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Karl-Franzens-Universität Graz, Band 21

2nd International Congress on Stratigraphy

STRATI 2015

19. - 23. July 2015, Graz, Austria

Abstracts

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Editorial

The 1st International Congress on Stratigraphy – STRATI 2013 – was held in Lisbon in July 2013 under the auspices of the International Commission on Stratigraphy (ICS). It was a follow up of a conference organized in 2010 by the French Committee on Stratigraphy in Paris and was supposed to internationalize the STRATI conferences and to demonstrate the great interest in and importance of stratigraphy. The Lisbon meeting was a great success, thanks to the local organizing committee, and thus the chair of ICS, Stanley Finney, urged to continue this type of conference in 2 years' time in order not lose the momentum that had been generated in Lisbon.

The Institute of Earth Sciences at the University of Graz, Austria, applied to organize the congress in 2015 in Graz and was elected. We decided not to launch a motto but to open the congress to all topics in stratigraphy. This led to submission of 31 scientific sessions with about 60 conveners covering Earth's and other planets' history from the Precambrian to the Quaternary and reflecting most methods applied in classical and modern stratigraphy. The broad field of topics is mirrored in the program which includes more than 260 oral and about 170 poster presentations. Besides these scientific presentations the congress also provides space and time for field trips and also for meetings of the ICS board and the subcommissions demonstrating its quasi-official position within ICS.

We invited 5 keynote presentations, dealing with various aspects of stratigraphy: (a) the hot topic of the 'Anthropocene' is referred by Stanley Finney – the chair of ICS, (b) Ken Miller integrates climate and geodynamics with stratigraphy, (c) Marie-Pierre Aubry provides a review of the classical methods, chrono- and biostratigraphy, in the Cenozoic, (d) Helmut Weissert deals with carbon isotope geochemistry and its stratigraphic-paleoceanographic interrelationships, and (e) Frederik Hilgen will provide a future prospect on the Astronomic Time Scale. Most of these approaches are already integrated in many of the presentations attesting the importance of these themes and methods. In addition, we want to particularly point at Session 01 "The contribution of fossils to Chronostratigraphy, 150 years after Albert Oppel" which is not a session dealing with historical aspects but clearly testifies that basic problems in stratigraphy are still unsolved!

The organizers want to express their sincere thanks to the session conveners, who constitute, in fact, the scientific committee! The effort of all these excellent scientists brought together the world's leading stratigraphers and gave adequate importance to the congress.

Werner E. Piller
for the organizing committee
Graz, 15th July 2015

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Correlation of the Purbeck Beds and their sequence-stratigraphical significance, Weald Basin, United Kingdom

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The Late Jurassic Purbeck anhydrite forms an excellent regional top seal in the Weald basin, United Kingdom. A study in Brightling Mine provides insight into the three-dimensional architecture and lateral continuity of evaporite-carbonate cycles within the basal Purbeck Beds. This is emplaced within a regional context with a further detailed correlation throughout the basin by integrating sedimentological and stratigraphical data from cores and wireline logs. We characterized evaporites and carbonates and undertook laboratory analysis (e.g., X-ray diffraction, petrographic microscopy, and $\delta^{13}C$ and $\delta^{18}O$ isotopes) of both 'subcrop' and core samples. Brightling Mine revealed laterally extensive evaporite-carbonate sabkha cycles. The dynamic process of evaporite deposition led to subtle stratigraphic heterogeneities and changes in bed thicknesses, but largely continuous lateral bedding at the <1 km scale. Variation in stratal geometries is interpreted as paleotopography resulting from dissolution, eolian processes, and coastal erosion. The paleo-topography for key stratal surfaces in the deposits has been reconstructed for the Weald basin. This mixed carbonate-clastic and evaporite system is characterized by a basin that conforms to an approximate bull's eye pattern with marginal anhydrite sabkha deposits with interbedded clastics and carbonates surrounding a basinal accumulation of halite and sulphates interbedded with deeper water clastics and carbonates. The transition between the marine strata of the Portland Sandstone into limestone has been interpreted as a sequence boundary resulting from a new rift pulse occurring in the latest Jurassic. Subsequently a thin layer of anhydrite, acting as a very efficient seal, was deposited basinwide with extensional faults controlling thickness variations. This work provides insight into process-based sedimentology of evaporites and their depositional patterns and diagenesis which can serve as an analogue to other significant formations, such as the Hith Formation in the Middle East. This has important implications for EOR or CCS operations as variability in facies and lateral continuity could alter caprock quality during carbon capture and storage operations, thereby reducing CO_2 storage efficiency and seal integrity.

We gratefully acknowledge funding from the Qatar Carbonates and Carbon Storage Research Centre (QCCSRC), provided jointly by Qatar Petroleum, Shell, and Qatar Science & Technology Park.

Lake Lisan Stromatolites along the eastern coast of the Dead Sea, Jordan: implications for paleoclimatic changes of the Levant during the Late Pleistocene

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In situ stromatolites were observed on most of the shoreline terraces of Lake Lisan- the glacial precursor of the Dead Sea- at −350 to −137 m, reflecting a shallow water environment and emphasizing that these terraces are recessional.
These stromatolites are layered, mostly calcareous organic build-ups or bioherms that form in highly CaCO3-supersaturated water by permineralization of algal, mostly cyanobacterial mats (e.g., Kempe and Kazmierczak, 2007). Some of these stromatolites form large, laminated, massive, head-like blocks; others are finely grey laminated crusts cementing and overgrowing beach gravels and stabilizing piles of rocks in the forms of small islands and cones (Abu Ghazleh and Kempe, 2009). On the high level terraces, red stromatolite crusts have been observed, overgrowing the grey stromatolite. Thin sections investigation of stromatolite samples taken from Lake Lisan terraces at -350 to -137 m show a typical lamination texture of stromatolites. This emphasises that all of these stromatolites were derived from the same lake and that the entire area up to -137 m was inundated by Lake Lisan.
Stromatolites at -137 to -160 m were dated using U/Th and analysed for their stable isotopes, mineral composition (XRD) and Mg/Ca ratios. This allowed reconstructing the lake level change during MIS 2 at a high resolution. In spite of the lake high stands during this period, the lake level dropped subsequently from -137 m to - 200 m between 32 and 22 ka BP, implying cold and dry climate of the Levant during MIS 2. The lake receded from its high stand of -137 m at 32 ka BP to -148 m at ~30 ka BP associated with H3. The lake level continued to drop to -152 m at ~27 ka BP and to -154 m at ~23 ka BP. Then, the lake level dropped sharply to -200 m at ~22.5 ka BP, consistent with the dry cold climate of H2. During the LGM, Lake Lisan recovered again to a high stand of -160 m at ~ 19 ka BP.
The Mg/Ca ratios and the mineral composition of the dated stromatolite samples in addition to the covariance trend of their isotopic values suggest that they were deposited primarily from the lake water and that diagenetic alteration is very limited. These characteristics, in addition to the good stratigraphic correlation between the U/Th dates and the shoreline terraces provide evidence as to the stromatolite dating accuracy.

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Timing, tempo and paleoenvironmental influence of Deccan volcanism, relation to the end-Cretaceous mass extinction

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The Chicxulub asteroid impact (Mexico) and the eruption of the massive Deccan volcanic province (India) are two proposed causes of the end-Cretaceous mass extinction, which includes the demise of nonavian dinosaurs. Despite widespread acceptance of the impact hypothesis, the lack of a high-resolution eruption timeline for the Deccan basalts has prevented full assessment of their relationship to the mass extinction. Chenet et al (2008, 2009) showed that Deccan Traps erupted in three main phases with 6% total Deccan volume in phase-1 (base C30n), 80% in phase-2 (C29r) and 14% in phase-3 (C29n). We have applied high-precision U-Pb CA-ID-TIMS geochronology to rocks from within the Deccan Traps that constrain the onset and termination of the main phase of volcanism. Because of the rarity of zircon in basalt, dated material includes both in situ zircon-bearing segregation veins within basalt flows and also volcanic ash beds found between individual basalt flows. The latter likely derive from distant, higher-Si explosive volcanic vents during periods of basaltic quiescence. We show that the duration of the main phase of the Deccan, which included >1.1 million cubic km of basalt, erupted in 750 kyr and began 250 kyr prior to recently published dates (Renne et al., 2013) for the Cretaceous-Paleogene mass extinction event. When combined with published paleomagnetic data from the Deccan traps (Chenet et al, 2008, 2009), our data place the main phase of Deccan eruptions precisely within the geomagnetic polarity timescale and thus permit correlation of their onset with other stratigraphic records that lack geochronology. Our ages improve on the precision of existing geochronology for the Deccan Traps by 1-2 orders of magnitude and are a crucial starting point for more quantitative estimates of volcanic gas emissions that could be implicated in ecosystem decline prior to the Chicxulub impact and mass extinction event, as well as the potential affect on post-extinction biologic recovery.

Closer to the eruption center, the lava flows are generally separated by red weathered horizons known as red boles, marking a quiescent period between two basalt flows. Red boles consist mainly of red silty clays characterized by concentrations of immobile elements such as Al and Fe^{3+} ions, which provide indirect evidence of a primitive form of paleo-laterite that probably developed during the short periods of weathering between eruptions. There are at least 15 thick red bole layers in C29r below the KT boundary, and all were deposited in phase-2 volcanic eruptions that occurred over a time span of about 250 ky. These short duration exposures are reflected in the mineralogical and geochemical data that indicate rapid weathering (high CIA) but arid conditions. Such accelerated weathering can be therefore explained by acid rain. These observations indicate that Deccan volcanism played a key role in increasing atmospheric CO_2 and SO_2 levels that resulted in global warming and acidified oceans, thus increasing biotic stress that predisposed faunas to eventual extinction at the KPg.

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The low-middle latitude response of calcareous nannoplankton to the MECO: an oceanic perspective

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The Middle Eocene Climatic Optimum (MECO) is a global, relatively long-lived (ca. 500kyr) warming event at ca 40 Ma that temporarily interrupted the long-term cooling through the Eocene (Bohaty and Zachos, 2003, Bohaty et al., 2009). Here we present preliminary data on the response of calcareous nannofossils to the MECO at Integrated Ocean Drilling Program (IODP) Site U1410 (*SE Newfoundland Ridge*, NW Atlantic Ocean; 41°20'N, 49°10'W; paleo-water depth: ~2600m) and Ocean Drilling Program (ODP) Site 1209 (*Shatsky Rise*, Pacific Ocean; 32°43'N, 158°38'E, paleo-water depth: ~2000m). The response of calcareous phytoplankton to transient warming is poorly known (e.g.; Toffanin et al., 2011), and new data spanning a range of latitudes and oceanographic settings are required to assess the magnitude and spatial distribution of biotic changes recorded in calcareous nannofossils during the MECO. To this aim, we have performed quantitative highly resolved calcareous nannofossil assemblage counts, which both improve the bio-magnetochronologic framework available for this time interval (~39 to 41 Ma) and provide paleoceanographic information. The first appearance (Base = B) and extinction (Top = T) of several species are recorded in conjunction with the MECO, including B *Dictyococcites bisectus*, B *Sphenolithus obtusus*, T *Sphenolithus furcatolithoides* and T *Sphenolithus spiniger*, as well as significant changes in the relative abundance of many taxa. Though our results are consistent with data from other low-to-mid latitudes sites, some biohorizons occurring across the MECO are diachronous relative to high-latitude settings (Villa et al., 2008), likely due strong latitudinal paleotemperature gradients that were already well developed at that time. A further effort to integrate changes in calcareous nannofossil assemblages with carbon and oxygen stable isotope profiles at these sites will help to unravel the mode and tempo calcareous phytoplankton response across the MECO event.

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The role of calcareous nannofossils during the last ~220 million years of Earth history

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Since they were first described and recognized as fossil algal remains (Wallich, 1861; Sorby, 1861), calcareous nannoplankton and nannofossils have been considered as a scientific curiosity for many years. Their importance became progressively evident to the geological community starting from the 50ies, following a landmark publication that evidenced for the first time their application in biostratigraphy and rock dating (Bramlette and Riedel, 1954). Subsequently, availability of deep-sea sediments and cores, provided by research drilling, facilitated the studies on nannoplankton and nannofossils and, in turn, expanded their importance as stratigraphic and chronologic tool. Moreover, it became evident that they played also an important role in the bio-geosphere history and therefore they could be used to reconstruct paleoenvironmental /oceanographic conditions in the geological past. The geologic record shows that appearance of calcareous nannoplankton and nannofossils in the Triassic represents an important step in the evolution of marine ecosystem and a significant change in pelagic sedimentation and biogenic carbonate production. The appearance in the Triassic was a breakthrough in the ocean realm, specifically for the marine carbonate system and the global carbon cycle. Approximately 220 My ago, calcareous nannoplankton developed and evolved while interacting with changes in climate, ocean structure and chemistry as well as in the geosphere. Increases in biodiversity and rates of evolution occurred through the Jurassic and Cretaceous and continued in the Cenozoic, and the (often) fast evolutionary changes resulted in several first and last appearance datums that are the basis for detailed biozonations, successfully applied in different intervals of geological time.

Here we illustrate the quality and pivotal role of calcareous nannofossils as stratigraphic and chronologic tools, and highlight their importance for paleoenvironmental studies. We also report on the major recent advances gathered as regards biostratigraphy in specific time intervals.

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Seismic-stratigraphic interpretation of Paleogene deposits in the Jan Mayen area

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The Jan Mayen is a micro continent in the Arctic Ocean. The evolution of the continent remains understudied due to sparse availability of data. However, recent exploration interest in the area will require adequate information and re-interpretation of existing data, which is necessary to assess the hydrocarbon potential of the margin. This work uses 2D seismic reflection profiles from the NPD database to reconstruct the paleogeography of Eastern Jan Mayen during the Paleocene to Oligocene.

The approach used includes identification and analysis of major megasequences, seismic facies, reflection terminations, and geometries. Five seismic surfaces were interpreted as four megasequences and the seabed. The Jan Mayen is characterized by two rifting events of Cretaceous to Paleocene and Eocene to Oligocene ages, respectively. This is in addition to two episodes of volcanisms which are distinctive structural and time markers separating the western area of the Jan Mayen from the eastern part.

Sedimentation in Paleocene to Oligocene times is reflected as complex interplay of sedimentation and faulting resulting from the deposition of marine successions, transgressive and regressive sequences, extensional faulting, and late stage slumping. Our work shows that Paleocene-Oligocene strata were sourced mainly from Eastern Greenland.

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New insights into the environmental precursors of the Paleocene Eocene Thermal Maximum based on benthic foraminifera and geochemical proxies from Zumaya section (Basque-Cantabric basin)

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The greenhouse world of the Paleogene underwent significant disruption during the Paleocene-Eocene Thermal Maximum (PETM), a period of exceptional global warming that is marked by a prominent negative carbon isotope excursion (CIE). This global perturbation of the carbon cycle is interpreted in terms of a rapid input of ^{13}C-depleted carbon into the ocean-atmosphere system. The onset of the PETM was characterized by rapid changes in terrestrial and marine biota, including the largest extinction of deep-sea benthic foraminifera recorded during the Cenozoic. The study of the benthic foraminiferal extinction event (BEE) is particularly interesting because deep-sea benthic foraminifera had survived without significant extinction through global environmental crises such as that related to the asteroid impact at the end of the Cretaceous. Although the biotic response to the PETM has been studied intensively, the exact sequence of events (carbon injection, warming and biotic changes) and the causes of the benthic extinction remain uncertain.
The combined study of benthic foraminifera and geochemical proxies from the middle to lower bathyal Zumaya section (Basque-Cantabric basin) allowed us to assess the response of the benthic ecosystem to such aspects of environmental change as carbon addition (e.g., ocean acidification, elevated pCO2), rising temperatures or changes in nutrient supply and redox conditions.
The inferred sequence of events shows prominent environmental perturbations at Zumaya prior to the onset of the carbon isotope excursion, which marks the Paleocene/Eocene boundary. Previous studies at Zumaya suggested that an initial perturbation phase in surface waters preceded the CIE and the main warming event of the PETM, but the low sampling resolution precluded identification of this initial perturbation in the deep sea (Alegret et al., 2009). The results of our new, higher resolution study across the PETM (in prep.) show that environmental instability during the last few thousand years of the Paleocene did not only affect the water column, but also the benthic ecosystem.

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Towards a regional eco-stratigraphic scale of the lowermost Danian based on benthic foraminifera from the Basque-Cantabric basin

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Many marine sections containing the Cretaceous-Paleogene (K-Pg) transition have been traditionally considered to be complete because of the presence of all planktic biozones, and paleoenvironmental reconstructions across the impact event have been made assuming this completeness of the stratigraphic record. For example, the K-Pg transition at Bidart (France) was considered as one of the most complete K/Pg boundary sections in southwestern Europe (Haslett, 1994). Various authors identified the lowermost Danian calcareous nannofossil and planktic foraminiferal biozones at Bidart (e.g., Haslett, 1994; Gorostidi and Lamolda, 1995) thus supporting the completeness of the record, but a lowermost Danian hiatus was recently inferred from a combined ichnological and benthic foraminiferal study (Alegret et al., 2015).

The latter study not only pointed out that part of the K/Pg boundary clay layer is missing, but also that previous reconstructions of the sequence of events after the K/Pg impact at Bidart are not complete. In this section, benthic foraminifera found inside burrows that were made during a post-K/Pg boundary colonization phase which penetrated Cretaceous sediments, indicate a short period of high export productivity to the seafloor immediately after the K/Pg impact. Subsequently, this very thin interval was burrowed and Danian foraminiferal shells infiltrated into the Cretaceous sediments. An erosion event along the slope in the Basque-Cantabric Basin might explain the complete disappearance of this interval not only at Bidart, but also in nearby sections (Alegret et al., 2015). These results pose questions regarding the completeness of other K/Pg sections that have been traditionally assumed to be complete.

