which turns this area into an exceptional region where other fossil groups can be considered in a broad biostratigraphycal and palaeoecological consideration.

The objective of this study is to present the stratigraphic distributions of chondrichthyans and conodonts taxa found in the sections cited above and evaluate the possibilities of chondrichthyan microremains as a biostratigraphical tool, comparing them with the well-known biostratigraphy of conodonts and ammonoids. Moreover, as during Triassic times the group of chondrichthyans underwent a rapid diversification, including the earliest neoselachian appearance, a well-established sequence is indispensable for the understanding of the evolution of the group. As Conodonts and fish microremains are usually found together, thus the first can be used as a biostratigraphic reference for the last ones.

Two species of conodonts have been found, and both belong to the Gondolellidae family: Pseudofurnishius murcianus Van den Boogaard 1966 and Sephardiella mungoensis (Diebel 1956).

The Chondrichthyan diversity in those sections was quite high and is composed by 6 well identified tooth-based species belonged to four families of the Hybodontoidea Superfamily Zangerld, 1981: Hybodontidae Owen 1846, Pseudodalatiidae Reif 1978, Homalodontidae Mutter 2007 and an unnamed family (sensu Rees 2008) represented by specimens assigned to the genus Lissodus.

Some of the species identified have been only found in the Iberian Peninsula; Pseudodalatias henarejensis Botella *et al.* 2009, Hybodus sp.1 and Hybodus sp.2. Other remains have been assigned to the homalodontids specie 'Polyacrodus' bucheri Cuny *et al.* 2008, which has only been found previously in the Anisian of North-Western Nevada (USA) and 'Polyacrodus' cf. contrarius Johns *et al.* 1997 currently know from the Ladinian and Carnian of British Columbia and the Ladinian of China. The widespread distributed specie Hybodus plicatilis Agassiz 1943 have also been found in the Iberian ranges. In addition, to these well-identified species, other less abundant teeth are preliminary assigned to the genus Lissodus and ?Vallisia. Together with teeth, abundant isolated scales occur. The stratigrapical occurrence of scales and teeth allows for a tentative association of some of them.

The presence of P. murcianus and S. mungoensis in the studied sections points out a Ladinian age for all the Chondrichthyan microremains found together.

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Sequence stratigraphic and biostratigraphic correlations in the Mississippian of Eurasia. From a local to a global stratigraphic pattern

Edouard Poty, Hance Luc, Aretz Markus

The biostratigraphy (mainly based on foraminifers and rugose corals) and the sequence stratigraphy of the European Mississippian have been recently revised (Poty *et al.*, 2006). The biozonation comprises respectively 16 foraminifer zones (MFZ) and 9 rugose coral zones (RC) from the base of the Tournaisian to the lower Serpukhovian. It is well correlated with the sequence stratigraphic zonation which comprises 11 third-order stratigraphic sequences (Hance *et al.*, 2001). Both were defined in Belgium, France, and England, and were latter extended to Poland and South China. In South China, several sections in Hunan, Guanxhi and Guiyang were investigated or revised in the last years and provide a complete Mississippian section. They have allowed to check, by comparison with Europe, what were local or global sea-level variations and to extend the biostratigraphic zonation. The recognized third-order sequences correspond to major eustatic sea-level variations and have usually 3-4 Ma durations. One of them (sequence 8 overlapping the Middle – Upper Viséan boundary) has probably less than 1 Ma. Among the sequences, some correspond to eustatic changes lower or larger than the others and can be correlated with major changes in marine faunas :

- The high-stand systems tracts (HST) of the sequences 1 (following the D/C boundary extinction event) and 3 are characterized by a widespread of corals, corresponding respectively to the most representative taxa of the RC 1 and 3.
- The uppermost Tournaisian sequence 4 is characterized by a very high HST and a flooding of lowlands previously emerged (' Avins event ' of Poty, 2007). This very high sea level caused good connections between marine basins and to the widespread of foraminifers, brachiopods and corals, through Australia, Japan, China, and the rest of Eurasia (MFZ 8 and RC4β1).
- It is followed by a very strong fall in the sea level corresponding to the falling stage of the sequence 4. This low level persisted during the sequence 5 (lowermost Viséan), so much so that its HST never reached the shallow marine platforms previously covered by the late Tournaisian sea (Hance *et al.*, 2001). Areas which were previously well connected became more or less isolated, and their common stock of uppermost Tournaisian corals gave rise, by separate evolutions, to lowermost Viséan coral endemic assemblages. It is from the base of the sequence 5 that a marked four and/or five-order cyclicity developed, whereas it was not marked during the Tournaisian. That shift between the Tournaisian and the Viséan sea levels and patterns of deposition is considered as a heralding change to the Carboniferous climate with glaciations and could correspond to the development of an ice-cap.
- Shallow platforms were progressively flooded during the transgressive systems tract (TST) of the following sequence 6 (upper lower Viséan). Its HST is marked by a high sea-level rise and a new widespread of corals through Eurasia (RC 5).
- During the sequences 7 and 8, the connections between basins were relatively limited, and it is from the HST of the sequence 9 (upper Viséan), and even more from the sequence 10, that a new widespread of marine faunas occurred (respectively MFZ14 and 15, and RC7β and RC8).

A strong fall of the sea-level occurred at the end of the Viséan and caused, for the second time (the first corresponding to the low-stand systems tract of the sequence 4 and to the sequence 5), the emergence of the carbonate platforms. These were affected by an intense karstification probably due to the replacement of the relatively dry Viséan climate by the Namurian wet climate, as shown by the shift of the Viséan carbonate-dominant sedimentation to the Namurian siliciclastic-dominant one. That is considered as corresponding to an enhancement of the ice-caps and the starting of the upper Carboniferous glaciations. From that time, foraminifer and coral faunas became impoveriched (MFZ 16, RC 9).

Thus now, both bio- and sequence stratigraphic zonations allow good and comprehensive correlations in the Mississippian of Eurasia, and also to have a better understanding of the eustatic and climatic changes and of the migrations and evolutions of marine faunas.

Latest Berriasian-Hauterivian carbon isotope stratigraphy and magnetic susceptibility: new data from three West Carpathian sections of Poland and Slovakia

Andrzej Pszczolkowski, Jacek Grabowski, Jozef Michalik, Katarzyna Sobien

New $\delta^{13}C$ and magnetic susceptibility (MS) records for the latest Berriasian-Hauterivian are used to improve stratigraphy and correlation of three West Carpathian sections, namely the Strážovce (Strážovske vrchy Mountains, Slovakia), Kryta Valley (Western Tatra Mountains, Poland) and Kapuśnica (Pieniny Klippen Belt, Poland) sections. Sixty three, eighty one and seventy bulk samples have been collected from the pelagic limestones exposed in the Kryta Valley, Strážovce and Kapuśnica sections, respectively. Powdered samples were analysed for C and O isotopic composition with a Finnigan Delta+ mass spectrometer in the Stable Isotope Laboratory of the Institute of Geological Sciences, Polish Academy of Sciences in Warsaw, while MS was measured on the same samples in the Paleomagnetic Laboratory of the Polish Geological Institute, using KLY-2 kappabridge (AGICO). Additionally rock magnetic studies were performed in order to evaluate mineralogical origin of MS signal. Carbon isotope and MS stratigraphy facilitates correlation of these sections located in two separate deep-water basins, that is, the Zliechov (Strážovce and Kryta Valley sections, Fatric domain) and Pieniny Klippen Belt (Kapuśnica section, Branisko succession) basins. Reliable magnetostratigraphic data, obtained within the frame of the project, are available only for the lowermost part of the Kryta section, embracing upper part of M16n up to lower part of M13r (Berriasian/Valanginian boundary interval).

The uppermost Berriasian-Lower Valanginian interval of the $\delta^{13}C$ curves is similar for the Kryta Valley and Strážovce sections. Weakly marked positive excursions (a1, a2) occur in the Upper Berriasian (at Kryta Valley) and the basal Early Valanginian *Calpionellites* Zone. These excursions fall, according to magnetostratigraphic data from the Kryta section, within uppermost part of M16n (a1) and M14n (a2). In the Kapuśnica section, another negative excursion (b) is located in the Early Valanginian Major Subzone, but it is recorded above the *Calpionellites* Zone in the Strážovce and Kryta Valley sections. The next weak negative shift (c) is located at the onset of the well-known Valanginian $\delta^{13}C$ positive excursion. The beginning of this excursion corresponds to the upper part of the Early Valanginian *L*. gr. *hungarica* (Acme) Subzone. A detailed outline of this positive excursion is shown on the Kapuśnica carbon isotopic curve. The rapidly ascending $\delta^{13}C$ values characterize the lower part of the positive excursion (interval A, which corresponds to the 'isotopic carbon period 2' in the Angles section - see Duchamp-Alphonse *et al.*, 2007). All three $\delta^{13}C$ curves from the studied sections show a positive excursion composed of two or three peaks: the upper peak (f) is indicated by the maximum $\delta^{13}C$ values and the lower one (d) is marked by somewhat lower results. In the Kapuśnica section, the maximum $\delta^{13}C$ value is 2.836 ‰ (VPDB), but only 2.41 ‰ and 2.52 ‰ in the Kryta Valley and Strážovce sections, respectively. The maximum $\delta^{13}C$ record is compatible

with the corresponding values reported earlier from the sections at Rochovica (Pieniny Klippen Belt) and in the Southern Alps.

In the Kryta Valley section, the Valanginian/Hauterivian boundary is interpreted within the B interval of the $\delta^{13}C$ curve, not far from its top. In the Strážovce section, carbon isotope-based position of the Valanginian/Hauterivian boundary is very similar to that proposed for the Kryta Valley section. The values *ca.* +1 ‰ (VPDB) mark a weak negative excursion (h) similar to that detected in the Vocontian basin (Van de Schootbrugge *et al.*, 2000) at the Lower/Upper Hauterivian boundary. In the Strážovce section, a weak negative excursion (h) occurs about 6 m below the base of the Hauterivian Strážovce Member. Thus, the Lower/Upper Hauterivian boundary may be located within the deposits previously assigned to the uppermost Valanginian. However, more data are needed as the carbon isotopic curve terminates at the base of the Strážovce Member. In the Kapuśnica section, the $\delta^{13}C$ record suggests the Lower/Upper Hauterivian boundary position about 3 m below the previously proposed location based on scarce ammonites and radiolarians.

Although the pelagic limestones studied were subjected to partial or complete remagnetization, it seems that variations of MS reflect the primary influx of detrital material towards the basins. MS is related to mixture of paramagnetic and ferromagnetic minerals (mostly magnetite) with significant contribution of superparamagnetic magnetite in Strážovce section.. MS values are systematically higher for the two sections situated in the Zliechov Basin (Strážovce and Kryta), which indicates higher influx of detrital ferro- and paramagnetic particles there, than towards the Pieniny Klippen Belt basin. Sedimentary events expressed by intercalations of sandstones (Kryta Member) and detrital limestones (Strážovce and Muraň members) are well marked on the MS curves of Zliechov Basin sections. Onset of the Valanginian $\delta^{13}C$ positive excursion (beginning of interval A) correlates with increase of MS values in all three sections. There are several other features of MS curves which apparently correlate between the sections (*e.g.* local MS peak situated between points a2 and b on $\delta^{13}C$ curve, corresponding to Kryta Mb. and its equivalent in the Strážovce section), however their interpretation is hampered by different sedimentation rates within the sections as well as variegated lithology and mineralogical source of MS signal.

Unravelling the PETM record in the Sparnacian facies of NW Europe: new data from the north-eastern Paris Basin

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The geological archives record 'hyperthermic' crises, along with their consequences on the biota and physical environment. Among these, the PETM (Paleocene-Eocene Thermal Maximum) is considered as the closest analogue to the current climate crisis due to its global character and the speeds at which the CO2 rate and average temperatures increased. Some 55.8 Ma ago (Aubry *et al.*, 2007), it affected the Earth for a period of almost 200,000 years; the terrestrial and marine paleoenvironments were marked by a negative $\delta^{13}C$ anomaly (or Carbon Isotopic Excursion, CIE) coinciding with a negative $\delta^{18}O$ anomaly indicative of a drastic temperature rise (+ 3 to + 8 °C).

The causes envisaged to explain the major global disturbances of the atmosphere and oceans are linked with the massive emission of 12C-enriched greenhouse gases whose origins are still debated and probably multiple. Moreover the PETM left a deep and long-lasting imprint on the living animal and plant world, both terrestrial and marine. The preserved paleoenvironments of the sedimentary record also show a recrudescence of clastic influx or are distinguished by specific sediments such as coal and lignite, phosphates, black shales, diatomites, etc.

The shallow to deep marine environments from all the paleolatitudes have been studied intensively, the data collected allowing to refine climate models and ocean/atmosphere responses. However, the terrestrial record was seldom examined and very few studies aimed at checking if the drastic rises of greenhouse gases and temperature had a real impact on the fluvial, lacustrine, palustrine sediments and on the paleosols and weathering profiles development during the PETM. Apart notable paleontological studies, its impact on the terrestrial realm at a regional scale and on different interconnected contemporary paleoenvironments has probably not been studied and integrated enough (Zachos *et al.*, 2008). We propose such a regional study in the Sparnacian facies of the Paris Basin.

To ensure correlation of the events and processes identified with a confidence level as precise as possible, high resolution temporal framework is essential. Historically, the Paris and adjacent basins are the cradle of stratigraphy, where the notion of 'Sparnacian' took shape (Dollfus 1880), pointing terrestrial to brackish deposits with particular facies and faunas, interstratified between two easily distinguishable Late Paleocene (Thanetian) and Early Eocene (Ypresian) mainly sandy and marine formations. Since that time stratigraphy has evolved, especially regarding the Paleocene and Eocene epochs, and we refer to the

lithostratigraphies of Aubry *et al.* (2005) and Steurbaut (1998) for the Paris and Belgian Basins.

In Avesnois, close to Belgium, the Paleocene and Eocene lithostratigraphy has been revised thanks to a geological mapping project supported by drillings (Quesnel, 2006). Detailed sampling and various analyses have been performed: granulometry and XRD mineralogy, heavy mineral assemblages, carbonate and organic carbon contents, biostratigraphy, palynofacies, pyrolyse rock-eval, and chemostratigraphy ($\delta^{13}C$ of the dispersed organic matter).

In the AVE 007 drilling (Mormal Forest), the CIE has been identified in a lignitic clay. The clay content is dominated by the illite-smectite mixed layers, with 10 to 20 % of illite and kaolinite. The palynological study of the pollen and spores assemblages confirms the Early Eocene age. The Paleocene markers are absent and using the palynozonation of Roche *et al.* (2009), the lignitic clay can be correlated to the lower part of the Tienen Fm and to the SP3 to SP4 units of the Cap d'Ailly section. The depositional environment is palustrine-lacustrine, with sporo-pollen fluvial inputs from the hinterland in a humid subtropical climate.

The lignitic clay overlies fluvial flint gravels and sands, above the Coniacian chalk. Those clastic deposits contain mainly illite-smectite mixed layers, a few kaolinite and illite and are richer in pyrite downwards. Paleocene pollens and dinocysts are present. The onset of the CIE is recorded at the top of this sandy unit, below the lignitic clay. Those fluvial flint gravels and sands are widespread in Avesnois, and named 'Cailloutis à silex de Mormal' (new name) and 'Sables et Grès du Quesnoy'. The lignitic clay corresponds to a palustrine deposit, filling the fluvial channel after the river bed migration. Similar units are well known in northern France and Belgium, they belong to the Upper Landenian fluvial sands, often display cross stratification, paleoweathering (oxidation and/or silcrete), lignite or marl lenses, vertebrate fauna and sometimes a rich flora in silicified slabs or beds. They can be attributed to the Tienen Fm. Similar sandy, clayey and lignitic units are also recognized southwards in the Paris Basin, in the first clastic units of the Mortemer Fm.

In Northern France and Belgium those terrestrial units often cap or incise Upper Thanetian marine sands. In Avesnois the latter are named 'Sables verts de l'Avesnois' and correlated to the 'Sables de Grandglise' (NP8) and 'Sables de Bois Gilles' (NP9). In the western part of the Avesnois, the AVE 31 drilling has yielded a shallow marine shelly sand ('Falun de Viesly'), with Upper Thanetian benthic foraminifera (P4c to P5), and a shelly clay ('Argile de Louvil'), containing Thanetian benthic foraminifera (P4). They are overlain by a sandy laminated clay ('Tuffeau de Valenciennes'), then a laminated silt at the top.

In the AVE007 drilling, the lignitic clay is also overlain by a silty laminated unit, containing the same clay minerals as the clay plus chlorite and vermiculite at the top. Lower Ypresian dinocysts (*Wetzeliella* sp.), phytoliths, rootlets moulds and agglutinated foraminifera similar to those contained in the Orchies Clay (NP10 – NP 11?) are present. That silty unit is widespread in Avesnois and Valenciennois. We name it 'Silt et Sablon de l'Avesnois' and we correlate it to a part of the Kortrijk Clay Fm in the Ieper Gp.

The new units described around the Paleocene-Eocene boundary in Avesnois allow correlation between the Belgian and Paris Basins and help to precise the

landscape evolution during this critical interval. The PETM record has also been recently identified around 80km southwestwards, at Sinceny (Aisne), a key locality for the Sparnacian facies. The data obtained in this drilling will be presented and compared to those obtained in Avesnois and integrated in the Paris Basin stratigraphic framework.

Biochronostratigraphic synthesis of Cretaceous and Cenozoic of Barinas sub-basin, western Venezuela

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It presents a high - resolution biochronostratigraphic synthesis from the review, validation, analysis and biostratigraphic interpretation of 34 wells belonging to the producing oilfields of Barinas (Bejucal, Borburata, Caipe, Guasimito, Guanarito, La Yuca, Las Lomas, Maporal, Obispo, Sabaneta and Torunos), in order to establish the lithostratigraphic, chronostratigraphic and paleoenvironmental framework in the Barinas area, and contribute to the identification and documentation of new locations which can incorporate hydrocarbon reserves to the exploration and production resource base, increase the exploratory success of future exploratory drilling in the area and improve the oil system documentation of the projects in the study area.

The study area is located within Barinas – Apure basin, bounded on the north by the states of Trujillo and Portuguesa, east by Portuguesa state and south by the Maporal and Bejucal oilfields.

The methodology of work started with the search, review and integration of sedimentological and biostratigraphic data available, which took into account the following criteria: type of samples, type of biostratigraphic analysis and sampling density, to validate existing information. Once validated, the information is reflected in a map of biostratigraphic data quality. In addition, biostratigraphic analysis was performed on those wells that required it, in order to complete the existing data. The integration of biostratigraphic and sedimentological results was realized, to proceed with the elaborating chronostratigraphic consensus of these wells. Finally, the consensus chronostratigraphic charts of Barinas area were elaborated.

Geological ages were determined by biostratigraphic studies to establish the chronostratigraphic and paleoenvironmental framework, managed to validate the proposed formational tops and the Cretaceous / Tertiary boundary at regional level. Average thicknesses were established for different stratigraphic units and geological correlations were conducted underground at the regional level.

The consensus chronostratigraphy was established from the integration of biostratigraphic data provided by planktonic foraminifera, calcareous

nannofossils and palynomorphs. The stratigraphic section is represented by the following chronostratigraphic and paleoenvironmental framework:

Pliocene - Oligocene: Assigned by stratigraphic position, because the lithotypes are not suitable for the preservation of microfossils. The sediments deposited during this period correspond to the Parángula and Río Yuca formations, usually deposited in Continental and / or Transitional palaeoenvironments. Thicknesses vary between 7,000 and 9,000 feet.

Middle Eocene: Pagüey Formation was deposited in marine paleoenvironments ranging between outer neritic and inner neritic, with a variable thickness between 1490 and 2684 feet. Gobernador Formation, including the Masparrito Member was also deposited during this period, ranging from Continental palaeoenvironments to Transitional and inner neritic. The association of fossils may be abundant and usually with good diversity, specifically in Pagüey Formation. However, the Masparrito Member has a poor and poorly diversified association and sometimes without fossils for the rest of the Gobernador Formation.

Maastrichtian: This age is associated with the regional unconformity, which corresponds to the contact Cretaceous - Tertiary different wells in the area, during which Burguita Formation was deposited in paleoenvironments ranging from Transitional to inner neritic (in some cases can be Continental and other, coastal environment). Note that in the Bejucal, Borburata, Torunos oilfields and others (located toward the south of the area) is not present, is eroded in its entirety or is represented by a very thin thickness. Thicknesses range from 0 (south and southwest) over 300 feet (north and northeast).

Campanian - Maastrichtian: This period is also associated with the regional unconformity Cretaceous - Tertiary different wells located south and southwest of the area (where the layers are heavily eroded.) During this period the Navay Formation's Quevedo Member was deposited in paleoenvironments ranging from Continental to Transitional. The thickness varies from 190 feet to 475 feet.

Turonian - Campanian: The Navay Formation's La Morita Member was deposited in paleoenvironments that vary from inner neritic to middle neritic. The average thickness ranges from 80 to 110 feet.

Cenomanian - Turonian: Escandalosa Formation was deposited in transitional to continental palaeoenvironments. The average thickness is between 260 and 675 feet.

Albian-Cenomanian: Aguardiente Formation was deposited in paleoenvironments ranging from Transitional to inner neritic and in some cases with a more Continental influence. The average thickness is 250 feet.

The maximum paleobathymetry in the area agree on the basal part of the Pagüey Formation (middle Eocene, outer neritic) and The La Morita Member of Navay Formation (middle Turonian, inner neritic). These data correspond to the maximum flooding surface (MFS) in the Tertiary (42 Ma) and Cretaceous (91.5 Ma), respectively (Hardenbol *et al.*, 1998). These surfaces were used as datum in stratigraphic correlations.

The results showed the usefulness of calcareous nannofossils, planktonic foraminifera and palynomorphs as biostratigraphic tool to define the

chronostratigraphy of Tertiary age, while the abundance of palynomorphs were very useful to define the column of Cretaceous age, Thus generating added value to the corporation to optimize operational costs at the time of drilling new exploration wells in the area of Barinas.

