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7. Palaeontology +

8. Fossils and plate tectonic events: Oceanic and continental gateways, landbridges and the dispersal of biota
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TALKS:

7.1 Andjic G., Baumgartner-Mora C., Baumgartner P.O.: Shallow-water events in the Sandino Forearc Basin, Nicaragua - Costa Rica, evidence for subduction of seamounts?

7.2 Baumgartner P.O., Sandoval M.I., Escuder-Viruete J.: Radiolarians and radiolarites, Pangea breakup and the plate tectonic evolution of the Caribbean region

7.3 Brosse M., Goudemand N., Frisk Å.M., Baud A., Bagherpour B., Bucher H.: New conodonts from the Griesbachian microbialite in South China: implications for an improved definition of the base of the Triassic

7.4 Costeur L.: The ruminant inner ear: evolutionary perspectives

7.5 Forasiepi A.M., Carrillo J.D.: Geographic isolation, land connection, and evolution of the terrestrial mammalian associations during the Cenozoic in South America: the carnivorous zone

7.6 Hiard F.: Eocene migrations of European mammals

7.7 Klug C., De Baets K., Kröger B., Bell M.A., Korn D.: Latitudinal shifts of Palaeozoic marine invertebrate gigantism and global change


7.9 Neenan J.M., Li C., Rieppel O., Bernardini F., Tuniz C., Muscio G., Scheyer T.M.: Unique method of tooth replacement in Placodontia (Diapsida, Sauropterygia), with new data on the dentition of Chinese taxa

7.10 Pictet A., Föllmi K.B., Linder P., Spangenberg J.: Ammonite biostratigraphy ... what utility? Example of the Aptian Grünten Member and Luitere Bed in the Alpine Helvetic domain

7.11 Sandoval M.I., Baumgartner P.O., Scientific Party of IODP (Integrated Ocean Drilling Program 344 Expedition): Radiolarian biostratigraphy and Miocene to Recent Cocos Plate motion in the frame of the tropical, E-Pacific palaeoceanographic setting (IODP Exp. 344, off Costa Rica)
POSTERS:

P 7.1 Baldessin E., Kindler P., Fischer G., Godefroid F.: Upper Cenozoic dolostones from the Mayaguana Bank, SE Bahamas: new insights from a core study

P 7.2 Baumgartner-Mora C., Baumgartner P.O., Andjic G., Barat F.: Mid Cretaceous to Oligocene rise of the Middle American landbridge – documented by south-eastwards youngung Larger Foraminifera in shallow water carbonates (Nicaragua – Costa Rica – Panama)

P 7.3 Bôle M., Baumgartner P.O.: Geochemistry and 30Si of Radiolaria and Mesozoic Radiolarites of Panthalassa and Tethys

P 7.4 Fischer G., Kindler P., Godefroid, F., Baldessin E.: The Mayaguana Bank (SE Bahamas) from the Late Oligocene to the present: A delicate equilibrium between tectonics and sedimentation

P 7.5 Marchegiano M., Gliozzi E., Buratti N., Ariztegui D., Cirilli S.: Middle Pleistocene ostracod assemblages from Lake Trasimeno, Perugia, (Italy)

P 7.6 Scherler L., Mennecart B., Hiard F., Becker D.: The «Microbunodon Event», or the European evolution of ungulates during the Oligocene-Miocene transition

P 7.7 Székely S. F., Spezzaferri S., Stalder C., Filipescu S.: Paleoenvironmental reconstruction based on foraminiferal assemblages and the sedimentary phosphorus record in the Oligocene of Romania (Transylvanian Basin)
7.1
Shallow-water events in the Sandino Forearc Basin, Nicaragua – Costa Rica, evidence for subduction of seamounts?

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The Sandino Basin corresponds to a latest Cretaceous – Neogene forearc basin that is exposed today in the southwestern Nicaraguan Pacific coastal plain and in the northwestern corner of Costa Rica (Astorga 1987, fig.1). It consists of an elongated, slightly-folded belt of approximately 160 km long and 30 km wide. The basin developed between the Campanian and the Pliocene and includes essentially deep-water detrital sequences and basinal to platform carbonates in minor proportions (Astorga 1987; Hodgson 1998). The latter deposited at different steps of the basin evolution. The initial stage of basin development is only observed in the Santa Elena Peninsula (Costa Rica), where the basement of the southern part of the basin crops out. The basement consists of a tectonic stack of a serpentinite massif (Santa Elena Ultramafic nappe) on a mid-Cretaceous accretionary complex (Santa Rosa Accretionary Complex; Baumgartner & Denyer 2006). The stacking of these two units is believed to have taken place when their intraoceanic arc collided with the pre-existing margin. This thrust uplifted parts of the tectonic pile to shallow-water environments, as it is deduced from the mid-Campanian El Viejo Fm. (Baumgartner et al. 1984). This formation exhibits rudist-rich platform limestones in its proximal parts and slope deposits in its distal parts, both containing reworked clasts of the serpentinitic basement (Baumgartner et al. 1984).

Shallow-water environments were rapidly drowned as the tectonic pile subsided in the forearc setting of the Mid-American Trench. A discordance (~ 20°) is observed between the slope sediments and the subsequent deposit of pelagic limestones (Piedras Blancas Fm., mid-Campanian – Up. Maastrichtian).

Basin evolution is then dominated by detrital sedimentation through Paleocene-Miocene times (Hodgson 1998). The detrital sediments range from thin-bedded distal turbidites to plurimetric proximal debris-flow and rarely record shallow-water conditions. However, Tertiary shallow-water limestones have been observed in several places, in Nicaragua and Costa Rica. They always appear as isolated outcrops which do not present stratigraphic contacts with the neighboring detrital sequences. The presence of these short-lived platforms could be attributed to localized uplifts in the forearc area, as the possible consequence of seamount subduction. The best-preserved exposure of platform limestones is located on the small, undescribed Isla Juaniilla (0.15 km²). The whole island is made of reef carbonates, displaying corals in growth position associated with coralline red algae. A small outcrop of a wackestone containing abundant Lepidocyclina ssp. of the L. undosa-favosa group permits to attribute an Oligocene age to this reef.

Finally, the Pliocene El Salto Fm. (Hodgson 1998; Nicaragua, fig.1) represents shallow-water, untilted terraces that deposited after the Miocene folding of the forearc basin (NW-SE fold axes).