In addition to combined ichnological and micropaleontological studies, which may allow us to infer intervals that are no longer present in the stratigraphic record, the study of benthic foraminifera as eco-stratigraphic markers is a useful tool to assess the completeness of the K/Pg geological record. The sequence of seafloor colonization by benthic foraminiferal species after the K/Pg impact event may allow us to define ecozones at a higher resolution than the lowermost Danian calcareous nannofossil and planktic foraminiferal biozones. For example, the sequence of benthic foraminiferal abundance peaks across the lowermost Danian in several sections from the Basque-Cantabric basin reveals that the lower part of the K/Pg clay layer is missing at the Sopelana beach section (Basque Country), while the lowermost Danian planktic foraminiferal biozone (P0) has been recognized in the clay layer at Sopelana (e.g., Kuhnt and Kaminski, 1993).

In order to refine the resolution of the present biostratigraphic subdivisions of the lowermost Danian, we propose the definition of ecozones based on benthic foraminiferal quantitative data from the Basque-Cantabric Basin.

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Conodonts and the position of the Moscovian/Kasimovian boundary in the South Urals

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The definition and global correlation of the Moscovian/Kasimovian boundary remain uncertain. Because of difficulties in recognizing well identifiable and globally comparable conodont taxa at the base of the Kasimovian Stage in the Moscow Basin, the study of the deep-water facies sections of the South Urals are of great significance (Chuvashov et al. 2001 etc.; Syngatulina, 2012). We studied conodonts from the boundary intervals of two sections. The first is Dalnyi Tulkas section 1, near the town of Krasnousolsk (Bashkiria). Limestones of the Zilim Fm. (about 18 m) and lowermost shales and cherts of the Kurkin Fm. (less than 1 m) are visible in this section. The conodont assemblage consists mainly of *Idiognathodus, Swadelina* and *Gondolella.* Five assemblages were recognized in this section. The lowermost assemblage is *Idiognathodus* sp. A (interval 0–9.7 m). The assemblage with *Idiognathodus podolskensis – I. obliquus* (9.7–14.6 m) is characteristic of the interval with the most abundant macrofossils and fusulinids. This assemblage is typical for the middle Podolskian-lower Myachkovian of the Moscow Basin (Makhlina et al. 2001). The assemblage with *Idiognathodus* sp. B (14.6–16.9 m) contains most of the species of the *podolskensis–I. obliquus* assemblage. It is possible that this interval is coeval with the Myachkovian of the Moscow Basin, because *Idiognathodus* sp. B morphotype occurs there. The uppermost part of the Zilim Fm. (16.9–18.9 m) contains "*Streptognathodus" subexcelsus* Alekseev et Goreva and *Gondolella magna* Stauffer et Plammer. This interval is of early Krevyakinian (Suvorovo) age. *Swadelina makhlinae* Alekseev et Goreva was found at a level of 18.9 m. This species is typical for the *S. makhlinae* Zone (Voskresensk Fm., Moscow Basin). This conodont data supports the conclusion that the Dalnyi Tulkas section embraces the Moscovian-Kasimovian boundary interval, which is here represented in deep-water facies showing dominance of gondollelids. The topmost samples from silicified limestones and cherts could not be disintegrated or were empty. The second, nearby section is Dalnyi Tulkas 2. The lower part of the section (Zilim Fm, interval 0-2.8 m) belongs to the Upper Moscovian and contains *Idiognathodus podolskensis, Idiognathodus* sp. B and *Gondolella laevis* Kossenko. The uppermost part of the Zilim Fm. (2.8-4.6 m) contains "*Streptognathodus" subexcelsus*, *Gondolella magna* and transitional specimens to *Swadelina makhlinae.* The samples from the interval 4.6-5.8 m contain "*S". subexcelsus*, *Gondolella* and *S. makhlinae.* The shales (5.8-6.2 m) contain *I. turbatus* Rosscoe et Barrick, a potential biostratigraphic marker of the base of the Kasimovian (Villa and Task Group, 2008). This species is characteristic of the *I. sagittalis* Zone in the Moscow Basin (Khamovnikian Substage, Neverovo Fm.). The wide distribution of *I. turbatus* shows its considerable potential for long distance correlation, and this species can be selected as a marker for the lower boundary of the Kasimovian Stage.

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Distribution of Diagenetic Alterations in Relationship to Depositional Facies and Sequence Stratigraphy of Wave- and Tide-Dominated Siliciclastic Shoreline Complex: Upper Cretaceous Chimney Rock Sandstones, Wyoming and Utah, USA

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This study constrains the distribution of diagenetic alterations and their impact on reservoir-quality evolution in relation to depositional environments (wave-dominated delta and tide and mixed-energy estuaries) and sequence stratigraphy (systems tracts and key sequence stratigraphic surfaces) of Campanian sandstones from Wyoming-Utah, USA. The diagenetic alterations include cementation by calcite, dolomite, pyrite, micro-quartz, and iron oxides, dissolution of carbonate cement and detrital dolomite, dissolution and kaolinitization of framework silicates, mechanical compaction of argillaceous grains, and infiltration of grain coating clays.

Calcite, which is the dominant cement, is most abundant in the shoreface sandstones of the HST and FRST. Oxygen and strontium isotope values ($\delta^{18}O$ = -15.9‰ to -3.7‰ and $^{87}Sr/^{86}Sr$ = 0.7095-0.7112) suggest that calcite cements precipitated from dominantly meteoric waters. Diagenetic dolomite is more abundant in shoreface HST than in the FRST, LST and TST sandstones and is attributed to the precipitation of dolomite under marine-meteoric mixing conditions, which is achieved through progradation and concomitant meteoric water incursion to the shoreface sandstones during highstand times. Kaolinite is most abundant in distributary channels of HST and FRST and in upper shoreface sandstones below the SB that is attributed to the flux of meteoric water in the paralic sediments during relative sea level fall and in outer-estuarine tidal bars below coal layers (TST) aided by the generation of organic acids and CO_2 during percolation of meteoric waters in the peat deposits. Iron oxide cement occurs in all systems tracts, but particularly in TST and HST. Pyrite occurs below coal layers and SB. Infiltration of grain coating clays is restricted to the TST marginal tidal-flat and marsh sandstones. Micro-quartz occurs in trace amounts in all systems tracts. The findings of this work can help to enhance the prediction of the distribution of diagenetic alterations and their impact on reservoir properties of sandstones.

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Shifting Eruptive Style in Monogenetic Basaltic Volcanoes: Example of Timahdite Volcano, Middle-Atlas, Morocco

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Timahdite volcano is a Quaternary monogenetic basaltic volcano, located in the volcanic province of the unfolded Middle Atlas in Morocco. The eruptive sequence exposed in the cone is almost 100m-thick. The deposits exhibit complex eruption dynamics ranging from an initial phreatomagmatic style that was gradually replaced by Strombolian with lava effusion. The initial phreatomagmatic phase is represented by basal explosion breccias and cross-bedded base-surge deposits, that grade into fine to medium bedded tuff and lapilli tuff that is locally disturbed by the ballistic impact sags. Large ballistic bombs commonly show cauliflower texture. The tuff ring around the crater is about 50 m high. In the tuff breccias, fragments commonly show peperite-like textures indicating that country rock and magma mixed during ascent the vent. Laminated lithic rich tuffs are made up of limestone and basaltic blocks wrapped in an ashy matrix containing carbonate elements. Certain of pyroclasts contain amphibole phenocrysts, reflecting water-rich magmas. With the depletion of the water supply through the initial phreatomagmatic stage, the eruptive dynamics become more magmatic gas driven with reduced violence developing scoriaceous deposits over the basal phreatomagmatic tuffs and lapilli tuffs. Near the end of this activity due to fluctuation of eruption flux erupted spatter that agglutinated formed some small clastogenic lava flows on the flank of the volcano near the crater rim. The sequence changes from phreatomagmatic to dry eruption progressively, recording a slow depletion of water input. This may have occurred by the progressive blocking of the river through which the volcano erupted as the cone grew.

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The redefinition of the Devonian-Carboniferous Boundary: recent developments and introduction to the workshop

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Since in the GSSP section at La Serre, southern France, the marker fossil for the base of the Carboniferous, the conodont *Siphonodella sulcata*, was found below the boundary just above a facies change, the definition of the base of the Carboniferous has been back on the agendas of the Devonian and Carboniferous subcommissions. A joined SDS/SCCS Task group was established in 2009 to redefine the base of the Carboniferous and thus to regain stratigraphical stability in this critical interval of Earth history.

Task group members have been active in various aspects related to the boundary definition and a wealth of new data has become available. Characteristic for many studies are multi-disciplinary approaches, which combine palaeontological, sedimentological, geochemical and petrophysical methods and data.

The task group is still gathering data and no decision has so far been made on a suitable level, an index taxon or a section. There are still many options to check. The task group is committed to stratigraphical stability, but also to a user-friendly definition of the base of the Carboniferous. In this respect the extinction events in the global Hangenberg Crises, which in the current definition predates the boundary, have been among many others one focus of our work. In any case, the recent works demonstrated that the GSSP section and the auxiliary stratotype sections in China and Germany are most likely not suitable for the definition of a new boundary.

To stimulate discussions and to give as many interests persons as possible the opportunity to participate in these discussions, meetings with the same objectives are organized at the 2nd International Congress on Stratigraphy, the 17th Congress on the Carboniferous and Permian in Kazan in August, and .the IGCP 596-SDS meeting at Brussels in September. These discussions are open in all directions and they require the input from all interested researchers.

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On the age of the Baruunhuurai Formation in south-west Mongolia

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The Baruunhuurai Terrane, which is located in south-west Mongolia, is poorly studied. The Devonian deposits are characterized by volcaniclastic rocks with intercalated fossil-rich marl to limestone lenses. In the Ulaanus subterrane of the Baruunhuurai Terrane all three Devonian series are distinguished: lower Devonian Nariinhar, middle-upper Devonian Baruunhuurai, middle Devonian Hurendush and upper Devonian Samnuuruul formations.

The Baruunhuurai Formation is widely distributed from boundary with China to south-east and separated by a tectonic boundary from the other rocks. Its key section is located in southern side of Baarangiin Har nuruu, and consists of volcanic-sedimentary rocks such as andesite, dacite, tuff, tuffaceous siliciclastics, jasper type rocks, conglomerate layer with quartzite boulders (40-100m), upward dacite, andesitic tuff, silicified limestone beds, shale, siliceous shale, siltstone and sandstone (1000-1200m).

Based on the fossils obtained and the preliminary lithofacies analysis, the Baruunhuurai Formation in the western part was deposited in a shallow marine nearshore setting with regionally dispersed limestone lenses produced by locally restricted fossil communities and intermittent volcanically derived sediment (Kido et al., 2013). Fossils are represented by rugose and tabulate corals, trilobites, bivalves, brachiopods, bryozoans, crinoids and fish dermal plates.

In Ruzhenzhev (2001) brachiopods such as *Stropheodonta* cf. *interstrialis*, *S. asella*, *Cariniferella tioga*, *Productella jubaculeata*, *Atrypa* sp., *Cyrtospirifer shelonicus*, conodonts such as *Polygnathus costatus patulus*, *P. communis communis*, *Pelekysgnathus* sp., *Icriodus* ex gr. *corniger*, *Bispathodus stabilis* and tabulate corals *Cladopora kokscharskaje*, *Thamnopora nicholsoni*, *T. cervicornis* have been reported from the Baruunhuurai Formation outcropping in the middle part of the subterrane. Based on these fossils the formation age was referred to range from the Eifelian to the Frasnian.

Ulitina (2001) reported rugose corals from the same formation cropping out in the vicinity of the Zagiin-Hara-Uul Mountains, west of Ih-Shovgor Mountain, and on the southern slope of the Indrengiin-Nuruu Range. They are *Nicholsoniella hurenensis*, *N. golovtshenkoae*, *Aulacophyllum exiguum* and *Temnophyllum ruzhentsevi*. Alekseeva et al. (2006) based on the rugose corals and on brachiopods such as *Cariniferella ulitinae*, *Streptorhynchus* sp., *Protoleptostrophia* sp., *Desquamatia* (*Seratrypa*) *pectinata*, *D.* (*Independatrypa*) sp., *Adolfia loriger*, *Cyrtiopsis* sp. and *Cyrtospirifer* sp. suggested a Frasnian age for the deposits of the Baruunhuurai Formation. Erlanger (1994) also described Frasnian brachiopods *Bulgania mongolica* from the Zagiin-Hara-Uul Mountains. Goryunova reported new bryozoans such as *Pileotrypella lautissima* and *Boardmanella richardi*. All these fossils come from the sections in the eastern part of Ulaanus subterrane near the Indrengiin nuruu mouintain. On the southern slope of the Idrengiin nuruu mountains remains of the middle Devonian tabulate corals *Thamnopora cervicornis* and *Emmonsia talteinsis*, are present in the calcareous sandstones. From the upper part of the section, late Famennian brachiopods *Barunkhuraya indrengynensis* were described.

Comparative study of the formations in the Baruunhuurai Terrane with well-studied middle to late Devonian sediments in the western and eastern Junggar regions are required. Application of conodont biostratigraphy could clarify the age of invertebrates and would enable to compare Mongolian invertebrates species with those developed in Europe and elsewhere.

Comparison between benthic foraminiferal turnover across the ETM2 and H2 hyperthermal events in the NE Atlantic Ocean

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The warming trend of the early-mid Paleogene was punctuated by several short-lived episodes of extreme warming, called hyperthermals. These events were associated with negative $\delta^{13}C$ excursions and carbonate dissolution. Changes recorded during the most pronounced hyperthermal event, the Paleocene-Eocene Thermal Maximum, include an increase in continental weathering, an intensification of the hydrological cycle, and biotic perturbations including the most extreme benthic foraminiferal extinction of the Cenozoic. In contrast, no extinctions of benthic foraminifera have been recorded during the less severe hyperthermal events. In order to understand the response of benthic foraminifera to early Eocene hyperthermal events of varying intensity, we analyzed the assemblages from DSDP Site 550 (Porcupine Abyssal Plain, northeast Atlantic Ocean). At this site, brownish and grayish marly nannofossil chalks were deposited at a paleodepth ~3800 m during the early Eocene. The position of Eocene Thermal Maximum 2 (ETM2, also called Elmo or H1, 53.7 Ma) and H2 (53.6 Ma) has been inferred from the benthic foraminiferal isotope record (D´Haenens et al., 2014). The carbonate content varies between 30-60%, and decreases to 0-14% across the hyperthermal intervals.

Assemblages are moderately diverse (fisher-α~14) and strongly dominated by calcareous taxa, with agglutinated taxa reaching 8% and 10% of the assemblages in the carbonate dissolution intervals associated with the ETM2 and H2 events. A ~15 cm-thick interval with very low %$CaCO_3$ content, the core of ETM2, was not included in our quantitative studies because it contains less than 50 specimens per sample, with similar abundances of calcareous and agglutinated taxa. Assemblages consist of mixed infaunal-epifaunal morphogroups. The species *Bolivinoides decoratus*, *Quadrimorphina profunda*, *Globocassidulina subglobosa* and *Oridorsalis umbonatus* dominate among infaunal taxa, and the species *Nuttallides truempyi*, *Osangularia* and *Gyroidinoides depressus* among epifaunal taxa. Across the ETM2 and H2 events, the diversity of the assemblages decreased and as did the relative abundance of bolivinids (mainly *B. decoratus*). Differences between both events include increased abundance of *N. truempyi* and *Q. profunda* during early ETM2, and peak abundance of the calcareous *G. subglobosa*, *Osangularia* sp. and the agglutinant *Glomospira* group during the H2 event.

The occurrence of mixed infaunal-epifaunal assemblages, together with high abundances of *N. truempyi* and bolivinids suggest meso-oligotrophic conditions during the early Eocene at Site 550. The increase in % *N. truempyi* and *Q. profunda* and decrease in % *B. decoratus* suggest more oligotrophic conditions across ETM2. The occurrence of a foraminiferal-poor interval with abundant agglutinated taxa indicates the presence of $CaCO_3$-corrosive bottom waters during the core of ETM2. The percentage of *B. decoratus* also decreased across H2, but proliferation of taxa such as *G. subglobosa*, *Osangularia* and species of *Glomospira* group, which have been interpreted as opportunistic taxa (e.g., Arreguín-Rodríguez et al., 2013), may indicate a pulsed food-input to the seafloor across this interval. Our results show minor differences in the response of benthic foraminifera to the ETM2 and H2 events, with differences possibly controlled by changes in $CaCO_3$ corrosiveness, and in the amount/seasonal distribution of food supply.

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Radiolarian biostratigraphy for the sedimentary cover of ophiolites in Armenia

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A good understanding of the various geologic aspects of ophiolites throughout the Alpine mountain chains is of key importance for reconstruction of the Neo-Tethys Ocean. In particular, volcanic rocks of ancient oceanic crust and their sedimentary cover (i.e. radiolarites) provide important clues to decipher the geodynamic evolution of Neo-Tethys, especially by constraining the time of opening and spreading of the various parts of this complex Mesozoic oceanic realm. In this respect radiolarian biochronology has become invaluable during the last thirty years for understanding the geodynamic and palaeoenvironmental evolution of Tethyan oceanic basins and continental margins.

Several ophiolite outcrops occur in the country. They are organised mainly in two ophiolitic zones:

– The Sevan-Akera Zone crops out at the E and SE of Lake Sevan and represents the main Tethyan suture zone between Eurasia and the South-Armenian Block (SAB). The Amassia-Stepanavan ophiolites that crop out in the north-western part of the country are considered as the north-westward extension of the Sevan-Akera ophiolites zone.

– The Vedi ophiolite, situated south-east of the capital city Yerevan.