The new analysis and interpretations provided important data on the geological characteristics of the area. One of the most important biostratigraphic contributions was to define the Cretaceous / Tertiary boundary in the wells of the Bejucal Oilfield, which corresponds to a regional unconformity with a marked erosion of the Cretaceous section (Burguita and part of Navay formations) toward the south of the basin, including most of the wells belonging to the Bejucal oilfield and others. Certainly, was achieved to update the geological model of the area.

Squamate reptiles and stratigraphy

Jean-Claude Rage

Squamates (*i.e.*, lizards and snakes) are generally of small size and therefore numerous. They are known since the Triassic, but they become relatively frequent in fossiliferous localities only in the Late Cretaceous and make up a substantial component of Cenozoic faunas. They are primarily terrestrial animals, but lizards and snakes entered the marine realm (several times) and significantly radiated there from the Late Cretaceous to the Eocene (the living marine snakes are paleontologically insignificant). However, fossils are mainly recovered from continental formations.

As far as stratigraphy is concerned, in the terrestrial realm mammals have evolved into an efficient stratigraphic tool that is indispensable for continental biochronology. On the other hand, squamates have been often regarded to have little or even no stratigraphic significance. This is generally based on the belief that reptiles are slowly evolving animals, which is not really true. For some decades, squamates have proved that they may be useful.

In vertebrates, we may use i) evolutive stages within a lineage, ii) marker taxa, and iii) events (appearances, immigrations, extinctions, that may result in characteristic faunas).

i) In mammals, mainly rodents, lineages may be identified. These lineages evolve directionally and are comprised of successive evolutionary stages; the latter may be regarded as species. Such lineages represent excellent stratigraphic tools. In squamates, various taxa can form, at least apparently, lineages, but these series are generally (always?) false lineages. While in mammals the recognized successive taxa do not stratigraphically overlap, in squamates the taxa that make up the series overlap: one taxon does not definitely replace the preceding one. Such series provide stratigraphic information but are not precise because of overlaps. Such so-called series are illustrated by lacertid lizards from the European Oligocene and perhaps by the highly aquatic palaeophiid snakes that were more or less worldwide in the Eocene. Some series, that are perhaps true lineages, are suspected in snakes but this cannot be definitely proven.

ii) In squamates, taxonomically isolated species without closely related (older or younger) taxa may appear in stratigraphically restricted levels; they represent good stratigraphic markers. The snake Simoliophis that is restricted to the Cenomanian is one of the best examples. Several palaeophiid snakes also appear to be significant in the Eocene. Simoliophis and palaeophiids were all highly aquatic, but in the terrestrial realm, good stratigraphic markers are also known. Their stratigraphic extent is short (for example, about one geological stage in the Eocene). However, while the geographic range of these markers is broad in the marine realm, on the continent markers occupy restricted areas.

iii) Events, faunal assemblages. In the terrestrial realm, but not in the aquatic one (from which too few taxa are known), sharp events affecting squamates are evidenced in the Cenozoic. Simultaneous appearances or extinctions of several taxa result in marked distinctions between successive time intervals. In addition, when such events are stratigraphically closely spaced, they frame faunal assemblages of short duration that are thus characteristic. More specifically, in the Cenozoic, among the most prominent events and characteristic faunas are the Eocene/Oligocene boundary, the fauna of the MP 22 standard level (early Oligocene), and the MN 3/MN 4 boundary (early Miocene). However, such information in the continental realm is reliable only in restricted geographic areas because immigrations may be diachronous and extinctions may not be synchronous everywhere.

In fact, I have presented here only the potential stratigraphic value of squamates because their study is still far from being exhaustive. However, it may be provisionally concluded that squamates are stratigraphically more significant than generally believed; they will likely never reach the precision provided by mammals but they represent a good extra tool.

Nannofossil age constraint for Rupsi Member, Baisakhi Formation, Jaisalmer Basin, western India

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We report here for the first time a moderately preserved, well diversified datable nannofossil assemblage from Rupsi Shale Member of Baisakhi Formation, Jaisalmer Basin, Western India. The Jaisalmer Basin is situated on the northwestern part of the Indian peninsula and is the largest sub-basin of the western Rajasthan Shelf basins. The Jaisalmer Basin contains almost uninterrupted sedimentary package from lower Jurassic to Albian with minor unconformities. Lithostratigraphic framework of the area given by DasGupta (1974, 1975), is followed herein. The low dipping Mesozoic succession comprising Lathi, Jaisalmer, Baisakhi, Bhadasar and Pariwar formations in ascending order overlies the Pre-Cambrian basement and is underlain by Palaeocene-Eocene age rocks representing Sanu, Khuiala and Bandah formations followed by subrecent Shumar Formation. The Baisakhi Formation is divisible into three members viz. Baisakhi, Ludharva and Rupsi in ascending order. The Rupsi Member exposed in hillock sections in the vicinity of Rupsi village NW of Jaisalmer, shows intercalations of fine grained light brown

argillaceous sandstone and grey shales containing ammonites. The Rupsi Member is dated to be on ammonite data Kimmeridgian (DasGupta, 1975) or Kimmeridgian to early Tithonian on ammonite and benthic foram assemblage (Garg *et al.*, 1998). The present nannofossil assemblage has been recovered from an ammonite specimen (identified as *Himalayaites* sp. by Sreepat Jain pers. comm.) obtained from the upper levels of Rupsi Shale containing *Hildoglochiceras – Aulacosphinctoides* association. The nannofossil assemblage contains *Cretarhabdus conicus*, *Cyclagelosphaera margerelii*, *Diazmatolithus lehmanni*, *Discorhabdus* sp., *Ethmorhabdus gallicus*, holococcolith spp., *Helenea chiastia*, *Lotharingus hauffii*, *L. sigillatus*, *Lucianorhabdus* sp., *Watznaeuria barnesae*, *W. britannica*, *W. fossacincta*, *Zeugrahbdotus embergeri*, *Z. erectus*, *Z.* sp.

Occurrence of *Z. embergeri* (FAD), *N. compressus* (FAD) and *E. gallicus* (LAD) in the assemblage is taken here as potential taxa for NJ 12 (T) *Conusphaera mexicana* Zone assignment of late Early Tithonian age. NJ 12 (T) Zone of Bralower *et al.* (1989) encapsulates Tethyan lower to middle Tithonian time slice (CM 22n – CM20). The assemblage can be more precisely correlated to NJ 12b (T) Middle Tithonian *Polycostella beckmanni* subzone. In boreal realm FO of *H. chiastia* and LO of *E. gallicus* puts the assemblage in time bracket of late Early Tithonian (NJ 17b). Occurrence of *Nannoconus* sp. in itself is indicative of advent of Tithonian.

The nannofossil data with cosmopolitan age markers is thus notably significant in providing precise age to the ammonite bearing upper part of the Rupsi shale dated earlier as Early Tithonian, but may also suggest slightly older age (late Early Tithonian) for *Himalayaites*, which is known to date to indicate Late Tithonian age.

Structure cranio-dentaire : Implication de la biomécanique de la mandibule et de la paléoécologie de deux nouveaux traversodontidés eucynodontes du Trias de Madagascar

Lovasoa Ranivoharimanana

L'implication de la biomécanique de la mandibule et de la paléo écologie de *Menadon besairiei* et *Dadadon isaloï*, deux nouveaux traversodontidés eucynodontes du Trias de Madagascar, par l'analyse de la corrélation structure fonction et l'application de la méthode à double leviers de Bramble (1978), aboutit aux propriétés suivantes : (i) habilité à réaliser une occlusion bilatérale dynamique entre les dents jugales typiquement gomphodontes supérieures et inférieures dans une direction postéro dorsale. (ii) occlusion dentaire complexe pendant laquelle domine une fonction broyeuse par le système du "pilon dans un mortier" chez *Menadon*. Lequel système exige une force de morsure énergique. De son côté, l'occlusion dentaire de *Dadadon* développe une fonction coupante dominante qui n'a pas besoin de beaucoup d'effort masticatoire. (iii) L'articulation mandibulaire "reptilienne" entre le carré et l'articulaire, est devenue fragile, particulièrement celle de *Dadadon*. (iv) Malgré

cela, une certaine charge verticale positive (compressive) agit au niveau de l'articulation mandibulaire. Cette charge est supérieure pour *Menadon* mais moindre pour *Dadadon*. Pour ce caractère, ils représentent un stade intermédiaire avant d'aboutir au stade mammalien (v) Pour y remédier, latéralement à la première, il se serait différencié une articulation secondaire entre le squamosal et le surangulaire ; elle est stable pour *Menadon*, mais moins extensive pour *Dadadon*. (vi) *Menadon* et *Dadadon* se démarquent des traversodontidés Africains mais rejoignent ceux de l'Amérique du Sud par la présence d'une ectolophe plus ou moins développée au niveau postéro externe de la dent postcanine.

Il ressort de ces résultats que : - *Menadon* et *Dadadon* sont tous les deux des herbivores se nourrissant de matériel végétal dur et tendre respectivement. – *Menadon* et *Dadadon*, occupant la même niche écologique ne s'empiètent pas dans leur nourriture. En plus, en dépit de la proximité de l'Afrique du Sud et de Madagascar en cette période, il semble que leurs faunes ne sont pas du tout similaires. La différence serait fonction de la disponibilité alimentaire, donc de la paléo écologie.

[EV]

Mandible biomechanics and paleo ecology implication of new traversodontid eucynodonts from the Triassic of Madagascar: *Menadon besairiei* et *Dadadon isaloï*, via analysis of correlation between structure and function, and application of Bramble (1978) bifulcral method, shows evidence of following properties: (i) ability of both animals to realize bilateral dynamic occlusion between upper and lower jugal gomphodont teeth in postero dorsal direction – (ii) This dental occlusion works with more crushing function by a mortar and pestle system in *Menadon* which needs high biting force. On the other hand, *Dadadon* dental occlusion develops more shearing function which doesn't need a lot of biting force. – (iii) "Reptilian" mandibular joint between quadrate and articular became fragile for both, particularly more for *Dadadon*. (iv) Despite this character state, there is some vertical positive load acting on their joint mandibular. This compressive force is larger for *Menadon* than for *Dadadon*. According to this feature, both represent intermediate stage before the mammalian stage– (v) To resolve this problem, a secondary articulation between squamosal and surangulaire occurs. It is stable for *Menadon*, but less expensive for *Dadadon*. (vi) *Menadon* et *Dadadon* are different of African traversodontids by lacking ectolophe at postero lateral region of postcanine tooth but share it with South American taxa.

So, according to these results: - Both *Menadon* and *Dadadon* are herbivorous eating respectively hard and tender vegetal material. – *Menadon* and *Dadadon*, occupant the same ecological niche, they don't encroach upon their diet. In addition, despite the proximity of South Africa and Madagascar in this period, it seems that their fauna are not at all similar. The difference would depend of food disponibility, so of the paleo ecology.

Architecture stratigraphique des systèmes carbonatés de l'Albien-Turonien sur la plate-forme Arabe : la Formation Sarvak dans le Haut-Zagros (Iran)

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Une étude sédimentologique et stratigraphique a été menée sur la Formation Sarvak d'âge Albien supérieur à Turonien dans la région du Haut Zagros dans le sud-ouest de l'Iran, dans une position paléogéographique proche de marge orientale de la plate-forme arabe. La qualité exceptionnelle des affleurements qui présentent l'organisation géométrique des faciès le long d'un profil plate-forme – bassin intrashelf, permet de comprendre l'influence relative de la production carbonatée et des variations du potentiel d'accommodation sur l'architecture stratigraphique des dépôts. Un modèle de séquence de dépôt peut ainsi être proposé pour ce type de système de plate-forme à rudistes et comparé à celui établi dans les Montagnes d'Oman pour les dépôts de même âge (Formation Natih).

Quatre ordres de séquence ont été reconnus au sein de la série Albien à Turonien. Celle-ci s'inscrit dans deux séquences de deuxième ordre de durée comprise entre 10 et 15 Ma, limitées par des surfaces d'émersion majeures sur lesquelles reposent en onlap des prismes de bas niveau marin. La première séquence regroupe la formation albienne Kazhdumi et le membre inférieur de la Formation Sarvak (première séquence de 3° ordre S1), la deuxième correspond au membre supérieur de la Formation Sarvak (séquences de 3° ordre S2 à S4). Quatre séquences de 3° ordre de durée comprise entre 1,5 et 3 Ma et d'épaisseur variant de 50 à 150 m ont été identifiées au sein de la Formation Sarvak. Ces séquences sont à leur tour constituées d'un empilement de séquences de 4° et 5° ordre correspondant à des cycles transgression - régression de haute fréquence servant de base aux corrélations stratigraphiques et à l'élaboration d'un modèle stratigraphique de haute résolution. Une corrélation régionale des séquences de 3° ordre est proposée avec la Formation Natih en Oman.

La Formation Sarvak est formée par l'alternance de deux systèmes sédimentaires carbonatés qui se succèdent au sein des différentes séquences : (1) un système de plate-forme peu profonde de géométrie très faiblement inclinée caractérisé par une sédimentation à dominance boueuse à foraminifères benthiques et débris de rudistes, et (2) un système de type plate-forme – bassin intrashelf qui se caractérise par des dépôts mixtes boueux et granulaires à rudistes sur le sommet de la plate-forme, des faciès bioclastiques à débris de rudistes sur les clinoformes de bordure de plate-forme et des dépôts de mudstone riche en matière organique dans les domaines confinés de bassin intrashelf dont la bathymétrie reconstituée n'excède pas 80 m. Le premier type de système carbonaté se développe au début de chaque phase transgressive de 2° et de 3° ordre, tandis que le second se met en place seulement pendant les grandes phases transgressives de l'Albien supérieur – Cénomanien inférieur et du Cénomanien supérieur – Turonien inférieur, lorsqu'à l'échelle de la plate-forme arabe, la production

carbonatée n'est plus capable de compenser l'élévation du niveau marin relatif et que se forment ainsi les bassins intrashelf.

Les variations du potentiel d'accommodation apparaissent ici comme le principal facteur contrôlant la morphologie du profil de dépôt et ainsi le fonctionnement du système carbonaté. L'inclinaison du profil de dépôt présente en effet une influence majeure sur (1) la dynamique du système (pénétration vs atténuation de la houle), (2) le type de production carbonatée et (3) le volume de sédiments produits.

L'inclinaison progressive des profils de dépôt au sein des séquences de 3° et 4° ordre s'accompagne d'un fort partitionnement volumétrique des dépôts, les faciès de plate-forme interne étant principalement préservés par aggradation/rétrogradation (limitée) en période d'augmentation du potentiel d'accommodation tandis que les prismes bioclastiques de bordure de plate-forme se forment par progradation lorsque la production carbonatée excède le taux d'accommodation.

L'interaction entre variations relatives du niveau marin et production carbonatée explique certaines des différences fondamentales avec les systèmes silico-clastiques. (1) l'augmentation simultanée du taux d'accommodation et de la production carbonatée en certains points est responsable de la création d'une topographie sous-marine différenciée qui favorise le développement de dépôts granulaires sur les zones hautes et limite la rétrogradation du système carbonaté. Pour cette raison, la distinction entre 'Early Transgressive Systems Tract' mis en place pendant les périodes de remontée lente du niveau relatif de la mer et le 'Late Transgressive Systems Tract' qui se forme pendant les périodes de remontée rapide du niveau marin est très importante pour les systèmes carbonatés. (2) L'émersion de la plate-forme provoque une chute de la production carbonatée qui limite ainsi le développement des prismes de régression forcée.

Le modèle d'évolution des géométries et de la dynamique des systèmes carbonatés au cours de cycles de variation du rapport accommodation / production sédimentaire (A/S) semble applicable pour différents ordres de fréquence (2°, 3°, 4° ordre), et pour différentes catégories de producteurs carbonatée (rudistes, oolites, ...) d'âges variés. Cette analyse tend à confirmer l'hypothèse du caractère fractal des séquences de dépôt.

Palaeoenvironmental changes associated to the T-OAE in the Radnet el Kahla section, western Saharan Atlas (Algeria)

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The Early Toarcian was characterized by an important environmental change, determining a global mass extinction event, usually related to the development of organic-rich sediments, and interpreted as a global oceanic anoxic event, the Toarcian Oceanic Anoxic Event (T-OAE). This mass extinction event significantly impacted in several benthic groups, for instance, brachiopods,

foraminifera, ostracods, and pelagic faunas, such as ammonites (Wignall *et al.*, 2005). The most widely accepted proposal is that the onset of the T-OAE is registered in the boreal tenuicostatum Zone (polymorphum Zone in the Mediterranean Biozonation, MB), the acme in the boreal mid-exaratum Subzone (mid-levisoni Subzone in the MB), and the end essentially at the boundary exaratum/falciferum subzones (levisoni/falciferum subzones in the MB), even the event has been proposed to be diachronous in Europe, between Tethyan and Boreal provinces (Wignall *et al.*, 2005).

In the western Saharan Atlas (Algeria), the first integrative micropaleontological and geochemical analysis of the continuous Radnet El Kahla section (Lower Toarcian; polymorphum and levisoni zones), has been conducted in order to approach the incidence of the T-OEA. This rhythmic succession of around 17-m-thick consists of limestone beds at the base and intercalated marls and marly-limestones upwards.

Benthic foraminifera have been mainly differentiated at the genus level, and according microhabitat depth in the substrate, benthic foraminiferal assemblages have been segregated into epifauna, shallow infauna and opportunistic potentially-deep infauna. Stratigraphic analysis along the studied succession, reveal the significant and generalized disappearance of benthic foraminifera as previously recorded by Sebane *et al.* (2007), from 9.1 to 12.6 m above the Pliensbachian-Toarcian boundary, just starting at the polymorphum/levisoni zone boundary. After this 3.5-m-thick interval, potentially-deep infauna is dominant, epifauna increases, and shallow infauna shows a significant diminution. At the genus level, Dentalina, being dominant before the interval, shows a drastic decreasing after, and Lenticulina, abundant before the interval, even increase after.

Geochemical proxies have been applied to interpret redox conditions (Pb/Al, V/Al, Th/Al, Co/Al, U/Al, V/Sc, and U/Th, among others) and detrital input (Zr/Al, Zn/Al and Fe/Al, among others). The geochemical analysis reveals relatively minor fluctuations in the studied proxies along the studied succession, except for the interval in which the foraminifera disappear. This 3.5-m-thick interval is characterized by significant increases of redox proxies, especially well registered in Pb/Al, V/Al, Th/Al, Co/Al, U/Al, V/Sc, and U/Th. However, even in most of the ratios three incursions can be differentiated along the interval, there is not a similar pattern for all the selected elements. Thus, Co/Al shows the maximum in the lower part, Pb/Al, V/Sc, and V/Al, in the middle part, and the rest in the upper part. Detrital proxies, reveal differences between the selected elements, most of them with fluctuations along the entire succession, but with several showing significant changes in the interval starting at the polymorphum/levisoni zone boundary (*i.e.*, Zr/Al, Zn/Al, and Fe/Al).

Integration of the micropalaeontological and geochemical results, allow the interpretation of an important palaeoenvironmental change occurring at the beginning of the levisoni Zone. According data, palaeoxigenation conditions in low bottom-water can be envisaged, with dysoxia and even anoxia determining disappearance of benthic foraminifera. After the acme of this unfavourable habitat for benthic foraminifera, a slow recovery is registered as revealed by the dominance of the opportunistic forms as Lenticulina (Reolid *et al.*, 2008).

Ecology of living planktonic foraminifera along an offshore-onshore transect in a marginal basin (NE Atlantic Ocean)

Sophie Retailleau, Hélène Howa, Ralf Schiebel

Objective

The seasonal and spatial variation of living planktonic foraminifers (LPF) is analysed in relation to environmental parameter changes in order to perform their application as paleoceanographic proxies.

The southern Bay of Biscay / Plateau des Landes is a highly strategic site for this research. It is situated at the boundary between subtropical and temperate marine plankton communities, which is inherently sensitive to climate change. Although the Bay of Biscay is open to the eastern North Atlantic, it is marginal to the Global Ocean Conveyor belt. Terrestrial input into the southern Bay of Biscay, most prominently river runoff from the Adour and the Gironde, amplifies the effect of environmental changes on the production (through nutrient input) and sedimentation of planktonic organisms.

Materials & Methods

LPF fauna was investigated with the R/V 'Côtes de la Manche' on a seasonal scale: June 2006, April and November 2007, March and July 2008. Four sampling sites were selected along an offshore-onshore transect between 145m and 2000m water depth.

Samples from plankton tows (>100µm) were collected on all five cruises down to 100m depth at 20m sampling intervals and 700m at 100 and 200m intervals. Simultaneously, temperature, salinity, oxygen and chlorophyll-a were recorded by CTD/sensors profiles.

Faunal changes on a seasonal scale.

LPF densities changed on a seasonal scale. In April, LPF were most abundant and lowest concentrations occurred in July. From March to June, densities of LPF decreased toward the coast, from the hemipelagic ocean (2000m water depth) towards the shelf (<200m depth). In contrast, in July and November low standing stocks of LPF occurred at offshore stations (Retailleau *et al.*, 2009).

In total, 21 species were recorded and six major species occurred during the five periods in abundance: *Globigerina bulloides*, *Globigerina calida*, *Neogloboquadrina pachyderma* dextral, *Turborotalita quinqueloba*, *Globorotalia inflata* and *Globorotalia scitula*. At the offshore station, presence and absence of species and seasonal changes were similar to the open north-eastern Atlantic (*e.g.* Schiebel and Hemleben, 2000).

High concentrations of *N. pachyderma* dextral, *G. inflata*, *G. scitula*, and *Globigerinita glutinata* marked the end of winter conditions and the beginning of spring in the plankton community. *Globorotalia hirsuta* and *Globorotalia truncatulinoides* were absent at the station most proximal to the coast. During

spring bloom events, *T. quinqueloba*, *Globigerinita uvula*, *G. bulloides* and *G. glutinata* were abundant. Consequently high abundance of these species could be considered as potential proxies of high availability of fresh nutrients and enhanced primary production in surface waters (quantitative study in progress).

In summer, these species were progressively replaced by others species, such as *Orbulina universa* and *Globigerinoides trilobus* at surface waters, and *G. scitula* below 100 m depth.