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7.2
Radiolarians and radiolarites, Pangea breakup and the plate tectonic evolution of the Caribbean region

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The now well-known Mesozoic radiolarian record yields several hundred morpho-species for any time interval. Most species have a global distribution either in a low latitude belt and/or in a still poorly defined, bipolar high palaeolatitude region (Figure 1).

While an intermittent marine connection through Pangea via the western Tethys-Central Atlantic – and the Proto-Caribbean rift area may have existed since the late Early Jurassic, low latitude cosmopolitan radiolarian assemblages are known only since the middle Bathonian from the Central Atlantic (DSDP Ste 534, UAZ95:6, Baumgartner & Matsuoka 1995). While a Toarcian (late Early Jurassic) breakup is well constrained for the Central Atlantic, the place and timing of initial ocean crust formation between the Americas (Gulf of Mexico or Proto-Caribbean?) is still poorly constrained. Although oceanic crust seemingly started to form in the early Late Jurassic (158 my), recent plate tectonic reconstructions show important obstructions throughout the Late Jurassic and early Cretaceous between the Central Atlantic, the Proto-Caribbean, and the Colombian back-arc basin, which in turn was separated from the Pacific by a mature arc.

Ribbon-bedded radiolarites are the most common oceanic sediment in Circum-Pacific remnants of Panthalassa. They range in age from Middle Palaeozoic to Late Cretaceous. Remnants of Palaeotethys also yield radiolarites of Late Palaeozoic to Early Triassic age. Remnants of Neotethyan ocean basins are characterized by Middle Triassic to Late Jurassic, sometimes early Cretaceous radiolarites. Although low latitude radiolarian assemblages spread into the early Central Atlantic, their productivity was too low to produce radiolarites. Middle to early Late Jurassic radiolarite facies can still be found in the Subbetic realm of SW-Spain and in the Rif on N-Morocco, but are absent from Jurassic sections of the Central Atlantic, such as exposed in Fuerteventura (Canary Islands) or drilled at DSDP Site 534 (Blake Bahama Basin). The radiolarite facies is also absent from pelagic realms related to the Proto-Caribbean (e.g. Guaniguanico Terrane of NW-Cuba) and the Gulf of Mexico (e.g. Taman Formation of East-Central Mexico). Detrital sediments dominate in the Middle Jurassic and pelagic carbonates characterise the late Jurassic-early Cretaceous in these “intra-Pangean” realms.

We interpret Jurassic-Early Cretaceous pelagic carbonates in the Central Atlantic and the Proto-Caribbean realms as the consequence of more oligotrophic surface waters than those of the adjacent Tethys and Panthalassa (Baumgartner 2013). The Central Atlantic was a ‘Mediterranean-type’ ocean basin, such as the Modern Red Sea. It was (and still is) a carbonate ocean, characterised by an anti-estuarine circulation.

What about the radiolite occurrences in the Antilles and Cuba? Ribbon radiolarites in these areas are systematically related to oceanic seafloor basalts of various (within plate, primitive island arc, or rarely MORB) origins. Many occur as blocks in serpentinite-matrix mélanges (Cuba, Puerto Rico) that are reminiscent of Franciscan-type, subduction-related mélanges of the Pacific façade of Central and N-America. Radiolarian biochronology indicates an age range from Aalenian to Cenomanian (Bandini et al. 2011). Pre-Late Jurassic radiolitae (e.g. Bermeja Complex, Puerto Rico) cannot be Proto-Caribbean in origin (Montgomery et al. 1994), because they would be coeval with syn-rift detrital and evaporitic sediments known from Proto-Caribbean margins. The Aguacate Chert resting on the MORB-type Loma La Monja volcano-plutonic sequence has been considered as Late Jurassic in age and of Proto-Caribbean origin. Our recent findings indicate that at least part of the Aguacate Chert is Middle Jurassic in age, hence cannot be of Proto-Caribbean origin.

Our conclusion is that the Jurassic-Early Cretaceous ribbon radiolarites of the Antilles belong to exotic terranes of Pacific origin, which were emplaced into the Caribbean area in front of the Caribbean Large Igneous Province. These radiolarites are a major augment for the allochthony of the Modern Caribbean Plate.
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7.3

New conodonts from the Griesbachian microbialite in South China: implications for an improved definition of the base of the Triassic

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A new sampling of Early Triassic (Griesbachian) conodonts is obtained from the microbialite overlying the latest Permian peri-reefal shallow water limestone in Wuzhuan section (Nanpanjiang Basin, Guangxi, South China). High resolution sampling in the lower twelve meters of the Luolou Formation provides rather diversified conodont faunas and allows constructing a well resolved conodont distribution for this crucial earliest Triassic interval. In the Wuzhuan section, the nine meters thick microbialite is bracketed by two calcarenite beds and contains several fossiliferous lenses. The co-occurrence of typical Permian foraminifera such as Paraglobivalvulina mira (Reitlinger) and Dagmarita chanakchiensis (Reitlinger) in the calcarenite underlying the microbialite indicates a late Permian age. Our preliminary results indicate the presence of one residual maximal horizon (RMH) based on conodont faunas in the microbialite and of a second one in the overlying calcarenite. The lowest RMH occurs four meters above the base of the microbialite and is defined by Neogondolella taylorae (Orchard) and Neogondolella n. sp. A. The second RMH from the calcarenite that caps the microbialite is defined by the co-occurrence of Isarcicella staeschei (Dai and Zhang) and Isarcicella isarcica (Huckriede). The lowest RMH including N. taylorae partly overlaps with the N. taylorae interval zone established in sections without microbialite such as Meishan and Shangsi. However, the N. taylorae RMH is here reported for the first time from section with microbialite in the Yangtze platform or the Nanpanjiang basin. The second RMH partly overlaps with the Isarcicella isarcica interval zone recorded above the microbialite in other sections. Although H. parvus is dominant in Wuzhuan and in other microbialite-bearing sections, its first occurrence has been documented as diachronous. In Wuzhuan, the most appropriate conodont association for constraining the base of the microbialite is the RMH with N. taylorae and N. n. sp. A.