Age data of Armenian ophiolites are of great importance for understanding the palaeogeographic and geodynamic evolution of Tethys in the Caucasus area and for lateral correlations of Tethyan ophiolitic belts in the Middle East area. There are not enough data and a number of still unsolved problems in the Lesser Caucuses concerning the exact location, characteristic features, age and more controverting opinions are a subject to be researched. Early studies pointed to a poorly constrained Late Jurassic-Neocomian time interval for radiolarites intercalated or overlying ophiolitic lavas. However, Carnian and Toarcian aged radiolarians have been observed (Knipper et al., 1997) Upper Triassic and Lower Jurassic radiolarian cherts intercalated with ophiolitic breccias at Old Sotk (Zod) Pass, but the structural relations of the ophiolitic complexes in the overlying rocks need to be reviewed.

There are many regions under-studied, the Zangezur ophiolitic assemblages among them, and also a lot of outcrops of ophiolitic assemblages in Sevan and Vedi, in the northern parts of Armenia, namely in Amasia and Stepanavan. There is very little information from the ophilitic belts of Gharabagh (Artsakh) in Sevan-Hagari ophilitic zone.

In spite of extensive sampling during the last ten years across the Sevan-Hakari (Akera) suture zone and the Vedi ophiolite we found no Triassic or Lower Jurassic radiolarites.

Radiolarian biostratigraphic results we have obtained establish that radiolarian ooze accumulated, and it was occasionally interrupted by lava flows, during (at least) the Bajocian to Cenomanian time interval.

The Bajocian is widely established (Vedi and Sevan ophiolites), late Tithonian – Valanginian radiolarian assemblages, recovered from the NE of Lake Sevan, while we have recently obtained a Cenomanian radiolarian fauna from Amasia (NW Armenia).

New radiolarian ages obtained recently on numerous tuffites intercalated in siliceous sequences along the Amasia-Sevan zone (Amasia, Sarinar, Daranak, Old Sodk pass sections) suggest that subaerial volcanic activity was underway for most of the Middle Jurassic to Lower Cretaceous (Bajocian/Bathonian to Albian).

Cenozoic Bio- and Chronostratigraphy: State of the Art

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With its broad arsenal of complementary methodologies, Cenozoic stratigraphy now has unprecedented capabilities of providing the geological community with the temporal framework that allows resolution of cause-effect relationships in Earth System history. Biostratigraphy has greatly benefitted from developments in geophysics (magnetostratigraphy), chemical oceanography (chemostratigraphy), and astronomy (orbital cyclicity), and this has guaranteed it to retain its prominent role in stratigraphic correlations and in estimating rates of physical, chemical and biotic changes. Stratigraphic resolution in continuous Paleogene and Neogene sections now reaches a precision of half a precessional cycle (~10 kyr), and diachrony of biotic events (generally <300 kyr at similar latitudes) between oceanic basins can be measured. New advances in understanding evolutionary modes and tempo among planktonic organisms is likely to help define precisely the FADs of species, and delineate firmly zonal boundaries that are contingent upon them. In addition, two thirds of the Cenozoic stage boundaries are GSSP-defined, many being correlatable over long distance using biostratigraphic markers. However, for all its strength, Cenozoic chronostratigraphy is still lacking in two areas. One is that global stratigraphy is not really global, because not all GSSPs are defined based on global means of correlation. Yet, marine-terrestrial correlations are paramount in determining global geochemical cycles. The other is that formalization of chronostratigraphic subdivisions of the Cenozoic record into series and stages is insufficient to support a common language among Cenozoic geologists. The most practical and broadly used rank in discussing Cenozoic history is that of subseries (lower/early, middle, upper/late), and we recommend that these be formalized in recognition of this fact. Another item of unfinished business is the case of the Neogene whose truncation at the level of the Gelasian Stage cannot be justified from a deep time perspective.

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Neogene Allostratigraphy in the Northern Gulf of Mexico along a Depth Transect from Main Pass to Green Canyon

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We have conducted an integrated Neogene biostratigraphic study of planktonic foraminifera and calcareous nannofossils from an ~ 600 km long, NE-SW six-wells transect extending from Main Pass (92m water depth) to Green Canyon (482m water depth) in the northern Gulf of Mexico. We determine the relative completeness of the Neogene stratigraphic succession by proceeding to an analysis of the sedimentary history in each well using magnetobiochronologically calibrated datum events of selected calcareous plankton (see Aubry, 1995). The hiatuses associated with inferred unconformities and the age of their bounding surfaces are calculated, estimated or, when (data are insufficient) approximated. Multiple unconformities are recognized in the six wells studied here and corresponding intra-Neogene hiatuses range from ~ 1 to 3 Myr; a lower Miocene/Oligocene unconformity (Chevron Main Pass) has a duration of ~ 10 Myr. The unconformity-bounded sedimentary packages roughly correspond to the sequences of the third order cycles of sequence stratigraphy. However, unlike the premises of sequence stratigraphy the unconformities have no chronostratigraphic significance in this allostratigraphic architecture. We determine that late Miocene-Pleistocene hiatuses and rates of accumulation increase with depth along the transect, contrary to predictions based on a “sedimentary sequence”, the basic model of sequence stratigraphy, but consistent with our observations in the DeSoto Canyon (Aubry, 1993b). Owing to a lack of seismic and well-log data we are unable to resolve this anomalous pattern.

The allostratigraphic framework described here serves as a framework for the delineation of Neogene neritic to upper bathyal benthic foraminiferal biofacies, paleobathymetry and paleoenvironments.

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Correlating carbon and oxygen isotope events in early to middle Miocene shallow marine carbonates in the Mediterranean region using orbitally tuned chemostratigraphy and lithostratigraphy

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During the Miocene prominent oxygen isotope events (Mi-events) reflect major changes in glaciation, while carbonate isotope maxima (CM-events) reflect changes in organic carbon burial, particularly during the Monterey carbon isotope excursion. However, despite their importance to the global climate history they have never been recorded in shallow marine carbonate successions. The Decontra section on the Maiella Platform (central Apennines, Italy), however, allows to resolve them for the first time in such a setting during the early to middle Miocene. The present study improves the stratigraphic resolution of parts of the Decontra section via orbital tuning of high-resolution gamma ray (GR) and magnetic susceptibility data to the 405-kyr-eccentricity metronome. The tuning allows, within the established biostratigraphic, sequence stratigraphic, and isotope stratigraphic frameworks, a precise correlation of the Decontra section with pelagic records of the Mediterranean region, as well as the global paleoclimatic record and the global sea level curve. Spectral series analyses of GR data further indicate that the 405-kyr orbital cycle is particularly well preserved during the Monterey Event. Since GR is a direct proxy for authigenic uranium precipitation during increased burial of organic carbon in the Decontra section, it follows the same long-term orbital pacing as observed in the carbon isotope records. The 405-kyr GR beat is thus correlated with the carbon isotope maxima observed during the Monterey Event. Finally, the Mi-events can now be recognized in the $\delta^{18}O$ record and coincide with plankton-rich, siliceous, or phosphatic horizons in the lithology of the section.

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Cambrian trilobite biostratigraphy and the emergence of an integrated Earth history

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One of the principle biostratigraphic tools used in the Lower Palaeozoic, and especially the Cambrian System, is trilobites. Historically, both polymerids and agnostoids have commonly been included as trilobite groups. An abundant and diverse polymerid and agnostoid record has been the source of the Cambrian Period's informal name, the "Age of Trilobites." Beginning about 1890, C. D. Walcott, working in North America, and W. C. Brøgger, working in Scandinavia, recognized the base of the Cambrian System by the lowest occurrence of olenelline trilobites. Determination of the Cambrian base by the first trilobites largely held sway until about the 1980s, when trilobites were recognized below the historic Cambrian base, and a rich fossil record even farther below became widely acknowledged.

Subdivision of the Cambrian stratigraphy of most major palaeogeographic regions revolved around guidance provided by trilobite zonation. High levels of endemicity in Cambrian shelf seas, however, led to the development of regional biostratigraphic schemes that had little in common from one palaeocontinent to another. This had the effect of complicating global correlation. Some regions, such as Laurentia, saw the introduction of multiple biostratigraphic schemes that were largely tied to lithofacies belts and extinction-delimited evolutionary units termed biomeres by A. R. Palmer in 1965. In the mid-1900s, A. H. Westergård introduced a zonation for the Alum Shale of Scandinavia that was mostly based on agnostoids. Beginning in the 1960s, R. A. Robison demonstrated the applicability of this scheme, with modification, to outer-shelf lithofacies of Laurentia. Subsequently, many others have adopted aspects of the scheme to outer-shelf and slope regions of most palaeocontinents. In the 1970s, A. R. Palmer explained the global distribution of Cambrian trilobite faunas in terms of restricted and unrestricted access to open oceans. Building on this, R. A. Robison recognized separate zonations of restricted-shelf polymerids, open-shelf polymerids, and open-shelf agnostoids for Laurentia. Many agnostoids and some polymerids characteristic of the open-shelf have cosmopolitan distributions, and this has facilitated identification of precise intercontinental tie points through much of the upper half of the Cambrian. Agnostoid and polymerid biostratigraphy can now be integrated with information about coastal onlap and eustatic sea level history, geochemical cycling, and other data to provide a more complete understanding of the early Palaeozoic biosphere and its complex physico-chemical context.

Restudy of the Cambrian base: challenges and prospects

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The Cambrian GSSP presents a complicated set of challenges for precise global correlation. In recent years, increasing evidence has emerged of an imperfect agreement between the definition of the Cambrian System/Terreneuvian Series/Fortunian Stage GSSP as a point in stratigraphy, and the means by which it is identified and correlated using chronostratigraphic tools. The point, 2.3 m above the base of Member 2 of the Chapel Island Formation, Fortune Head section, Newfoundland, Canada, was ratified in 1992. The point was intended to coincide with the lowest occurrence of an ichnofossil, *Phycodes* (later *Treptichnus* or *Trichophycus*) *pedum* at the base of the *T. pedum* Zone. Contemporary discussion made clear that the appearance of *T. pedum* occurred within the context of a broader pattern of increasing trace fossil complexity and diversity. After ratification of the GSSP, *T. pedum* was discovered to range downward into the Ediacaran System, which reduced the precision with which the boundary horizon could be correlated beyond the stratotype. Secondary chronostratigraphic tools at the stratotype, which comprise other ichnofossil, vendotaenid, and acritarch body fossils, help to constrain the GSSP, but not precisely mark it. One such indicator, the uppermost known occurrence of the trace *Harlaniella podolica*, occurs slightly below the GSSP.

Precisely correlating the position of the ratified Cambrian base beyond the stratotype and Western Avalonia has been problematic, in part because of the lithofacies dependence of many trace fossils. Globally, on a rough stratigraphic scale, the Ediacaran-Cambrian transition is certainly recognizable, as it records events associated with a time of significant change in the biosphere accompanied by physico-chemical changes in the marine realm. Increasing trace fossil complexity documents or tracks some of this change, and broadly serves to constrain the Cambrian base. Intercontinental correlation is limited, however, as the key trace fossils associated with the Cambrian base are not documented in all major paleogeographic regions. An alternative chronostratigraphic method, $\delta^{13}C$ chemostratigraphy, has been introduced to estimate the position of the Cambrian base, but chemostratigraphic data are unavailable for the stratotype, and uncertainty in global correlation is inevitable.

Restudy of the Cambrian base is proceeding, and multiple options for how to overcome the recognized correlation issues are open. Under ideal circumstances, the ratified base would be conserved if an acceptable set of stratigraphic guides were to be discovered. In the alternative, it is possible that some change in definition may be required to ensure precision in stratigraphic correlation. If it is agreed that such a change is necessary, it is worth considering whether such a change will have a destabilizing effect on post-1992 correlations and derivative work, how sizable that effect would be, and over what time span correlation work would be affected.

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Onset, development and cessation of the Permian-Triassic boundary microbialite in the Nanpanjiang Basin (South China)

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In shallow water successions from northern Guangxi and southern Guizhou (South China), Permian-Triassic Boundary is placed between Late Permian Heshan and Early Triassic Luolou formations.
The Late Permian Heshan Fm. is characterized by thick bedded gray limestone with chert nodules intercalated with frequent ash layers. The abundant and diversified benthic fauna of the Heshan Fm. includes sponges, calcareous algae, corals, gastropods, foraminifera, bivalves, brachiopods, bryozoans, and crinoids. The last bed of Heshan Fm. is usually an ash layer.
Unconformably overlying the Heshan Fm., the base of the Early Triassic Luolou Fm. is represented by a unit of microbialite whose thickness varies from 3.5 to 9.5 meters.
Before the onset of the microbialite unit, five successive events are recognized in our sections:
1- Deposition and preservation of an ash layer at the top of the Permian Heshan Fm.
2- Deposition of a high energy grainstone with unusually abundant Permian fauna (mostly foraminifera) due to reworking
3- Deposition of a first and thin microbialite bed on top of the reworked grainstone (2)
4- Deposition of a second, high-energy grainstone containing a reworked late Permian fauna with *Nankinella* on top of the first microbial episode
5- Deposition of the main microbial episode
High resolution $\delta^{13}C_{carb}$ data show a ca. 1 per mil jump between event 1 and 2, thus suggesting the presence of gap straddling the Permian-Triassic boundary. Moreover, the ash layer at the top of the Heshan Fm. opens the possibility that any younger Permian limestone may have been removed prior to event 2. Although submarine corrosion by acidic waters cannot be excluded, these new sections clearly document multiple events of mechanical erosion before deposition of the main microbial unit.
The microbial unit is devoid of any siliciclastic deposits, suggesting that it was deposited in clear waters with no clastic load. The lower half of this unit mostly shows tubular macrostructures, while dome-shaped constructions are predominant in the upper half. Shelly lenses containing highly diversified benthic faunas may locally occur between the domes. Rare ammonoids also sporadically occur within the youngest shelly lenses. This change of microbialite macrostructures is interpreted as a response to rising sea level and light competition. Predominant mesostructures include layered stromatactis-type, fenestral, labyrinthic, spotted, and vesicular structures in the lower half of the microbialite unit. Digitated structures occur in the dome-shaped constructions.
In all studied sections, the microbialite unit is overlain by a greywacke ranging from a few centimetres to 5 meters in thickness. The base of this greywacke may locally contain a breccia with clasts of microbial limestone. This unit indicates a sudden drowning of the microbial platform. The overlying strata consist of mudstone with few intercalated thin bedded micritic limestone yielding ammonoids and conodonts of late Griesbachian age. Hence, deposition and cessation of the microbial unit was at least partly controlled by bathymetry and corresponding clastic load of the water, which were in turn controlled by regional tectonics.

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Quaternary Stratigraphy and Natural conditions of Kazakhstan and the application of remote sensing for mapping it

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In Kazakhstan Quaternary was associated primarily with the rise of mountain ranges in conditions of intense tectonic processes and, as a result of this, cooling of the climate. Quaternary Stratigraphy was divided into Eopleistocene (Q_E), Early (Q_I), Middle (Q_{II}) and Late (Q_{III}) Pleistocene and Holocene (Q_{IV}) sections. Each section began with an active tectonic phase at the end of that geologic events occurred quite easily. In Eopleistocene there was a set of mountain peaks covered with snow. In the area of the ridge Big Karatau most ancient instruments of a man revealed in the area of the valley Arystandy River on its left high bank, among the preserved from erosion lower Antropogenic conglomerates. Lower Antropogene conglomerates' thickness is 9 m and more evident in a number of points as the left bank and right bank of Arystandy River. Dynamic water flow eroded slopes, formed deep ravines and mountain valleys, terraces and precipices. Rocks blurred from the slopes and valleys, rocks imposed in the form of blocks, boulders and piled up at the foot of the mountains. Streams carried on the sandy plains of the masses. Sand deposits formed in the southern Balkhash, in the areas Moiynkum and Kyzylkum. The thickness of the permafrost engulfed these regions for thousands of years up to several meters. With the rise of mountains on the earth's surface layers came out hard rock. In areas of maximum accumulation of archaeological material gave an identical picture of strata: 1) yellow-gray clay loam 0-0,30 m; 2) dark gray sandy loam, sand significantly 0,30-0,45 m; 3) coarse gravel with some large boulders – 0,45-1,5 m.

At Middle Pleistocene in the conditions of intensive tectonic movements the mountains and the earth's surface continued ascent. Water flows of Mountain Rivers washed away the spirits of rocks and their clastic sand-gravel material in the form of cones accumulate in the foothills. The mass of river sand material grew in parts of southern Balkhash region, Kyzylkum and Moiynkum. By the end of mid-Quaternary time the glaciers from the mountain tops fell into the lower valley due to strong cooling. Water in the rivers began to freeze, dramatically reduce the flow. Increased wind in dry areas began to form shapes of aeolian terrain: sand mounds, ridges and hills. The dust mass raised from these areas settled in the piedmont plains. Pale yellow loess sediment with thickness up to 10-30 m was clearly visible along the shores of Arys River.

Analysis of river flows and the morphology of the valley, located across the ridges Karatau, showed that they were the result of active tectonic phases, about 350-400 thousand years ago, which marked the beginning of the rise of mountain ranges. Lots of river valleys formed by erosion in its path uplift mountain ranges and ridges were called antecedent. Antecedent valleys are usually steep rocky slopes, but their depth is determined by the intensity of uplift sites located across the river flows and erosive power of rivers.

Late Quaternary is known in geology as significant tectonic changes period. Rivers flew from the mountains of Alatau and Karatau, their erosion activities grew. River watershed Saryarka flew into the northern and southern areas, erosion of their power increased eroded valleys, rocks and sand deposited sediments. Holocene or modern section of the Quaternary by modern scientific data began with the activation of the Almaty tectonic phase. In the early Holocene due to a sharp rise in temperature mountain-valley glaciers quickly melted, permafrost and the northern plains and formed flood covered the earth's surface.