Depth distribution

The majority of (globigerinid) species were found in the upper 80m and most living specimens of all species were found from surface to 500m depth. The average water depth inhabited by planktonic foraminifers varies between species, reproduction cycle, season, and hydrologic conditions. Globorotalids, *i.e.*, *G. hirsuta*, *G. inflata* and *G. scitula* did significantly vary in mean depth habitat at a seasonal scale and occurred at surface waters in winter and descended to depths in spring. As in a pelagic environment (*i.e.* offshore), *G. hirsuta* and *G. truncatulinoides* are surface dwellers in late winter, disappeared from the surface below 700m. These two species were always found in homogeneous sea water. Other species as *G. inflata* and *G. scitula* showed similar changes in depth habitat, but never disappeared from the upper 700m of the water column.

Coastal influence on LPF communities

Hydrological seasonal variability derived from river discharge did affect the distribution of planktonic foraminifers at the onshore stations: in spring, within the low salinity/high turbidity lens, the LPF standing stocks reached low values; in contrast, fresh water input, characterised by low turbidity (November situation), do not hampered LPF production.

Nutrient input, derived from river discharge in oligotrophic coastal waters, triggered opportunistic species production: in November, *G. calida* (usually <15%) represented more than 75% of the community at onshore stations.

The species *G. scitula* shows a particular pattern at onshore Station D, in June: in contrast to its normal open marine habitat at and below the pycnocline, high density of *G. scitula* occurred in the uppermost water column. This presence could be due to the presence of labile organic matter at surface waters (derived from rivers), or to expatriation from their deep habitat by currents at the Cap Breton canyon head. Hydrological effects caused by submarine canyons may affect the distribution of planktonic foraminifers at the onshore stations.

Stable oxygen isotopes values of LPF

$\delta^{18}O$ values of the LPF showed a maximum negative offset of 0.9 ‰ with respect to equilibrium calcification (Kim and O'Neil, 1997). The offset varies between species showing a vital effect: $\delta^{18}O$*G. bulloides* < $\delta^{18}O$*N. pachyderma* < $\delta^{18}O$*G. inflata* = $\delta^{18}O_{\text{calcite equilibrium}}$.

In June, $\delta^{18}O$ values of LPF were clearly lighter than March and April populations, suggesting that they are from a new generation, with at least one reproduction period in between.

Conclusions

Ours results indicate that the abundance of planktonic foraminifera along the offshore-onshore transect in the south of the Bay of Biscay is mainly driven by the availability of food, and can be strongly affected by fresh water, sediment and nutrient input from rivers and mixing of the surface ocean.

Paleomagnetic dating of ferricretes in New Caledonia: constraints on the morphogenesis and paleoweathering of the Grande Terre

Caroline Ricordel-Prognon, Brice Sevin, Florence Quesnel, Dominique Cluzel, Pierre Maurizot, Jocelyn Barbarand, Catherine Lerouge, Johan Yans, Bernard Robineau

Although the description of the emplacement and the weathering of the New Caledonia peridotites are well documented in the literature (Trescases, 1975), the processes and the age of the planation surfaces formed upon the ultramafic massifs are poorly documented. Ambiguities remain on: 1) the timing and modality of weathering, 2) formation of supergene nickel ore and 3) the role of the parameters controlling its evolution:

- The overall geometry of the ophiolitic nappes and structures possibly inherited from the obduction history,
- The lithology of the bedrock (dunite, wehrlite, harzburgite, gabbro, amount of serpentinisation …),
- The post-obduction uplift history, and the paleogeographic and paleoclimatic evolution of New Caledonia up to Present.
- The geomorphologic evolution related to recent tectonics and sea level changes,

Several planation surfaces have been recognised along the island and their correlation in the southern part of the Grande Terre has been done (Chardon and Chevillote, 2006), but no reliable ages could be attributed up to now. Authors established relationships with recent tectonic events; however several issues remain unresolved:

- Are all planation surfaces of the same age? Are they deformed (faulted) at a regional scale?
- Or alternatively are there stepped planation surfaces of different ages? Are differences in elevation related to variations of the uplift rate?
- Are there 1, 2 or more generations of weathering profiles associated to those surfaces? Are possible differences in petrography, mineralogy and geochemistry related to different ages and thus to contrasting paleoclimatic and/or geodynamic settings?

The weathering being still active on the peridotites in the current differentiated landscape and tropical climate, the beginning of the lateritic profiles development is not well constrained and assumed to have occurred between 34 Ma (end of obduction) or 25 Ma (last granodiorite intrusions) and Present.

Llorca & Monchoux (1991) have found hollandite minerals which are judged as reliable to estimate the age of weathering (Vasconcelos *et al.*, 1992). Work is in progress to analyse this kind of material. Moreover, ferricretes and various ferruginous materials are largely present in the weathering profiles and in the fluvio-lacustrine sediments as well. They would record the ancient geomagnetic field providing means of age determination (*e.g.* Théveniaut & Freyssinet, 2002 ; Ricordel, 2007). In tropical soils, most of the primary remanence carrying minerals are dissolved during weathering and secondary magnetic minerals, such as goethite and haematite, are formed in situ acquiring a crystallisation (or chemical) remanent magnetization (CRM). Assuming that no significant tectonic movements occurred between New Caledonia and Australia during the Neogene, the paleomagnetic pole recovered by demagnetizing the CRMs are plotted on the apparent polar wandering (APWP) reference curve of the Australian Plate, providing an age for the different parts of the paleoweathering profiles (ie ferricretes capping the lateritic profiles, and iron oxide concretions occurring deeper in the profiles).

The data and interpretations we present here are based on paleomagnetic analysis of ferricretes capping the weathering profiles along the Grande-Terre. Well constrained ages have been obtained for the first time. Four sub-sites along a section crosscutting the Tiebaghi plateau (Northwest) have consistently provided an age of ca. 25 ± 5 Ma. In contrast, the samples of the Goro site (South) span over a larger time range of 0-5 Ma to 25 Ma, highlighting possible stepped paleosurfaces. These paleomagnetic data give the first dating constraining the morphogenesis of the Grande Terre paleolandscapes. They could allow reliable correlation of the planation surfaces.

The planed future developments include:

- The study and dating by paleomagnetism and U-Th/He geochronology (Lippolt *et al.*, 1998) of a larger number of lateritic ferricretes and an analysis of fluvio-lacustrine ferruginous material (iron oxides concretions), which are of major importance for discriminating the different paleosurfaces, refining the steps of downwards progression of weathering, and reconstructing the regolith history,
- A comparison with isotopic curves and paleoclimatic evolutions at a global and a regional scale in the Southwest Pacific during the Neogene,
- Additional O and H isotopic data on Fe oxides from the same ferricretes, iron oxide concretions and from kaolinite sampled in weathering profiles developed from felsic rocks below similar planation surfaces, to precise the paleoclimatic conditions of the weathering (Girard *et al.*, 2000),
- Additional thermochronological data (Gallagher *et al.*, 1998) and petrographic studies of the weathering profiles from the ferricrete until the unweathered bedrock.

They all should help to decipher the roles of climate, tectonics and lithology respectively.

La connaissance géologique du bassin de Paris pour l'évaluation des ressources du sous-sol

Christophe Rigollet, Anne Bialkowski, Didier Bonijoly, Eric Lasseur, Olivier Serrano

Le bassin de Paris constitue une formidable base de données géologique pour tester des concepts nouveaux en Sciences de la Terre. Peu de bassins dans le monde sont aussi bien connus. Les premières publications datent du milieu du XVIII^{ème} siècle ; la cartographie géologique, la stratigraphie et la sédimentologie y sont nées.

Plusieurs questions scientifiques très 'sensibles' y sont testées et développées dans le cadre du programme Référentiel Géologique de la France : (1) les effets et causes des déformations à grande à très grande longueur d'onde (x 100km - 1000km), (2) la construction d'une nouvelle charte eustatique et (3) la quantification et la compréhension du paramètre flux sédimentaire. Ces questions font l'objet de projets de recherche menés en partenariat avec les laboratoires universitaires, dont Géosciences Rennes, l'ISTeP (UPMC) et l'ISTO (Orléans).

Cette connaissance exceptionnelle, apporte aujourd'hui des outils puissants pour caractériser et modéliser les formations géologiques et pour évaluer les multiples ressources du bassin de Paris.

Si l'historique de l'exploitation des bassins sédimentaires français repose essentiellement sur la recherche de ressources en eau, en hydrocarbures et en stockage géologique de méthane on assiste depuis une trentaine d'année à une multiplication et une diversification des projets d'investigation (géothermie profonde, ressource en eaux profondes, E&P non-conventionnelle, stockage de CO^2, stockage de déchets).

Ces projets permettent d'explorer des cibles nouvelles, comme par exemple (1) en approfondissent la connaissance des formations argileuses et marneuses pour l'E&P non-conventionnelle ou le stockage des déchets nucléaires, (2) en reprenant l'étude des réservoirs et aquifères profonds dans des perspectives non-pétrolières comme la recherche de nouvelles cibles géothermiques, de ressources alternatives en eau et l'évaluation du potentiel de stockage de CO^2.

- L'exploration-production des hydrocarbures en France, après avoir connu un pic de production entre 1985 et 1995 est en déclin constant depuis 1995. Toutefois, avec la remontée récente du prix du baril de brut, l'exploitation des hydrocarbures français est de nouveau rentable, avec le développement des gisements existants ou la reprise de champs abandonnés. Mais l'actualité de l'Exploration pétrolière en France est surtout marquée par la multiplication des demandes de permis d'exploration pour la recherche de gisements non-conventionnels (D. Leblond, 2009, European shale gas prospects heat up, Oil & Gas). Ces nouvelles problématiques permettent d'explorer de nouvelles cibles comme les marnes du Lias du bassin de Paris ou les 'Terres Noires' du Jurassique Moyen du bassin du Sud Est de la France.

- Parallèlement au développement de l'énergie électrique nucléaire, la question de la gestion des déchets radioactifs haute activité et à vie longue est cruciale et une des solutions adoptée est le stockage géologique dans des couches profondes (loi de programme du 28 juin 2006). Pour cela de nombreuses études sont en cours sur les séries argileuses callovo-oxfordiennes de l'est du bassin de Paris.
- Suite aux chocs pétroliers de 1973 et 1979, le développement de la géothermie profonde a explosé en France entre 1980 et 1986. Les formations carbonatées du Dogger du Bassin de Paris ont été la cible principale des projets d'exploitations. Aujourd'hui, pour anticiper sur la baisse programmée du potentiel thermique des aquifères du Dogger du Bassin de Paris, les aquifères sous-jacents du Trias sont à l'étude.
- La multiplication des énergies renouvelables, dont la production est intermittente (énergie éolienne, photovoltaïque), pose la question du stockage d'énergie de grande capacité. Ce type de stockage pourrait être envisagé dans les bassins sédimentaires sous la forme de chaleur ou d'air comprimé, en aquifère.

The magnetic signal of the Beringhauser Tunnel section (Sauerland, Germany) at the Frasnian-Famennian boundary: origin and implications

Laurent Riquier, Xavier Devleeschouwer, Olivier Averbuch, Clément Breziat, Nicolas Tribovillard

In marine sediments, the low-field magnetic susceptibility (MS) is a composite signal integrating variable contributions of the diamagnetic (calcite, quartz) and paramagnetic (clay minerals, pyrite) matrix as well as a ferromagnetic component residing generally in iron oxides. Along section MS variations are thus generally expected to give information on changes with time of fluxes and/or sources of detrital inputs during deposition. The possible biogenic production or chemical precipitation of a secondary (authigenic/diagenetic) mineralogical phase prevents, however, a straightforward interpretation of the MS in ancient sedimentary series. In order to progress in the understanding of the origin of MS variations in diagenetic rocks, a multi-approach study was conducted on a Late Devonian marine carbonate sequence. The Late Devonian (Frasnian-Famennian) is a period of major environmental perturbations, such as biotic crisis, climatic changes, eustatic variations (Racki, 2005). The study includes MS measurements complemented by magnetic hysteresis parameters, inorganic geochemistry and clay mineral analyses.

For this study, we focus our attention on the Beringhauser Tunnel section (Sauerland, Germany). This section is mainly composed of limestones with few intercalated marly beds and is interpreted as an outer-ramp environment. This section is one of the few Late Devonian sections, that record the Frasnian-Famennian (F-F) boundary but does not show the well-known black, organic carbon rich facies of the Kellwasser horizons, which are usually observed in deepest sections, like in Coumiac (France) or Steinbruch Schmidt (Germany).

During the Late Devonian, the Beringhauser Tunnel section belonged to the south margin of Laurussia. This section was already studied for isotopic δ13C and δ18O signals (Joachimski & Buggisch, 2002) and microfacies evolution (Schülke & Popp, 2005), but has never been studied so far for magnetic signal.

By comparing the low field MS and carbonate-free MS, it clearly appears that the diamagnetic contribution of calcite, even if it represents the major part of the limestones (mean 85%), does not control the MS signal of the Beringhauser Tunnel section. This is confirmed by hysteresis loop measurements that suggest MS evolution is dominantly controlled by the fluctuation in the concentration of low-coercivity ferromagnetic magnetite grains and in minor way of paramagnetic clays. More specifically, hysteresis ratios suggest the coexistence of two magnetite populations with significantly different grain-size:

- a dominantly coarse-grained detrital fraction including a mixture of multi-domain and single-domain particles
- an authigenic fine-grained fraction mainly composed of superparamagnetic particles.

Clay mineral assemblages, mainly dominated by illite and chlorite, indicate that the Beringhauser Tunnel section would have been submitted to a significant burial (close to anchizone).

Nevertheless, no clear correlation was established between MS values and the illite cristallinity or with the illite content (a proxy to the illitization process). This confirms that paramagnetic clay minerals are not the dominant fraction controlling the MS signal. In addition, it suggests that diagenetic reactions during burial, such as the transformation of kaolinite to illite, may have caused formation of authigenic superparamagnetic particles. Nevertheless, these mineralogical transformations did not produce a significant distortion of the primary MS evolution.

Lastly, the detrital origin of the magnetic signal fluctuations is corroborated by significant correlations between the MS signal and terrigenous geochemical proxies (*e.g.*, Zr, Ti and Th). A poorer correlation of MS with the Fe content is also observed. This is consistent with the existence of a very fine-grained authigenic magnetite component that possibly increases locally the MS signal but also largely preserves the signal along the section.

The MS curve of the Beringhauser Tunnel section would thus provide a record of the evolution of the detrital flux and of the carbonate productivity in the South margin of Laurussia through the Late Devonian times. It argues for the F-F boundary to represent a transition between a period of Frasnian gradual decrease of detrital input, punctuated by two negative peaks, corresponding to the Kellwasser horizons, and an Early Famennian period of significantly enhanced detrital supply.

The variations at the F-F boundary are interpreted as caused by a climate change, between a Late Frasnian warm period and an Early Famennian cooler stage.

Évolution des systèmes sédimentaires paléogènes sur la marge orientale de la plaque Arabe (Huqf, Sultanat d'Oman)

Jeremy Robinet, Philippe Razin, Josep Serra Kiel, Bruno Carayon, Jack Roger, Carine Grelaud, Sylvie Leroy

L'analyse stratigraphique et sédimentologique des séries tertiaires du secteur du Huqf (Sultanat d'Oman) vise à comprendre la géométrie des dépôts et l'évolution tectono-sédimentaire de la bordure orientale de la plate-forme paléogène de la plaque Arabe.

Six séquences de dépôts d'âge paléocène à miocène enregistrent les principales étapes d'évolution d'une marge transformante (séquences paléocène à éocène) à une marge passive (séquences oligocène et miocène). Elles sont principalement formées de dépôts carbonatés sur un profil plate-forme / bassin de polarité le plus souvent W-E.

La séquence paléocène repose en discordance angulaire sur la série crétacée déformée lors de l'obduction omanaise. Cette unité, représentée par des dépôts de plate-forme carbonatée à algues passant latéralement à des marnes hémipélagiques, marque une première phase de flexuration en relation avec la mise en place de l'ophiolite de Masirah.

La fin de cette séquence marquée par une discontinuité sédimentaire correspond à une augmentation rapide du taux de subsidence entraînant une rétrogradation importante du système sédimentaire.

Les trois séquences de l'Eocène enregistrent les différentes phases de rétrogradation / déstabilisation puis de progradation d'une plate-forme carbonatée à foraminifères benthiques.

À la base de *la séquence éocène inférieur (Ilerdien-Cuisien)* des dépôts gravitaires chaotiques carbonatés surmontant les faciès de plate-forme à algues traduisent la phase de rétrogradation majeure du système.

Ces formations sont surmontées de prismes progradants formés d'une alternance de grainstones fins à mégarides et de dépôts gravitaires (olistolithes, brèches carbonatées). Cette phase régressive se poursuit par l'installation d'une plate-forme carbonatée à foraminifères d'âge cuisien dessinant des prismes de régression forcée. Le cortège de bas niveau marin est caractérisé par l'installation, en domaine plus distal, d'une alternance de boues carbonatées et de débrites.

La séquence éocène moyen (Lutétien) repose en discordance sur les dépôts éocènes inférieur. Un complexe gravitaire constitué de blocs de plate-forme cuisienne remobilisés, de brèches et de débrites surmontés par des argiles représente la phase transgressive de ce cycle. Viennent ensuite des grainstones à HCS qui témoignent de la progradation d'une plate-forme externe présentant une polarité sédimentaire de direction opposée (E-W).

La séquence éocène supérieur n'est représentée que dans le domaine de bassin. Sa base est marquée par une phase de déstabilisation entraînant la mise en place de brèches et de débrites le long de failles normales synsédimentaires. Ces dépôts sont surmontés par une formation argileuse dans laquelle s'intercalent des débrites. Cette séquence se termine par des dépôts gravitaires proximaux issus du démantèlement d'une plate-forme péri-récifale progradante. Le sommet de cette séquence correspond à une phase tectonique majeure synchrone du début du rifting du golfe d'Aden. Celle-ci entraîne une surrection relative du secteur occidental qui est soumis à une phase d'émersion et subit d'importants phénomènes d'érosion.

Une discordance angulaire marque la base de *la séquence oligocène* qui représente la séquence synrift précédant l'ouverture du golfe d'Aden. Des dépôts carbonatés transgressifs de plate-forme très peu profonde, épisodiquement émergée reposent en onlap sur la surface d'érosion majeure précitée. Une deuxième phase transgressive datée de l'Oligocène supérieur entraîne une légère rétrogradation du système représentée par la mise en place de dépôts caractéristiques d'un environnement de plus haute énergie. Cette séquence de dépôt se termine par une surface d'émersion qui s'accompagne du développement d'un paléosol.

Cette nouvelle phase d'émersion résulte probablement d'un soulèvement lié à la rupture continentale du golfe d'Aden. Elle marque la base de *la séquence miocène (Burdigalien-Langhien)* constituée d'une alternance de calcaires biocalcarénitiques à mollusques et coraux, et de calcaires crayeux bréchifiés. Cette unité, considérée régionalement comme des dépôts post-rift, représente la dernière incursion marine sur la plaque Arabe.

La série sédimentaire paléocène / éocène qui précède l'ouverture du golfe d'Aden, enregistre différentes phases de déformation en contexte de marge transformante. À la limite éocène / oligocène, une phase tectonique majeure marque le début du rifting oligo-miocène du golfe d'Aden et entraîne un bouleversement de la dynamique sédimentaire. Finalement, les séquences oligocène et miocène enregistrent l'influence des différentes phases d'ouverture du golfe d'Aden sur un domaine proximal de la marge passive néoformée.

Tentative high resolution palynostratigraphy of the Late Paleocene and Early Eocene in the southern North Sea Basin

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The geological record preserves episodes of past climate change in which the response of plant communities can be studied in detail and on different time scales. Specifically, predictions on geographical range changes and diversity

dynamics as a result of rapid warming can be explored using the fossil record of plant organs such as pollen and spores.

During the Paleocene, drastic changes affect the 'Paleotropical' flora (Takhtajan, 1969, Krystofovich, 1957). Especially the *Normapolles*, originating from Cretaceous taxa, gradually decreased and were replaced by 'modern' assemblages known as 'Eocene paleotropical element' (Krutzsch, 1967) or as 'Tethyan element' (Muller, 1980, 1981). The evolution of this flora in the southern North Sea basin was studied by one of us focusing particularly on the paleoenvironmental and palynostratigraphical aspects of the Paleocene-Eocene boundary (Roche, 1973 a, 1973b, 1982, 1990).

More recently we have summarized the results of high resolution samplings of this interval studied to highlight these changes and to test their stratigraphic potential in the Kallo borehole (KB) and the outcrops of the Cap d'Ailly reference section (CA), two well expanded records encompassing the P-E boundary (Roche *et al.*, 2009). The KB is located in Belgium, in the onshore outcrops of the Cenozoic of the North Sea Basin (Gulinck, 1969; Dupuis *et al.*, 1991; Steurbaut *et al.*, 2003). The CA section crops out about 200 km to the southwest in Upper Normandy (France) (Dupuis & Steurbaut, 1987; Dupuis *et al.*, 1998). Both sections of the studied interval have been also sampled with high resolution for the dinocysts study and chemostratigraphy (δ^{13}Corg: Magioncalda, 2004). They both comprise a terrestrial to lagoonal unit marked by the CIE (Tienen Fm and Mortemer Fm of the Ieper Group and the Mt Bernon Group respectively, Steurbaut *et al.*, 2003; Aubry *et al.*, 2005) followed by the Lower Ypresian marine units (Ieper Fm and Varangeville Fm).

In both sections we identified three main episodes of change evidenced by last occurrences (LO) and/or first occurrences (FO) recorded. The first floral change (FC1) is characterised by the LO of *S. pseudoporites*, *L. globosus*, *R. hians*, *S. spissoexinus* and the FO of *T. roboratus/aroboratus*, *S. subporatus*, *P. macgregorii*, *M. hungarica*. The second one (FC2) is mainly marked by the LO of *S. magnoporatus tectopsilatus*, *S. magnoporatus magnoporatus*, *B. basalis*. The third one (FC3), is mainly marked by the FO of *Spinizonocolpites*, *S. angki*, *D. luteticus*, *M. incerta*.

FC1 with both LO and FO looks as a renewal of the flora. It coincides with the onset of the CIE and reflects the environmental impact of the incoming PETM. Major floral composition and diversity changes are also recorded elsewhere during the PETM (in Wyoming: Wing *et al.*, 2005; in the US Gulf coast: Harrington & Jaramillo, 2007) as a result of the ensuing warming.