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The ruminant inner ear: evolutionary perspectives

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The inner ear or bony labyrinth contains the organs of hearing and balance. It’s housed inside the petrosal bone which has historically been a source of phylogenetic information for mammals and for cetartiodactyls in particular (e.g., Luo and Gingerich, 1999; O’Leary, 2010; Theodor, 2010). After the seminal work of Gray (1907), several studies focused on the inner ear itself in primates, rodents, “insectivores” or marsupials to investigate functional signals (Schwarz, 2012), phylogenetic patterns (e.g., Gunz et al., 2012; Ekdale, 2013) or developmental issues (Sánchez-Villagra & Schmelze, 2007). But its use remains very limited in ruminants. The morphology of the inner ear in basal artiodactyls has been described only recently (Theodor, 2010; Orliac, 2012) and very few is known on morphological variability, ontogenetic changes or relevance of potentially significant phylogenetic characters. The inner ear being a strongly functional structure, the relevance of characters has to be taken with caution. However, recent works successfully started to tackle this issue (Jeffery et al., 2008).

I will review the use of the inner ear in ruminant research and show how this structure can be useful. The more and more widespread use of high resolution X-ray computer tomography has made it possible to reconstruct relatively easily the inner ear in extant and extinct taxa without destruction of the skull. Studying the bony labyrinth involves looking at variability, a time-consuming but feasible task. I will show examples taken from extant taxa in different ruminant families (Tragulidae, Bovidae, Cervidae and Moschidae) to illustrate ontogenetic changes or morphological differences. I will also incorporate extinct taxa from the same families (especially the musk-deer family, i.e., Moschidae) for which I could investigate morphological variability and possibly discriminate species of the same genus.

Comparative morphological descriptions of the inner ear yield interesting insights, but quantitative data are needed for statistically sound comparisons. I will then emphasize this need and show what future works, especially involving geometric morphometrics, could bring to the understanding of the shape signal born by the ruminant inner ear.

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Figure 1. Four inner ears of the fossil musk deer Micromeryx (Mammalia, Moschidae), reconstructed from high resolution CT-scans of a skull and three isolated petrosals from the Middle Miocene German locality of Steinheim. Note the variability in the number of cochlear whorls for instance.
7.5

Geographic isolation, land connection, and evolution of the terrestrial mammalian associations during the Cenozoic in South America: the carnivorous zone

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The physical isolation of the South American continent during most of the Cenozoic resulted in an endemic fauna. The eutherians and metatherians were the major components of the mammalian associations with the carnivorous adaptative zone occupied by metatherian sparassodonts. The Sparassodonta has been registered from the Paleocene to the Pliocene. They were predominantly hypercarnivores and with a broad range of body sizes, locomotory capabilities, and morphologies, including some extreme specializations, such as the sabre-tooth thylacosmilids.

Placental Carnivora started to occupy the carnivorous adaptative zone since the Late Miocene in South America. However, after the complete formation of the Panama Bridge, during the Pleistocene, the richness of the placental carnivores massively increased. There was temporal overlap of Sparassodonta and Carnivora during the Late Miocene–Early Pliocene but no ecological superposition. This suggests an opportunistic ecological replacement, as part of a larger faunistic turnover, in contrast to a competitive displacement.

The oldest placental carnivores in South America currently found are in Argentina, in the south tip of the continent. Recent discoveries in northern South America provide further information about the interchange with North America.

Fossil and present day distribution of mammals in South America highlight the importance of the tropics and the Andes during the interchange. The diversity of northern immigrants in South America abruptly increased since the Late Miocene, reaching in the Quaternary about half of the total mammalian fauna. In fossil and current terrestrial ecosystems from South America, mammals with North American origin dominate in temperate and high altitude zones, whereas mammals with South American origin dominate in the tropics.

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Figure 1. South American Land Mammals Ages (SALMAs), sparassodont and carnivorn richness line, major faunistic events, temperature line, environments, and major tectonic events in the Cenozoic of South America (modified from Prevosti et al. 2013).
7.6

Eocene migrations of European mammals

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During the Eocene, Europe was an isolated archipelago, separated to Africa by the Tethys, to Asia by the Turgai strait and, since the late early Eocene, to North America by the opening of the Atlantic Ocean (e.g. Brinkhuis et al 2006, MacFadden 1992). During this epoch, the mammalian fauna of Europe was characterised by a high level of endemism, such as in the terrestrial cetartiodactyls (e.g. Erfurt and Métais 2007).

However, the biostratigraphy and of the evolution of European mammals suggest several arrivals of migrants from other continents. Two main questions remain: Where they came from and which ways did they use. Asia and North America are the two main possibilities of their origin. From America, the mammals could cross the North Atlantic by the DeGeer dispersal route. Mammals could also come from Asia, crossing the Turgai strait or following a corridor made by central Asia and Anatolia. Arguments in favor or at the contrary in the detriment of those different possibilities will be discussed. Furthermore, an overview of the Eocene mammals from other parts of the world will highlight the difficulties to answer to those different questions.

\[\text{Figure 1. Eocene paleogeography with potential origins and migratory ways of European mammals (Modified from Scotese 2001).}\]

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7.7

Latitudinal shifts of Palaeozoic marine invertebrate gigantism and global change

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Since the Cambrian Explosion, giant marine invertebrate species have evolved iteratively in several groups. In the Palaeozoic, marine invertebrate gigantism was heterogeneously distributed through time and space; changes in maximum sizes show no clear relationship with atmospheric or oceanic oxygen and other environmental factors. Although gigantism has found an explanation for Carboniferous land invertebrates in the atmospheric oxygen peak, marine gigantism has not been studied empirically and explained comprehensively.

By quantifying the spatiotemporal distribution of the largest representatives of some major marine invertebrate clades, we assessed links between ecological parameters and giant growth. These occurrence data suggest that temperature and latitude in combination with oxygen played important roles. Marine invertebrate gigantism developed in certain phases and regions with a greater number of extremely large species and their occurrences shifted independently from middle towards low latitudes during the Palaeozoic in all examined groups. This trend roughly coincides with the Late Devonian to Carboniferous cooling and regression as well as with a rise in atmospheric oxygen. This shows how global environmental changes can control the geographical distribution of organisms and that the optimal ecological requirements might differ depending on body size: extremely large organisms might react less flexibly to ecological changes.
The evolution of Pleistocene camelids from El Kowm, Syria

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The Camelidae (Artiodactyla) originated in North America during the middle Eocene (~45 Ma). In the Miocene they became very successful, and diversified into at least 20 genera (Honey et al. 1998). The first genus in the Old World was Paracamelus, which is recorded since the latest Miocene (MN13, ~7 Ma). It was likely ancestral to modern Camelus (Pickford et al. 1995). However, the evolution of Eurasian camelids is poorly known. Several species are recognized, but most are based on scarce material or have been described only superficially.