The most ancient paleovalleys first type can presumably be attributed to karst erosion, blurry chalk and carbon deposits foundation. Paleovalleys may include significant groundwater resources as drinking and industrial purposes. Also can be control the position paleovalleys zinc and bauxite mineralization area and alluvial deposits include uranium mineralization valleys infiltration type and placer gold. Direction paleovalleys choppy, but in general they have a north-east orientation, which is controlled by tectonic zones of the foundation. These zones are defined as the burial place themselves paleovalleys and position of karst cavities in areas interfacing with other structures orientation.

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Multiproxy cyclostratigraphy and astrochronology of a Valanginian (Lower Cretaceous) section in Hungary

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A high-resolution, multiproxy cyclostratigraphy was developed in a Valanginian to lowermost Hauterivian section in the Bersek Marl Formation (Gerecse Mts., Hungary) which comprises alternating layers of marls with varying clay and carbonate content. The first cyclostratigraphic studies on these strata were carried out in the 1990's but despite much development of the relevant methods internationally and increasing interest in Early Cretaceous stratigraphy and Earth history, no new studies have been carried out on this formation. The Bersek Marl Formation was deposited from the Early Hauterivian to the Barremian, but its stratigraphy is not yet well understood. Reliable ammonoid biostratigraphic constraints exist for the Upper Hauterivian upsection, but fossils are rare in the lower part of the formation. Astrochronology has the potential to estimate the duration of deposition and the sedimentation rate, whereas carbon isotope stratigraphy could help correlate the studied section with global anomalies such as the Weissert event.

$\delta^{13}C$, $\delta^{18}O$, magnetic susceptibility measurements and gamma-ray spectrometry were carried out on a total of 169 samples that were collected with a uniform sample step of 10 cm. The magnetic susceptibility measurements were made at the University of Pau in France, the isotope studies (IR-MS) were done at the University of Plymouth. The gamma-ray measurements were performed in the field using a portable instrument.

Analyses of the multiproxy dataset helped establish the presence of precession, obliquity, long and short eccentricity signal in the geological record. Power spectra and evolutionary spectrograms were constructed to see which of these periodicities are the best preserved. The $\delta^{13}C$ and the $\delta^{18}O$ signal is somewhat overprinted by meteoric diagenesis. The $\delta^{18}O$ signal is too much altered for cyclostratigraphic use. In the data obtained by gamma-ray spectroscopy and magnetic susceptibility the short eccentricity signal is the best preserved. In the $\delta^{13}C$ data the obliquity cycles are dominant and were used to determine the sedimentation rate. The frequency of the precession signal is too close to the Nyquist-frequency thus it could not be used for further evaluation. The 405 kyr long eccentricity cyclicity could be detected in all of the signals.

Slightly different sedimentation rate estimates were derived from these results. A sedimentation rate of 11.3 m/Myr was assessed based on the magnetic susceptibility signal that was the overall least disturbed from the three proxies hence the most reliable. Thus the 16.8 m thick section was deposited during a 1.49 Myr interval. The preservation of the different Milankovitch cycles in the record can be explained by the monsoonal climate of the Western Tethys. The influx of continental sediment reaching the ocean basin varied according to the precipitation which, together with other climatic variables, was controlled by the Earth's orbital parameters. The lack of a linear trend in the $\delta^{13}C$ signal and the high (2.7 ‰) average of the $\delta^{13}C$ values suggest that this part of the section may represent the sustained, flat plateau of the well-known Valanginian positive carbon isotope anomaly, the Weissert-event.

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The Serravallian-Tortonian boundary at Eastern Roztochya (Western Ukraine): criteria for definition

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The Serravallian-Tortonian boundary has been traced and investigated in the sections near to the villages Glynske and Stara Skvaryava at Eastern Roztochya. It is plainly determined by lithological characteristics and consists of a cyclic alternation of sand and clay beds with sapropel layers. It has been traced three sapropel layers, which vary in colors and thickness. The first (lowest) layer (10-15 cm) is black, the second (middle) (5-7 cm) and the third (upper) (3-5 cm) layers are dark brown. Between the first and the second sapropel layers there are brownish purple sand with sapropel lenses (up to 2 cm); between the second and the third there is a volcanic ash layer, which is presented by light gray clay (15-18 cm). The third sapropel layer is covered by mica dark greenish gray clay that becomes an ocher color up to the top (35 cm), where dipping pockets filled with medium grained white or light gray sand occur. These sedimentary structures indicate a break in the sedimentation and are of erosion origin. Between the upper sapropel layer and dark greenish gray clay occur a thin layer (up to 5 cm) of sand with fragments of fossil wood that are without bark and lying horizontally. This layer is well traced at the outcrop near to Glynske and there are only rare findings of fossil wood fragments at other outcrop. The whole boundary sequence is composed of siliciclastic sediments without any fauna remains and is covered transgressively by Lower Tortonian yellow sand with fragments of the Lithothamnium limestone.

On the global level the base of the Tortonian Stage (GSSP) is defined as the mid-point of the sapropel layer (Hilgen F. et al., 2005; GTS-2012). It is based on cyclostratigraphy like for a majority of Neogene stages, thus lithological criteria are the primary markers. Biostratigraphic criteria are the secondary markers and mostly depend on the facies conditions that were various in the Neogene – from deep sea to shallow freshwater, and therefore can not be taken as a global or primary markers.

The main differences between the Serravallian-Tortonian boundary at Eastern Roztochya and the GSSP of the Tortonian Stage at Monte dei Corvi (Italy) (Hilgen F. et al., 2005) are on the facial features of sedimentation, the total thickness of boundary sequence, quantity of sapropel layers and absence of biostratigraphic markers in Ukrainian section. The similar features are the occurrence of sapropel layers, a volcanic ash layer and the presence of sedimentary structures that might be taken as the main criteria for defining the Serravallian-Tortonian boundary at Eastern Roztochya of Western Ukraine. Execution of more detailed research will allow to propose this sequence as Regional boundary Stratotype Section and Point (RSSP) for the Serravallian-Tortonian Boundary of Western Ukraine.

The importance of ammonoids for a modern integrated Triassic chronostratigraphy

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The Triassic was a great time in the evolution of the Ammonoidea. This group experienced superfast radiations, as well as crises, and very wide varieties of evolutionary trends. The first experiment of uncoiling took place in the Late Triassic, and Triassic ammonoids developed what is probably the widest variety of suture lines in the history of the group. This extraordinary evolutionary liveliness allows the subdivision of the Triassic ammonoids in about 80 families, more than 800 genera and some thousands of species, many of them with short to very short stratigraphic range.
This extraordinary pattern of the Triassic ammonoids was quite soon recognized by the paleontologists during the 19th century. Among them Edmund von Mojsisovics, who built on ammonoids the first chronostratigraphic scale of the Triassic in 1882. This scale, that was updated several times by Mojsisovics until his death, was developed under a strong influence of Albert Oppel and the concept of "zone" applied by Mojsisovics was exactly the same as conceived by Oppel.

Mojsisovics' scale had a tremendous impact on the history of Triassic chronostratigraphy. Most Tethyan substages were introduced on the basis of lithofacies and/or Mojsisovics ammonoid zones in the 19th century. The North American Triassic scale, presented by Silberling and Tozer as an independent scale in the 1960s, was also based on a concept of zone that does not differ notably from that of Mojsisovics (and of Oppel).
The new wave of research started in the 1960s quite soon emphasized several problems with the Triassic ammonoid-based chronostratigraphy. The most important one is the rare occurrence of ammonoids in the Triassic successions, that makes this accurate tool not always of very practical application. In order to overcome this problem, at the end of the 1960s several additional tools were examined by Triassic specialists, and conodont, palynomorph, radiolarian and pelagic bivalve zonations have become gradually more and more popular. No one of these tools actually really challenges the ammonoids in term of power of resolution but, no doubts, these fossils can be applied much more commonly than the ammonoids.

The major innovation in the history of Triassic chronostratigraphy was developed between the 1980s and the 2000s and is directly related to the research aimed at the definition of the GSSPs of Triassic stages. Specialists of different groups were encouraged to work in close cooperation in order to compare and to discuss events and correlations using an integrated general framework. The discussion within the Induan, Ladinian and Carnian Working Groups re-evaluated the chronostratigraphic significance of the ammonoids, that were commonly used as calibration tool for conodonts, palynomorphs and pelagic bivalves. Ammonoids have often resulted more age-diagnostic than other tools, and it is not a coincidence that two GSSPs out of three have been based on ammonoid events.

The ammonoid chronostratigraphy itself has greatly benefited from the discussions within the WGs. Ammonoid specialists changed the way to define zones and started to work on range charts and to look for bioevents, following the approach used by conodont specialists. This new approach led to the revision of many Oppel zones of the Tethyan Middle Triassic. Some conodont specialists, on their side, are now focusing on bioevents and on the reconstruction of evolutionary lineages to identify FADs, instead of improving the resolution of the conodont zones.

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High resolution integrated biomagnetostratigraphy of the Carnian/Norian boundary at Pizzo Mondello and Pizzo Lupo (western Sicily, Italy)

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The Pizzo Mondello section in western Sicily provides one of the best marine record in the world for the Late Carnian and Norian, in term of continuous pelagic sedimentation, high sedimentation rate, quality of primary magnetization and stable isotope record. The succession is quite rich in fossils, specially halobiids, conodonts and ammonoids, then in the last decade the Pizzo Mondello has been studied in details and proposed as candidate section for the definition of the Norian GSSP. This section is thus far the best in the Tethys Realm, and has been compared with the other GSSP candidate Black Bear Ridge in northeastern British Columbia (Canada).
In order to test the quality of the record of the Pizzo Mondello, in 2010 we have started the study of a new section in the Sicano Basin, located in a quarry at Pizzo Lupo (Castronovo di Sicilia), about 20 km from Pizzo Mondello. The new section, perfectly exposed, has been sampled for ammonoids, conodonts and halobiids. At the same time in 2014 and 2015 we have increased the detail of the sampling of Pizzo Mondello, especially within the interval from the latest occurrence of ammonoids of the Upper Carnian Spinosus Zone and the Lower Norian Selectus subzone. The new results can be summarized as follows:

1) the resolution of the C/N boundary bio-chronostratigraphy is increased and calibrated to magnetostratigraphy with the accuracy of the single bed.
2) the biozones and most of the bioevents previously identified and Pizzo Mondello have been identified also at Pizzo Lupo.
3) the two sections are bed-by-bed correlated.
4) the FO of *Halobia austriaca* has been recognized at Pizzo Lupo, in level CPL78, equivalent to FNP135A at Pizzo Mondello.
5) conodont samples yielded very rich populations that show a typical Neotethyan affinity, allowing to recognize one of the most important conodont bioevents for the definition of the Carnian/Norian boundary interval (i.e. the mass occurrence of the *communisti* group in sample CPL63) and the occurrences of significant guide forms, such as *Carnepigondolella tuvalica*, *Carnepigondolella orchardi*, *Epigondolella heinzi, Epigondolella quadrata*, and *Epigondolella uniformis.*
6) a small ammonoid fauna has been collected from Pizzo Mondello bed FNP135A and from Pizzo Lupo bed CPL78. The collection includes *Pinacoceras*, *Tropiceltites*, *Gonionotites* and div. Juvavitinae still under study.

The new data from Pizzo Lupo replicate the fossil record of Pizzo Mondello and demonstrate the quality and significance of Pizzo Mondello within the Sicano Basin. Furthermore, the significance of the Sicano Basin in the Western Tethys is supported by conodont correlations between Pizzo Mondello and other Tethyan key sections (Silická Brezová in Slovakia; Bölücektasi Tepe and Erenkolu Mezarlik in Turkey). Trans-panthalassan correlations are mostly based on some species of *Halobia*, namely on *H. radiata* and *H. austriaca*.

PRo3D – Interactive Geologic Assessment of Planetary 3D Vision Data Products

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The FP7-SPACE project PRoViDE (Planetary Robotics Vision Data Exploitation) has been conducted to exploit the wealth of orbital, probe and rover derived planetary surface imagery data taken from missions which have successfully travelled to other planetary bodies in the Solar System. A major element of the data transmitted from Mars in particular is stereo-imagery from the Pancam (NASA Mars Exploration Rovers MER-A and MER-B), Mastcam (NASA Mars Science Laboratory Curiosity Rover) and Navcam (MER and MSL) instruments. Stereo images can be processed to form 3D data sets including image texture that can be represented as Ordered Point Clouds (OPCs). Such OPCs allow viewers to visualize different levels of texture and geometry detail for immersive interactive presentation of large datasets. 3D real-time rendering of rock outcrops on the Martian surface can be achieved within the PRo3D tool, in which OPCs generated from the landers' instruments can be fused together with OPCs obtained from more regional stereo orbit-derived HiRISE digital elevation models (DEMs) and combined with Super-Resolution images for enhanced textural detail. PRo3D allows for geological analysis of such 3D models fused from multiple sources, namely to:

- Study 3D representations of rock outcrops by moving around efficiently and providing different perspectives.
- Visualize data from orbital imagery down to the magnifier-scale imagery (seamlessly investigate multi-resolution data sets) for global context and spatial referencing between differently located phenomena.
- Annotate and interpret the geological features of 3D OPCs.
- Measure geological structures to determine their dimensions and other geometric features.

We demonstrate the capabilities of PRo3D for geological analysis using terrestrial point cloud data from the Ferron sandstone in Utah, an exposed Cretaceous section which records changes in conditions from near-shore marine, shoreface and to meander-belt subaerial deposits from a fluvial and tide dominated delta. The interpretation and analysis techniques derived from this can then be applied to OPCs obtained from combined short baseline and serendipitous long baseline stereo Pancam rover imagery from the MER-B (Opportunity rover). Complete coverage was not possible with the available data, therefore fusion of OPCs from different locations of the sites-of-interest (along the rim of Victoria Crater) within the PRo3D viewer enables correlation of observations between well-imaged locations.

The PRo3D tool is currently being developed for exploiting the stereo capabilities of the PanCam instrument on board of the ExoMars Rover to be landed on Mars in 2019.

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The Late Cretaceous arid climate of Mongolia and Dinosaur Communities

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Non-marine Upper Cretaceous strata of Mongolia is divided into three major units: Bayanshire, Djadokhta (Lower Senonian) and Nemegetu. The Djadokhta unit is correlative with its approximate analogues, Javkhlant and Barungoyot, and, due to priority (1), all three divisions are herein united under term Djadokhta Horizon. It comprises a single Upper Cretaceous dinosaur-bearing correlative horizon, respectively wide-spread in some regions of Gobi Desert. The Djadokhta Horizon demonstrates an arid climate, corresponding sedimentation regime, dinosaur communities and their burial conditions (2,3,4). Proper Djadokhta dinosaur community**:** herbivors - Protoceratops and its babies, Udanoceratops, Pinacosaurus, Plesiohadros, Goyocephale; carnivores - Velociraptor, Saurornithoides, Oviraptor, Avimimus, unidentified babies of hadrosaurids, ornithomimid, rare teeth of tyrannosauroid type, the fossil eggs. Well-known Fighting Dinosaurs (protoceratops vs velociraptor) are particularly noted. Barungoyot contains herbivores - Tylocephale, Bainoceratops, Bagaceratops, Platyceratops and others; carnivores - Conchoraptor, Citipati and Khaan, oviraptorid in brooding position, dromaeosaurid Tsagaan, the nests of fossil eggs. Javkhlant conatins carnivores - dromeosaurid, close to Adasaurus, fossil eggs, supposedly referred to terizinosauroids. Proper Djadokhta community is inimitable in dinosaur composition, and its main member, the protoceratopses significantly predominated all other dinosaurs in numbers, transforming the community into an almost stable monospecific group. In the Barungoyot assemblage, the oviraptorids shows close ties with their relatives in proper Djadokhta, with clear evolutionary shift, what`s expressed in reduction, if not complete loss of their foreleg`s grasping ability. The Javhlant community, being incomplete, nevertheless clearly differs from the two others. Yamaceratops, more primitive, than prevailing protoceratops from the proper Djadokhta, perhaps indicates an older age of Javkhlant within the Djadokhta Horizon. The Djadokhta Horizon includes the small-sized dinosaurs, being reasonably named "a pressed fauna" (5), connected with respectively low biological productivity during arid time.

The Late Cretaceous was the most remarkable and long-termed time of the dinosaur blossom in the world, with a stable warm climate, though some cooling took place in Turonian (6), but, probably, without clear influence in the inner continental regions, like the Gobi Desert.