FC2 probably corresponds to a regional change in the environment only preserved in the CA section. With many FO, FC3 may indicate a new step in the plant diversification. It is diachronic (in NP11 in Ca to NP12 in KB) according to the available NP biostratigraphy (Aubry, 1983; Steurbaut,1998). This may reveal a northwards migration of a specific environment (proto-mangrove).

More studies are needed to decipher the floral composition and diversity changes at the Paleocene-Eocene boundary and during the PETM, to check possible adaptations to more humid or arid events or to seasonality differences. Nevertheless, the floral changes observed in KB and CA already offer, especially FC1 and FC2, valuable new interesting correlation criteria. Indeed those floral changes have been evidenced in other sections of the Paris

Basin (Sotteville-sur-Mer, Therdonne, Sinceny, Laon, AVE007 drilling in Avesnois). Associated to the δ^{13}Corg data and the occurrence of the *Apectodinium* acme and the first *Wetzeliella* in shallow marine to lagoonal environment they help the correlations of the regional units deposited between the major or local hiatuses identified in the Late Paleocene to Early Eocene succession.

Geochemical analysis at the Lower Toarcian in the Fuente de la Vidriera section, Betic Cordillera, Spain: approaching the T-OAE

Francisco Javier Rodriguez-Tovar, Matias Reolid, Isabel Abad

The Toarcian Oceanic Anoxic Event (T-OAE) is usually related to the development of millimeter-scale, laminated, organic-rich black shales, and interpreted as a global oceanic anoxic event. The record of the T-OAE has a diagnostic positive carbon-isotope excursion within the falciferum Zone (Jenkyns, 1988), then a pronounced, negative excursion in δ^{13}C, directly followed in some sections by a positive excursion (Hesselbo *et al.*, 2007). Different hypothesis have been proposed to explain this phenomena but some authors consider anoxia as the only factor coinciding with the associated global extinction throughout the European region during the mid semicelatum Subzone (Wignall *et al.*, 2005).

In the Betic Cordillera, southern Spain, the deep-marine Fuente de la Vidriera section is a well developed section to examine the T-OAE as recorded at the westernmost Tethys. The studied Lower Toarcian section contains an approximately 30-m-thick rhythmic succession of soft and hard marlstones. Two biozones were defined within the Lower Toarcian –the polymorphum and the serpentinus biozones, but the scarcity of ammonites difficult to fix the exact boundary. Previous TOC and isotopic analyses (Jiménez *et al.*, 1996), revealed the presence of black shale facies, as well as three positive δ^{13}C excursions. Between the three maximum δ^{13}C values, two negative carbon isotope excursions were recognized. According to Jiménez *et al.* (1996), the anoxic event started at the beginning of the Toarcian (polymorphum Subzone) and continued throughout the serpentinum Subzone, with the main positive δ^{13}C excursion in the upper part of the serpentinum Subzone; then, the 30-m-thick rhythmic succession of soft and hard marlstones studied here was deposited during the T-OAE. However, recent ichnological analysis of the T-OAE interval conducted from this section, reveals that sediments are totally bioturbated, except for one bed displaying cross lamination (FV-18; Rodríguez-Tovar and Uchman, in press). Trace fossil assemblages are relatively abundant, moderately diverse (Alcyonidiopsis, Chondrites, Nereites, Palaeophycus, Planolites, Teichichnus, Thalassinoides, and Trichichnus), and uniform throughout the succession, indicating that sea-floor palaeoecological parameters remained constant. The ichnological assemblage suggests oxic or slightly dysoxic bottom waters, relatively favorable for benthic organisms, especially low-oxygen tolerant trace makers. The abundance of Chondrites could be indicative of comparatively low oxygen levels in pore waters in deeper

tiers, but the continuous presence of ichnotaxa such as Planolites and Nereites, whose trace makers use oxygen from pore water, indicates oxygenated sediments in shallower tiers. No significant fluctuations of oxygenation can be detected in the section. Thus, T-OAE did not have a significant impact on the endobenthic macrobenthos in the study area of the westernmost Tethys.

To evaluate the significance of the T-OAE event in the Fuente de la Vidriera section a detailed geochemical analysis has been conducted in the 30-m-thick rhythmic succession previously studied by trace fossils, focusing in proxies of paleoredox conditions and detrital input.

Several redox-sensitive trace metal ratios have been analyzed in order to approach a possible change in paleoxygenation in bottom waters, including Mo/Al, Co/Al, Ni/Al, Cr/Al, Pb/Al, Zn/Al, Cu/Al, V/Al, Mn/Al, Fe/Al, and U/Th. The stratigraphic evolution of the analyzed ratios reveals continuous fluctuations along the succession, but the most frequent variations are located in samples FV-8 and FV-18. In FV-8, important incursions are registered in Ni/Al, Va/Al, Mo/Al, Co/Al, and Fe/Al, but without changes in Mn/Al. In FV-18, maxima are recognized for Cr/Al, Mn/Al, Ni/Al, V/Al, U/Al and U/Th, but other redox proxies do not increase (Co/Al, Cu/Al, Mo/Al, and Pb/Al). In this sample station, a maximum in Mn/Al, together with an increase in Fe/Al are registered.

In a generalized context of oxic to slightly dysoxic bottom waters, punctual dysoxic conditions can be interpreted associated to samples FV-8 and FV-18. The return to oxic conditions below the sediment-water interface after sample FV-18 could be related to the input of well-oxygenated waters to the basin or bottom water ventilation. The oxic front could remove the Co, Cu, Mo and Pb explaining the absence of maximum of the elements in the FV-18.

Respect to a possible detrital input, some elemental/Al ratios have been selected, including Si/Al, Mg/Al, K/Al, Rb/Al, Ti/Al, and Zr/Al. Some of these ratios do not reveal significant increases, but only minor fluctuations along the succession (*i.e.*, Rb/Al). However, some of the selected ratios show significant increases in the ratios (*i.e.*, Zr/Al, Ti/Al, Mg/Al, even Si/Al), especially in the upper part of the studied succession (around FV-18), and occasionally in the middle (FV-7 and FV-8: Mg/Al, K/Al, Zr/Al), and lower part (FV-1: Mg/Al, K/Al, Ti/Al).

According to the obtained geochemical data along the Fuente de la Vidriera section, a significant, continuous and long-term decreasing in bottom-water oxygenation can be discarded, and only punctual diminutions can be recognized associated to samples FV-8 and FV-18. For the latter, this is consistent with the absence of bioturbation, that could reveal punctual lower bottom water oxygenation rates, in a general context of oxic or slightly dysoxic conditions (Rodríguez-Tovar and Uchman, in press). The absence of a generalized bottom water anoxia during development of the T-OAE, could be related with the lower intensity of this event in this westernmost part of the Tethys. Even previous TOC and isotopic data (Jiménez *et al.*, 1996) indicated the development of the T-OAE, the reported values are comparatively lower than the usually ones obtained in other Tethyan Toarcian sections (Jenkyns, 1988; Wignall *et al.*, 2005), that could reveal a less intense anoxic event in this area (only local dysoxic conditions).

The Devonian conodont-based stratigraphy of the Kuznetsk Basin (Russia)

Sergei Alexandrovich Rodygin

The Devonian deposits are widespread in the marginal parts of the Kuznetsk Basin (Kuzbass). They are confined to the Givetian Stage of the Middle Devonian, to Frasnian and Famennian of the Upper Devonian. The studied sections are located in the vicinity of the town of Anzhero-Sudzhensk, in the Yaya, Barzas basins, in the Tom' Basin downstream of the city of Kemerovo (the northern district of the Kemerovo Region) and in the vicinity of village Vassino of the Novosibirsk Region (Type sections.., 1991). The sections are composed by terrigene-carbonaceous, mainly shallow deposits bearing rich associations of benthic fauna with brachiopods, rugoses, tabulates and stromatoporoids predominating. Crinoids, ostracodes, tentaculites, bivalves are encountered; less common are gastropods and cephalopods, trilobites, fish integument fragments. Along with the fauna, stromatolites, algae, vegetable debris and spores are met from certain of the sections.

These sections were tested for conodonts being of great stratigraphic importance. The representative conodont assemblages were established, that enabled the stratigraphical position of horizons to be defined more precisely and the correlation between the sections and the standard conodont scale to be made. L.M. Aksyonova and V.G. Halymbadzha took part in studying conodonts jointly with the present author (Aksenova *et al.*, 1994).

The Givetian deposits compose the Mazalovsko-Kitatskian Horizon subdivided into the Mazalovsko-Kitatskaya, Siberian-Lebedyanskaya and Izylinskaya Formations. The Mazalovsko-Kitatskaya Formation encloses the conodonts: Polygnathus timorensis Klapper, Philip et Jackson, Icriodus obliquimarginatus Bischoff et Ziegler, I. brevis Stauffer and others indicating its belonging to the Lower varcus conodont zone. The Siberian-Lebedyanskaya Formation containing the conodont species *Polygnathus ansatus* Ziegler et Klapper, *P. timorensis* Klapper, Philip et Jackson, *P. ovatinodosus* Ziegler et Klapper, *P. varcus* Stauffer, *Icriodus brevis* Stauffer, *Ozarkodina semialternans* (Wirth), among others, is assigned to the Middle and Upper varcus zones and, probably, to the hermanni-cristatus zone. The Izylinskaya Formation, containing *Polygnathus* cf. *webbi* Stauffer, *P.* cf. *decorosus* Stauffer, *P. dubius* Hinde, *Icriodus brevis* Stauffer, *I. difficilis* Ziegler et Klapper, *I.* cf. *difficilis* Ziegler et Klapper, *I.* aff. *expansus* Branson et Mehl, *I. expansus* Branson et Mehl and other conodont species, is correlatable to the Early falsiovalis (norrisi) zone.

The Frasnian Stage of the Kuzbass is subdivided into the Vassinskian and Solominskian horizons. The Vassinskian Horizon contains the conodont assemblage including the following species: *Polygnathus webbi* Stauffer, *P. alatus* Huddle, *P. decorosus* Stauffer, *P. aequalis* Klapper et Lane, *P.* aff. *angustidiscus* Youngquist, *Ancyrodella lobata* Branson et Mehl, *Icriodus expansus* Branson et Mehl, *I. brevis angustulus* Seddon, *I. subterminus* Youngquist, and others. This horizon can be confined to the interval of the falsiovalis-jamieae zones. The Solominsky Horizon containing the conodont

assemblage composed of *Polygnathus decorosus* Stauffer, *P. evidens* Klapper et Lane, *P.* cf. *normalis* Miller et Youngquist, *P. webbi* Stauffer, *Ozarkodina gradata* Youngquist and others is confined to the interval of the rhenana-linguiformis conodont zones.

In the Famennian Stage (northern margin of the Kuzbass), the Peshcherkinskian, Podoninskian and Topkinskian horizons are established. The conodont assemblage distinguished in the Peshcherkinskian Horizon includes *Palmatolepis triangularis* Sannemann, *Pa. minuta minuta* Branson et Mehl, *Pa. subperlobata* Branson et Mehl, *Pa. delicatula delicatula* Milleret Youngquist, *Pa.* aff. *quadrantinodosalobata* Sannemann, *Polygnathus brevilaminus* Branson et Mehl, *P. pacificus* Savage et Funai, *P.* aff. *xylus* Stauffer, *Icriodus iowaensis ancylus* Youngquist et Peterson, *I. cornutus* Sannemann, etc. This assemblage is indicative of the possibility to confine this horizon to the interval of the conodont triangularis-trachytera zones. The Podoninskian Horizon contains the conodont complex (Y.M. Gutak's sampling) composed of *Polygnathus delicatulus* Ulrich et Bassler, *P. inornatus* Branson, *Siphonodella praesulcata* Sandberg, and some others, which is characteristic for the praesulcata zones of the uppermost Famennian. In the limestones of the Topkinskian Horizon the following conodonts are distinguished at present: *Polygnathus inornatus* Branson et Mehl, '*Icriodus*' *costatus darbyensis* Klapper Morphotype 2; *Mehlina strigosa* (Branson et Mehl). They are widely occurring in the expansa and praesulcata zones of the uppermost Devonian (Gutak *et al.*, 2004; 2007).

Consequently, the deposits of the northern margin of the Kuznetsk Basin represent the section that is almost continuously characterized by conodonts and confidently correlatable with the zones of the Standard Conodont Scale.

The evidence for the occurrence of Devonian forests in Siberia

Sergei A. Rodygin, Alexander L. Arkhipov

The Devonian Period was unique in the evolvement of the primary terrestrial vegetation. In this period the land became completely occupied by plants.

Each of three Devonian epochs is characterized by its own stage of the land plants development that is well justified by Siberian materials.

In the Early Devonian, Propteridophyts (Psilophyts), small shrubby leafless plants, have occurred in the maritime areas of the Angarida continent, and their prints are well- known from Khakassia, Krasnoyarsk Region, the Altai Mountains and other areas.

In the Middle Devonian the plants have become more highly evolved and abundant, though the forests did not still exist. Along with the ancient lycopsids, arthrophytes, pteridophytes, there existed plants transitional to gymnosperms (progymnosperms). The finds of Aneurophyton germanicum Krausel et Weyland among others were reported from the Altai-Sayan folded area (Antonova, 2009).

The true arboreal plants appeared in the Frasnian Age of the Late Devonian. The '*Archaeopteris* flora' was the most widespread in the Northern Hemisphere. *Archaeopteris* was previously taken for tree fern, but nowadays it is referred to the above-stated Progymnosperms, Class Progymnospermopsida (Meyen, 1987). A new locality of Archaeopteris and accompanying plants was discovered by a field team of Tomsk State University (TSU), led by A. Arkhipov in 2007 and it was extended in 2009. This locality is situated in North Khakassia nearby Lake Oshkol within a quarry uncovering the Upper Frasnian deposits of the Kokhayskaya Formation (Late Devonian). The beds containing the flora prints are composed by tobacco-green, yellow-green siltstones, argillites and fine-grained sandstones.

As V. Antonova determined, the assemblage of the fossil flora includes *Archaeopteris fissilis* Schmalhausen, *Arch*. cf. *macilenta* Lesquereux, *Niayssia plumata* Zalessky, *Sphenopteridium lebedevi* (Schmalhausen) Ananiev, *Rhacophyton condrusorum* Crepin and others.

Along with fragments of shoots and leaves, trunks were also found belonging presumably to one of these plants. The trunks are confined to the thick (up to 0.5 m) bed of the greenish-grey fine-grained sandstone with the clayey limonite crust divided into blocks by numerous shrinkage cracks and covered by 'hieroglyphs'. By this geological term any bas-relief signs on clayey surface of beds are indicated. These signs either appeared over the vital functions of organisms or had mechanical reasons. Within this bed, there is a thin, in places cross and wave-like lamination which is characteristic for the continental reservoirs, most likely small lakes and rivers discharging into them. Within the quarry the layers are weakly tilted north-eastwards. The penetrated bed thickness does not exceed 70 meters, which is an incomplete part of the whole thickness of the formation. The fossiliferous locations go beyond the two above-stated beds. Several beds containing the plant prints and thin interbeds with debris were also discovered.

The Kokhayskaya Formation is composed by an interbedding of the terrigenous cherry-red and yellowish-green members. This gives evidence of the alternation of oxidizing and reducing conditions, the periodic land and climate aridization (the cherry-red beds rich in iron oxide) and the formation of numerous reservoirs of a lake-marsh type, where the moribund plant remains (yellowish-green beds) were preserved in the oxygen-deficient conditions.

In 2008, two such sandstone plates weighing as much as 5 tons were transported to the geological museum of the TSU field station; three trunks of fossil plants are easily observable on their surface. The trunks are about 2 meters in length and 10 centimeters in diameter.

The finds of the trunks provide support for the data on the wide occurrence of the forest vegetation in the Frasnian in Angarida. It is of interest that, besides fossil plants, the prints of large fresh-water bivalves was encountered, inhabiting reservoirs with wooded watersides.

Atmospheric oxygen levels change during the Palaeozoic times: Contradictory data and incentive for new research

Jacky Rousselle

This presentation is dedicated to highlight the seemingly conflicting data about the atmospheric oxygen levels changes through Palaeozoic and more globally through the entire geological times.

Indeed, some curves show an increase in atmospheric oxygen content over time during the Paleozoic. In this first category, the curves are characterized by atmospheric oxygen levels that stay below the Present Atmospheric Level (PAL) for all geological time. An example of these curves has been proposed by Kasting (2004).

Meanwhile, a second group of authors (*e.g.* Berkner and Marshall, 1965; Berner and Canfield, 1989 or Berner 2009) provides curves in which values are sometimes substantially above the levels of the PAL in several Paleozoic periods.

Also, the differences between these two types of curves will be investigated and their underlying hypotheses highlighted. Lines of reflection will be offered to initiate further work and try to advance research in this area.

[VF] Évolution du taux d'oxygène atmosphérique au Paléozoïque : Données contradictoires et incitation à recherches

L'objectif de cette présentation est de mettre en évidence les données a priori contradictoires sur l'évolution de la teneur en oxygène atmosphérique au cours du Paléozoïque et dans l'ensemble des temps géologiques.

En effet, certaines courbes montrent une augmentation de la teneur en oxygène atmosphérique en fonction du temps pendant le Paléozoïque. Dans cette première catégorie, les courbes sont caractérisées par des teneurs en oxygène atmosphérique toujours inférieures au niveau actuel (PAL: Present Atmospheric Level), et ce pour l'ensemble des temps géologiques. Un exemple de ce type de courbes a été proposé par Kasting (2004).

Parallèlement, un second groupe d'auteurs (ex. Berkner et Marshall, 1965; Berner et Canfield, 1989 ou encore Berner 2009) propose des courbes dont des valeurs sont parfois nettement supérieures au PAL pour certaines périodes du Paléozoïque.

Aussi, l'accent sera mis sur les écarts observés entre ces deux catégories de courbes et, dans une certaine mesure, il sera présenté leurs hypothèses sous-jacentes. Des axes de réflexion seront proposés pour initier de futurs travaux et tenter de faire progresser les recherches dans ce domaine.

The ORS Vertebrates of Spitsbergen (Svalbard)

Jean-Claude Roy, Alain Blieck, Daniel Goujet, Philippe Janvier, Vincent Pernegre, Gaël Clément, Vincent Dupret, André Nel

In the Arctic, Spitsbergen (Svalbard archipelago) comprises a Caledonian metamorphic basement structured around 420 Ma, cut by faults that demarcate a sedimentary, NS graben, filled up by siliclastic detrital series of Old Red Sandstone facies (ca. 418 - ca. 326 Ma), with a lateral cumulative thickness of 6300 to more than 10,800 meters. The latter yields a particularly abundant fauna of early fishes, which are the main guide fossils for stratigraphic purposes (Agnatha, Placodermi and Crossopterygii). These sediments are faulted and folded, and disconformably overlapped by the unfolded, marine Carboniferous - Permian carbonate platform. The Old Red Sandstone of Spitsbergen is a reference for all the contemporaneous series of the ORS Continent. However, since the outcrops were hitherto discontinuous in the Polar zone, the stratigraphic correlations were difficult to establish, and the definition of the lithostratigraphic units are still discussed. This region is one of the least studied as for paleontology and stratigraphy, even if several fossil collections and partial field mappings have been made, notably in 1939 with the Anglo-Norwegian-Swedish palaeontological expedition, and in 1969 with the French CNRS-MNHN expedition, later completed by the Russian and German works (Murasov and Mokin 1976, 1979; Schweitzer, 1999). Since the acceleration of the melting of the glaciers and of the ice-cap, the gradual continental rise by glacioisostasy and the erosion by torrents and the tide cause incisions in the moraines, and new outcrops appear. In the framework of a collaboration with the Norsk Polarinstitutt, our field teams could visit some of them, such as LGGST - Chorowicz 1986 to 1994, Roy 1999, CAST 401 IFRTP - ipev 2002 and 2003, Roy 2008, and SPITZ P3 1005 ipev 2010, and the stratigraphical correlation of the nunataks is in progress. Palaeontology, geology, geophysical and geochimical geochronology show that, in Spitsbergen, the deposition of the ORS began in Late Silurian (?Pridoli) times and continued in the Devonian and Carboniferous until the beginning of the late Mississipian. The new information we now have, thanks to studies led in the framework of the International Geologic Correlation Programme 328 (Blieck and Turner 2000) and IGCP 406 Programme, 'Circum Arctic Lower - Middle Paleozoic Vertebrate Palaeontology and Biostratigraphy', with H. Blom (Uppsala) and V. Talimaa (Vilnius), lead us to consider the sedimentation of the graben and its tectonic behaviour as an essential source of data for understanding the natural history of the Arctic: the consequences of the closure of the Iapetus ocean and the dismantling of the Caledonian chain. The bio- and litho- stratigraphy begins to be accurately known, notably thanks to the vertebrate-based biozones (Agnatha, Placodermi and Crossopterygii); a work that was been initiated by Daniel Goujet (1984) and continued by the research team on vertebrate fossils of Spitsbergen (Blieck, 1982, 1984; Goujet, 1984; Janvier 1985; Blieck *et al.*, 1987; Clément, 2001; Pernegre, 2004). If some of these vertebrates seem endemic to Spitsbergen and to the Arctic, they are closely connected to marine species of global distribution, notably with Australian species.

Paleosols and weathering profiles related to Sequence Boundaries: their development and their preservation

Jean-Loup Rubino, François Lafont, Jonathan Pelletier, Jean-Michel Deharbe, Celia Beaudouin, Eddy Metais, Philippe Duringer, Mathieu Schuster, Olivier Parize, Ali Sbeta

Since the beginning of sequence stratigraphic analysis, little attention has been paid to the paleosol or weathering profiles developed during the low stand phase and therefore representing a sequence boundary marker. They are mentioned in Van Wagoner *et al.* (1990) and in Posamentier & Allen (1999), where they are considered as subordinate markers because of (i) their poor preservation potential during the following sea level rise and associated transgressive erosion and (ii) the difficulty to pick them on well logs.