A good opportunity to study the diversity and evolutionary trends of Eurasian camelids is provided by the fauna of the El Kowm Basin (central Syria). This region is rich in Palaeolithic archaeological sites with abundant mammalian fossils. The complete sequence spans the early to late Pleistocene, from 1.5-1.8 Ma to 50 ka (Jagher and Le Tensorer 2011). Camelids are the most frequent faunal elements in all layers. Here we present preliminary results from the analysis of this camelid succession. The material studied was excavated in three sites (Aïn al Fil, Hummal and Nadaouiyeh Aïn Askar) within few km from each other.

The oldest remains from Aïn al Fil (Early Palaeolithic, Early Pleistocene, between 1.8 and 1.5 Ma) suggest the coexistence of two species, one dromedary-sized and one much larger. Later forms from the lower section of Hummal are also larger than modern camels, with long limbs and small heads. A size reduction is seen from the Early to the Late Pleistocene. A Middle Pleistocene skull from the rich sample of Nadaouiyeh Aïn Askar (Acheulean layers, about 400 Ka) has a unique morphology. Fossils that are similar and somehow intermediate between the two modern species are frequent only in the Late Pleistocene of Hummal (Mousterian layers, 150 to 50 Ka). During this period they coexisted with a highly distinctive giant species, which is the most recent example of the formerly common giant camels.

The study of Pliocene and Pleistocene fossil camelids is hampered by the lack of knowledge about the comparative morphology of the recent camel species, the dromedary C. dromedarius L. and the Bactrian camel C. bactrianus L (Peters & von den Driesch 1997). Our project begins with a morphometric analysis of the modern species that will allow the identification and description of the several species found in the El Kowm sequence.

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Unique method of tooth replacement in Placodontia (Diapsida, Sauropyrgia), with new data on the dentition of Chinese taxa

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The placodonts of the Triassic period (~251–201 mya) represent one of the earliest and most extreme specializations to a durophagous diet of any known reptile group (e.g. Rieppel 2000). Exceptionally enlarged crushing tooth plates on the maxilla, dentary and palatine cooperated to form ‘crushing areas’ in the buccal cavity (Mazin & Pinna 1993). However, the extreme size of these teeth, combined with the unusual way they occluded, constrained how replacement occurred (Rieppel 2001). Using an extensive μCT dataset of 11 specimens that span all geographic regions and placodont morphotypes, tooth replacement patterns were investigated. In addition, the previously unknown dental morphology and formulae of three Chinese taxa is described for the first time.

Placodonts have a unique tooth replacement method and results appear to follow a phylogenetic trend (Fig. 1). The plesiomorphic *Placodus* species show many replacement teeth at various stages of growth, with little or no discernable pattern. On the other hand, the more derived cyamodontoids tend to have fewer replacement teeth growing at any one time, replacing functional teeth diagonally across the palate and/or in functional units. *Cyamodus*, *Sinocamodus* and *Macroplacus* in particular show strong modularity, with unilateral replacement of teeth that form functional units. The highly nested placochelyids *Psephoderma* and *Psephochelys* have fewer teeth and, as a result, only have one or two replacements in the upper jaw, and supports previous suggestions that these taxa had an alternative diet to other placodonts (Rieppel 2002). Importantly, all specimens show at least one replacement tooth growing at the most posterior palatine tooth plates, indicating increased wear at this point and supporting previous suggestions that this was the main site of crushing (Rieppel 2002).

*P. inexpectatus* has a very similar dentition to the European *P. gigas*, although there is one extra anterior dentary tooth plate and the anterior dentary teeth as well as premaxillary teeth are much shorter and bulbous in the former (Fig. 2A). The teeth of *Sinocamodus* are numerous and small (Fig. 2B), similar to the condition seen in a sub-adult *Cyamodus hildegardis* (Kuhn-Schnyder 1959), evidence that this is also a sub-adult. *Psephochelys* has fewer teeth and an edentulous rostrum (Fig. 2C) and is very similar to that of the European *Psephoderma*, indicating a comparable diet and feeding strategy.

![Figure 1. Schematic representations of placodont skulls in palatal view showing tooth replacement stages. Grey teeth indicate presence of a functional tooth, whereas white represents absence. Stage 1, the replacement tooth is a thin layer of enamel and does not resemble a functional tooth. Stage 2, the replacement tooth begins to resemble a functional tooth, but has not reached full size. Stage 3, the replacement tooth has reached approximately full size.](image-url)
Figure 2. The dentitions of the Chinese placodonts *Placodus inexpectatus* (A), *Sinocyamodus* (B) and *Psephochelys* (C). Abbreviations: d, dentary; m, maxilla; pl, palatine; pm, premaxilla.

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7.10

Ammonite biostratigraphy ... what utility? Example of the Aptian Grünten Member and Luitere Bed in the Alpine Helvetic domain.

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A first model for the stratigraphy of the Aptian sedimentary succession in the northern Alps originated early in the twentieth century (Jacob & Tobler 1906; Heim 1913; Fichter 1934) with the following age attribution to the lithological succession: the Upper Urgonian Member (*Deshayesites oglanlensis* to *D. deshayesi* ammonite zones), the Grünten Member (*Dufrenoyia furcata* zone), the Luitere phosphatic Bed (*Epicheloniceras martini* and *Parahoplites melchioris* zones), Gams Beds (*Parahoplites melchioris* zone), and the Brisio Sandstone and Limestone Beds (*Acanthoplites nolani* zone). In the early XXth, more precise studies based on sedimentological, geochemical, mineralogical and biostratigraphic analyses, allow to assign more precise ages to these units (Linder et al. 2006; Föllmi & Gainon 2008; Föllmi 2009) with an age corresponding to the *D. oglanlensis* and *D. forbesi* zones for the Upper Urgonian Member, *D. deshayesi* and *D. furcata* zones for the Grünten Member, and *E. martini* and *P. melchioris* zones for the Luitere bed.