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Carbonate factory in the aftermath of the end-Permian mass extinction: Griesbachian crinoidal limestones from Oman

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In the Batain region of Oman, basal Triassic crinoid limestones occur as exotic boulders within the Jurassic Guweiza Formation near Asselah. Some of these boulders contain the conodont association *Hindeodus parvus* - *Isarcicella isarcica*, indicating a Griesbachian age. Disarticulated crinoid columnal segments are the main component of these calcarenitic boulders. Additional fauna include small-sized ammonoids (Permian holdovers such as medlicottids and xenodiscids), numerous gastropods, ostracods, bivalves, brachiopods, echinoid spines, microconchids, and foraminifers. The rock is a crinoidal packstone with a dominantly micritic matrix and a great abundance of bioclasts, showing in some cases an early phase of cementation (partly coarse spar and cement fringe). The cylindrical columnals are 0.2 - 2mm in diameter and display up to 32 radial ridges. These ossicles are not well sorted and mixed with mostly unbroken molluscan shells showing no signs of abrasion or bioerosion. This preservation suggests minimal lateral transport. Thin-sections also reveal that the limestone yield a diverse assemblage of small gastropods which cannot be extracted from the rock due to strong cementation. The neritimorph gastropod *Naticopsis* sp. is abundant. Their specimens are well-preserved due to a thin, primarily calcitic outer shell layer. The size of these specimens of *Naticopsis* sp. can exceed 20 mm, demonstrating the presence of relatively large gastropods (‘Gullivers’) (1) as soon as during the Griesbachian, thus questioning the presumed Lilliput Effect that would have affected gastropods after the end-Permian crisis. Late Paleozoic *Naticopsis* species range from less than 10 mm to more than 130 mm in size. 20 mm as reported here for the present Griesbachian species from Oman is common in many Late Paleozoic *Naticopsis* species. *Naticopsis*, has been reported from various Early Triassic sites including the Wadi Wasit block of the Hawasina nappes in Oman Mountains (2) (3). However, *Naticopsis* occurrences from Asselah and Wadi Wasit are not conspecific. Despite the seemingly low taxonomic diversity of earliest Triassic crinoids (but see (4)), the Batain blocks show that some populations were sufficiently abundant to produce material in rock forming quantity. These neritic plateaus colonized by crinoids and various skeletal organisms obviously functioned as local and healthy carbonate factories. Such crinoidal sediments are rare during the Griesbachian: they have never been reported from the inter-tropical realm (Tethyan northern margins and South China) and are known only from mid-latitude localities such as Wadi Wasit (2) (4), Batain (this study) and Salt Range (dolomitized encrinite at the base and within the Kathwai Member) (5). Yet, it is not understood what factor(s) constrained their occurrences. According to (6), after the end-Triassic extinction, crinoidal limestones often developed on topographic highs and seamounts of the Western Tethys and corresponded to stratigraphically condensed sequences. As for the post-extinction Early Jurassic, the Griesbachian crinoidal limestones developed on hard-substrate, well-oxygenated submarine topographic highs, during the drowning and faulting of a former shallow platform. These carbonate ‘oases’ indeed imply: (a) paleotopographic areas protected from clastic input, (b) an adequate (shallow?) water depth, and (c) normal water chemistry (oxygen, pH, salinity) and temperature. They contradict the common view of global, homogeneously catastrophic conditions in the oceans in the direct aftermath of the end-Permian mass extinction.

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Contribution of mineralogical and granulometric analysis in the paleoclimatic reconstruction of the alluvial sediments in the region of Ain Zerga NE of Algeria

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The study of Quaternary formations in Algeria exactly in its NE part (Tebessa, Ain Zerga) gave a very interesting result in paleoclimate and paleoenvironmental reconstructions. The sedimentlogical and mineralogical characteristics of the sediments taken from the river terrace of Oued Ziet had provided results for better understanding the sediment dynamics. Granulometric analysis (laser granulometry), mineralogical (XRD clay),and quartz grains morphoscopy were performed on 81 samples.
Important results have been obtained and the comparison between these results help for better knowledge of the impact of climate change on short lived palaeoenvironments.

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Relic Methane-Seeps (Albian, Tunisia) Associated to the Oceanic Anoxic Event 1D

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The lower part of the late Albian Fahdene Formation in northern Tunisia consists of authigenic carbonates, centimeter-sized carbonate mounds, flat concretions typified by soft sediment deformation (slumps) and doughnuts-shaped concretions hosted in organic-rich marls. Microfacies analyses of these bodies reveal multiple generations of carbonate cements such as fibrous, acicular and sparry calcite, as well as botroidal, *in situ* brecciation, framboidal pyrite, fenestrae, encrusting algae and clotted pelmicrite. Scanning electronic microscope analysis performed on clotted micrite show the presence of micrometer-sized filamentous structures.
Oxygen isotopes of micrite revealed slightly depleted values ranging from -3.92 to -0.6‰ PDB, similar to normal marine values. Depleted values of $\delta^{13}C$ (ranging between -36.88 and -0.47‰ PDB) for these carbonates, suggested a methane-derived carbon source and its anaerobic oxidation. In addition, the ^{13}C moderate depletion likely suggests thermogenetic methane or a petroleum source; it can also be a mixture of methane derived carbon with marine dissolved inorganic carbon (DIC). These results provide unequivocal evidence that this carbonates are cold seeps – related, developed during the late Albian.
The cold seep features indicate that microbial communities have used ascending methane fluids and contributed to the precipitation of authigenic carbonate via methane oxidation under anaerobic conditions. Probably, the microbial communities have contributed to the projection of cold seep framework through the water column, coeval with the spreading of oxygen minimum zone near water/sediment interface during the late Albian OAE1d.

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The Albian Planktic Foraminifera Biostratigraphy and Biological Events – An Update of Zonal Scheme in Southern Tethyan Margins

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The Albian pelagic sequences of Northern Tunisia comprise planktic foraminifers and radiolaria – rich, thick successions attributed to the Lower Fahdene Formation. It is composed of limestone and marl alternations including organic-rich beds. The Lower Fahdene Formation outcropping in northern Tunisia can be subdivided into five members: 1) The “Marnes Inférieures” member is composed of intraclast and belemnite rostrum-bearing, sandy limestone beds overlaid by an alternation of clay interval and argillaceous limestone bearing Triassic clasts. The top of this member is outlined by bioturbated glauconite-rich limestone bed. 2) The Allam Member is composed of alternations of lenticular beds including boulder-sized intraclasts and organic–rich black shales. 3) The “Marnes Moyennes” Member is composed of rhythmic alternations of marl – limestone couplets including organic-rich black shale intervals. 4) The Mouelha Member is composed of organic-rich black shale beds, recognizable as a regional marker bed. 5) The Defla Member is a thickening upward sequence composed of ocherous marl interval including schistose limestone beds. Six sections were used in this study in order to establish planktic foraminifera zonal subdivision of the Albian stage. Nineteen species were identified belonging to *Ticinella, Biticinella, Hedbergella, Thalmaninella* , *Pseudo-thalmaninella* and *Planomalina* which have been used to recognize six biozones, from the base to the top, we distinguish: The *Microhedbergella rischi* Zone corresponds to the lower Albian age has been identified in the Jebel Garci section and includes in its upper part, organic-rich black shale beds of Allam member. A lower Albian age has been assigned to this zone. The *Ticinella madecassiana* Zone has been identified in Ain Slim section and attributed to the upper part of lower Albian. The *Ticinella primula* Zone locally includes in its lower part, thin organic rich black shales beds of Allam Member. It outlines the lower to middle Albian. The *Biticinella breggiensis* Zone includes limestone and dark marl alternations; it is characterized by high diversification rates of planktic foraminifera and radiolarian faunas. The *Pseudothalmaninella ticinensis* Zone is characterized by the blooming of *Biticinella breggiensis* planktic foraminifera, the appearance of keeled forms and high abundance of radiolaria. The sedimentary sequences of *ticinensis* Zone are composed of alternations of thin limestone beds and organic rich marl including concretions bearing “cone-in-cone” structures. The *Thalmanninella* Zone is characterized by the blooming of keeled forms. The first appareance of *Planomalina buxtorfi* is recorded within the Mouelha black shales. The biostratigraphic study of albian pelagic successions of northern Tunisia has revealed hiatus of planktic foraminifera zones, particularly across the Albian-Aptian transition and the middle Albian, affecting peridiapiric and northeastern outcrops. Periods of radiolarian blooming are confined to *Microhedbergella rischi* and *Biticinella breggiensis* zones which are coeval with salt intrusions and extensive tectonic phases, leading to the formation of restricted basins with anoxic conditions.

Planktonic Foraminifera from the Early Cretaceous of Northern Tunisia

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Numerous zonation schemes have been proposed for the early Cretaceous. A comparison of the zones of the Hauterivian –Albian interval in different regions of Tunisia or elsewhere in France, Italy or Spain shows the difficulty to obtain a homogeneous and coherent biozonation. Heterogeneities appear in the cases of first appearences (First appareance datum's: FADs) and disappearances (last appareance datums: LADs) of taxa. The extensive exposure and the great thikness of the comprehensive Cretaceous series of Northern Tunisia are suitable for a detailed study of the rich microfossils content of these Cretaceous strata. The micropaleontological inventory of the stratigraphic sequence reveals a particularly good preservation and richness of planktonic foraminifera. The oldest are Upper Hauterivian age. Only a few specimens of the genus *Gorbachikella* are present in this interval. The Barremian is characterised by an assemblage yielding *Praehedbergella sigali, Gorbachikella kugleri, G. anteroapertura, G. grandiapertura* and *G. depressa*. The species *Blowiella blowi, B. duboisi, B. gottisi, Leupoldina cabri, L. pustulans, Lilliputianella bizonae* and *L. globulifera* are dominant and persistent components of early Aptian assemblages. The species *Globigerinelloides ferreolensis, Globigerinelloides algerianus, Hedbergella trochoidea, Globigerinelloides barri* and *Planomalina cheniourensis* are characteristic species for the middle Aptian. The species *Ticinella bejaouaensis* is a good index for the upper Aptian. The microfaunal content, at the Aptian - Albian boundary shows a considerable drop in the number of species and tests of planktonic foraminifera, particularly coarse sized forms found in the uppermost Aptian. In the lower Albian numerous tests of an indetermined species of *Microhedbergella* are present. In contrast with the basal Albian, the number and frequency of species of foraminiera and sizes of their tests become highly variable in the remaining of the Albian sequence. This stage is characterized by the presence of *Hedbergella planispira, Ticinella primula* and *Ticinella raynaudi* in its lower and middle part and by *Biticinella breggiensis, Rotalipora subticinensis, Rotalipora ticinensis*, *Rotalipora appenninica* and *Planomalina buxtorfi* in its upper part. A distribution chart for the main taxa is prepared and the most significant species illustrated by SEM pictures.

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Stratigraphic continuity across the early – middle Eocene transition

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Planktonic foraminiferal zonation of the early - middle Eocene transition has undergone a continuous flux of redefinition of the classical zonation schemes of Bolli (1957; 1966) from Trinidad. It appears that the original scheme did not accommodate the fundamental evolutionary changes in planktonic foraminifera from the early to middle Eocene. New studies filled this gap, and Bolli's original stratigraphy was codified by P and later E letter schemes that were repeatedly modified as better transitional sections were discovered and more species were defined. A partial summary demonstrating the fluidity of the letter stage definitions has the early-middle Eocene transition initially commencing in P9 at the First Appearance Datum (FAD) of *P. palmerae*, until P10 at FAD *Hantkenina*. Subsequently, most of P9 was removed to P10. More recently E7 replaced part of P9, overlain by E8 that included P10 and part of P11. At this writing, E7 is transformed into E7a and E7b, with E7a terminating in the *T. frontosa* FAD, erasing the previous subdivision of the lower E7, but E7b now extending to the FAD *Gds. nuttali* (previously, *higginsi*), and E8 is changed to include parts of ex-E7, all of ex-E8, and part of E9 and extending to FAD *Gka. kugleri*, erasing the importance of FAD *Hantkenina*. Stratigraphies merge at the top of the E9.

Much of the need for such improvements is attributed to the paucity of preferred marker species in deep ocean settings. Preferential deposition of silica over carbonate, and the shallow level of the CCD at this time, led to widespread deep ocean gaps in biostratigraphic information, bridged by chemo- or astronomically calibrated- stratigraphy (the 'Eocene gap'). However, this gap is in fact an artefact of departure from classic biostratigraphic practice (Hedberg, 1976). Despite universal preference for the continuity afforded by deep ocean cores, a stratigraphy based on sections unaffected by the shallow CCD, and specifically, more proximal to the continental rise, could have provided the required continuity and obviated the need for this constant readjustment.

In the background, the land-based stratigraphic succession of the Levant margin, Israel, has long been resolved in the classical mode using same marker species as the letter system, correlated to calcareous nannofossils and the Cuisian-Ypresian boundary using nummulites (e.g., Benjamini, 1980; Schaub et al., 1985; Weinbaum-Hefetz and Benjamini, 2011). The *P. palmerae* zone as the TRZ of the nominate species is entirely within NP13; replacement of this marker by the more common *Acarinina cuneicamerata* can be accommodated. The *'Sphaeroidinellopsis' senni* Zone of Benjamini (1980) was defined as the interval between the LAD of *P. palmerae* and the FAD of *Hantkenina*. The *'S'. senni* zone until FAD *T. frontosa* correlates to upper part of NP 13 and NP 14a prior to FO *Blackites inflatus*. From FAD *T. frontosa* to FAD *Gds. nuttalli* correlates to NP 14b and NP15-16 (undiff.). The Cuisian-Lutetian boundary based on nummulites coincides with the FO of the calcareous nannofossil *N. fulgens* at the base of NP15-16 (undiff.) nannozone, within the FAD *T. frontosa* – FAD *Gds. nuttali* interval. The part until FAD *Hantkenina* is within NP 15-16. This interval is the zone of evolution of *Hantkenina* from *Clavigerinella* (Benjamini 1980; rediscovered recently after 30 years). Staged evolution of many other typical Middle Eocene species, e.g., *Morozovella crassata* and *Acarinina bullbrooki*, is within the *'S'. senni* Zone. The *H. nuttalli* (formerly *H. aragonensis*) TRZ Zone is readily defined as the TRZ of the nominate species, while FAD *Gka. kugleri* is clearly marked somewhat above. Unsurprisingly, these species are the same ones used today to define E7a,b and E8 boundaries. So where is the improvement after all these years, and where is the Eocene gap?

More cautious use of classically defined biostratigraphic zonation for this interval is necessary. The Levant margin biostratigraphy is not a localized phenomenon, e.g., it is well expressed in northern and southern Spain. Continuity is in fact the logical result of high rates of carbonate deposition on the continental rise, a result of balancing of the global carbonate budget by increased carbonate sedimentation above the CCD near continental margins.

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Conodonts in Ordovician Chronostratigraphy

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Although the study of conodonts was initiated by Pander's 1856 monograph, pre-1900 conodont investigations were few, restricted to northern Europe and North America, and not concerned about the potential biostratigraphic value of these fossils. Although primarily of taxonomic nature, the pioneer studies by Branson and Mehl and Stauffer in North America during the 1930s represent the beginning of the use of conodonts as guide fossils but no formal zones were introduced for the Ordovician anywhere in the world until in the 1960s, which represents the beginning of the modern era of conodont biostratigraphic research. The revolutionary change from form taxonomy to multielement taxonomy also took place at this time. Because the striking provincialism exhibited by Ordovician conodonts, separate biostratigraphic classifications were necessary for Baltoscandia, North America, and some other parts of the world. The first formal conodont zone classification of the Ordovician was established in Baltoscandia around 1970 whereas at that time, 17 numbered units, referred to as 'Faunas', were recognized through the Ordovician in North America. A milestone volume, published in 1971 and entitled 'Conodont Biostratigraphy', provided a broad summary of the conodont biostratigraphy known at that time. The Baltoscandic zone scheme presented in that volume, which was based largely on changes in evolutionary lineages, has subsequently undergone only minor changes. The number and scope of the North American 'Faunas' were somewhat modified during the late 1970s. In the late 1970s and early 1980s, Sweet introduced a classification of Middle and Upper Ordovician chronozones based on graphic correlation, and in 1984, he also proposed an alternative biozonation of the Darriwilian through Katian interval that included 17 named biozones based on the first appearance of index taxa. This classification has been used mainly in the North American Midcontinent. The Baltoscandic zonal scheme, which includes 17 zones and 8 subzones, has been closely tied to graptolite zones and recently also to $\delta^{13}C$ and Sr chemostratigraphy. It has, locally slightly modified, also been used in, among other key regions, Argentina, China, United Kingdom, and Australia. The great importance of conodonts in Ordovician chronostratigraphy is shown by the fact that conodonts are used for the definition of two of the seven global stages, and seven of the 18 stage slices, now recognized within this system.

Gravitational sediments as markers for constraining the Late Pleistocene to Holocene stratigraphy in the Eastern Alps

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The stratigraphy of the Late Pleistocene to Holocene in the Eastern Alps resting on the glacial chronology is based mostly on isolated morphostratigraphic and occasionally on lithostratigraphic characteristics. In combination with modern geochronological data (Radiocarbon, Surface Exposure Dating, Pollen) it is possible to establish a chronological framework. This enables the correlation with high-resolution marine and ice-core records and the elaboration of paleoclimatic considerations. However, superimposed event-based depositional sequences have so far often not been used to reconstruct landscape evolution in Alpine valleys and therefore the chronological framework is commonly not verified by an accompanying relative stratigraphy. Ongoing comprehensive geological mapping shows that gravitational deposits (landslides) could serve as an excellent marker to improve the Late Pleistocene to Holocene glacial stratigraphy considering the whole landscape evolution. We will show examples of partly absolutely dated glacial, glaciofluvial and gravitational sedimentary sequences in the Austrian Eastern Alps for the pre-LGM time in the lower Inn valley (Starnberger et al. 2013 and Reitner & Gruber 2014) and for the post-LGM time (Alpine Lateglacial) in the Fusch valley (Gschnitz, Oldest Dryas) and Rauris valley (Egesen, Younger Dryas; Bichler et al. 2015).

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Palaeoenvironmental variability of $\delta^{13}C_{carb}$ at the Silurian Wenlock-Ludlow boundary

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The Wenlock-Ludlow boundary (Silurian) has been recognized as a time of rapid sea level rise and change within the global carbon cycle. However, the precise timing and synchronicity of the end of the Mulde positive carbon isotope excursion (CIE) with respect to the Wenlock-Ludlow boundary is debated. Within Shropshire (UK), a high resolution $\delta^{13}C_{carb}$ study has been undertaken across the Wenlock-Ludlow boundary and the corresponding transition between the shallow marine carbonates of the Much Wenlock Limestone Formation and the deeper marine shales of the Lower Elton Formation. In total, four localities have been studied representing a platform (reefal) to platform margin (non-reefal) transect. Localities include platformal sections within the type Wenlock area (Benthall Edge and Lea South Quarry) and platform margin sections that include Goggins Road (Mortimer Forest, Ludlow), a supporting section for the nearby base-Ludlow Series GSSP at Pitch Coppice. Within the Much Wenlock Limestone Formation, the upper declining limb Mulde CIE has been recorded. Here, clear spatial variations in $\delta^{13}C_{carb}$ values are identified between sections, with heavier $\delta^{13}C_{carb}$ values recorded from the shallower, platform environments and lighter values from more distal settings. However, minimal temporal variations in the δ13Ccarb trend have been documented between sections with isotope profiles converging at the Wenlock-Ludlow boundary. This apparent synchronicity of the carbon isotope record across the type area and between palaeoenvironmental settings suggests that the Mulde CIE ended at the *M. ludensis* – *N. nilssoni* graptolite Biozone boundary.