However some authors (*e.g.* McCarthy & Plint, 1998) assume that paleosols are the best markers of sequence-bounding surfaces in interfluve setting. More recently, Cataneanu (2001) pointed out that it is very important to discriminate soils formed during period of sediment aggradation in continental settings from soils formed during periods of non deposition or erosion and associated to stratigraphic hiatuses and unconformities. He also assumes that paleosols related to sequence boundaries are more mature than those developed during periods of sediment accumulation. Finally few authors, (Lander et al, 1991; Webb, 1994; Wright, 1994) described preserved soils affecting palaeo-sea floor or preexisting coastal to shelfal deposits.

Recent investigations of ancient successions from Permian to Miocene worldwide allow proposing a reappraisal of the paleosols related to sequence boundaries, with special emphasis on their preservation potential.

In the first example, coming from the Miocene of SE France, a yellowish weathering profile outlined by an iron concentration is preserved below an erosional sequence boundary and a tidal ravinement surface. In that case preservation seems to have been helped by the fact that the initial profile was quite thick, affecting porous sandy shoreface sandstones deeply downward. It is also important to notice that the preservation increases away from the incised valley axis.

In a second example, coming from the Upper Triassic of Madagascar, a mature soil profile is preserved on top of a paralic succession; in that case it is well preserved because the overlying trangressive systems tract starts with aggradation of low energy lagoonal deposits prior to further erosion by the tidal ravinement surface.

The third case comes from the Triassic of Algeria. The TAGI sandstones are estuarine deposits overlain by lagoonal shales or bay deposits, as demonstrated by the trace fossils association. These fine grained deposits are reddish and pedogenised. We assume that the soil preservation below the

overlying sequence boundary and transgressive tidal ravinement surface is most likely related to the initial thickness of the weathering profile.

A very similar case can be observed in the Permian of Saudi Arabia within the Unayzah Formation where a very thick weathering profile with long roots is preserved below the transgressive tidal sands.

In another example, also coming from the Upper Triassic of Madagascar, a mature paleosol affecting marine wave dominated deposits is very often preserved below low energy flood plain deposits. At the opposite, as soon as a fluvial channel rests over the sequence boundary the soil is truncated and fluvial channel deposits sharply overlie shallow marine deposits.

Finally, in the Lower Cretaceous of Northern Libya and Southern Tunisia, several sequence boundaries within the Cabao and Khiklah formations are characterised by thick soils and weathering profiles preserved below tidal ravinement surfaces. In this case the good preservation seems to be related to the strong cementation of the profile which was not entirely removed by the wave or tidal transgressive ravinement surfaces thanks to its physical resistance to mechanical erosion.

In conclusion, the preservation of a well developed soil profile on top of shallow marine succession at a sequence boundary seems primarily function of the initial characteristics of the weathered interval, including its initial thickness and its cohesion, and second to the amount of erosion related to the transgressive ravinement surfaces (wave or tide). In other words, when an early transgressive system tract occurs prior to the ravinement surface, the preservation potential of the soil is much greater.

Finally a good preservation is also noticed when a significant depositional environment change occurs across the sequence boundary, more specifically when an aggrading flood plain caps a weathering profile related to a lowering of sea level.

Palynostratigraphic method: a successful tool for establishing the allostratigraphic units correlation of three fragments of a half-graben related to the Gulf of Mexico origin

Jaime Rueda-Gaxiola

North American Stratigraphic Code defines an Allostratigraphic Unit as a mappable stratifome body of sedimentary rock that is defined and identified on the basis of its bounding discontinuities. Frequently, it is not easy to differentiate and to place geochronologically those units, because they are composed by redbeds and conglomerates, which are considered as azoic bodies among the sedimentary sequences deposited in grabens and half-grabens.

The Palynostratigraphic Method has been the main successful tool for establishing the allostratigraphic units correlation of three fragments from the

Late Triassic-Early Jurassic half-graben, named El Alamar-Tlaxiaco, more than 1000 km long, related to the Gulf of Mexico origin. X Rays diffraction and fluorescence analyses and the Miall's method of facies analysis applied to fluvial deposits supported the palynostratigraphic results. These sedimentary continental sequences, from the Huizachal-Peregrina, Huayacocotla and Tlaxiaco anticlinoria, bordering the western Gulf of Mexico, were deposited in three sectors of the same half-graben, one of two basins parallel to the western border of Pangea, but crossing perpendicularly three main tectonic blocks delimited by long faults.

The first palynostratigraphic analysis was made from the redbed sequence outcropping at the northern Huizachal-Peregrina Anticlinorium; the results permitted to know that it is composed by three units (Huizachal, La Boca and La Joya) characterized by 8 palynozones based on color and abundance of palynological residues. The first two are alloformations from the Los San Pedros Allogroup; the third one is La Joya Formation. Microscopic analyses from palynologic residues show dominantly continental organic matter but in sample 359, from palynozone B, were found continental and marine palynomorphs from Sinemurian and Pliensbachian ages. X Rays Diffracction and Fluorescence analyses, from rocks and palynologic residues, permitted to support a marine environment based on the presence of glauconite in rocks above and beneath sample 359. Structural and palynostratigraphic data allow conclude that a Liassic allostratigraphic sequence was deposited into a half-graben (named Huizachal-Peregina), bordered by alluvial fans along an anastomosed fluvial system, invaded by marine incursions.

Marine palynomorphs and glauconite permitted to explain why an especimen from the piscicole pterosaur Dimorphodon weintraubi Clark, J.M. *et al.* 1998 had been unearthed from this half-graben. This genus was found initially in english Liassic rocks from Dover. Thus, in order to reconstruct the regional Liassic Paleogeography, it was necessary to establish the southward half-graben continuity. It was not found toward SE in the Tampico-Misantla Basins, as considered, but at the Huayacocotla Anticlinorium. Both sedimentary sequences correlate very well because the palynozones from the Los San Pedros Allogroup have equivalent units into the Huayacocotla Group established by Schmidt-Effing, R., 1980, but showing more and more marine influence toward SE. On the other hand, the palynostratigraphic and X ray data show a southwestward Toarcian-Aalenian displacemnt of the Huayacocotla Block, wich is at the origin of the Tampico-Misantla Basin with an initial lacustrine and shallow marin sedimentation, caracterized by palygorskite and sepiolite argillous minerals.

Recently, sedimentary results from two thesis works (De Anda-García, A., 2008 and Osorio-Nicolás, M.A., 2009) permitted to enhance the palynostratigraphic knowledge from the Tlaxiaco Anticlinorium northern region, previously established by Jiménez-Rentería, J., 2004. These new data were used for deducing that the Liassic and Middle Jurassic sedimentary sequence was deposited also into a half-graben, bordered by alluvial fans, invaded by estuarine waters. Thus, Jurassic allostratigraphic units outcropping at the three known anticlinoria were correlated successfully and compared to that from the Tampico-Misantla Basin subsoil. Nevertheless, the main obtained conclusion was related to the northern sedimentary provenance from the quartzose units deposited above the Los San Pedros Allogroup, at the Huizachal-Peregrina, and the proposed Consuelo Allogroup, at the Tlaxiaco Anticlinorium. The

sedimentary sequences and structural data show that there were not three isolated basins, but only one and unique half-graben, the Alamar-Tlaxiaco Basin. The basal units were formed by riolites northwestward (Allomember Río Blanco at Huizachal-Peregrina) and andesites southeastward (Diquiyú Alloformation at Tlaxiaco).

Paleogeographic evolution

During Sinemurian-Pliensbachian time, the Huayaocotla Block was lower and filled by an epicontinental sea, named 'El Portal del Balsas', which received the fluvial sediments (known as the Huayacocotla Group) coming from the two remained Huizachal-Peregrina (known as Los San Pedros Allogroup) and Tlaxiaco (proposed as Consuelo Allogroup) fragments. During Toarcian-Aalenian time, the Huayacocotla and Tlaxiaco blocks and also South America moved southwestward at the same time that a hot spot appeared at the NE, forming a dome in the central part of the present Gulf of Mexico. During this doming stage, huge volumes of cratonic interior metamorphic rocks were eroded and quarzose sediments transported by fluvial systems toward S and SW. They were conformably and unconformably deposited above the Lower Liassic redbed sedimentary units; they are known, in the three fragments from the Alamar-Tlaxiaco Basin, as Cuarcítica Cualac Formation at the Tlaxiaco, as Cahuasas Formation at the Huayacocotla and as the Cuarcitic Allomember of the La Boca Alloformation at the Huizachal-Peregrina. During Bajocian-Oxfordian time, follow the rifting, sinking and drifting tectonic stages, giving origin, first, to the 'Hispanic Corridor' and, later, to the Gulf of Mexico.

Vers une écostratigraphie du Messinien ?

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L'affinement des données biostratigraphiques, magnétostratigraphiques, cyclostratigraphiques et téphrochronologiques a permis de mieux circonscrire temporellement les divers événements, certains spectaculaires, qui ont jalonné l'histoire du Messinien. Les modèles récemment proposés pour expliquer les divers aspects de la fameuse Crise de Salinité du Messinien peuvent être maintenant discutés en fonction d'un canevas stratigraphique beaucoup mieux contraint qu'au temps des plus vives controverses. Cependant un certain nombre de ces données ne peut être directement utilisé, notamment pour des faciès littoraux, lorsque les affleurements ne concernent qu'une partie du Messinien ou que les informations stratigraphiques sont oblitérées par des déformations post-dépôts. Le cas des grands panneaux de dépôts messiniens disloqués et déplacés observés récemment à la marge nord du bassin du Chelif (monts des Dahra) est à cet égard très représentatif. Dans ces conditions il est

sans doute légitime de compléter ou de confronter les données stratigraphiques évoquées précédemment avec divers indicateurs écostratigraphiques. C'est l'occasion d'utiliser de tels critères écostratigraphiques dans ces faciès de plate-forme carbonatée abondamment représentés sur les marges de la Méditerranée messinienne.

Le Messinien est caractérisé par nombre de phénomènes paléoocéanographiques dont la traduction se retrouve dans les changements et l'évolution des peuplements marins. Dans ce cadre, si les microfaunes et microflores du Messinien ont été assez bien étudiées, en revanche peu de travaux ont été consacrés à l'évolution des peuplements de macrofaune des fonds méditerranéens. À ce jour aucun recensement exhaustif global de ces peuplements n'a été effectué de manière à suivre pas à pas les modifications survenues dans leur structure et leur composition. Pourtant des variations dans la composition des faunes et flores littorales sont très sensibles, aussi bien avant le début de la crise, estimée aux alentours de -5,96 Ma, que durant la crise marquée par la généralisation des dépôts à caractère évaporitique, l'instauration des environnements de type 'lago mare' et l'abaissement du niveau marin méditerranéen.

Plusieurs événements ou évolutions biologiques semblent ainsi bien repérables au sein de la sédimentation messinienne et pourraient être replacés dans un cadre stratigraphique général :

- présence des marqueurs d'eaux froides dans les populations de diatomées,
- variations dans la composition des foraminifères benthiques,
- évolution de la composition de la faune de coraux constructeurs,
- architecture des constructions coralliennes à Porites,
- disparition des coraux hermatypiques,
- 'bloom' à Halimeda,
- accumulations à hétérostégines,
- exclusion temporaire de certaines mégafaunes,
- distribution de la biodiversité des gastéropodes,
- exclusion temporaire des brachiopodes térébratulidés,
- exclusion temporaire des clypeastréidés,
- distribution des assemblages de bryozoaires,
- association coraux-stromatolites,
- développement des constructions à stromatolites et thrombolites associés,
- développement des faunes saumâtres caractéristiques du faciès 'lago mare'

Dans le cas des blocs de sédiments messiniens de la bordure nord du bassin du Chélif évoqués plus haut, plusieurs de ces événements ont ainsi pu être identifiés permettant de conclure à l'existence d'un système de plate-forme à l'évolution faciologique et paléontologique tout à fait similaire à ceux représentés classiquement dans l'ensemble de la Méditerranée à cette époque. Cependant, 'blooms', apparitions et disparitions au sein du biota méditerranéen au Messinien pourraient ne constituer parfois que des événements apparents et résulter en partie de l'absence de 'fenêtres' d'observation de certains biofaciès. De ce fait, un travail de prospection sur le terrain et de compilation des informations paléontologiques doit vraiment être

entrepris, afin de pouvoir proposer un outil écostratigraphique fiable particulièrement bien adapté au cas du Messinien.

Delta and deep basin Jurassic deposits from Iran: relationship between magnetic susceptibility and facies

Mehrdad Sardarabadi, Anne-Christine Da Silva, Seyed Mohammad Zamanzadeh

This study concerns, the first sedimentary cycle in Jurassic from Iran, the Kashafrud Formation from Kopet Dagh Basin in its type section. Sedimentary studies were carried out to propose a paleoenvironmental model of the sedimentary succession. Furthermore, magnetic susceptibility (MS) measurements were performed and compared with sedimentological evolution. The MS curve evolution is related to the abundance of magnetic minerals, which itself is related to lithogenic supplies which could be related mostly to sea level and climatic changes. Theoretically, a regression will lead to a more important proportion of landmass exposed and so to an increase of detritic minerals in the sedimentary system and so to an increasing MS. A transgression will decrease MS (Ellwood *et al.*, 2000). On the basis of sedimentary environment study, this succession from base to top consists of a flood dominated delta, deep basin deposits, silisiclastic and mixed silisiclastic and carbonate shoreface. Comparison between facies evolution and MS curve shows that the facies which are deposited in Delta and shoreface have low MS values; on the contrary basinal deposits are presenting high MS values. The facies deposited in mixed silisiclastic and carbonate shoreface have lowest MS values. So it appears that the deeper basinal deposits have the highest MS values and the shallower deltaic and shorelines facies have the lowest MS values, in opposition with theoretical background. This could be related to water agitation and sedimentation rate during deposition. In the deltaic and shoreface environments, a high water agitation could prevent the detritic particles to settle and a high sedimentary rate could dilute the magnetic minerals (see also Da Silva *et al.*, 2009). Also it appears that production of carbonate in the upper parts of system has led to a dramatic decrease in MS values. This study clearly shows the significant role of MS in environmental analysis.

Delta13C carbon-isotope stratigraphy in the Berriasian - summary of results and new projects in Carpathian sections: an early report

Johann Schnyder, Jacek Grabowski, J. Hejnar, Katarzyna Sobien, Marc De Rafélis

Late Jurassic (Kimmeridgian-Tithonian) - earliest Cretaceous (Berriasian) carbon-isotope curves are characterized by a smooth, regularly decreasing

trend in the western Tethys (*e.g.* Weissert and Channel, 1989; Weissert and Mohr, 1996; Cecca *et al.*, 2001). This is followed by an inversion toward more positive values in the Early Cretaceous (Berriasian to Early Valanginian), before a marked positive peak in the Late Valanginian (the so-called 'Weissert event'; Erba *et al.*, 2004). In addition, climatic fluctuations have been recognized in this time-interval, in several sections in the western Tethys, using clay minerals, spectral gamma-ray analyses and/or pollen assemblages. An increasing aridity is developing toward the Late Jurassic - Early Cretaceous, replaced by more humid climatic conditions from the Middle -Late Berriasian higher up (*e.g.* Deconinck and Strasser, 1987; Wignall and Ruffell, 1990; Hallam *et al.*, 1991; Deconinck, 1993; Allen, 1998; Abbink *et al.*, 2001, Schnyder *et al.*, 2006; Schnyder *et al.*, 2009; Hesselbo *et al.*, 2009). The possible links between carbon-isotope fluctuations, long-term climate changes and the trophic state of the paleo-oceans during this time-interval are not fully evidenced up to now (see for example discussion in Westermann *et al.*, 2010). Moreover, Berriasian bio- (calpionellid) and magnetostratigraphical framework is relatively well established, which enables precise dating of sedimentary and climatic events in open marine sections (Grabowski and Pszczółkowski 2006, Hejnar 2008).

In the framework of a Polish - French cooperation, we recently logged and sampled several well dated Latest Tithonian – Early Valanginian pelagic sections in the Polish part of Carpathians (in the Tatra Mts and the Pieniny Klippen Belt, Grabowski and Pszczółkowski 2006; Pszczółkowski and Myczyński 2004). Our aim is to obtain a robust bio- and magnetostratigraphically calibrated integrated δ13C carbon-isotope curve and a set of palaeoclimatic data, notably based on clay minerals in this area. Ultimately, we plan to compare this integrated data-set from the Polish Carpathians to well-calibrated equivalent data from the Slovakian Carpathians (Michalik *et al.*, 2009) and the Vocontian Basin in France. This study could contribute to build a sequence of paleoceanographic events in the Carpathians, together with the study of other workers. Finally, it could improve our knowledge of palaeoceanographic events in the Tethyan and peri-Tethyan areas at the J/K boundary.

Depositional environments in the 'Lo Hueco' palaeontological site (Upper Cretaceous, Cuenca, Spain)

Manuel Segura, Fernando Barroso-Barcenilla, Oscar Cambra-Moo, Beatriz Carenas, José Francisco García-Hidalgo

The exceptional fossil site of 'Lo Hueco' is close to the village of Fuentes, in the centre of the province of Cuenca, in the middle east of Spain. It was discovered in 2007, during the trench works of the Madrid-Levante highspeed railway, in Upper Cretaceous marly mudstones lying below Cenozoic conglomerates. This site comprises a stratigraphic interval in 'Garumnian' facies (an informal term for marls, clays and gypsums, mainly of reddish coloration, deposited in shallow marine, coastal or continental environments in

southwestern Europe during Latest Cretaceous and Early Palaeogene times) corresponding to the upper part of the heterolithic and poorly known 'Villalba de la Sierra' Formation. To date, 'Lo Hueco' has provided more than 8,500 macroremains from different taxa, including plants, invertebrates and vertebrates. The vertebrate fossil assemblage is mainly composed of titanosaur sauropod dinosaurs (some of them with nearly complete skeletons), but also of actinopterygian and teleostean fishes, amphibians, panpleurodiran (bothremydids) and pancryptodiran turtles, squamate lizards, eusuchian crocodiles, pterosaurs, and euornithopod (rhabdodontids) and theropod (mainly dromaeosaurids) dinosaurs. The collected fossil sample represents a singular accumulation not only for the Iberian record but also for the entire Upper Campanian-Lower Maastrichtian European vertebrate record.

The stratigraphic succession of 'Lo Hueco' is composed, from base to top, of the following levels separated by transitional boundaries. An interval of green marly mudstones (V), 2 m of grey marly mudstones (G1), 2.75 m of red marly mudstones (R1), 1.5 m of grey marly mudstones (G2), 2.25 m of red marly mudstones (R2) and an interval of brown marly mudstones (M). Laterally, these levels can show differences in thickness of up to 0.75 m. This stratigraphic succession changes slightly in three areas of the outcrop. In its eastern area, a first sulphated interval (S1) can be distinguished, which has some points that are especially enriched with mudstones and carbonates. This sulphated interval reaches, at least, 1 m of height, and interrupts the V level by means of a net boundary. In the southern area of the outcrop, a channel structure (C) can be seen, which follows a N120ºE direction and is composed of sandy conglomerates, sandstones and sandy mudstones. This elongated structure reaches up to 10 m of width and 3 m of height in transverse section, and interrupts the V, G1 and R1 levels by means of an erosive surface. In the north-eastern area of the outcrop, a second sulphated interval (S2) can be distinguished, which has some points that are especially enriched with mudstones and carbonates. This irregular sulphated interval reaches up to 1.5 m of height, and, at least, interrupts the G2 level by means of a net boundary.

Concerning the environmental interpretation of 'Lo Hueco', the entire succession seems to correspond to a near coast muddy flood plain crossed by sandy channels, which suffered successive depositional intervals (mainly clayey but, occasionally, also chalky or sandy) and syn- or early post-depositional periods of sulphatation and ferruginization. This continental plain (with abundance of terrestrial plants, invertebrates and vertebrates) apparently registered intermittent intervals of aquatic influence (burrows, bivalves, fishes, bothremydid and pancryptodiran turtles, crocodiles), clearly evident in the G1 and G2 levels, the C structure and the S1 and S2 intervals, and of partial or total desiccation (roots), especially manifest in R1 and R2. The same aquatic influence probably was mainly of fresh water (unionid bivalves), but occasionally also was of marine or brackish water (*Thalassinoides*, herringbone or chevron bedding, pancryptodiran turtles). This aquatic influence seemingly suffered notable oscillations in volume and energy. Apparently, during the high energy intervals, some of the registered sediments and organisms were transported and fragmented, mainly across a channel (C structure), but also across its overbank zones (G1 and G2 levels). During the diminishing energy intervals, some of the registered sediments and organisms were orientated, parallel and perpendicular to the axis of the channel, and deposited on the overbank zones and inside the channel. During the low

energy intervals, mainly on the overbank zones, relatively isolated water masses could be formed, acting maybe as miring areas. Progressively, these areas might give place to trampling areas (oblique or infilled breakages in vertebrate remains near the C structure). Finally, during the intervals without aquatic influence, the environment of 'Lo Hueco' site was partially or totally dried up and vegetation settled over the muddy plain (R1 and R2 levels).

Introduction to the new Cenomanian palaeontological site 'Algora' (Upper Cretaceous, Guadalajara, Spain)

Manuel Segura, Fernando Barroso-Barcenilla, Oscar Cambra-Moo, Adán Pérez-García, Angélica Torices

This new Cenomanian vertebrate site, geographically, is located in the district of Algora (Castilian Branch of the Iberian Ranges, province of Guadalajara, centre of Spain) and, geologically, is situated in the upper part of the 'Arenas de Utrillas' Formation. In Algora and surrounding area, this terrigenous lithostratigraphic unit is represented by an interval of 100-80 meters of sandstones. It is overlaying, by mean of a net boundary, Jurassic and, in a lesser extend, Lower Cretaceous materials. The Utrillas Formation changes laterally southeastwards, by mean of a transitional boundary, to 85-75 meters of limestones and dolostones with benthic foraminifers of the lower-basal upper Cenomanian belonging to the 'Dolomías de Villa de Vés' Formation. To the top, it changes, by mean of a net boundary, to 10-15 m of limestones and dolostones with ammonoids of the uppermost Cenomanian-lower Turonian also attributed to the Villa de Vés Formation. Eastwards and southeastwards, the Utrillas Formation has some interbeds of sandstones with chalky cement, dolostones and limestones with benthic foraminifers belonging to the 'Arenas, Arcillas y Calizas de Santa María de las Hoyas' Formation, whose abundance and thickness become progressively increased until it change to the Villa de Vés Formation. The Villa de Vés and the Santa María de las Hoyas formation contain praealveolinids and orbitolinids: *Praealveolina iberica* (attributed to the lower Cenomanian) in the lower part of the Villa de Vés Formation, *Orbitolina conica* in the lower part and *P. pennensis* and *P. debilis* (middle Cenomanian) in the middle part of the Santa María de las Hoyas Formation, and *P. tenuis* (upper, no uppermost, Cenomanian) in the upper part of the Villa de Vés Formation. The presence in these chalky interbeds of benthic foraminifers and their relative stratigraphic position have allowed determining that, in Algora, the Utrillas Formation ranges from lower Cenomanian to upper (no uppermost) Cenomanian. This range is corroborated by the presence some meters above the Villa de Vés Formation of 15-25 meters of limestones and marlstones with ammonoids of the uppermost Cenomanian-lower Turonian attributed to the 'Calizas y Margas de Picofrentes' Formation. On the basis of the stratigraphic position of Algora, in the upper part of the Utrillas Formation, and its palaeontological content, this site can be attributed to the uppermost middle Cenomanian - lowermost upper Cenomanian.