Recent results, based on comparisons with the Chabert Formation on the Ardèche Platform (SE France), and geochemical analyses and numerous new ammonite findings including Deshayesitidae and Cheloniceratinae from the Helvetic Alps, allow for a new and more precise stratigraphic and biostratigraphic subdivision of the Grünten member and the Luitere Bed, resulting in a new interpretation of the age of the Luitere bed and some important modifications in the ammonite biozonal attributions.
A correlation with the Ardèche Platform allows to date the basal Rohrbachstein interval to the late early *D. forbesi* zone based on the discovery of the last *Procheloniceras* accompanied by classical *Deshayesites* from this zone. The lower Grünnten Member is dated as the *Rohlboceras hambrovi* subzone and the *D. deshayesi* zone thanks to the index fossil from the *R. hambrovi* and *D. grandis* sub-zones, and also by comparison of the carbon isotope curves. The Plaine Morte Bed is dated as the late *D. grandis* subzone – early *D. furcata* zone by the discovery of the index forms. The Upper Grünnten Member is dated as the *D. furcata* zone by the observation of the index fossil. The alpine ammonite fauna composing the Luitere Bed allows the recognition of three distinctive phosphatic fauna (Luitere 1 to 3), which may separate two third-order sequences belonging to the *D. furcata* zone and to the *E. martini* zones. For the moment, only the first sequence was observed in the Rawil (Swiss Alps) outcrop (Föllmi & Gainon 2008), separated by two distinct phosphatic layers, the Plaine Morte and Luitere Beds, which meet laterally.

Inversely, these new stratigraphic scheme allows for a better understanding of the ammonite species created by the past on these beds of reworking (e.g. Jacob & Tobler 1906) and of their age attribution, species used as indexes in the past or present biostratigraphy by ammonites (e.g. *Colombiceras tobleri, Epicheloniceratinae buxtorfi*).

![Figure 1](image1.png)

Figure 1. Schematic plot of lithostratigraphic units in the Helvetic Realm from Linder et al. (2006) with on the right the different ages assigned, the position of the phosphatic beds, and the FAD / LAD of Deshayesitidae and Cheloniceratinae ammonite families and subfamilies.

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Radiolarian biostratigraphy and Miocene to Recent Cocos Plate motion in the frame of the tropical, E-Pacific palaeoceanographic setting (IODP Exp. 344, off Costa Rica).

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The IODP Expedition 344 (the “Costa Rica Seismogenesis Project” CRISP 2) drilled a transect across the convergent margin off Costa Rica (Figures 1, 2).

Five sites were drilled during seven weeks of expedition: Site U1381 (8°25.7027′N, 84°9.4800′W, 2064.6 m water depth) is ~4.5 km seaward of the deformation front on the incoming (Cocos) plate, offshore Osa Peninsula and Caño Island, Costa Rica. Recovery was 103.8 mbsf. Site U1414 (8°30.2304′N, 84°13.5298′W, 2459 m water depth), also located on the incoming plate, recovered 375.2 mbsf of sediments and basalt. The following sites were drilled in the Neogene slope apron of the upper (Caribbean) plate. Site U1380 (8°35.9879′N, 84°4.3918′W, 502.7 m water depth). The coring reached 800 mbsf. Site U1412 (8°29.1599′N, 84°7.7512′W, 1965 m water depth), involved drilling four holes with a maximum depth of 350.4 mbsf. Overall core recovery at this site was moderate (average of 59%), but became poor toward the bottom. Site U1413 (8°44.4593′N, 84°6.8095′W, 540 m water depth), recovered sediments to 582.2 mbsf.

Micropaleontological samples were collected at all sites. Two sites from the Cocos plate were selected to obtain a detailed biostratigraphy of the middle Miocene to Recent oceanic sequence deposited on the incoming plate. At both localities radiolarian assemblages are well preserved and abundant. The sediments recovered from the two sites consist mainly of calcareous nannofossil ooze with foraminifers, diatoms and radiolarians. 295 samples were prepared with the standard method for Neogene Radiolarians. It consisted of extracting the radiolarians by washing the sample first with HCl 10% in order to digest carbonate and then washing it with H2O2 10% to destroy organic matter. Residues were collected with a 60μm mesh sieve.

The objectives of this study are: 1. detailed radiolarian biostratigraphy of the early-middle Miocene to Recent sequence of the incoming plate (Site U1381C, U1414A) and 2. a taxon-quantitative analysis aimed at tracing faunal changes related to the northward movement of the sites and to palaeoceanographic changes in context of the final closure of the Middle American Isthmus.

According to the modern plate motion vector, (7.3 cm/year, Mann 2007). Site U1414 A and U1381 C were located slightly south of Equator during the middle Miocene. Radiolarian assemblages of that age should therefore reflect the influence of the cold tongue generated by the South Equatorial Current. In contrast, today the sites are located in the influence of the warm North Equatorial Countercurrent (Fig. 2).

To achieve these objectives, 300 specimens will be counted per sample to obtain a representative faunal spectrum. An age model will be based on the radiolarian zonation for the tropics (Riedel et al 1978), the nannofossil zonation and paleomagnetic data that will be analyzed by others scientists of the expedition.

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Figure 1: Location of the drilled sites of IODP 344 Expedition off Costa Rica

Figure 2: Oceanography of the tropical E-Pacific and projected displacement of the studied sites since middle Miocene. Taken from Baldessin et al. (in preparation)
Upper Cenozoic dolostones from the Mayaguana Bank, SE Bahamas: new insights from a core study

Erika Baldessin, Pascal Kindler, Gyöngyvér Fischer and Fabienne Godefroid

Preliminary study of a core retrieved from the Mayaguana Bank (SE Bahamas) reveals the occurrence of two distinctive dolomitization episodes in Cenozoic limestones. One of them only affects karst infills without influencing the encasing limestone, whereas the other is pervasive and completely replaces the parent carbonate facies.

Massive, pervasive dolomites have been described in the subsurface of the Bahamas for decades (Supko, 1970; Dawans, 1988), but the precise dolomitization mechanism remains uncertain (Machel, 2004). One core drilled on the north coast of Mayaguana contains intervals of both “karstic” and massive dolomite, and offers an opportunity to better constrain the dolomitization processes at the origin of these rocks.