Integrating stratigraphic methods in complex sedimentary basins: the example of the Late Cretaceous northeastern Basque-Cantabrian basin (westernmost Pyrenees)

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The establishment of the stratigraphy of rifted margins may be problematic due to several factors. This is the case of the Albian - Campanian (Early to Late Cretaceous) sedimentary record of the north-eastern Basque-Cantabrian Basin (westernmost Pyrenees). This area shows a complex Cretaceous rift record where compartmentalization of the rift basin margin obscures stratigraphic correlations. The strong synsedimentary tectonic deformation resulted in low-continuity strata, high-angle angular unconformities and adjacent small scale distinct depositional carbonate-siliciclastic systems that complicate stratigraphic correlations. Moreover, the area presents a strong Alpine tectonic signature, showing compressive deformation structures that obscure the Cretaceous synsedimentary deformation and enhance the dissolution of dating fossils in the vicinity of reactivated synextensional faults.

The base of this field study is detailed geological mapping of anticline structures overlaid by angular unconformities. Folded upper Albian - lower Cenomanian strata (braidplain delta conglomerate, sandstone, mudstone and limestone) have been dated based on benthic foraminifera preserved in the limestones of the base of the succession. The lack of dating fossils in the siliciclastic upper part of the succession makes it difficult to date the upper part as upper Albian or lower Cenomanian. The overlying unconformable hemipelagic marl and limestone succession has been dated based on planktonic foraminifera, which indicate a Turonian-early Campanian age. Considering that sedimentation occurs horizontally, restored strata indicate that by the time of the Turonian-early Campanian deposition, upper Albian to lower Cenomanian (and older) deposits formed anticline structures which limbs rotated between 08º and 79º. Considering the oldest and youngest deposits separated by the angular unconformity, a hiatus up to 21.2 My is registered in the hinge of the anticlines. However, in limb areas of the anticlines Turonian deposits overlying unconformably the upper Albian-lower Cenomanian rocks indicate that in these sectors the hiatus is of approximately 6 My.

These results show that rotation of strata and formation of anticline structures occurred between the late Albian-early Cenomanian and the Turonian. The absence of strata of these time interval has a great significance in the understanding of the basin evolution: the Cretaceous extensional rift basin underwent a compressive/transpressive pulse between the late Albian - early Cenomanian and the Turonian. This conclusion remarks the importance of field based solid stratigraphic support in complex areas (such as basin margin areas), where the absence of continuous sections hinder the application of single stratigraphic methods.

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Volcaniclastics and pelagic biostratigraphy in the Upper Cretaceous of the Western Pontides, Northern Turkey

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Upper Cretaceous volcaniclastics interbedded with hemipelagic to pelagic sediments were investigated along the southwestern coast of the Black Sea, in the Western Pontides. Volcaniclastic complexes are intercalated with limestones, marls and turbidites. Tuffs were investigated with focus on their geochemistry, plankton stratigraphy was used to date sections and complexes. In the Black Sea region two Upper Cretaceous volcanic units can be distinguished, separated by distinct red pelagic limestone successions, belonging to the Unaz Formation. The lower volcaniclastic unit, the Dereköy Formation, is thought to be deposited within extension structures, contemporaneously with rifting in the Western Black Sea basin. Biostratigraphic ages from the Dereköy Formation indicate Turonian (*Dicarinella primitiva*) up to late Santonian, with nannofossil zones CC17/UC13. The red pelagic limestones of the Unaz Formation record an interval without volcanism during the latest Santonian to early early Campanian. The upper volcanic unit, the Cambu Formation is assumed to be deposited when spreading in the western Black Sea basin was initiated. This formation starts in the early Campanian (CC18b/UC14) and continues locally up to the middle Campanian (CC20/UC15a). However, turbidite intercalations are already present in CC19-20/UC14-15b. Consequently, the overlying Akveren Formation is diachronous, ranging from CC19 to CC20 (middle to late Campanian) to the Maastrichtian with *Abatomphalus mayaroensis*.
The geochemically classified rock types range from basaltic to rhyodacitic in both volcanic formations. Further volcanic series are specified as calc-alkaline to shoshonitic. Moreover, a volcanic arc setting seems to be the most likely case, following several discrimination diagrams, as well as normalized multi-element plots. The Cambu Formation can be assigned as less alkaline and acidic then the lower volcanic succession. Further, the volcanic series seem to be more tholeiitic in the upper volcanic succession. Generally samples belonging to the Dereköy Formation are enriched in Zr, Th and Nb with respect to samples of Cambu Formation.
Correlation of the volcaniclastics with biostratigraphic events and ages from the same outcrops refers to a relative time span between Turonian and Campanian when the magmatic arc was active, at least.
Paleo-tectonic reconstructions favor a northward subduction of the northern branch of Neotethys, creating an extensional setting in the north of the Pontides. This kind of back arc extension is interpreted as the reason of a southward drift of the Istanbul continental fragment from Eurasia and the following rifting and opening of the Western and Eastern Black Sea basin. Favoring this model means, the back-arc interpretation is not precluded by the existence of a Pontide magmatic arc, as referred in literature and confirmed by geochemistry.

General stratigraphic Chart of the Quaternary of Russia

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Commission on the Quaternary System was established by the Interdepartmental Stratigraphic Committee of Russia (ISC) in 1958. During the last 25 years, based on many years' experience in the geological mapping of the Quaternary deposits, the ISC has proposed the series of decisions on the status of the Quaternary System and its subdivisions. This contributed to the increasing the detail and quality of the State Geological Maps of the Quaternary formations at 1: 200,000 and 1: 1,000,000 scales.

Currently, the General Stratigraphic Scale (GSS) of the Quaternary System in Russia, as well as the International Stratigraphic Chart (ISC) of this system consists of two series: Pleistocene and Holocene (Stratigraphic Code of Russia, 2006). The lower boundary of the Quaternary System in the GSS, subsequent to the ISC, was approved by the ISC Bureau at 2,588 Ma level on 7 April 2011 (Resolutions of the ISC and its standing commissions, 2012, iss. 41, pp. 9-11). Previously, the Lower Quaternary boundary was confirmed at the VI Russian Conference on the Quaternary Research in Novosibirsk (19-23 November 2009).

As opposite to the ISC, Pleistocene in the GSS is divided into two subdivisions: Eopleistocene and Neopleistocene. The first of them corresponds to the Matuyama magnetozone, the second one, to the Brunhes magnetozone.

Eopleistocene and Neopleistocene have various biostratigraphic and climatostratigraphic characteristics. They differ in the number of local climatostratigraphic units (links and steps), correlated with the stages of Marine Isotope Scale (MIS). This scale reflects the global climate changes. The even-numbered stages correspond to coolings, and the odd ones – to warmings. But the formation of ice sheets in the middle latitudes (especially during the Eopleistocene) is not always associated with coolings (as in the Neopleistocene) as well as high temperatures of typical interglacial periods are not always associated with warmings. However, both coolings and warmings are reflected in glacioeustatic changes of the ocean level: increasing of the ocean level took place during warmings. In the GSS, odd numbers also indicate steps corresponding to the warmings, and even ones to coolings (Article 111.19 of the Stratigraphic Code, 2006).

The Neopleistocene subdivision is approved by the ISC, and currently it is not discussed. The Neopleistocene includes three links. According to their scope, the lower and middle links correspond to the Middle Pleistocene of the International Chronostratigraphic Chart, 2013. The lower link consists of eight steps, corresponding to 19-12 of the MIS. The middle link includes six steps, corresponding to 11-6 of the MIS. The upper link of the GSS corresponds to the Upper Pleistocene of the ISC, 2013 in full, and includes four steps.

The stratigraphic volume and subdivision of the Eopleistocene continue to be debated. In accordance with our proposal, the stratigraphic volume of Eopleistocene is increased and corresponds to the Lower Pleistocene of the ISC, 2013. Thus the Lower Eopleistocene is considered in the scope of the Gelasian, and the Upper Eopleistocene in the scope of the Calabrian. The Upper Eopleistocene includes two links: the lower one corresponded to 63-36 of the MIS and the upper one – to 35-20 of the MIS.

In General, specification of the GSS, accepted by the ISC, has enabled in recent decades to precise the interregional correlation of the Quaternary regional stratigraphic schemes, to adapt them to international projects and to improve the quality of the State Geological Maps.

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A potential reference section for the Albian – Cenomanian transition in the Boreal Realm: High-resolution integrated stratigraphy of the Anderten research cores

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The upper Albian to lower Cenomanian of the central NW German Basin is represented by an expanded offshore succession of basinal marly claystones and marls, comprising the Peine, Herbram and Baddeckenstedt formations. Here we present a new c. 160-m-thick composite record spanning the uppermost Albian to mid-lower Cenomanian based on two cored boreholes that have been drilled at Anderten, east of Hannover (Germany). Both cores have been subject to an integrated study including detailed bed-by-bed and geophysical logging, sedimentological analyses as well as bio-, event and chemostratigraphic calibration.

Correlation of the high-resolution Anderten $\delta^{13}C$ record to European reference sections and to records from the NW German Basin provided the basis for chronostratigraphic dating. Based on the observed pattern, the base of the succession can be placed in the upper Albian *Mortoniceras rostratum* and the top in the upper lower Cenomanian *Mantelliceras dixoni* ammonite zone. The $\delta^{13}C$ markers of (1) the OAE 1d, (2) the Albian–Cenomanian Boundary Event (ACBE) and (3) the Lower Cenomanian Event(s) (LCE) can be identified. Right above the LCE, a well developed unconformity has been observed that is succeeded by the common occurrence of rotaliporids and a major increase in inoceramid abundances. The chemostratigraphic age assignments are supported by bio- and event stratigraphic results: calcareous nannofossils indicate an extended CC9 zone up to the lowermost CC10 (UC0–UC3) as indicated by the FAD of *Microrhabdulus decoratus* at the top, ammonites of the topmost Albian *Arrhapoceras briacense* Zone occur between the B and C peaks of the ACBE, and the early Cenomanian *ultimus*/*Aucellina* and *crippsi* events have been identified at levels of the isotope curve that strictly correspond to their position elsewhere. The major sea-level fall in the latest Albian, resulting in a hiatus across the Albian–Cenomanian boundary interval in most basin margin section of NW Europe, is represented in the Anderten core by a correlative conformity at the base of the argillaceous Bemerode Member of the Herbram Formation that ranges into the lowermost Cenomanian. Due to the continuous, expanded record and integrated stratigraphic data set, the Anderten succession can be considered as a potential reference section for the Albian–Cenomanian transition in the Boreal Realm.

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Astronomical calibration of the Eocene-Oligocene transition from a 7-Myr-long lacustrine record in the Rennes basin (NW France)

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Geological records and climate modeling have demonstrated that lacustrine environments are sensitive areas to solar radiation change induced by Milankovitch orbital forcing, and that are potential sites to undertake astronomical calibration of the geological time scale. Here we present a ~7 millionyear long lacustrine record spanning the Late Eocene (uppermost Bartonian to Priabonian) to the earliest Oligocene (lower Rupelian) from a drill-core in the Rennes basin (NW France). High-resolution natural gamma-ray (GR) logging along this time interval shows a strong cyclic pattern, reflecting variations in clay contents driven by lake-level fluctuations.
We carried out an integrated cyclo-magnetostratigraphic study on the interval that faithfully captures magnetochrons C12r through C16n.1n. Time-series analysis of the GR data shows evidence for Milankovitch cycle bands (precession, obliquity and eccentricity). In particular, the 405 kyr eccentricity cyclicity is documented with the strongest amplitudes. Tuning the GR data to the 405 kyr stable periodicity, and then anchoring the 405 kyr tuned GR to the orbital eccentricity signal provide two optimal ages of 33.7 Ma and 34.1 Ma for the Eocene–Oligocene boundary. The 405-kyr-tuning permits to calibrate durations of magnetochrons, which could be potentially used in the next generation of geologic time scale.
Finally, two prominent changes in clay's composition were detected around the Eocene–Oligocene boundary. Correlation with deep-sea records indicates that these two changes were temporally equivalent to EOT-1 and Oi-1 glacial events. Accordingly, we suggest that these two major glacial events of the Eocene–Oligocene transition may have influenced lake-level via the hydrological cycle, and consequently the change in the clay's composition.

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Plankton response and restructuring at the Eocene/Oligocene transition

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Calcareous nannoplankton (coccolithophores) were the dominant phytoplankton group in the Paleogene yet during the environmental change of the ‘greenhouse to icehouse’ transition they underwent significant turnover and diversity loss from which they have arguably never fully recovered. The ‘greenhouse to icehouse’ transition culminated at the Eocene-Oligocene transition (EOT), a rapid cooling event when continental ice sheets formed on Antarctica, marking the initiation of the Cenozoic icehouse world. The EOT saw significant disruption to physical, chemical and biological parameters in the oceans, including elevated rates of extinction and turnover in plankton groups. Calcareous nannoplankton suffered diversity losses over a protracted period but display a closely spaced series of significant assemblage shifts around the EOT itself. Here we present new biotic data from the recently drilled IODP Site 1411 (NE Atlantic Ocean) and present compiled global records that highlight diversity change, species bioevents and major shifts in nannoplankton abundance patterns. These data reveal that striking reorganization within the dominant, reticulofenestrid, group was a particular feature of the interval, reflecting the significant oceanographic changes and indicating a shift to quite different plankton population structure in the Oligocene.

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Sea-Level Fluctuations Inferred by Microfaunal and Isotope Fluctuations in the Romanian Black Sea Shelf during the last 25,000 years

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During the Quaternary, the Black Sea experienced a series of sea level fluctuations driven by the global glaciations and deglaciations, which led to successive episodes of isolation followed by the re-connection with the Mediterranean. During low-stand periods, the entire Black Sea basin evolved as a giant lake, being isolated from the Mediterranean. During the late Pleistocene deglaciation, the connection between the Black Sea and Mediterranean via the Marmara Sea was re-established through the narrow Bosporus and Dardanelles Straits. In the sedimentary record this deglaciation accumulated allochthonous continentally derived red sediments, simultaneous with the global Heinrich Event 1, 18 to 15 kyr BP. This sediments are characterized by depleted $\delta^{18}O$ and Mn, increased Ti/Ca ratio as well as higher values of kaolinite and illite, probably indicating that their origin is from a more northern location (i.e., the Alps and the Fennoscandinavian Ice Sheet).
This study is focused on the fluctuations in composition and abundance of the ostracods encountered in a core collected from the Romanian Black Sea shelf area, integrated with AMS ^{14}C dating, oxygen and neodymium isotopes and $CaCO_3$ measurements. In the core, situated at 200 m water depth, two lithological units, respectively the youngest Unit 1 (Coccolith Mud) and the oldest Unit 3 (Lacustrine lutite), were identified, with the base dated 24.5 kyr BP. Since Unit 2 is missing, either the water depth was not enough to develop the sapropel facies or it was naturally eroded. In this core, based on the ostracods, two distinct assemblages were identified: (1) in Unit 3, a low salinity lacustrine fauna with a relatively high diversity and low abundance, mainly containing taxa that tolerate a salinity comprises between 3-8 ‰; (2) in Unit 1, a brackish ostracod assemblage, with low diversity and abundance. The ostracods of Unit 1 tolerate salinities comprised between 17-21 ‰, being related to a sub-littoral environment.
The ^{14}C dating was measured on juvenile valves of the molusk *Dreissena rostriformis* in the core intervals 159 and 59 cm and gave ^{14}C ages of 15,000 and 13,800 years, respectively (calibrated to 18,400 and 16,800 years). $\delta^{18}O$ isotopes of the surface water (derived from juvenile *Dreissena* shells) recorded values of -6.87 ‰ at the beggining of the deposition of the red layers and rises to values of -7.852 ‰ at the top. Hence, a sedimentation rate of 62.5 cm/1000 years can be assumed. This allows to assign calendar ages to the three intervals on which Nd isotopes were analyzed: 17,780, 17,100 and 16,800 calendar years (Yanchilina et al., in prep.).
Based on AMS ^{14}C dating, oxygen and neodymium isotopes, $CaCO_3$ measurements and qualitative and quantitative ostracod analysis of the core, the fluctuation pattern is interpreted in term of environmental changes.

Litho- and biostratigraphy of the Pliocene regional stages in the Dacian Basin (E Romania)

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The Dacian Basin refers to the area extending from the foreland of the Southern Carpathians (towards NW) up to the Eastern Carpathian bend region (towards E) and the present course of the Lower Danube (towards S), being almost entirely comprises on the Romanian territory. The above-mentioned regions were included within the Central Paratethys during the Early Miocene, while since the occurrence of new restricted basins in the Middle Miocene they become part of the Eastern Paratethys.

In the outer part of the Eastern Carpathians, i.e. their southern foreland, there are good exposures of the Upper Miocene and Pliocene successions. Specifically, in the area belonging to the Buzău Land Geopark, the stratotypes of two Pliocene regional stages of the Paratethys, the Dacian and the Romanian, are located. In terms of global stages, the Dacian and the Romanian cover almost the whole Pliocene (i.e., Zanclean, Piacenzian and Gelansian), except the lower Zanclean (Snell et al., 2006).

The depositional palaeosetting of the Dacian and Romanian stages is a brackish up to a fresh water one (Jipa and Olariu, 2013). Lithologically, the Dacian and Romanian successions are mainly made by clays and silts, containing thin cm up to dm lignitic levels and sands, more consistent towards the top of the Pliocene.