Specifically, the Algora site includes a stratified sandy interval composed by medium-large grain size sandstones divided in 2-3 meters banks, with erosive

base and trough crossbedding, many of them showing two-way orientation (herringbone or chevron bedding), and containing soft clast, armored mud balls, fragments of ferruginous scabs and vegetal and vertebrate remains. These banks are separated by 0,2-0,4 meters sandy mudstone interbeds, with wavy-bedding and notable lateral continuity. As a whole, these materials can be interpreted as coastal deposits (bars and channels) with submareal and intermareal events. This sandy interval contains numerous silicified or (mainly) ferruginized trunk fragments (gymnosperms and cicadaceans) and ferruginized vertebrate remains (fishes, turtles, crocodiles and dinosaurs), specially at the basis of the banks of sanstones. It also presents, especially in the upper part of this sandy interval, where sandstones present notable proportion of chalky cement, some bioturbations (burrows) that can probably be caused by shallow marine organisms.

Taphonomically, vertebrate sample is mainly composed by macrofossils (hardparts as scales, bones and teeth), mostly incomplete, ranging on centimetric size and with evidences of taphonomical alteration. Bone tissue structure seems to be externally and internally well preserved, and most remains appear reddish stained possibly related with ferruginous materials deposited during fossilization process. Several of those vertebrate remains present rounded edges, altered surfaces by erosion and cracks, which could be probably related with transport or reworking events during fossilization process. Moreover, it is also remarkable that hardest biomineralized tissues, such as teeth, appear also altered (several teeth have been recovered fragmented and with punctual small depressions on their surfaces).

The palaeontological diversity recognized in this site is high, being fishes and reptiles the groups best represented. Fish remains are scales and teeth. One morphotype of ganoid scales could be attributed to problematic *Stromerichthys*, and other one could belong to semionotids or lepisosteids. Teeth are very small and subconical, which is typical of lepisosteids. Chelonian fauna is represented by plates. The decoration of some of these plates, consisting of granulations, allows considering the probable presence of members of the pancryptodiran Solemydidae, the exclusive or predominant turtle group in most of the Cenomanian European outcrops. However, most of the specimens from the Algora site are assignable to Panpleurodira. This group is represented in the European outcrops before the Senonian only by Dortokidae, but the collected specimens do not share the characters that diagnose the members of this family. Crocodyliforms are represented by osteoderms, bones and teeth of a probable advanced taxon of Neosuchia. The phylogenetic relationships of the basal radiation of advanced Neosuchia are one of the most poorly understood aspects of crocodyliform evolution, because the available evidences about this group in Europe between the Barremian and the Campanian are very scarce. In this context, the evidence from this site is especially noteworthy. Theropod teeth have been found and assignated to Carcharodontosauridae indet. They present rough enamel and arcuate wrinkles, being similar to those found in contemporary outcrops of southern France.

Finally, it must be emphasized that the finding of this new and singular site in the Iberian Peninsula is very significant and particularly noteworthy because, due to its geographical position, will be fundamental to establish similarities with the few Cenomanian Southwest-European and North-African sites and enriches the relatively poor faunistical knowledge of this period.

The ecological succession in the Aptian recovery of the southern Apennines Lower Cretaceous shallow water carbonate systems

Lucia Simone, Gabriele Carannante, Daniela Ruberti

The Cretaceous shallow water limestone cropping out in southern Apennines (Italy) records significant climatic and tectonic events that affected the peri-Tethyan Region during Cretaceous times. These events resulted in drastic changes in the carbonate factory characterization and consequently in the related depositional systems.

The Lower Cretaceous Apennines limestone documents healty shallow water carbonate systems, which grew bearing mainly chlorozoan assemblages and non-skeletal grain-rich deposits although minor crisis moments in the growth of the carbonate factories have been recognized.

Mid-Cretaceous tectonic events dramatically controlled the Aptian-Turonian evolution of the analysed area. Apart from the related tectonic overprints, in the studied sections, we point out signs of illness in the carbonate factories suggested by significant changes in the carbonate production modes as well as appearance of diagnostic biota that characteristically pass by one after the other. The unhealty carbonate factory occurrence seems to precede, coincide with, strictly follow to or, however, to be in relation with bacinal anoxic events. Both unhealty carbonate factories and bacinal anoxia are probably symptoms, not necessarily strictly coeval, of worldwide climatic perturbations, in shallow- and deep-water environments respectively. The fading and the following bloom of the sediment-donor communities in relation with generalized events of crisis, are characterized by peculiar biotic assemblages in a typical trajectory of ecological change. Although biota obviously changed through time, a typical ecological succession can be envisaged.

In particular, following the Aptian-Albian crisis events (OAE1), highlighted by unhealthy platform conditions inferred by the flourishing of cyanobacterial consortia (Lithocodium-Bacinella-type) and other mesotrophic-tendentially eutrophic condition-adapted assemblages, the southern Apennines reconstructed shallow-water domains were forced to change sediment production modes, depositional patterns and internal sedimentary architecture. This was accomplished by the progressive reduction of the previous mainly aragonite-dominated chlorozoan assemblages and an increase of calcite-dominated skeletal components among which rudists with calcitic outer shell layer. Pioneer biota characteristically marked the early recovery in the still deteriorated shallow water domains, rapidly evolving to more complex and differentiated assemblages. The related ecological succession will be outlined.

Implications of New 40Ar/39Ar and U/Pb ages for the Cenomanian-Turonian OAE2

Brad Singer, Dan Condon, Bradley Sageman, John Obradovich, Sarah Siewert, Brian Jicha, Dave Sawyer, Stephen Meyers

New $^{40}Ar/^{39}Ar$ dating of sanidine from Cenomanian-Turonian ash beds in the Western Interior Basin has implications for the Cretaceous time scale and possible drivers of OAE2. Samples include those of Obradovich (1993) plus material recently collected from the E. septemseriatum, N. juddii, W. devonense, and V. birchbyi ammonite zones which give ages of 94.23±0.11, 94.11±0.14, 93.83±0.15, and 93.82±0.20 Ma, respectively, relative to the astrochronologically-calibrated age of 28.201 Ma for the Fish Canyon sanidine (Kuiper *et al.*, 2008). Four of seven zircons from ash in the juddii zone measured by CA-TIMS using the ET535 tracer yield a $^{206}Pb/^{238}U$ age of 94.11±0.11 Ma (analytical uncert.). Propagating full uncertainties (standard or tracer composition+decay constant errors), the $^{40}Ar/^{39}Ar$ age of this ash is 94.11±0.17 Ma, identical to the $^{206}Pb/^{238}U$ age of 94.11±0.30 Ma, and supporting the Kuiper *et al.* (2008) calibration.

In GTS04 the Cenomanian-Turonian boundary is 93.55±0.80 Ma based on $^{40}Ar/^{39}Ar$ ages of Obradovich (1993) that assume Fish Canyon sanidine is 28.02 Ma. Interpolation between revised ages of the juddii and devonense zones shifts the boundary to 93.97±0.20 Ma. In turn, the time between the astrochronological K-Pg and Cenomanian-Turonian boundaries is 27.99±0.20 Myr, with an uncertainty smaller than a single long eccentricity cycle, a finding that will help test forthcoming astrochronologic time scales for the Mesozoic.

Our revised ages provide a direct test of Sageman *et al.*'s (2006) astrochronologic age model which suggests a duration of the C-isotope excursion associated with OAE2 of between 563 and 601 ka. Three ash beds spaning OAE2 are 400±182 ka apart. Thus $^{40}Ar/^{39}Ar$ dating supports the hypotheses that sedimentation was orbitally-forced and that OAE2 lasted 500-600 kyr. The new age of 93.97 Ma for the Cenomanian-Turonian boundary is, however, problematic for the hypothesis of Mitchell *et al.* (2008) that ocean anoxic events of the mid-Cretaceous, including OAE2, are coincident with, and may even be triggered by, simultaneous nodes in eccentricity, obliquity and precession, predicted by Laskar *et al.* (2004). Our new ages imply that OAE2 began 590 kyr before the nodal insolation minimum. This finding lends credence to the hypothesis that submarine volcanism, rather than orbital forcing, is the trigger for OAE2.

Spatial patterns of changes in the Aptian: problems of resolution and interpretation

Peter William Skelton

The Aptian Stage illustrates all the characteristic signatures of the Cretaceous world, including plume-related volcanism, major perturbations of the global carbon cycle, oceanic anoxic events, a pelagic biocalcification crisis, episodic growth and demise of carbonate platforms with extensive turnover of platform biota, and extreme climatic fluctuations. Causal linkages between these phenomena cannot be doubted, but establishing the nature of the interactions and feedbacks involved requires precise documentation of the relative temporal and spatial patterns of change. Despite improvements of Aptian chemo-, and biostratigraphy over the last couple of decades, problems remain both in terms of resolving these patterns in detail – especially their variable palaeogeographical expression – and interpreting their palaeoenvironmental meanings. Some issues that require particular critical attention are: (1) the precise chronostratigraphical schedule of the global carbon cycle perturbations, especially the major OAE1a; (2) regional variation in the expression of these perturbations and of biotic recovery from them; (3) associated climatic changes (both heating/cooling and arid/humid trends); and (4) the palaeoenvironmental significance of biotic changes. In relation to the last point, for example, speculative interpretations of given biotic associations in terms of a nutrient flux spectrum ('oligotrophic' to 'eutrophic') may be simplistic, if not misleading in ignoring the roles of other possible factors such as temperature and pH. Uncritical 'pre-emptive' application of essentially interpretative terms such as 'photozoan' and 'heterozoan' to such associations, with little or in some cases no supporting evidence, is unhelpful in this context.

Biostratigraphie par ammonites du Cénomanien supérieur du plateau de Tademaît (Sahara algérien)

Bouregaa Slimane

Des récoltes récentes sur le terrain des ammonites du cénomanien supérieur nous permettent de préciser les zones d'ammonites corrélables à distance avec le Plateau du Tinrhert, la Tunisie et avec les zones standards. Les coupes révèlent la présence des zones suivantes soit du bas en haut : 1) zone à *Neolobites vibrayeanus* seule 2) Zone à *N. vibrayeanus* + *Eucalycoceras pentagonum* + *Calycoceras naviculare* + *Nigericeras gadeni* 3) Zone à *Nigericeras gadeni* seule 4) Zone à *Vascoceras* sp. + *Vascoceras gamai* + *Vascoceras* (*Paravascoceras*) sp. Ces résultats nous permettent d'enrichir les connaissances sur cet endroit.

Integrative analysis of the Paleocene-Eocene Mortemer Formation in the Sotteville-sur-Mer section of Upper Normandy, France

Thierry Smith, Christian Dupuis, Annelise Folie, Florence Quesnel, Jean-Yves Storme, Paola Iacumin, Janine Riveline, Pieter Missiaen, Sandrine Ladevèze, Johan Yans

Several outcrops recording the Paleocene-Eocene boundary are scattered along the Upper Normandy coast. The well-exposed sections can be considered as reference sections for the NW European continental-shallow marine P/E deposits. However, European terrestrial vertebrate sites of the Upper Paleocene - Lower Eocene deposits are predominantly known from the central and eastern parts of the Paris Basin. Here we report the discovery of a new terrestrial vertebrate site in the Mortemer Formation, at the top of the cliffs of Sotteville-sur-Mer in Upper Normandy, France.

The Paleocene-Eocene deposits that belong to the Mont Bernon Group are exposed on more than 7m in thickness and overly the Campanian chalk. From the base to the top of the measured section, four main members are delineated following the new lithostratigraphical classification of the 'Sparnacian' in the Paris Basin (Aubry *et al.*, 2005): the Pays de Caux Member and the Calcaire d'Ailly Member that belong to the carbonate-rich continental Mortemer Formation, underlying the Sotteville-sur-Mer Member (new name) and the Craquelins Member that belong to the Soissonnais Formation.

We recognize the onset of the Paleocene-Eocene Carbon Isotope Excursion (CIE) evidenced on dispersed organic carbon (from -25.0 ‰ to -29.6 ‰) and corresponding to the P/E boundary in the unit 1 of the Calcaire d'Ailly Member. A diverse and rich charophyte flora is well represented throughout the lower part of the outcrop and allows to precise that the CIE falls into the *Peckichara disermas* biozone. Invertebrates are also present in this part of the section and correspond to a typical fresh water malacofauna based on the abundant occurrence of the gastropod molluscs *Hydrobia* sp. and *Bithinella* sp. and by sphaeriid bivalves.

The vertebrate level is situated in the upper part of the unit 2 of the Calcaire d'Ailly Member and about 1.5 meter above the onset of the CIE and is therefore earliest Eocene in age. The vertebrate fauna is composed of fish, amphibians, lizards and mammals. Based on otoliths, fish are attributed to the percoid *Anthracoperca* sp. and to the salmoniform *Thaumaturus* sp. Two different salamanders are recognised. One is here referred to cf. *Nothophtalmus* sp. and the other is similar to the genus *Salamandra*. The presence of frogs is attested by a typically anuran ischium and surangular. Scincomorph lizards are represented by fragments of dentaries, maxillaries and quadrate osteoderms whereas oval osteoderms with a central crest are attributed to anguimorph lizards. Numerous small crocodilian teeth are also present.

Finally, despite their small number, the remains referred to mammals represent a diversified fauna. Beside indeterminate claws and worn teeth, the site of Sotteville-sur-Mer delivered teeth of the oldest peradectid marsupials, attributed to the genus *Peradectes* and also the oldest paramomyid plesiadapiform in Europe. This latter could be attributed to Ignacius or Arcius. The mammal assemblage that also includes the erinaceomorph insectivore *Macrocranion* and typical ischyromyid rodents is best correlated with the reference-level MP7 of the mammalian biochronological scale for the European Paleogene (BiochroM'97, 1997).

The Sotteville-sur-Mer reference section thus documents a perfect example of the progressively marine influence from the base of the continental Mortemer Formation to the top of the brackish-lagoonal Soissonnais Formation in Upper Normandy. Moreover, the deposits have recorded the Paleocene-Eocene boundary, yielded earliest Eocene mammals, and allowed to demonstrate the importance of the Peckichara disermas biozone for this time interval.

High-resolution carbon and nitrogen stable isotopes of organic matter at the Paleocene-Eocene boundary in the Vasterival section, Upper Normandy, France

Jean-Yves Storme, Christian Dupuis, Johann Schnyder, Paola Iacumin, Florence Quesnel, Johan Yans

The Paleocene/Eocene boundary and the PETM (Paleocene Eocene Thermal Maximum) are defined chemostratigraphically from carbon and oxygen isotope ratios. In this study, we aim to precise the position of the beginning of PETM in a terrestrial-lacustrine section of the Upper Normandy coast (France) from carbon isotope analyses performed on dispersed organic matter (δ^{13}CCorg). Moreover, isotope analyses of nitrogen on dispersed organic matter (δ^{15}Norg) are associated to carbon isotope data to constrain the paleoclimatic and environmental changes during the beginning of the PETM in terrestrial setting. Our results confirm the presence of the onset of CIE (Carbon Isotope Excursion) and suggest some variations of the humidity conditions before and during the beginning of PETM.

Mixing of in situ and reworked palynomorphs during a transgressive event: an early Devonian example from the Armorican Massif

Christine Strullu-Derrien, Céline Ducassou, Alain Le Hérissé, Michel Ballèvre, Cécile Robin, Marie-Pierre Dabard, Hubert Lardeux

The Châteaupanne Unit belongs to the South Armorican Domain of the Armorican Massif (France), which is part of the Variscan belt. This unit consists

of Ordovician marine sediments unconformably overlain by the Chalonnes Formation. The Chalonnes Formation predominantly composed of massive limestones shows at its base terrigeneous layers with occurrences of plant fragments (= Basal Member of the Chalonnes Formation). Conformably overlying the Chalonnes Limestones is the Sainte-Anne Formation of Emsian age. Until recently the age of the Basal Member of the Chalonnes Formation has been matter of debate.

Productive samples from this level from the Châteaupanne quarry (Montjean/Loire, Maine et Loire, France) yield marine and continental palynomorphs that permits to reassess and attribute the level to the Pragian-earliest Emsian interval (Strullu-Derrien *et al.*, 2010).Marine palynomorphs dispersed in the material are represented by acritarchs and prasinophycean phycomata. This assemblage appears to be mixed containing in situ Devonian species and reworked ones represented by classic Upper Ordovician species. Occurence of these reworked acritarchs are in agreement with the location of the Basal Member of the Chalonnes Formation just above the unconformity.

Correlations with the Armorican Massif show that the spore assemblage described in the Basal Member of the Chalonnes Formation has much in common with the assemblages from Saint Pierre-sur-Erve (Montguyon Formation, Laval syncline, Central Armorican Domain). The Montguyon Formation has been studied both for macro-paleontological and palynological (marine and continental palynomorphs) contents and is considered to be late Pragian/early Emsian.

The results obtained from the Basal Member of the Chalonnes Formation are used to update the Ancenis succession in the stratigraphic correlations previously made for the Devonian successions in the Armorican Massif. They also highlight the interest of the palynological studies for the underlying levels for both precise dating and biostratigraphical correlation.

An approach to reconstruct the paleoenvironments by the ratio of age of molting stages of ostracod index-species

Ekaterina Tesakova

The author has studied Early Callovian ostracods of the Kursk region (Central Russia) from two boreholes (no. 4 and no. 7, a total of 36 samples received from A.V. Chereschinsky, Voronezh Uniersity) and from one outcrop (open pit of the Mikhailov mine, with 50 samples collected by Dr. A.V. Guzhov, PIN RAS). Two quite different ecological associations of ostracods, which follow each other in all studied sections, were recognized. These associations are characterizing different paleodepths and their changes reflecting transgressive-regressive cycles. Each association is characterized not only by a distinct assemblage but also by its own index-species. Thus, Neurocythere cruciata franconica (Triebel, 1951) and Fastigatocythere interrupta ssp. A (Lutze, 1960) are typical for a shallow-water association (~5-20 m), while F. interrupta directa Wienholz, 1969 characterizes deeper environments (probably 30-50 m). In both boreholes these two associations alternate abruptly, without any

visible transition, which is indicating the presence of gaps within these successions. In the samples from the outcrop, which is located in the deeper part of the paleobasin and shows a more continuous succession, the transition between the two associations is gradual. This transition is characterized by the co-occurrence of some ostracod species, typical for different associations. Noteworthy this transition zone is characterized by co-occurrence of larvae of the ecological opposite taxa N. cruciata franconica and F. interrupta directa, while adult shells of the same subspecies were not found here. During the change of environment from sample to sample larvae of the older age of one subspecies gradually disappeared while such larvae of the other subspecies became more and more adult. Thus ostracods are marking a gradual facial change by gradual change of two ecologically opposite species, expressed by a decrease of the larvae age of the disappearing taxon and an increase of the larvae age in the newly appearing one. Other species in these associations show the same changes, but not necessarily simultaneous.

Regularity in ecologically opposed ostracod larval generation occurrences could be used for detailed paleoenvironmental reconstructions in case of co-occurrence of such species within the same samples. In this case even if we will have short trend in larval displacement, trend in paleoenvironmental changes also could be reconstructed.

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Planktonic foraminiferal biostratigraphy and paleoecology of Cenozoic West Atlantic continental margin deposits in the Casamance Region of Senegal

Malick Thiam, Raphael Sarr, Michal Kucera

Assemblages of planktonic foraminifera have been examined in samples from seven piezometer wells along an East-West onshore transect through the Senegalo-Mauritanian Basin in the Casamance region of Senegal. The westernmost part of the transect contains abundant planktonic foraminifera, which allow correlation with global biozonation. Further to the east, the transect becomes progressively shallow, but the high spatial resolution of this study allowed us to link the standard planktonic foraminifera zones with local ecozones. From West to East, the Paleogene planktonic foraminifera assemblages dominated by *Acarinina sp.*, *Morozovella sp.* and *Subbotina sp.* graded into a benthic foraminifera and ostracoda dominated fauna. These shallow water assemblages contain only rare small planktonic foraminifera with generalized morphology, comparable to the genus *Globoturborotalita*, indicating that these forms may have been adapted to shallower habitats. Based on the planktonic foraminifera fauna of the western wells, the oldest part of the analysed sequence was deposed during the Paleocene-Eocene (zones P1to E16) and is represented by carbonate sediments (calcareous marls). The calcareous sequence is terminated by a large regional hiatus encompassing the planktonic foraminifera zones E16 to O3, followed by deposition of Oligocene-Miocene (up to zone M3) clastic sediments (sand,

clayey sand), reflecting a major change in the depositional facies towards a shallower, clastic-dominated system. This terminal marine facies overgoes into continental sedimentation without a change in the sediment type, but marine microfossils completely disappear. Significant correlations were recorded between the percentage of planktonics, used as proxy for palaeodepth, and both the benthic foraminifera and ostracoda diversity (measured using the Information Function H') and the species dominance (measured using the Equitability Index E), indicating a persistent sea-level control on the depositional environment. This is also reflected in quantitative analysis of the faunas in individual cores, where the largest faunal shifts - as revealed by depth-constrained cluster analysis - correspond with changes in sediment properties.