Mayaguana is a small, elongated (57 x 13 km) carbonate island lying between latitudes N 22°15’ - N 22°30’ and longitudes W 72°40’ - W 73°10’ (Pierson, 1982) in the SE part of the Bahamas archipelago. Godefroid (2012) described several lithostratigraphic units exposed on the island, including the Mayaguana and the Little Bay Formations. The Mayaguana Formation consists of a Lower Miocene (18.4-18.7 Ma), fine-grained, hard limestone with numerous larger benthic foraminifers, whereas the Little Bay Formation is an Upper Miocene (5.59-6.81 Ma), solid, fine-grained, fabric-destroying dolostone, made of a dense network of microsucrosic dolomite.

A 43 m-long core was drilled at Little Bay with a CME 750X rubber-tired core drill by Martin Marietta Materials Company. Back in Geneva, the core was cut in half, logged and sampled for analyses.

Different findings were made during the preliminary examination of the core. First, the core spans a time interval from the Oligocene (Rupelian-Chattian according to the occurrence of the porcelaneous benthic foraminifer Praerhapydionina delicata) to the Early Miocene, with the Mayaguana Formation forming its top. This formation presents small karstic cavities and fissures filled with white, laminated, hard dolomite (Fig. 1) which is tentatively correlated to the Little Bay Formation. A pervasive dolomite occurs more deeply in the core (Fig. 2) and completely replaces the parent bioclastic limestone. These two types of dolomite likely result from distinctive and diachronous diagenetic events, and reflect different conditions of dolomitization during the Neogene on Mayaguana.

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Figure 1 - Karstic dolomite

Figure 2 - Pervasive dolomite
Mid Cretaceous to Oligocene rise of the Middle American landbridge – documented by south-eastwards youngung Larger Foraminifera in shallow water carbonates (Nicaragua – Costa Rica – Panama)

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Basements of Southern Central America are oceanic in origin, including the southern half of the classical “Chortis Block” formed by subduction/accretion mélanges named Mesquito Composite Oceanic Terrane (MCOT, Baumgartner et al., 2008). The rise of these oceanic basements into the photic zone and their occasional emergence was controlled by convergent, collision tectonics, and/or arc development. In this context, shallow carbonate palaeo-environments were short-lived and formed on uplifted basements and arcs, and also on (now accreted) volcanic edifices of Pacific oceanic seamounts.

From Northern Nicaragua (NW) to Eastern Panama (SE) we observe a systematic younging of the first shallow water carbonate facies encroaching on basements and/or older deep-water formations: In the Siuna area (NE-Nicaragua) Aptian-Albian shallow water limestones dated by rudists and Orbitolina texana (Figure 1) rest unconformably on the Jurassic/Early Cretaceous Siuna Serpentinite Mélange, part of the MCOT. In N-Costa Rica, the assembly of several terranes (Santa Elena Ultramafic Unit, Nicoya Complex s. s., Matambu and Manzanillo Terranes) is overlapped by Late Campanian-Maastrichtian shallow water facies dated by rudists and Larger Foraminifera, such as Pseudorbitoides ruteni, Pseudorbitoides israelski, Sulcoperculina sp. and Sulcoperculina globosa (Baumgartner-Mora & Denyer, 2002). Reworked Campanian-Maastrichtian shallow water material including Larger Foraminifera was found in the Herradura Promontory (central Pacific coast of Costa Rica). It could be derived from an accreted seamount. No shallow carbonates are known so far from the early Palaeocene.

The Tempisque Basin (N-Costa Rica) hosts the Barra Honda carbonate platform (originally >900 km²) dated as late Palaeocene (Thanetian) by planktonic Foraminifera, ⁸⁷Sr / ⁸⁶Sr ratios and Ranikothalia spp. (Jaccard et al., 2001). Other late Palaeocene shallow carbonates documented in S-Costa Rica/W-Panama (Quepos, Burica) are interpreted as insular carbonate shoals (atolls?) on now accreted seamounts.

To the SE of the S-Nicoya fault line (Central Costa Rica) Late Cretaceous oceanic plateaus may represent actual outcrops of the trailing edge of the Caribbean Large Igneous Province (CLIP). These include the SE corner of the Herradura Promontory (Costa Rica) and the Azuero Plateau cropping out in Coiba, Sona and Azuero (Panama). CLIP formation triggered a new, E-dipping subduction zone and Campanian-Maastrichtian arc initiation on the CLIP edge (Buchs et al. 2011). By middle to late Eocene times this Middle American Arc and forearc areas reached the photic zone leading to widespread formation of carbonate banks/ramps. They are dated by many Larger Foraminifera of the genera Amphistegina, Asterocyclina, Discocyclina, Euconoloides, Eufabiania, Fabiania, Gypsinia, Helicolepidina, Heterostegina, Lepidocyclina, Linderina, Neodiscocyclina, Nummulites, Operculina, Orthophragmina, Polylepidina, Proporocyclina, and Sphareogypsina.

The first shallow carbonates that encroach on arc forearc basements in Panama are dated as Late Eocene in Azuero and the Canal Basin and as Oligocene, dated by Lepidocyclina miraflorensis, L. giraudi, L. canellei around the Chucunaque Basin of Eastern Panama.

Progressive shallowing of the trailing edge of the Caribbean plate from NW (middle/Late Cretaceous) to SE (Late Eocene-Oligocene) implies a growing restriction of the Atlantic – Caribbean – Pacific seaway that must have affected global circulation patterns, to be considered in palaeo-oceanographic/palaeo-climatic models of the Late Cretaceous –Tertiary.
Figure 1. left: *Orbitolina texana* in a Aptian-Albian bioclastic shallow water limestone from the Siuna area (NE-Nicaragua). Center & right: Campanian bioclastic shallow water facies from Rio Nisperal, Santa Elena peninsula, N-Costa Rica. microsperic form of *Pseudorbitoides israelii* (center), rudistid fragment (right).

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Geochemistry and $\delta^{30}\text{Si}$ of Radiolaria and Mesozoic Radiolarites of Panthalassa and Tethys

Bôle Maximilien & Baumgartner Peter Oliver

Radiolarians, diatoms and sponges are currently the main consumers of silica in ocean. Until the Cenozoic explosion of diatoms, radiolarians had dominated the oceanic silicon cycle. Despite their important role in the past, only scarce geochemical data exists on radiolarites. In the frame of a SNF project, we are planning to compare radiolarites form the Mesozoic Panthalassa and Tethys Oceans.