At the stratotype, in the Slănicul de Buzau Valley (included in the territory of the Buzău Land Geopark), the Dacian stage reaches a stratigraphical thickness of around 500 m. The base of the Dacian is marked by the occurrence of bivalve assemblages with *Pachydacna*, *Parapachydacna*, *Stylodacna* and *Zamphiridacna*. The lower part of the Dacian stage, i.e. the Getian substage, mainly contain species of the *Prosodacna*, *Stylodacna*, *Limnocardium*, *Phyllocardium*, *Viviparus*, *Pachydacna*, *Zamphiridacna*, *Dacicardium*, *Pseudocatillus* and *Dreissena* genera. The upper part of the Dacian stage, namely the Parscovian substage, is characterized by the presence of *Prosodacna haueri*, *Stylodacna heberti*, *Viviparus rumanus*, *Prosodacna (Psilodon) conversus*, *Limnodacna rumana*, *Dacicardium rumanum* and *Viviparus heberti*. The top of the Dacian, i.e. the Dacian/Romanian boundary, is pointed out by the dominance of unionids. Typical bivalve assemblages of the Romanian stage contain endemic macrofaunas, such as *Jazkoa sturdzae*, *Psilunio slanicensis, Prosodacnomya sturi* and *Viviparus bifarcinatus*.

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Integrated biostratigraphy and paleoenvironments of the Postalm section (Northern Calcareous Alps)

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A continuous late Santonian to Maastrichtian succession displaying marly limestone- marl alternations is recorded at the Postalm section (Northern Calcareous Alps). The implementation of a cyclostratigraphic model was followed by a high resolution assessment of foraminifera and nannoplankton communities of this interval (Wagreich et al., 2012). Over 300 samples were taken bed-by-bed aiming at high resolution investigation of the palaeoenvironmental changes in the Tethyan Late Cretaceous. Upon the examination of the planktonic foraminifera fauna at Postalm the following planktonic foraminifera suggest ages from the uppermost Santonian *Dicarinella asymetrica* Zone up to the late Campanian to Maastrichtian *Gansserina gansseri* Zone, or nannofossil zones CC17 to CC22. Variations in the composition of foraminifera communities, planktic as well as benthic, reflect several changes in palaeoenvironment throughout the Upper Cretaceous. A conspicuous event recorded from the lowermost part of the section is a distinct deepening around the Santonian-Campanian boundary. We follow the development from a comparatively shallow shelf environment yielding high percentage of benthic foraminifera, to a hemipelagic to pelagic setting displaying planktic/benthic foraminifera ratios of more than 95 percent. Furthermore, bivalves, sponges and echinoderms are highly abundant in the lower parts of the section and decrease in number up section.

Differences in the benthic foraminiferal communities reflect the changing palaeoenvironment. Epifaunal calcareous walled foraminifera are most abundant in shelf-samples while we witness a shift towards evenly distributed infaunal calcareous as well as in- and epifaunal agglutinating foraminifera in samples from hemipelagic and pelagic subsections.

As a consequence of the deepening of the section as well as increasing tectonic activity in the Penninic realm, frequent turbidite events are recorded towards the late Campanian and Maastrichtian parts of Postalm section.

Reconstructing palaeoenvironmental change inferred from variations in planktic and benthic foraminifera communities in respect to an established chronostratigraphic framework will give valuable insights into the course of events in the northwestern Tethyan Penninic realm in the Upper Cretaceous.

The importance of petrography and stable isotope stratigraphy of speleothems in the inference of Holocene climate changes at Cuevas de Fuentes de León, Extremadura, southwestern Iberian Peninsula

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Considering that speleothems growth in caves usually reflects external climatic conditions, a petrographic and stable isotope study of stalagmites from Los Postes cave was carried out. The cave is located in the Natural Monument "Cuevas de Fuentes de León", Spanish Extremadura, and the study's goal is to assess Holocene climate changes in this region.

The petrographic study shows that the stalagmites from Los Postes cave mainly consist of calcite, but small clasts of quartz, plagioclase, zircon, "terra rossa", limestone, iron oxides and hydroxides and clay minerals are also present. The stalagmites consist of different layers of textured calcite that are associated with different stable isotopic values and can be related with different climatic conditions. Layers with columnar open (Co)/columnar elongated (Ce) and columnar elongated with lateral overgrowth (Celo) textures tend to yield the lowest $\delta^{18}O$ and $\delta^{13}C$ values. These layers have the highest calcite content and are attributed to stalagmite growth during intervals of relatively slow but constant drip, inferred to reflect the regular occurrence of rain. In contrast, layers with columnar microcrystalline texture (Cm) are attributed to growth with seasonally variable drip rates, and the radial-acicular texture (Ar) reflects a large decrease in the drip rate. The Cm and Ar textures exhibit the highest $\delta^{18}O$ and $\delta^{13}C$ values. Finally, layers formed of aggregates of detrital materials, cemented with micrite have porous structures, are darker, and are related to low drip rates or even intervals of dryness. However, detrital elements are suggested to have entered the system through transport processes with more or less torrential character.

Generally, $\delta^{13}C$ and $\delta^{18}O$ values co-vary, but $\delta^{13}C$ exhibit a range from -10.31 ‰ to -2.73 ‰, whereas $\delta^{18}O$ ranges between -5.33 ‰ and -2.39‰. The interpretation of carbon and oxygen isotope fluctuations in a continuous sequence, formed by two stalagmites, show the occurrence of two dry and warm periods at ca. 5.3 ka BP and 2.6 ka BP, with $\delta^{18}O$ and $\delta^{13}C$ values higher than -5.47 ‰ and -3.72 ‰, respectively, which led to a rapid dominance of C_4 plants over C_3 plants. A more humid period occurs at ca. 4.1 ka BP, exhibiting the lowest $\delta^{13}C$ values (-10.31 ‰) recorded. Therefore, the 5.3 ka BP record can be related to the final stage of Holocene Thermal Maximum, whereas the short-lived 2.6 ka BP excursion (300 to 400 years) is probably related to the phase 3 of the Bond cycle. The low $\delta^{13}C$ values at 4.1 ka BP record points to an increase in the prevalence of C_3 plants, most likely related to the environmental changes caused by the 4.2 ka BP event.

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Paleoceanographic changes in the Lagonegro Basin (southern Italy) during the Late Triassic linked to oceanic rifting in the western Tethyan region

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The Lagonegro Basin was considered part of the southwestern branch of the western Tethys Ocean during the Late Triassic (Ciarapica and Passeri; 2002). The sedimentary environment was a deepening-upward basin, bordered to the north by a carbonate platform system (Apenninic and Apulian platforms). The Lagonegro succession is characterized by Permian to Miocene formations deposited in shallow to deep basinal environments. The Upper Triassic is comprised of deep-marine sediments belonging to the Calcari con Selce Fm (late Ladinian to late Norian - early Rhaetian) and the Scisti Silicei Fm (late Norian - early Rhaetian to Late Jurassic). Lithologically, the Calcari con Selce Fm. changes transitionally upward to the Scisti Silicei Fm through the “Transitional Interval” (Miconnet, 1983).

The sedimentary record of the Lagonegro Basin, reveals changes in watermass chemistry during the Late Triassic that were linked to hydrographic restriction possibly triggered by contemporaneous oceanic rifting. Sedimentologic and elemental geochemical analysis of three sections in the Southern Apennines (southern Italy) representing a proximal-to-distal transect across the basin (Pignola-Abriola, Monte Volturino and Madonna del Sirino sections) documented changes in redox conditions, surface productivity, and chemical weathering intensity. Redox proxies suggest predominantly suboxic conditions in the deep basin, and productivity proxies suggest moderate and relatively uniform productivity levels. A weathering proxy, the chemical index of alteration (CIA) (Young and Nesbit, 1998), shows an unambiguous shift toward higher values in all study sections, suggesting development of warmer and/or more humid conditions around the Norian/Rhaetian boundary. Two of the study sections record the “Transitional Interval” from the Calcari con Selce (“Cherty Limestone”) Formation to the Scisti Silicei (“Siliceous Shale”) Formation, a major lithologic change that was probably related to changing in the climate rather than to changes in surface-water productivity. Extremely low concentrations of SO_4^{2-}, U and Mo, which developed despite suboxic bottom water conditions, were due to a low TOC content as a consequence of strong water-column stratification within a silled basin. Paleoseismic activity, as evidenced by frequent debris flows on the basin margins (Passeri et al., 2005), may have been linked to the tectonic evolution of the Ionian Ocean, which was actively spreading during the Late Triassic (Ciarapica and Passeri, 2005).

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The Upper Triassic Monte Volturino section (Lagonegro Basin, Southern Italy): Evidence for felsic volcanic activity in the western Tethyan realm

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The Monte Volturino section of the Southern Apennines (southern Italy) belongs to the Lagonegro succession, which was characterized by accumulation of pelagic sediments of the Calcari con Selce ("Cherty Limestone") and Scisti Silicei ("Siliceous Shale") formations during the late Norian to early Rhaetian. The evolution of the Lagonegro Basin was connected with the opening of the Ionian Ocean, the southern branch of the Neotethys (Ciarapica and Passeri, 2005), and its sedimentary record reflects the interaction of tectonic and oceanic influences during a key interval in the early break-up of Pangea (Passeri et al., 2005).
The Monte Volturino section exposes the uppermost Calcari con Selce (comprising the "Transitional Interval") and lowermost Scisti Silicei formations and is considered an intermediate section in a proximal-to-distal basin transect (Giordano et al., 2011). The basal 4 m of this section contain red argillite beds that mark the base of the "Transitional Interval", followed by cherty limestones with red shale intercalations. Strata in the overlying Scisti Silicei become thinner, consisting mainly of shales and radiolarian cherts, and the youngest exposed strata at this site represent an alternation of black siliceous shales and silicified calcarenites that are rich in organic matter. This section accumulated mainly through pelagic and hemipelagic sedimentation, although the calcarenites in the upper part of the section were deposited as grain or turbidite flows (Giordano et al., 2011). These calcarenitic beds contain volcanic lithic fragments exhibiting a devitrified volcanic glass matrix and small (micron-size), euhedral albite phenocrysts. It is possible that these lithic fragments were deposited as volcanic ash. One plausible source for this volcanic material is the Afyon Zone on the northern margin of the Tauride Anatolide Block, along which rifting activity connected to the opening of the northern branch of the Neotethys occurred during the Late Triassic (Okay et al., 1996; Akay et al., 2011, 2012). The Late Triassic volcanism in this region was compositionally bimodal: dominantly felsic early eruptions were followed by less voluminous mafic activity. Geochemical analysis of the volcanic fragments in the Monte Volturino section yields a rhyolitic composition, suggesting a continental crustal provenance of the magma (Okay et al., 2011).

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Review of calcareous nannofossil events in the Late Tithonian-Early Berriasian time interval: implications for the definition of the base of the Cretaceous.

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Calcareous nannofossils have been proved to be a powerful biostratigraphic tool for dating and for interregional correlations of Jurassic to Recent marine sequences. The latest Jurassic-earliest Cretaceous time interval was crucial for calcareous nannoplankton that experienced a major speciation episode, with the appearance of new taxa that persisted through the rest of the Mesozoic. The dramatic change in calcareous nannofloras, becoming rapidly dominated by highly calcified nannoconids across the J/K boundary interval provides the opportunity to achieve high-resolution biostratigraphic data, amplifying the possibility of dating and correlating.

We collected new data and critically revised published nannofossil biostratigraphies for the Tithonian-Berriasian interval to evaluate reproducibility and variability of individual biohorizons with the aim of determining primary, secondary and local events. We estimated the age of nannofossil events relative to magnetostratigraphy, calpionellid and ammonite zonations in the interval spanning magnetochrons (CM) CM20 to CM17. Our work intends to contribute to the Berriasian Working Group effort aimed at the improvement of a self-reinforcing stratigraphic matrix useful for the future choice of the GSSP of the base of the Cretaceous.

Our database comprises sites from different paleogeographic settings (Europe, America, Atlantic Ocean). We critically evaluated sampling rates, nannofossil preservation and abundance, and taxonomy applied by individual specialists. We privileged calibrations against magnetostratigraphy to highlight reproducibility of single nannofossil events against magnetochrons, and more specifically their time variability within CM19 and CM18. We also evaluated nannofossil events relative to ammonite and calpionellid biostratigraphies.

The main results of our critical revision, point out a sequence of several first occurrences (FO) and that some nannofossil events are more reproducible and reliable than others. We confirm the nannofossil potential as a stratigraphic tool for high-resolution dating and long-ranging correlations, a tool able to overcome paleoprovincialism often shown by ammonites.

The majority of the events characterizing the J/K boundary interval are the FOs of some *Nannoconus* species, specifically: *N. globulus minor* and *N. erbae* correlating with the topmost part of CM20N and lowermost part of CM19R, respectively. The FOs of *N. globulus globulus* and *N. wintereri* correlate with the middle part of CM19N, and the FOs of *N. steinmannii minor* and *N. kamptneri minor* correlate with the lowermost part of CM18R. Other events in the J/K boundary interval include the FOs of *Rhagodiscus asper*, *Cretarhabdus surirellus*, *Cruciellipsis cuvillieri*, *Hexalithus geometricus*, and *Cretarhabdus octofenestratus*.

The appearance and diversification of nannoconids are accompanied by a major increase in their total abundance. Consequently, the J/K boundary interval is also characterized by distinctive changes in "nannofacies" that are reproducible in the Tethys and Atlantic Oceans. Such assemblage changes further corroborate the nannofossil biostratigraphic characterization of the J/K boundary interval and might be used as additional marker levels.

Based on new and literature data, we propose the FO of *N. steinmannii minor* as the most robust and globally recognized event close to the J/K boundary, as documented in all available nannofossil biozonations of the past four decades. This bioevent correlates with the basal portion of CM18R.

If ammonite or calpionellid biohorizons are taken to define the base of the Cretaceous, the FOs of *N. globulus globulus, H. geometricus*, *N. wintereri* and *C. cuvillieri* approximate the base of both the *Calpionella* (B) Zone and ammonite *jacobi-grandis* Zone in the middle part of CM19N.

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Stratigraphy and paleoenvironments of the Upper Pleistocene deposits in North Tunisia

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The deposits of the Upper Pleistocene in North Tunisia show significant variations in facies, thickness and faunal assemblages. Field investigation, detailed facies analyses and faunal content in six sections along a transect of 20 km bordering the present coastline from Rafraf to Cap Zebib, allow to specify the temporal and spatial succession of the Pleistocene paleoenvironments varying between coastal dunes to marine inner platform. These variations are mainly due to the inherited geomorphology, environmental distribution and sea level fluctuations. Especially in the Rafraf region, an important sandy marine feature including scattered buildups of *Vermetus triquetrus* associated with a Senegalian fauna including the biomarker *Persististrombus latus* is identified for the first time at 14 m altitude on Rafraf beach. This deposit is substitued towards the east by sandy dunal deposits rich in helicids. Locally this single marine deposit, rich in *Persististrombus latus*, records neotectonic features which produce steps outcropping at diverse altitudes and vary between 1 m and 14 m above the present sea level.

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Recovery pattern of brachiopods after the Permian-Triassic crisis in South China

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In South China, the Changhsingian brachiopods are extraordinarily abundant and diverse, comprising 468 species in 144 genera. However, approximately 91% of brachiopod species were eliminated during the Permian-Triassic (P-Tr) mass extinction event. Brachiopods in the aftermath of the P-Tr mass extinction were extremely rare, with only one disaster taxon, *Lingula*, occasionally found in the Griesbachian and Smithian at a high abundance. Species-diversity of articulated brachiopods in the early Griesbachian, late Griesbachian, Dienerian, and Smithian are 35, 2, 2, and 1, respectively. Although a number of Mesozoic-type species occurred in the Griesbachian, Dienerian and Smithian, a marked diversification of brachiopods occurred in the Spathian and early Anisian and was characterised by 9 and 17 Mesozoic-type species, respectively. The two-phase diversification of brachiopods coincides with the two explanations of the refuge zone, suggesting that the improvement of marine environmental conditions (e.g., lethally hot temperature and anoxic seawater) played a key role in brachiopod recovery after the P-Tr mass extinction.

A unique Early Triassic conodont sequence from Idrija–Žiri area, Slovenia and its implications for conodont paleoecology

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The first recovery of the conodont *H. parvus* from Žiri area a few years ago highlights this area for Early Triassic biostratigraphic study. Systematic sampling of five sections in Idrija–Žiri area has resulted in the discovery of new species: *Platyvillosus corniger* sp. nov. and *Neospathodus planus* sp. nov. Based on these new species and other conodont elements obtained from these sections, a unique conodont sequence is proposed for this area. It composes of nine conodont zones that span from uppermost Dienerian (upper Induan) to lower Spathian (lower Olenekian). In ascending order they are: *Eurygnathodus costatus* Z., *Neospathodus planus* Z., *Neospathodus robustus* Z., *Foliella gardenae-Pachycladina obliqua* A. Z., *Platyvillosus corniger* Z., *Platyvillosus regularis* Z., *Triassospathodus hungaricus* Z., *Triassospathodus symmetricus* Z., *Neospathodus robustispinus* Z. This conodont sequence is valuable for stratigraphic correlation within Central and South Europe, and it also promotes a better correlation between western and middle-eastern Tethys. A global comparison with conodonts indicates that the unique conodont sequence in the Idrija–Žiri area seems to have been more controlled by the ecological parameters of the epeiric ramp than by potential migration barriers.