Chronostratigraphic framework and cyclostratigraphy of upper Campanian–Maastrichtian sediments of the northwestern margin of Australia (ODP Hole 762C)

Nicolas Thibault, Dorothée Husson, Bruno Galbrun, Silvia Gardin

Using previously published results on magnetostratigraphy and foraminifera bio-events and new results achieved on carbon stable isotopes and calcareous nannofossil biostratigraphy at Site ODP 762C, off NW Australia, an integrated stratigraphic framework of the upper Campanian–Maastrichtian is presented for this region of the Indian Ocean and calibrated with cyclostratigraphy performed on the color alternations of the sediments. Results obtained from the cyclostratigraphic study suggest a continuous sedimentary record with no major discomformity. ODP Site 762C thus constitutes an excellent reference for the Maastrichtian of the Transitional Province in the Southern hemisphere. 11 carbon-isotope events, 30 nannofossil bio-events and 14 foraminifera bio-events are calibrated with cyclostratigraphy, and provide a solid basis for correlation with future studies and estimation of possible diachronism in calcareous microfossil events between the intermediate latitudes of the southern hemisphere and the Tethyan Province.

[VF] Schéma stratigraphique intégré et cyclostratigraphie de sédiments du Campanien supérieur–Maastrichtien de la marge nord-ouest de l'Australie (Site ODP 762C)

Un schéma stratigraphique intégré du Site ODP 762C, marge nord-ouest de l'Australie, est présenté en utilisant les données publiées sur la magnétostratigraphie et les bio-événements de foraminifères ainsi que de nouvelles données acquises sur la biostratigraphie des nannofossiles calcaires et les isotopes stables du carbone. Le schéma est calibré en âges par une étude cyclostratigraphique réalisée sur les alternances de couleur des sédiments. L'étude cyclostratigraphique montre un enregistrement continu

sans discordance majeure. Le site 762C constitue ainsi une excellente référence pour l'étage Maastrichtien dans la province de transition de l'hémisphère Sud. 11 événements de la géochimie du carbone, 30 bio-événements de nannofossiles calcaires et 14 bio-événements de foraminifères sont calibrés par la cyclostratigraphie, fournissant ainsi une base très solide pour la corrélation avec d'autres sites du même intervalle de temps et pour l'estimation du diachronisme des bio-événements de microfossiles calcaires entre les latitutes intermédiaires de l'hémisphère Sud et la province téthysienne.

Upper Campanian–Maastrichtian stable isotopes of the Danish Basin: stratigraphic calibration with calcareous nannofossil and dinoflagellate bio-events and implications for the Late Cretaceous climate of the Boreal Realm

Nicolas Thibault, Rikke Harlou, Niels Schovsbo, Poul Schiøler, Lars Stemmerik, Finn Surlyk

High-resolution carbon isotope stratigraphy of the upper Campanian–Maastrichtian of the Boreal Realm is characterised using data from 1968 bulk chalk samples from the Stevns-1 borehole, eastern Denmark. Isotopic trends are calibrated by calcareous nannofossil bio-events and correlated with a lower-resolution $\delta^{13}C$ profile from Rørdal, northwestern Denmark. The Campanian–Maastrichtian boundary (CMB) transition is identified by dinoflagellate biostratigraphy, allowing the definition of new chemical and biostratigraphic markers that provide a precise identification of the stage boundary at the regional scale. The boundary transition corresponds to the second phase of a two-step 0.8 ‰ negative $\delta^{13}C$ excursion, lies in calcareous nannofossil subzone UC16d^{BP}, encompasses the highest occurrence of Tranolithus stemmerikii Thibault 2010 and lowest occurrence of Prediscosphaera mgayae Lees 2007. Thirteen $\delta^{13}C$ events are defined and calibrated by sixteen reliable nannofossil biohorizons. Bulk oxygen stable isotopes and significant changes observed in the distribution of Watznaueria barnesiae and high-latitude nannofossil taxa delineate a concordant evolution of sea-surface palaeotemperatures in both localities. These boreal climate trends are correlated to previously published results from the tropical Atlantic, Pacific and Indian oceans using calibrated carbon-isotope trends. The evolution of sea-surface palaeotemperatures in the upper Campanian–Maastrichtian of the Boreal Realm is concordant to the worldwide evolution of oxygen isotopes from benthic foraminifera but differs from the evolution of $\delta^{18}O$ from planktonic foraminifera. One of the most likely explanation is that upper Campanian–Maastrichtian planktonic foraminifera could migrate up and down quite deeply within the photic zone. Therefore, supposed temperature records of surface-waters from $\delta^{18}O$ values of upper Campanian–Maastrichtian planktonic foraminifera are more likely a record of mixed layers whereas bulk $\delta^{18}O$ performed on pure nannofossil chalk from this interval may, in some cases, provide a better record of sea-surface palaeotemperatures.

[VF] Isotope stables du Campanien supérieur–Maastrichtien du Bassin danois: calibration stratigraphique avec les bio-événements de nannofossiles calcaires et dinoflagellés et implications pour le climat du Crétacé supérieur du domaine boréal

La stratigraphie à haute résolution des isotopes stables du carbone du Campanien supérieur–Maastrichtien du domaine boréal est caractérisée par l'analyse chimique de carbonates totaux sur 1968 échantillons de craie du forage continental de Stevns-1, Est du Seeland, Danemark. Les tendances isotopiques sont calibrées par les bio-événements de nannofossiles calcaires et corrélés à un profil de $\delta^{13}C$ de plus faible résolution obtenu sur le site de Roerdal, Nord du Jutland, Danemark. La limite Campanien–Maastrichtien est identifiée par la biostratigraphie des dinoflagellés et permet la définition de nouveaux événements chimiques et biostratigraphiques qui caractérisent cette limite dans le domaine boréal. La transition Campanien–Maastrichtien correspond ainsi à la seconde phase d'un accident négatif en deux étapes de $\delta^{13}C$ d'une ampleur de 0,8 ‰. Cette transition se situe au sein de la sous-zone de nannofossiles UC16d^{BP} et est encadrée par la dernière occurrence de Tranolithus stemmerikii Thibault 2010 et la première occurrence de Prediscosphaera mgayae Lees 2007. 13 événements de $\delta^{13}C$ sont définis et calibrés par 16 biohorizons fiables de nannofossiles. Les isotopes stables de l'oxygène sur carbonate total et des changements significatifs observés dans la distribution de Watznaueria barnesiae et des espèces de nannofossiles de haute-latitude décrivent une évolution concordante des paléotempératures de surface dans les deux localités. Ces tendances climatiques boréales sont corrélées aux résultats obtenus précédemment dans l'Atlantique tropical, le Pacifique et l'Océan indien par la stratigraphie du $\delta^{13}C$. L'évolution des paléotempératures de surface dans le Campanien supérieur–Maastrichtien du domaine boréal est concordante à l'évolution globale des isotopes de l'oxygène des foraminifères benthiques mais diffère de celle obtenue sur les foraminifères planctoniques. L'une des explications les plus probables est que les foraminifères planctoniques du Campanien–Maastrichtien utilisés dans ces précédentes analyses ne vivaient pas exactement dans les eaux de surface mais étaient capables de migrer sur un intervalle relativement large de la zone photique. Les valeurs du $\delta^{18}O$ de ces foraminifères planctoniques représente donc plutôt le signal d'une zone mixte plutôt qu'un enregistrement des températures des eaux de surface, tandis que les valeurs de $\delta^{18}O$ obtenues sur le carbonate total de craies pures à nannofossiles de cet intervalle peuvent, dans certains cas, fournir un bien meilleur enregistrement des paléotempératures des eaux de surface.

Anisotropic magnetic susceptibility (AMS) studies in terrestrial to shallow marine sandstones of Çardak-Dazkiri Molasse Basin (Denizli, Turkey)

Ezher Toker, Ali Aydin

Çardak-Dazkiri molasse basin is located in the northern of Acigöl graben which is NE-SW trending in SW Turkey. This graben basin has developed in control of the active Neogene tectonic regime in the western Anatolia. The Çardak-Dazkiri molasses deposits are restricted by NE-SW strike Maymundagi Fault (Çardak Fault) in the south; NW-SE strike Dinar Fault in the northeast and NE-SW strike Baklan Fault in the northwest.

The main objective of this study is, to interpret the tectonic activity changes by using anisotropic magnetic susceptibility (AMS) method on terrigenous terrestrial to shallow marine deposits and additionally, to determinate how influence the Oligocene sandstones from compressional and extensional phases in regional tectonic forces by using AMS techniques. In this work we also present the results in terms of the shape parameter and the geometric mean of the three principal susceptibilities or average of three eigenvalues representing the tensor, respectively.

Çardak-Dazkiri molasse basin is composed of Eocene, Oligocene and Pliocene sediments which are deposited in terrestrial to shallow marine environments. The AMS method has been used on sandstones which are belonging to two formations of Oligocene deposits. It is taken 72 directional samples from characteristic these Çardak and Hayrettin formations which are consists of sandstones, siltstones and mudstones and obtained AMS (Anisotropic Magnetic Susceptibility) measurements belonging to these samples. Also it has been taken MS (Magnetic Susceptibility) measurements from study field.

AMS measurements have sustained very clear data about tectonic activity of the study area and surrounding. The prevailing tension forces are NW-SE strike depends on the result of the crack measurements of the sandstones which are close located to Baklan Graben. The results of the AMS measurements in sandstones which are belong to Hayrettin and Çardak Formations are demonstrated on the geological map and specified, respectively. It is commonly assumed that long axes of sand grains in sedimentary deposits parallel to direction of the flows that formed the deposits. The sandstones which are located in SE of the study area are less influenced by regional tectonics comparing with the sandstone presented in NW of the study area. The rose and contour diagrams which are depicted to depending on data of Dmax and Imax are well-matched with the crack measurements of the study area.

First attempt at stratigraphic correlations of continental vertebrate localities in the Upper Cretaceous of Aix-en-Provence Basin (Southeastern France)

Thierry Tortosa, Yves Dutour, Gilles Cheylan, Eric Buffetaut

The Aix-en-Provence sedimentary basin (Arc syncline, southeastern France), the most important in Provence, is 75 km from East to West and 20 km from North to South. This basin has been famous since the 19th century for its continental Upper Cretaceous levels, and its fluvio-lacustrine series, rich in vertebrate remains (dinosaurs, crocodiles, turtles, pterosaurs, mammals, fishes). The Aix-en-Provence Basin is also the place where the local stages Valdonian, Fuvelian, Begudian and Rognacian have been defined. Since Matheron's work (1869, 1870) a number of studies on the paleontological record of Provence have led to a better understanding of its faunal assemblages (Lapparent, 1947; Le Loeuff, 1991, Buffetaut *et al.*, 1997, Allain and Pereda Suberbiola, 2003). However, these faunal lists were considered as a single group, generally dated as Late Campanian-Early Maastrichtian, and comparable with those from the other coeval fossiliferous regions of France (Upper Aude Valley, 'Chainon de Saint-Chinian') and Europe (Spain, Transylvania). The studies of particular taxa discovered since the 1970s have not included stratigraphic correlations with other sites or a precise repositioning in the general stratigraphy of the basin (Buffetaut *et al* ., 1986, 1988 ; Le Loeuff *et al* ., 1992; Le Loeuff and Buffetaut, 1998 ; Garcia *et al* ., 1999, 2000 ; Allain and Taquet, 2000 ; Tabuce *et al.*, 2004 ; Buffetaut, 2008; Martin and Buffetaut, 2008 ; Chanthasit and Buffetaut, 2009). Besides the complexity of the fluvio-lacustrine series, this was a result of the low number of studied sites, the very fragmentary character of the specimens brought to light, and the scarcity of useful biostratigraphic data (such as charophytes, ostracodes, gastropods), especially for the clay and sandstone levels. In fact, only the marly or marno-calcareous levels with vertebrate remains were studied with some precision (Garcia *et al.*, 1999, 2000) but never with the purpose of stratigraphic correlation on the scale of the Aix-en-Provence Basin.

Therefore, a certain ambiguity developed concerning the definition of the typical horizons containing fossil sites. Indeed, the literature dealing with vertebrate remains from the Upper Cretaceous of southeastern France always mentions the famous 'Argiles et grès à reptiles' as a reference stratigraphic level but also as a geological formation. But the real nature of the continental Campano-Maastrichtian series is only known to a limited number of specialists of its local fauna and flora. The 'Argiles et grès à reptiles' appellation does not take their considerable thickness (more than 400 metres only for the Rognacian) into consideration and can correspond to the Begudian as well as to the Rognacian in the eastern part of the basin (the limit between these stages is not clear in this area). The vertical repetitiveness of the series and the important horizontal facies variations, with alternating lacustrine (limestones layers) and fluviatile (clayey levels interrupted by sandstone

lenses) levels, make the stratigraphic correlations of distant sites more difficult.

Since 2006, excavations conducted by the Museum of Natural History of Aix-en-Provence, funded by the motorway company ESCOTA, have revealed ten new continental vertebrate localities in the course of the works carried out to open new lanes along the A8 Motorway between Chateauneuf-le-Rouge (Bouches-du-Rhône) and Ollières (Var), East of the city of Aix en Provence. For the first time, a large number of fossil sites over a large geographical area can be repositioned in the Upper Cretaceous even if the constraints due to the low abundance of biostratigraphic data are important. To this series of sites, are added other unpublished or reanalyzed sites, which are interesting because of their stratigraphic biomarkers. The use of other dating techniques, such as magnetostratigraphy (Cojan and Moreau, 2006) and fossil eggshells (Garcia and Vianey-Liaud, 2001), as well as numerous drillings in the basin, will allow to complement the classic biostratigraphic data. An ongoing study concerning the polymorphism of some isolated vertebrate bones (especially of titanosaurs) should indicate whether these taxa could serve as good biostratigraphic tools. Indeed, some bones (limb bones, vertebrae) appear to show clear anatomical variations from one site to another, depending on their geographical position.

The compilation of the biostratigraphic data and the stratigraphic repositioning of various fossil sites will provide a better understanding of the Late Cretaceous continental vertebrate assemblages in the Aix-en-Provence Basin in time as well as in space.

Evidence of an Early Triassic age (Olenekian) in Argana Basin (High Atlas, Morocco) based on new chirotherioid traces

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New chirotherioid traces are described in the Tanameurt Conglomerates Member of the Timezgadiwine Formation in Argana Basin. The tetrapod footprint assemblage is dominated by *Synaptichnium*, *Chirotherium*, *Brachychirotherium* and *Isochirotherium*. The description of these ichnospecies and their statistical comparison with those of other Early and Middle Triassic areas in Europe, suggest an Olenekian age for this footprint site, and consequently for the Tanameurt Conglomerate Member which was tentatively referred to the Triassic. The trackmakers were tetrapod community dominated by archaic Archosaurian *Crurotarsi*. The sedimentological analysis of the beds bearing the footprints level suggests an alluvial fan setting.

A revised Cenozoic tropical planktonic foraminiferal biostratigraphy: recalibration to the Global Polarity and Astronomical Time Scale

Bridget S. Wade, Paul N. Pearson, William Alfred Berggren

Robust stratigraphic correlations are essential to decipher Earth history. Planktonic foraminifera are extensively used for the biostratigraphy of Cretaceous and Cenozoic marine sediments and a fundamental component of Cenozoic chronostratigraphy. The recent enhancements in deep sea drilling recovery, multiple coring, high resolution sampling both offshore and onshore, has improved the calibrations with the magnetostratigraphy and/or modified the species ranges and allowed many of the planktonic foraminifera events to be revised. This accumulated new information presents the opportunity for a reassessment of the planktonic foraminiferal calibrations and to incorporate developments and amendments to the existing biostratigraphic zonal scheme.

We integrate planktonic foraminiferal data from multiple sources and have incorporated these recalibrations into a revised Cenozoic planktonic foraminiferal biochronology and review and synthesize these calibrations to both the Global Polarity Time Scale (GPTS) and Astronomical Time Scale (ATS). As with previous compilations, our magnetobiochronology has been derived from first order calibrations between biostratigraphic events and the magnetostratigraphic polarity zones (chrons and subchrons) in ocean drilling cores and land sections where available. These are supplemented with orbital compilations when a magnetostratigraphy was absent (*e.g.*, Ocean Drilling Program Leg 154, Ceara Rise).

We compile 187 revised calibrations of planktonic foraminiferal bioevents for the Cenozoic and provide calibrations to the GPTS of the Cenozoic and ATS of the Neogene and late Paleogene. Here, we present an amended low-latitude (tropical and subtropical) Cenozoic planktonic foraminiferal zonation of planktonic foraminiferal bioevents for the Cenozoic. On the whole, these recalibrations are consistent with previous work, however, in some cases, they have led to major adjustments to the duration of biochrons. Recalibrations of the early middle Eocene first appearance datums of *Globigerinatheka kugleri*, *Hantkenina singanoae*, *Guembelitrioides nuttalli* and *Turborotalia frontosa* have resulted in large changes in the durations of Biochrons E7, E8 and E9. We have introduced (Upper Oligocene) Zone O7 utilizing the stratigraphic utility of '*Paragloborotalia*' *pseudokugleri*. For the Neogene Period, major revisions are applied to the fohsellid lineage of the middle Miocene and we have modified the criteria for recognition of Zones M7, M8 and M9, with additional adjustments regarding the *Globigerinatella* lineage to Zones M2 and M3.

Our revised and recalibrated datums provide a major advance in biochronologic resolution and a template for future progress to the Cenozoic time scale. With recent progress in astronomical tuning, it is clear that high resolution biostratigraphic work and integrated biochronologies are needed to

reduce the uncertainty of a number of events and evaluate diachronism between the Atlantic and Pacific oceans. Future developments in astrochronology will undoubtedly lead to further revision and refinements in Cenozoic planktonic foraminiferal biochronology.

Quantifying mid-Cretaceous sea-level changes: the potential of high-resolution, integrated stratigraphic approaches

Markus Wilmsen

The mid-Cretaceous greenhouse phase was characterized by generally rising or high sea-level stands repeatedly punctuated by large and obviously relatively rapid sea-level falls and subsequent rises. The reasons for these sea-level changes, however, are still poorly understood as glacio-eustasy, the principal mechanism for rapid and fast sea-level changes, was thought to be very unlikely as a major driver of sea-level changes during greenhouse times. Nevertheless, some of the falls have been speculated as glacio-eustatically driven by means of positive $\delta^{18}O$ shifts, *e.g.* in more-or-less diagenetically unaltered foraminiferal calcite from ODP legs but the isotopic evidence is often ambiguous. Furthermore, offshore core logs and onshore sequences are still difficult to correlate. Onshore sequences, however, bear key information on, and have uncompeted potential for deciphering the rates and temporal pattern of (mid-Cretaceous) sea-level change: they can be stratigraphically calibrated by high-resolution macrofossil biostratigraphy (in contrast to lower resolution micro- and nanno-biostratigraphy in drill cores), unconformities are usually well expressed and can be traced laterally, and high-resolution cyclo-chronologies based on orbital forcing within the Milankovitch band can be elaborated. Along with detailed studies of biofacies and stratal architectures such as on-/offlap geometries or erosional incision at unconformities, a fairly precise reconstruction of the rates of mid-Cretaeous sea-level change is possible.

Preliminary results of a long-distance sequence stratigraphic study of selected Albian-Turonian shelf successions on different tectonic plates (Europe, northern Africa, Middle East) support an isochrony of the major unconformities (*i.e.*, 3rd order sequence boundaries) and, thus, a eustatic control on mid-Cretaceous sea-level changes. Correlations will be or have been established by means of high-resolution ammonoid biostratigraphy, partly calibrated by carbon stable isotope chemo-stratigraphy. Cyclostratigraphy based on orbital forcing within the Milankovitch band (precession, short eccentricity) is used to construct high-resolution cyclo-chronologies for the investigated sea-level events. These analyses suggest that the rates of sea-level change at some of the major unconformities, *e.g.*, the latest Early (~96.2 myr) and mid-Late Cenomanian (~94 myr) ones, calculated based on estimated magnitudes of sea-level change, can only be explained by glacio-eustasy (or another, yet unknown process). The study of stratal architectures at suitable sites within high-resolution integrated stratigraphic frameworks may thus yield physical evidence for potential glacio-eustatic changes during the mid-Cretaceous

greenhouse and may be an independent test for other (*i.e.*, geochemical) sea-level proxies such as oxygen stable isotopes. Further studies are in progress.

Cretaceous stratigraphy and facies development of the Yazd Block, Khur area, Central Iran

Markus Wilmsen, Franz Theodor Fürsich, Mahmoud Reza Majidifard

Cretaceous strata are very thickly developed, widely distributed and superbly exposed in the Khur area of Central Iran. They are part of the sedimentary sequence of the so-called Yazd Block, the western structural element of the Central-East Iranian Microcontinent (CEIM), an independent microplate within the complex Mesozoic plate tectonic mosaic of the Middle East. During the Cretaceous, the CEIM was detached from Eurasia (Turan Plate) and surrounded by small oceanic basins (Sistan, Sabzevar, Nain Baft oceans) which opened and closed in response to (inferred) counter-clockwise rotational movements of the microplate. The Cretaceous sedimentary sequence of the Yazd Block bears important information for the geodynamic history of that area. However, apart from lithostratigraphical mapping, little was hitherto known about the exact chronostratigraphy of the succession and its facies development.