Geochemical and mineralogical investigations are carried out to constrain the depositional conditions of radiolarians. For example, trace elements will be used to determine paleo-productivity and paleo-oxygenation of the water column (Tribovillard, 2006). In the Tethys, which was surrounded by continents, a stronger detrital influence is expected and will be verified by analysing the clay mineralogy and abundance.

The measurement of precise accumulation rates of biogenic silica is affected by the presence of non-biogenic silica in clays and detrital (aeolian) quartz. We are developing analytical methods to determine the biogenic silica fraction.

Concurrently, we are studying silicon isotopes of Jurassic to Recent radiolarians and in Mesozoic radiolarites, as very few data are currently available. Most data on silicon isotopes of biogenic silica were carried on diatoms and sponges. De La Rocha et al. (1998) have inferred a positive correlation for diatoms between primary productivity ($\delta^{13}\text{C}_{\text{org}}$) and $\delta^{30}\text{Si}$, considered to be a proxy for silicic acid consumption in the water column. We expect to examine such relationships on a global scale based on measurements in Mesozoic open ocean radiolarites. $\delta^{30}\text{Si}$ should show similar but a little smoother trends than $\delta^{13}\text{C}$ due to a longer residence time in sea water. Based on the result of Wu et al. (1997), radiolarians seem to have a lower fractionation factor than diatoms ($\Delta^{30}\text{Si}_{\text{water-diatoms}} = -1.1\text{‰}$) but more work as to be done. In the modern ocean, De la Rocha et al. (1998) and Fripiat et al. (2011) demonstrated that $\delta^{30}\text{Si}$ is influenced by currents. This is of particular interest in the search for understanding paleocurrents and oceanic changes during the Pangea break-up.

There are several challenges in this project. 1) Radiolarians produce their skeleton as biogenic opal that is recrystallized during diageneosis as microcrystalline chalcedony. We do not know is the silicon isotope signal is preserved in this process. 2) The radiolarian silicon isotope signal, present in chalcedony, needs to be distinguished from that of interstitial clays and oxides. However, many new insights will be obtained on the long-term silicon cycle and on the radiolarite dispersal trough time coupled with the Pangea break-up.

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P 7.4
The Mayaguana Bank (SE Bahamas) from the Late Oligocene to the present: A delicate equilibrium between tectonics and sedimentation

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Four drill cores from the north and south coasts of Mayaguana (SE Bahamas), combined with a literature review on the surface geology of the island (Kindler et al., 2011; Godefroid, 2012), reveal that its stratigraphic units are distributed asymmetrically. This implies an initial ramp morphology of the bank with a northward dip in the Late Oligocene/Early Miocene, followed by a southward tilt of the platform during the Pleistocene.

The Mayaguana Bank is a small, rectangular carbonate platform (57x13 km) located in the south-eastern portion of the Bahamas archipelago in close proximity to the convergent margins of the North American and Caribbean plates (Dolan et al., 1998). A low relief island (maximum +30 m) covers most of the bank area (Pierson, 1982). An industrial drilling campaign, conducted in 2011, led to the recovery of several cores from the south-western part and from the north-western coast of Mayaguana. This paper presents the preliminary results obtained from four cores along a south-north transect in relation with outcrop data from the northern shoreline (Godefroid, 2012).

Petrographic, micropaleontological and geochemical (²⁶⁷⁸Sr/⁶⁸Sr) analyses enabled us to define four lithostratigraphic units briefly described below (from the top to the bottom):

- Poorly lithified reefal to peri-reefal limestones of Pleistocene age. This unit is characterized by the presence of corals of the genera Acropora, Montastrea and Diploria;
- Partly dolomitized, well-lithified reefal limestones of Middle Pliocene age. This unit contains corals of the genus Styllophora and encrusting algae;
- Microsucrosic, laminated dolostones yielding a Messinian age, essentially based on Sr-isotope data;
- Well-lithified and locally dolomitized bioclastic limestones (grainstone to rudstone). This unit is rich in hyaline and/or porcelaneous benthic foraminifers (Miogypsinae, Praehapydionina delicata) with an age ranging from the Chattian to the Burdigalian (Eames et al., 1968; Godefroid, 2012).

These units form a 12 m-thick exposure along the north coast representing a condensed succession from the Early Miocene to the Middle Pleistocene (Godefroid, 2012). The Plio-Pleistocene boundary is exposed at up to +4 m above sea level (Godefroid, 2012). In the south, the Pliocene reefal carbonates and the Messinian dolostones are missing, leaving a discontinuity surface between the Pleistocene and the Lower Miocene strata found between -8.75 and -17 m below the present-day sea level.

The asymmetrical distribution of these stratigraphic units suggests a northward-dipping ramp configuration of the Mayaguana Platform, at least in the Middle Miocene. The positive accommodation in the north resulted in the deposition of the Messinian dolostones and of the Pliocene reefal carbonates, while in the south karstification and erosion of Upper Oligocene/Lower Miocene bioclastic limestones took place. The bank was likely tilted towards the south in the Middle Pleistocene, exposing the Lower Miocene to Lower Pleistocene succession on the north coast of Mayaguana.

The Mayaguana Platform represents a unique example of the behavior of a carbonate bank in the close proximity of an active tectonic margin.

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Middle Pleistocene ostracod assemblages from Lake Trasimeno, Perugia, (Italy)

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Lake Trasimeno is a meso-eutrophic, shallow (<6 m deep) and large lake (~120km2) located in central Italy, at 259 m above sea level. As it is common in shallow-water ecosystems, climate change plays a fundamental role in the Lake Trasimeno evolution and its history is signed by a strong dependence of the water balance on meteorological conditions (Dragoni, 2004; Ludovisi & Gaino, 2010). Recent geophysical data reveals that the Lake Trasimeno evolution was accompanied by a constant subsidence rate driven by normal faults. The extensional tectonic regime does not show substantial changes since the lake formation and it is probably responsible for its long-term preservation against sediment infill (Gasperini et al., 2010).

A 175 m long sedimentary core was retrieved by the Geological Survey of the Umbria Region along the present southern shore of the lake (north of Panicarola town). A multidisciplinary study of the core (i.e. palynology, paleontology, geochemical analyses, magnetic susceptibility, paleomagnetism) is now in progress and a preliminary age model based on pollen data suggests that the record may be as old as Middle Pleistocene. The investigation of the first 30 meters of the Panicarola core revealed its great potential as archive of palaeoclimatic/palaeoenvironmental changes in the region.

As widely recognized, ostracod assemblages in lacustrine sediments represent a main tool for palaeoenvironmental reconstructions (von Grafensteine, 2002; Decrouy et al., 2012). The absence or presence of different species, their possible polymorphism, and the geochemical composition of the valves are strongly controlled by the prevailing environmental parameters (i.e. water and/or air temperature, oxygen content, isotopic composition of the host waters, water quality, water chemistry, salinity) during their moulds (Horne et al., 2012; Viehberg & Mesquita-Joanes, 2012).

A first inspection of the Panicarola core reveals a constant presence of ostracod assemblages along the uppermost part (from 30 m to 5 m). On the whole, 13 species referable to 10 genera were collected (Ilyocypris gibba, Candona neglecta, Candona angulata, Cypridopsis vidua, Heterocypris salina, Limnocythere sp1, Limnocythere stationis, Darwinula stevensoni, Cyprideis sp., Leptocythere spp., Fabaeofaeciscandona fabaeformis, Cyprideis ovum). Some changes in the frequency and composition of the ostracod assemblages have been detected along the sediment core, allowing to recognize different environmental variations. In particular, two intervals are significative for the palaeoenvironmental reconstruction of the sedimentary successions: 1) the interval from 25.60 m to 23.50 m is characterized by a rich ostracod fauna (dominated by Cyprideis sp., Candona angulata and Leptocythere spp.). This assemblages is possibly indicating an increase in salinity; 2) the interval from 21.05 m to 17.60 m contains Ilyocypris gibba, Candona neglecta, Cypridopsis vidua, Heterocypris salina, Limnocythere sp1, Limnocythere stationis and Darwinula stevensoni. Limnocythere stationis is a central European species, until now only signaled in Italy at the Panicarola core (this study) and in the Holocene of Sicily (Curry et al., 2013) probably suggesting a period of cool waters.

Further ostracod identifications as well as geochemical analyses on their valves will provide a more detailed reconstruction of the timing and magnitude of palaeoclimate changes in the Lake Trasimeno area

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P 7.6

The “Microbunodon Event”, or the European evolution of ungulates during the Oligocene–Miocene transition

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The biostratigraphy and diversity patterns of terrestrial, hoofed mammals help to understand the transition between the Palaeogene and the Neogene in Western Europe. Three phases are highlighted: 1) the beginning of the Arvernian (Late Oligocene, MP25-27) was characterised by a “stable” faunal composition including the last occurrences of taxa inherited from the Grande Coupure and of newly emerged ones; 2) the latest Arvernian (Late Oligocene, MP28-30) and the Agenian (Early Miocene, MN1-2) saw gradual immigrations leading to progressive replacement of the Arvernian, hoofed mammals towards the establishment of the “classical” Agenian fauna; 3) the beginning of the Orleanian (Early Miocene, MN3-4) coincided with the African-Eurasian faunal interchanges of the Proboscidean Datum Events and led to complete renewal of the Agenian taxa and total disappearance of the last Oligocene survivors. Faunal balances, poly-cohorts and particularly cluster analyses emphasise these three periods and define a temporally well-framed Oligocene-Miocene transition between MP28 and MN2. This transition started in MP28 with a major immigration event, linked to the arrival in Europe of new ungulate taxa, notably a stem group of “Eupecora” and the small anthracothere Microbunodon. Due to its high significance in the reorganisation of European ungulate communities, we propose to name it the Microbunodon Event. This first step was followed by a phase of extinctions (MP29-30) and later by a phase of regional speciation and diversification (MN1-2). The Oligocene-Miocene faunal transition ended right before the two-phased turnover linked to the Proboscidean Datum Events (MN3-4). Locomotion types of rhinocerotids and ruminants provide new data on the evolution of environments during the Oligocene-Miocene transition and help understand the factors controlling these different phases. Indeed, it appears that the faunal turnovers were primarily directed by migrations, whereas the Agenian transitional phase mainly witnessed speciations.
Paleoenvironmental reconstruction based on foraminiferal assemblages and the sedimentary phosphorus record in the Oligocene of Romania (Transylvanian Basin)

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Oligocene deposits from Romania outcrop in the Vima Formation along the northwestern border of the Transylvanian Basin. Three outcrops in the Fântânele section were sampled for this study. The lithology is characterized by alternations of clay, silty-clay, sandy-clay and sandstone. More than one hundred samples are analyzed for their benthic and planktonic foraminiferal content.

The presence of the species Chiloguembelina cubensis and Paragloborotalia opima places the assemblages of the first outcrop in the P21a Zone (04 Zone, Wade et al., 2011), while the younger sediments in the last two outcrops were probably deposited in the “Late Oligocene”. Other planktonic foraminifera such as Globigerina lentiana, Globigerina praebulboides, Globigerinella obesa are also present together with small sized tenuitellids e.g., Tenuitella clemenciae, Tenuitella munda, Tenuitella angustiumbilicata.

Paleoecological interpretations of the depositional environment are based on benthic calcareous and agglutinated forms. Benthic specimens are divided into three groups: epifaunal, shallow infaunal and deep infaunal. Epifaunal species such as Heterolepa praecincta, Cibicidoides ungerianus filicosta suggest higher oxygenation in the bottom water, while infaunal species indicate lower oxygen content (Bulimina schischkinskayae, Bolivina dilatata dilatata, Fursenkoina spp.). The assemblages are sometimes dominated by agglutinated foraminifera represented by Haplophragmoides carinatus, Recurvoides spp., Karreriella spp. and tubular forms (Rhabdammina spp., Bathysiphon spp.).

Phosphorus is extracted from the bulk sediment samples using the five-step SEDEX method (Ruttenberg et al., 2009). The distinguished sedimentary phosphorus phases (Loosely-bound P, Iron-bound P, Authigenic P, Detrital P and Organic-bound P) together with the distribution of the foraminiferal assemblages give a better view of the paleoenvironmental conditions during the Oligocene.

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