The succession starts with conglomerates and sandstones of the Chah Palang Formation covering a pronounced palaeo-relief of basement rocks (metamorphics, granitoids) of various ages related to the Mid- and/or Late Cimmerian tectonic Event/s (Middle to Late Jurassic). The Chah Palang Formation was given a Late Jurrassic age but no reliable data exist so far and an exclusively early Early Cretaceous age may also be possible. The onlap onto the palaeo-relief continues with the succeeding Noqreh Formation, consisting of an intercalation of continental and marginal marine sediments (reddish sand- and siltstones, gypsum layers, dolomites, oolitic-bioclastic limestones, sandy marls). Biostratigraphic data are again sparse, but calcareous algae in the upper part of the formation indicate already a Barremian age. The thickness of the two lower formations is strongly variable on short distances, ranging from >1 km to nearly zero. The next unit is the Shah Kuh Formtion (up to 500 m thick), consisting of thick-bedded to massive, dark-coloured muddy limestones (wacke-, pack- and floatstones) with abundant orbitolinids and rudists. Microfossil data suggest a Late Barremian – Early Aptian age for the unit which represents shallow-marine (lagoonal) carbonate platform environments. Still in the Early Aptian, the Shah Kuh Formation was replaced by the basinal sediments of the up to 1.5 km-thick Bazyab Formation (marls and nodular limestones with intercalated fine-grained sand- and siltstones as well as some limestone levels). Ammonites are common and date the formation as Early Aptian to early Late Albian. The available data suggest a temporal relation of the Shah Kuh platform drowning with the global Early Aptian oceanic anoxic event OAE 1a (black shale-like dark marks occur in the lowermost part of the Bazyab Formation). Along a major Late Albian unconformity, the Bazyab Formation was replaced by the shallow-water limestones of the upper Upper Albian – Cenomanian Debarsu Formation (up to

1 km-thick). The formation mainly consists of oolitic-bioclastic limestones which interfinger with deeper water marls. Facies transitions suggest a ramp-like depositional geometry, and rare ammonites from marly intercalations provide the biostratigraphic age control. The base of the overlying Haftoman Formation is characterized by another, even more pronounced unconformity clearly associated with tectonic movements: along uplifted blocks, erosion down to the Shah Kuh Formation took place, removing 2-3 km of sediment in places and creating spectacular palaeo-karst topographies. Above the basal transgression conglomerate, the Haftoman Formation commences with shallow-water limestones containing rudist biostromes and intraclastic limestones of a large carbonate platform. The find of an inoceramid bivalve from the lower part at one locality suggests an Early Coniacian age for the transgression of the Haftoman Formation. After several hundreds of metres of widespread and uniform carbonate platform deposition, a deepening trend is indicated in the upper part of the formation by the appearance of marly facies with irregular echinoids, inoceramid bivalves and ammonoids of Late Campanian age. The near absence of terrigenous input and the widespread, uniform facies development of the Haftoman Formation suggest a period of tectonic quiescence during the Coniacian – Campanian. Along another karstic unconformity, the last Cretaceous unit, the marly Farokhi Formation was deposited during the Maastrichtian. It is erosinally truncated along the base of the overlying Palaeogene Chupanan Formation. The complete Cretaceous succession of the Khur area of the Yazd Block is in excess of 3-5 km thick. Major (tectonic) unconformities are recognized at the base of the succession (Mid-/Late Cimmerian events), in the Late Albian (base Debarsu Formation), the ?Late Cenomanian – Turonian (base Haftoman Formation), the Campanian – Maastrichtian boundary interval (base Farokhi Formation), and in pre-Chupanan times (Cretaceous – Palaeogene boundary interval). The new data obtained in the frame of the international DARIUS project on the age, thickness and facies development of the Cretaceous formations of the Khur area as well as on their bounding unconformities now allow a much better understanding of the complex geodynamic history of the Yazd Block.

The onset of the negative Carbon Isotope Excursion on dispersed organic matter as criterion for the Paleocene-Eocene boundary: potential uses and limits

Johan Yans, Jean-Yves Storme, Paola Iacumin, Christian Dupuis, Florence Quesnel, Thierry Smith, Peter Stassen, Roberto Magioncalda, Etienne Steurbaut, Johann Schnyder

The onset of the negative Carbon Isotope Excursion (CIE) in both marine and terrestrial settings is ratified as the Paleocene-Eocene (P-E) boundary. Organic matter may be judged as a (very) reliable material to locally refine the P-E boundary. Here we focus on several examples of successions (Belgium, Egypt, France, Morocco, Spain, Tunisia, USA-Wyoming) where i) isotopic analyses on

organics are necessary to define the P-E boundary ii) organics are not the best material to precise the P-E boundary and iii) geological processes may perturb the reliability of the carbon isotope results (on both organics and carbonates including calcitic shells, bulk rocks and pedogenic nodules).

Calcareous nannoplankton assemblage and paleoenvironmental interpretation of the Late Eocene units from SW Thrace Basin (NW Turkey)

Aysegül Yildiz

Seventeen species of 9 calcareous nannoplankton genera such as *Coccolithus pelagicus*, *Cribrocentrum coenurum*, *Cyclicargolithus floridanus*, *Dictyococcites bisectus*, *Discoaster barbadiensis*, *D. deflandrei*, *D. tanii*, *Ericsonia formosa*, *E. obruta*, *E. robusta*, *Markalius inversus*, *Reticulofenestra dictyoda*, *R. gelida*, *R. hambdanensis*, *R. hillae*, *R. reticulate*, *Sphenolithus radians* have been recognized in an investigation of 76 samples from 4 measured sections yielding submarine fan sediments (Kesan and Yenimuhacir Fm) in the northeast of the Saros Bay and around Yeniköy, Korudag, Malkara, Inecik regions.

In the study area, the Mezardere Fm is concordantly laying on the Kesan Fm. They contain similar calcareous nannoplankton associations.

Late Eocene age was inferred from nannoplankton assemblages. Distributions of the relative abundances of nannofossil in the samples were generally rare in both Formations, they may be related to the water depth during the deposition of those Formations. Distribution and abundances of temperature-sensitive calcareous nannoplankton species are observed.

Sea-surface water temperature was variable in the study area during the Late Eocene with probably warm and cool water currents or climatic changes.

Résultats préliminaires de l'étude biostratigraphique (foraminifères planctoniques) du forage Drj6, Gharb (Prérif, Maroc)

Mohamed Zakaria Yousfi, Nadia Barhoun, Nezha Belamar

Les bassins sédimentaires du Maroc septentrional, objet de notre travail présente un intérêt géologique et économique important, concernant la recherche en hydrocarbures.

L'étude du forage Drj6 fait partie d'un programme d'exploration stratigraphique dans le bassin du Gharb qui se trouve au nord-ouest du Maroc, et qui est limité à l'est et au nord-est par les affleurements du complexe de nappes du Prérif, à l'ouest par l'océan Atlantique et au sud et sud-ouest par les affleurements paléozoïques de la Meseta marocaine.

Le forage Drj6 à traversé une série sédimentaire néogène d'une puissance de 1336 mètres d'épaisseur. Il a fait l'objet d'un échantillonnage serré, 140 échantillons ont été traités et analysés.

L'objectif de notre travail est d'établir un cadre biostratigraphique précis pour la série néogène du forage étudié par les foraminifères planctoniques et tenter de reconstituer et d'interpréter les paléoenvironnents en se basant sur les données quantitatives, qualitatives et les renseignements paléoécologiques des associations de foraminifères planctoniques et benthiques.

L'analyse de la microfaune montre une grande richesse en espèces et en individus. Elle offre un matériel intéressant pour une étude biostratigraphique fine et fournit les éléments de corrélations avec des coupes de références d'une part et des coupes appartenant à d'autres bassins néogène d'autre part.

L'étude détaillée des associations de foraminifères planctoniques du Néogène supérieur du forage Drj6 a permis d'identifier une série de bio-événements qui ont permis de reconnaitre le Tortonien supérieur, le Messinien et le Pliocène.

Latest Permian and Earliest Triassic paleofloras as biostratigraphical and paleoenvironmental markers for the Permian - Triassic transition in South China

Jianxin Yu, Jean Broutin

Based on the changes of the composition, abundance and diversity of fossil plants across the Permian-Triassic boundary in western Guizhou and eastern Yunnan (South China) two macrofloral assemblages were established: *A:* Late Permian (Changhsingian) upper Xuanwei Formation Gigantonoclea guizhouensis- Annularia pingloensis assemblage, standing for the late Cathaysian flora. This assemblage is very different in composition from the coeval paleofloral assemblage of North China, reflecting two-typed paleofloras and climates. In south China, the paleoflora kept with the features of the former Wuchiapingian Cathaysian Flora reflecting the persistance of a warm and humid climate. Whereas in North China Euramerican conifers had invaded the area, showing a vegetation typical of a dryer climate. *B: Annalepis* - Peltaspermum and relicts of Permian gigantopterids (Early Triassic Induan, uppermost Xuanwei Fm. and basal Kayitou Fm.). This newly described assemblage fills the biostratigraphic gap between the Changhsingian Gigantonoclea guizhouensis- Ullmannia cf. bronnii and the Olenekian Neuropteridium-Albertia-Voltzia assemblages in South China.

Until now the genus Annalepis was considered as an excellent biomarker for dating Late Early and Middle Triassic period in terrestrial deposits. Therefore, it is very significant that, in eastern Yunnan and western Guizhou, this genus occurred associated with typical Induan bivalves, ostracods, brachiopods and ammonites in the marine basal deposits of the Kayitou Fm. This indicates that the F.A.D. of Annalepis is Early Triassic (Induan) in southwestern China, thus much earlier than in the Yangtze River area and any other area in South Asia. It is now to be considered as marking the very beginning of Triassic deposition for the western Guizhou and eastern Yunnan domain. During Early and *Middle*

Triassic, it may have migrated to the north and spread widely to the others areas of South-East Asia.

In south China The Latest Permian paleoflora contains many coal-forming fossil plants, such as Lepidodendron, Paracalamites, Gigantopterids etc. Coal seams deposited in multiple horizons, extending up to the Permian-Triassic boundary level. The climate was indeed warm and humid during the Latest Permian in this area. Although the coal bed/seam disappeared in Early Triassic the composition of the Annalepis - Peltaspermum – Permian gigantopterids relicts Assemblage shows that the climate remained similar to the Late Permian one.

Cretaceous/Paleogene boundary event Impact on planktonic and benthic foramifera at the Bidart section (southeastern France)

Dalila Zaghbib Turki, Njoud Gallala, Eustoquio Molina

Based on high resolution sampling close to the Cretaceous/Paleogene boundary (K/Pg) at the Bidart section and on medium resolution sampling of both sides, species range and quantitative data regarding the planktonic foraminifera support that the Cretaceous-Paleogene transition interval is continuous and complete. It records all the biozones and subzones with their appropriate biomarkers. At the K/Pg boundary (65 MA ago), planktonic foraminifera suffered catastrophic species mass extinctions. Indeed, over 72 Upper Maastrichtian species of this foraminiferal group, 53 species became suddenly extinct at the K/Pg boundary. It means that these extinct species represent at least 73.6 %. They belong to keeled Globotruncanids and large heterohelicids which assigned to specialists dwelling the deeper microhabitat of warm and photic marine water. Most species crossing the K/Pg boundary persisted short time after the K/Pg boundary and did not surpass the *Parvularugoglobigerina eugubina* zone. The long time survivors are confined to *Guembelitria* genus (*i.e.*, *G. cretacea*, *G. trifolia*), behaving as opportunists.

Regarding the benthic foraminifera, they did not suffer species mass extinctions at the K/Pg boundary. Over 76 upper Maastrichtian species, only 23 species (30 %) showed temporary disappearance. Therefore, the benthic foraminiferal assemblages became low diversified at the base of the Danian. The main species affected by this disturbance are assigned to be claiming high trophic level. The persisted benthic species are assigned to be adapted to oligotrophic conditions.

Paleoenvironmental conditions recovery was stated across the *Parasubbotina pseudobulloides* (from -64.945 MA to -64.545 MA).

Vertebrate microremains as a stratigraphic key to the Devonian basin of Spitsbergen

Zivile Zigaite, Daniel Goujet

The wide distribution of vertebrates in Devonian strata of the Northern Hemisphere permits the establishment of an explicit vertebrate-based biostratigraphy. The Lower and Middle Devonian of Spitsbergen is one of the best examples of vertebrate implication in stratigraphy, and sedimentary basin analysis. Previous studies of the Red Bay Group (Lochkovian, Lower Devonian) made a notable analysis of the earliest Devonian vertebrate record, and their use in biostratigraphy (Karatajute-Talimaa, 1978; Blieck and Heintz, 1979, 1983; Blieck 1982, 1984; Blieck *et al.*, 1987; Janvier 1981, 1985; Talimaa, 2000; Blom and Goujet, 2002).

Our current study concerns the Lower to Middle Devonian of the Andrée Land Group, which comprises Wood Bay Formation, aging Pragian or latest Lochkovian to Emsian, and Grey Hoek Formation, representing the Eifelian. It consists of thick layers of terrigenous sediments formed by continental molasse deposition under arid to semi-arid climatic conditions, and in three main depositional environments, such as rivers, alluvial plains, and perennial lakes (Blomeier *et al.*, 2003). The stratigraphy there is largely based on the lithofacies.

Two new thelodont assemblages are considered to represent different depostional phases of the late Lower - early Middle Devonian of the Andrée Land Group. The first, older assemblage comprises turiinid, talivaliid, and furcacaudid thelodonts, and identifies the lower Wood Bay Formation. The second, younger assemblage is prevailed by the talivaliid thelodont *Amaltheolepis winsnesi*, and is characteristic to the upper Wood Bay Fm., as well as the lower Grey Hoek Fm. Definition of these two new thelodont assemblages allows to precise the relative age of the Lower – Middle Devonian strata. Following this new vertebrate fossil record, certain separate lithostratigraphic units of the Andrée Land Group have to be regarded as contemporaneous lithofacies subjected to different sedimentary environment, rather than stratigraphic members.

Pteropod zonation in the Cenozoic from Aquitaine Basin (SW France)

Bruno Cahuzac, Arie W. Janssen

Holoplanktonic Mollusca collected from *ca.* 60 localities in Cenozoic (Eocene-Ypresian to Miocene-Serravallian) marine deposits of the Aquitaine Basin (southwest France) are represented by 75 taxa : five supposed Heteropoda (Pterotracheoidea) and 70 Pteropoda (69 Thecosomata, one Gymnosomata). The Aquitaine Basin assemblages are correlated with the existing holoplanktonic mollusc zonation for the North Sea Basin, and with classic foraminifera-nannoflora zonations. The following pteropod zones could be recognised in the Aquitaine Basin :

- in the Eocene : zones 9 (Ypresian of Gan, Nannoflora NP12/13, with 14 Pteropod taxa in Aquitaine, e.g. the index species *Camptoceratops priscus*), 10 (Lutetian of Peyrehorade, NP15) and 11/12 (Priabonian of Peyrehorade and Biarritz, NP19/20, 5 taxa),
- in the Oligocene : zones 15a (Rupelian of Gaas, P18/19 and larger foraminifera SBZ21, 5 taxa, e.g. *Praehyalocylis maxima*) and 16b/c (Chattian of Bélus - St-Étienne-d'Orthe palaeocanyon and St-Paul-lès-Dax area, NP25 / P22 / SBZ23, 17 taxa, e.g. the markers *Vaginella chattica* and *V. tricuspidata*),
- in the Miocene : zones 17, 18, 18a and 19. Zone 17 (Aquitanian-Burdigalian, with *Vaginella depressa*) could be subdivided on the basis of occurrences observed in the Aquitaine Basin, into three subzones : 17a (Aquitanian of St-Paul-lès-Dax, Meilhan and Saucats - La Brède, N4 / SBZ24, 8 taxa, e.g. *Diacrolinia cluzaudi* and *Gamopleura taurinensis* and the FOD of *Heliconoides inflata*, *Limacina bulimoides*, *L. valvatina* and *Creseis roesti*), 17b (earlymost Burdigalian of St-Paul-lès-Dax, N5 / NN2, 16 taxa, e.g. *Heliconoides mermuysi*, *Creseis tugurii*, *Diacrolinia orbignyi*, *Vaginella victoriae*, *Johnjagtia moulinsii*) and 17c (early-middle Burdigalian of 21 localities in the whole Aquitaine Basin, N5 / SBZ25, 10 taxa, e.g. the marker *Diacrolinia aquensis*). The North Sea Basin subdivision of pteropod zone 18 into subzones 18 and 18a could also be recognised in the Aquitaine Basin : zone 18 (Late Burdigalian of St-Jean-de-Marsacq, NN3/4 and N6/7, 13 taxa, e.g. *Vaginella austriaca*), zone 18a (Langhian of St-Martin-de-Hinx and Saubrigues, NN5 and N8/9, 11 taxa, e.g. *Diacrolinia aurita*, *Vaginella lapugyensis*, *Cavolinia zamboninii*). In the zone 19 (Serravallian of Orthez and Salles, NN6/7 and N11/13), only 6 taxa occurred, e.g. *Edithinella varanica*, *E. caribbeana*, *Clio ortheziana*.

Otherwise, twelve species of pteropods from Aquitaine Basin are described as new to science, *viz. Heliconoides daguini*, *H. merlei*, *H. pyrenaica*, *Limacina* ? *vegrandis*, from the Ypresian; *Creseis antoni* and *Vaginella gaasensis* from the Rupelian, *Clio lozoueti* and *Clio vasconiensis* from the Chattian; *Diacrolinia cluzaudi* from the Aquitanian; *Creseis roesti* from the Aquitanian/Burdigalian

and *Heliconoides mermuysi* and *Creseis tugurii* from the Early Burdigalian (see reference below).
Cahuzac B. & Janssen A.W. (2010, under press). Eocene to Miocene holoplanktonic Mollusca (Gastropoda) of the Aquitaine Basin, southwest France. *Scripta Geologica*, 141: 194 p., 1 table, 7 fig., 27 pl., Leiden.

Study of the modern benthic Foraminifera of the margin of the Western Mediterranean sea

Leila Moulfi-El-Houari

The aim of this work is to realise a synthesis on the distribution of benthic Foraminifera and their relationship to the nature of the substrate and the bathymetry in the Western Mediterranean sea. The qualitative and quantitative analysis of this microfauna on the southern margin concerned the Gulf of Arzew, Bou-Ismail and Algiers bays. The results were compared with those made by various authors on the northern margin (Italian, French and Spanish margin).

The underwater morphology is characterized by the abrupt coastal plunge towards deep seas which attests narrow continental shelves extended by slopes notched by submarine canyons. The instability of the Atlantic current on the southern margin is the source of upwelling currents responsible of an original productive system. The result is a density and a high diversity of benthic Foraminifera due to the proliferation of the diatoms. The basin of the western Mediterranean sea is characterized by a loose and distributed sedimentation parallel to the coast. Many factors interact in the control of the nature and distribution of the marine sedimentary facies and thus of the distribution of its associated microfauna.

The plateau or the continental platform is subdivided in two infralittoral and circalittoral stages. The infralittoral field of the moderate areas is rich in Foraminifera with porcelané test (Miliolidae) and in Foraminifera with thin and small hyaline test. It is characterized by a series of relative species common to all the infralittoral mediums belonging to the Quinqueloculina, Cycloforina, Rosalina, Valvulineria, Ammonia, and Elphidium kinds. The circalittoral stage represents the field of Foraminifera with agglutinated test. It is occupied by shelly relic which is characterized by a mixture of faunas. We identified in this facies old infralittoral microfauna (*Ammonia* and *Elphidium*) and a recent to actual circalittoral microfauna (*Cassidulina* and *Melonis*). This facies corresponds to a fossil offshore bar built during the last regression and installation of the shoreline at 100 to 120m depth. This regression is dated 18.000 years BP (Würm IV) and described on almost all Mediterranean and oceanic margins.

This work on the Algerian margin and the synthesis of those realised on various areas of the western Mediterranean basin bring new data on the mediums of life of the microfauna of benthic Foraminifera and its quantification

in sedimentation during the recent Quaternary. The fluctuations of the benthic Foraminifera thanathocenoses composition depend primarily on the nature of the substrate and partially for planktonic Foraminifera, on circulations as well as water masses exchanges (Atlantic and Mediterranean).

[VF] Étude des foraminifères benthiques actuels de la marge de la Méditerranée occidentale

L'objectif de ce travail est de réaliser une synthèse sur la répartition de foraminifères benthiques et leur relation avec la nature du substrat et la bathymétrie en Méditerranée occidentale. L'analyse qualitative et quantitative de cette microfaune sur la marge sud a concerné le Golfe d'Arzew, les baies de Bou-Ismail et d'Alger. Les résultats ont été comparés à ceux réalisés par différents auteurs sur la marge nord (marge italienne, française et espagnole).

La morphologie sous-marine se distingue par la brusque plongée des côtes vers les grands fonds ce qui lui atteste des plateaux continentaux étroits prolongés par des talus entaillés par des canyons sous-marins. L'instabilité du courant d'origine atlantique sur la marge sud est à l'origine de courants d'Upwellings responsable d'un système productif original. Il se traduit par une richesse et une diversité élevée en foraminifères benthiques dues à la prolifération des diatomées. Le bassin de la Méditerranée occidentale est caractérisé par une sédimentation meuble et distribuée parallèlement à la côte. De nombreux facteurs interagissent dans le contrôle de la nature et de la répartition des faciès sédimentaires marins et donc de la répartition de la microfaune qui lui est associée.

Le plateau ou la plateforme continentale est subdivisé en deux étages infralittoral et circalittoral. Le domaine infralittoral des régions tempérées est riche en en foraminifères à test porcelané (Miliolidae) et en foraminifères à test hyalin mince et de petite taille. Il est caractérisé par un stock d'espèces relatives communes à tous les milieux infralittoraux appartenant aux genres : *Quinqueloculina*, *Cycloforina*, *Rosalina*, *Valvulineria*, *Ammonia* et *Elphidium*. L'étage circalittoral représente le domaine des foraminifères à test agglutiné. Il est occupé par le coquillier relique qui est caractérisé par un mélange de faunes. Nous avons identifiés dans ce faciès une microfaune infralittorale ancienne (*Ammonia* et *Elphidium*) et une microfaune circalittorale récente à actuelle (*Cassidulina* et *Melonis*). Ce faciès correspond à un cordon littoral fossile édifié lors de la dernière régression et stationnement de la ligne de rivage aux profondeurs de -100 à - 120 m. Cette régression est datée 18 000 ans BP (Würm IV) et décrite sur une grande partie des marges méditerranéennes et océaniques.

Ce travail sur la marge algérienne et la synthèse de ceux réalisés sur différentes régions du bassin méditerranéen occidental apportent de nouvelles données sur les milieux de vie de la microfaune de Foraminifères benthiques et la quantification de celle-ci dans la sédimentation au cours du quaternaire récent. Les fluctuations de la composition des thanatocénoses de Foraminifères benthiques, dépendent essentiellement de la nature du substrat et

partiellement pour les foraminifères planctoniques des circulations ainsi que des échanges des masses d'eau (Atlantique et Méditerranéenne).

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