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Complete biotic and sedimentary records of the Permian-Triassic transition from Meishan section, South China: ecologically assessing mass extinction and its aftermath

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The Meishan section, South China is the Global Stratotype Section and Point (GSSP) for the Permian-Triassic boundary (PTB), and also is well known for the best record demonstrating the Permian-Triassic mass extinction (PTME) all over the world. This section has also been studied using multidisciplinary approaches to reveal the possible causes for the greatest Phanerozoic biocrisis of life on Earth; many important scenarios interpreting the great dying have been proposed on the basis of data from Meishan. Nevertheless, debates on biotic extinction patterns and possible killers still continue. This paper reviews all fossil and sedimentary records from the Permo-Triassic (P-Tr) transition, based on previously published data and our newly obtained data from Meishan, and assesses ecologically the PTME and its aftermath to determine the biotic response to climatic and environmental extremes associated with the biocrisis. Eight updated conodont zones: *C. yini, C. meishanensis*, *H. changxingensis*, *C. taylorae*, *H. parvus*, *I. staeschei*, *I. isarcica*, and *C. planate* Zones are proposed for the PTB beds at Meishan. Major turnover in fossil fragment contents and ichnodiversity occurs across the boundary between Bed 24e-5 and Bed 24e-6, suggesting an extinction horizon in thin section. The irregular surface in the middle of Bed 27 is re-interpreted as a firmground of *Glossifungites* ichnofacies rather than the previously proposed submarine dissolution surface or hardground surface. Both fossil fragment contents and ichnodiversity underwent dramatic declines in Beds 25–26a, coinciding with metazoan mass extinction. Fossil fragment content, ichnodiversity and all ichnofabric proxies (including burrow size, tiering level, bioturbation level) indicate that the P-Tr ecologic crisis comprises two discrete stages, coinciding with the first and second phases of the PTME in Meishan. Ecologic crisis lagged behind biodiversity decline during the PTME. Pyrite framboid size variations suggest that depositional redox condition was anoxic to euxinic in the latest Changhsingian, became euxinic in Beds 25–26a, turned dysoxic in Bed 27, then varied from euxinic to anoxic through most of the Griesbachian. The ~9 °C increase in seawater surface temperature from Bed 24e to Bed 27 at Meishan seems to result in dramatic declines in biodiversity and fossil fragment contents in Beds 25–26a, but had little effect on all ecologic proxies. Both metazoans and infauna seem not to be affected by the pre-extinction anoxic-euxinic condition. The anoxic event associated with the PTME may have occurred in a much shorter period than previously thought and is only recorded in Beds 25–26a at Meishan. Fossil fragment contents, ichnofaunas, ichnofabrics and pyrite framboid size all show that no signs of oceanic acidification and anoxia existed in Bed 27. The early Griesbachian anoxia may have resulted in rarity of ichnofauna and metazoans in the lower Yinkeng Formation, in which the ichnofauna is characterized by small, simple horizontal burrows of *Planolites*, and metazoan faunas are characterized by low diversity, high abundance, opportunist-dominated communities. The rapid increase of ~9 °C in sea-surface temperature and a short anoxia or acidification coincided with the first-pulse biocrisis, while a prolonged and widespread anoxia probably due to a long period of high seawater temperate condition may be crucial in morality of most organisms in the second-pulse PTME. Marine ecosystems started to recover, coupled with environmental amelioration, in the late Griesbachian.

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Paleogene - Neogene Boundary transition in Bucovina, northern Romania

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The present study synthesizes our investigations from the last years in Bucovina, especially concerning the content of calcareous nannofossils.
Four sections are compared concerning the calcareous nannoplankton, for the Paleogene – Neogene Boundary transition, in northern Romania, in Bucovina, from Dumbravnic Valley, Lupoaia Valley (Moldovita), Loba Valley (Rasca) and Boului Valley (Paltin).
The Oligocene/Miocene boundary has been recognized in the northern part of the Tarcau Nappe, in the Vinetisu Formation, which represents the last term of the Moldovita Lithofacies (consisting of sandstones and clays, 100 – 120 m thick). The calcareous sandstones are disposed in beds with thicknesses of 30 – 40 cm.
On the **Dumbravnic** Valley, near Moldovita locality, in the first part of the section, the most frequent species are representative for the Oligocene: NP21–22: *Reticulofenestra umbilica, Lanternitus minutus, Coccolithus formosus, Cyclicargolithus floridanus* and NP23–24: *Helicosphaera ethologa*, a.o. In the second part of the section the calcareous nannofossils assemblages contain species that are present at the Oligocene/Miocene boundary, which are frequent also in the Lower Miocene: *Helicosphaera scissura* (NP24 – NN4), *H. recta* (NP24 – NN4), *Discoaster deflandrei* (NP11 – NN7), *Sphenolithus moriformis* (NP12 – NN9), a.o.; also Paleogene species are present. Thus, the presence of the Paleogene/Neogene boundary could be documented in the section from the Dumbravnic Valley.
In the lower part of the **Lupoaia** Valley section, near Vatra Moldoviţei locality, calcareous nannofossils are rare. The Oligocene – Miocene boundary could be located in the first part of the section. The calcareous nannoplankton assemblages across the boundary contain: *Coccolithus pelagicus, C.* cf. *eopelagicus, Helicosphaera scissura, H. recta, Cyclicargolithus floridanus, Reticulofenestra dictyoda, Triquetrorhabdulus* cf. *carinatus*, and in the upper part of the section also *Helicosphaera ampliaperta* appear. Samples in the upper part of the section contain only scarce calcareous nannofossils: *Coccolithus pelagicus* and rare reticulofenestrids and sphenoliths.
In the first part of the investigated section of **Loba** Valley, the nannofossil assemblages are rich in Upper Oligocene forms: reticulofenestrids, sphenoliths, *Zygrablithus bijugatus*, a.o. The presence of *Sphenolithus conicus* (NP23-NN2) has been recognized in the upper part of the section, besides *Helicosphaera scissura, Coccolithus pelagicus, Reticulofenestra* spp., etc., which prove the presence of Lower Miocene.
The analized section from Boului Valley at **Paltin** proved the presence of abundant calcareous nannofossil assemblages belonging to the Lower Miocene. The presence of *Triquetrorhabdulus carinatus* suggests the NN1 Biozone (Lower Miocene) while the helicospheres (*Helicosphaera* cf. *compacta*, *H. recta, H. scissura, H. carteri, H. ampliaperta*) are characteristic for NN2 - NN4 zones.
The most representative of these sections for the Paleogene-Neogene Boundary transition is Dumbravnic section, which was also the most detailed analysed.

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Biostratigraphic and chemostratigraphic data from Ediacaran sections in South China: implication for subdivision and global correlation of the Ediacaran System

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Intensive investigations on Ediacaran sections in South China have greatly advanced our understanding of the evolution of multicellular life and the atemospheric-oceanic system during the Ediacaran Period. Particularly, the well-established carbon isotope profile and rich acritarch microfossils from the composite carbonate and shale successions of the Yangtze Gorges area provide potential for the chronostratigraphic subdivision and global correlation of the Ediacaran System. The δ^{13} C profile in most studied Doushantuo sections in the Yangtze Gorges area appears a similar of three positive and three negative excursions. First, a negative δ^{13}C excursion appears in the cap carbonate at the base of the Doushantuo Formation (EN1, with δ^{13}C values from -0.1‰ to -5‰). Second, a positive δ^{13}C excursion occurs in the lower part of the Member of the Doushantuo Formation (EP1, wich δ^{13}C values from 0.3‰ to 7.5‰). Third, a negative δ^{13}C excursion occurs in the upper part of the Member II (EN2, wich δ^{13}C values from -1.1‰ to -6.5‰). Fourth, a positive δ^{13}C excursion occurs in the lower and middle part of the Member II (EP2, wich δ^{13}C values from 0.3‰ to 7.5‰). Fifth, a negative δ^{13}C excursion occurs from the upper part of Member III to the basal part of the Dengying Formation (EN3 wich δ^{13}C values from -0.4‰ to -10.3‰). Then, a positive δ^{13}C excursion occurs in lower part of the Dengying Formation with δ^{13}C values from 0.7‰ to 1.7‰. The distribution of acanthomorphic acritarchs from studied Doushantuo sections in the Yangtze Gorges area confirms that the Doushantuo Formation includes two distinct assemblages of acanthomorphic acritarchs. The lower assemblage occurs in the stratigraphic interval corresponding the first δ^{13}C positive excursion (EP1) and it is dominated by representative taxon *Tianzhushania spinosa*. The upper assemblage appears in the stratigraphic interval corresponding the second δ^{13}C positive excursion (EP2) and these two assemblages are separated by a distincte negative δ^{13}C excursion (EN2). The upper assemblage is dominated by *Hocosphaeridium scaberfacium – Hocosphaeridium anozos* (=*Tanarium conoideum*, *Tanarium anozos*, Liu et al., 2013). Based on bio- and chemostratigraphy combined with intra- and interbasinal correlation, these stratigraphic markers can be used to suddivide the Ediacaran System in South China into two Series and four Stages. The lower Series includes the Jiulongwanian and Chenjiayuanzian Stages and the upper Series includes the Diaoyapoan and Dengyingxian Stages in ascending order. The chronostratigraphic boundary of the lower and upper Series was proposed to use the nadir of the negative δ^{13}C excursion EN3 (DOUCE). In a word, using biostratigraphic and δ^{13}C chemostratigraphic data and U-Pb zircon ages as a basis, the suddivision of the Ediacaran System in the Yangtze Gorges area, South China provide potential for the chronostratigraphic subdivision and global correlation of the Ediacaran System.

Towards quantifying the spatiotemporal variations in the composition and geometry of the Permian Whitehill Formation, main Karoo Basin, South Africa

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The Permian Whitehill Formation of the main Karoo Basin of South Africa has attracted attention from geologists since the late 1940s. More recently, renewed interest in this organic-rich rock unit is due to its perceived shale gas potential. The Formation is dominated by black carbonaceous shales (average 4.5% total organic carbon) with intermittent chert lenses and some pyritic stringers along the western and southern portion of the main Karoo Basin. However, this distinctive lithological character diminishes towards northeast where the lower Whitehill Formation contains siltstones and very fine-grained sandstones. Furthermore, changes in body and trace fossil assemblages of the Whitehill Formation are well-documented. While the latter permitted the biostratigraphic subdivision of the unit, the spatiotemporal variations in the internal composition and geometry of the Whitehill Formation across the main Karoo Basin are largely unquantified and unexplained.

The approach taken in this current study is to systemically document these lithostratigraphic changes within the Whitehill Formation via outcrop based facies analysis as well as geochemical mapping/profiling of its mineralogy and organic content on a basinal scale. By testing the link between these changes and the documented shifts in tectonic and climatic conditions during the Permian in the main Karoo Basin, this ongoing study aims to untangle the strongly interrelated controls on the sedimentation of the Whitehill Formation (e.g., source area composition, transportation paths, the dynamics of the physico-chemical depositional processes, including fluctuations in oxygen and salinity levels). The outcomes of the study ought to refine the reconstruction of the Early Permian palaeo-environments and regional correlations in SW Gondwana as well as provide a proxy for the original distribution of the organic matter in the Whitehill sediments both through time and space.

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Ocean Acidification at the Permo-Triassic Mass Extinction. Clues from the Arabian Platform

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Ocean acidification triggered by Siberian Trap volcanism is considered as possible kill mechanism for the Permian Triassic Boundary (PTB) mass extinction, but direct evidence for an acidification event is lacking. We present a high resolution seawater pH record across this interval, utilizing boron isotope data (delta^{11}B) combined with petrographic analysis and quantitative modeling approach. We analyzed boron and carbon isotope data from two complementary transects in a shallow marine, open water carbonate succession from the Musandam Peninsula (United Arab Emirates, U.A.E.), where depositional facies and delta $^{13}C_{carb}$ are well constrained. During the PTB interval the U.A.E were part of the Arabian Platform, an expansive carbonate platform that remained connected to the central Neo-Tethyan Ocean. Conodont and the distinct delta $^{13}C_{carb}$ curve constrain the stratigraphy.

Through the integration of geochemical and petrographical data and quantitative modeling, we are able to produce an envelope that encompasses the most realistic range in pH, which then allows us to resolve three distinct chronological phases of carbon cycle perturbation, each with very different environmental consequences for the Late Permian-Early Triassic Earth system. In the latest Permian, increased ocean alkalinity, primed the Earth system with a low level of atmospheric CO_2 and a high ocean buffering capacity. The first phase of extinction was coincident with a slow injection of carbon into the atmosphere and ocean pH remained stable. During the second extinction pulse, however, a rapid and large injection of carbon caused an abrupt acidification event that drove the preferential loss of heavily calcified marine biota.

The boron signal cuts across primary lithological boundaries, including micritic carbonates, grainstones, and intervals with calcispheres. Delta ^{11}B trends are therefore both facies and fabric independent but the short-lived acidification event is manifest in a loss of any biotic component, and unusual and anomalous carbonate precipitates may indicate profound carbon cycle disruption.

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Integrated stratigraphy of the middle–upper Bottaccione pelagic sequence in the Umbria-Marche basin (northeastern Apennines, Italy): A potential candidate for defining the Global Stratotype Section and Point (GSSP) for the Lutetian–Bartonian boundary

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Here we present the results of an integrated, high–resolution study of the Lutetian-Priabonian Bottaccione (BTT) section that belongs to the pelagic succession of the Umbria–Marche Apennines (central Italy). The section is located near the town of Gubbio and includes a complete and continuous sequence of marly limestones, calcareous marls and marls rich in well–preserved planktonic foraminifera, calcareous nannofossils and dinoflagellate cysts with several intercalations of biotite–rich volcaniclastic layers. In order to further check the stratigraphic completeness of the section and constrain in time the critical interval for defining the Bartonian Stage, we performed a high–resolution and detailed magneto–, bio–, and chemostratigraphic study of the BTT section, which accurately records calcareous plankton and dinoflagellate cyst biozones, magnetic reversals and environmental magnetism, and carbon and oxygen isotopic variations. We also carried out an astrochronologic calibration of the BTT section based on orbital tuning of high-resolution magnetic susceptibility data series. In addition, geochronologic results from the intercalated volcaniclastic layers might provide the means for an accurate and a precise radiometric calibration of the middle Eocene Epoch, and a reassessment of the accuracy of existing geochronologic time scales. This section bears all the stratigraphic and geochronologic attributes for driving the 'golden spike', which defines the Lutetian–Bartonian boundary according to the International Union of Geological Sciences recommendations. Therefore, the BTT section is a potential candidate for defining the GSSP of the middle Eocene Bartonian Stage.

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Thirty years of Integrated Stratigraphy in the Umbria-Marche Apennines (central Italy)

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This contribution aims to highlight the application of Integrated Stratigraphy in the Umbria-Marche (U–M) Apennines of central Italy, which has resulted from our continual involvement in the geological research of this area for the last thirty years within the framework of cooperative international research projects as a key tool for the study of the U–M Lower Cretaceous to Miocene pelagic sedimentary successions. The features of this essentially continuous and complete succession make it an unique venue for documenting the geologic history of Earth through the application of a multi–disciplinary approach, which is valuable not only to sedimentologists, paleontologists, and paleoclimatologists, but is also useful to more specialized biostratigraphers, magnetostratigraphers, chemostratigraphers as well as geo– and astrochronologists who address their effort to reach an ever improving global chronostratigraphy. Our use of Integrated Stratigraphy has followed broad purposes, such as: identification of potentially useful sections for the definition of chronostratigraphic units, forward recommendations on the choice of particularly interesting sections and points for the refinement of the chronostratigraphic time scale (GSSP: Global Boundary Stratotype Section and Point), detailed reconstruction of the tectono–sedimentary evolution of the U–M basin, and paleoenvironmental, paleoclimatic, paleogeographic and paleoceanographic reconstructions. As stratigraphic methods improved in both precision (resolution) and accuracy, the integrating of various component aspects of stratigraphy has resulted in major improvements in our understanding of the nature, sequence, and chronology of events in Earth history, and in placing Earth history in a truly historical context.

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Stratigraphic architecture and biostratigraphic constraints of the Bolognano Formation (Majella, Central Apennines).

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The Oligo-Miocene shallow-water succession outcropping in the Majella Mountain represents a case study for analyzing the sedimentary product from different global e regional events that characterized this time interval, providing that a well-constrained stratigraphic frame is available. With this intent we analyzed a succession belonging to the Bolognano Formation (Oligocene-Messinian) that represents a homoclinal carbonate ramp dominated by heterozoan skeletal assemblages. Eight stratigraphic sections, spanning from the Orfento Valley to the Lettomanoppello area (PE), in the North-eastern sector of the Majella Mountain, have been investigated to reconstruct the stratigraphic architecture. The Bolognano Formation includes seven different units, with shallow-water carbonates alternating marly hemipelagic carbonates. The basal unit is the "*Lepidocyclina* Limestone I" that comprises cross-bedded calcarenites, 20 to 50 m thick, dominated by larger benthic foraminifera tests, bryozoans, red algae, mollusks and subordinated planktonic foraminifera. It represents a wide dune field developed in a gently inclined middle ramp environment, within the oligophotic zone, where the downslope migrating dunes inter-finger with bioturbated, horizontally bedded deposits. Benedetti *et al*. (2010) ascribe this unit to the SBZ22A (Chauzac & Poignant, 1997), Rupelian in age, for the presence of *Nephrolepidina praemarginata*. The "*Lepidocyclina* Limestone I" is overlain by a marly limestone unit characterized by widespread cherty nodules, the "Cerratina Cherty Limestones", 8 to 25 m in thickness. Calcareous nannofossil content of this unit has been analyzed for obtaining stratigraphic constraints. A nannofossil assemblage with *Sphenolithus delphix* (top of Zone CNO6 of Agnini et al., 2014) was observed in scattered samples from the lower part of the unit, while the assemblage observed in the upper part indicates an undifferentiated interval from Zone CNM1 to CNM3. This biostratigraphy places the unit "Cerratina Cherty Limestones" in the upper Chattian-Aquitanian p.p. interval (between ~ 23.4 and ~20.9 Ma). Above this marly interval another cross-bedded limestone unit occurs, "the *Lepidocyclina* Limestone II", that shows the same compositional and sedimentologic features of the basal one, but different thickness (from 2 up to 50 m). A hardground surface marks the end of the deposition of the "*Lepidocyclina* Limestone II", which is overlain by a cross-bedded calcarenitic unit dominated by bryozoans in the Orfento Valley, and by hemipelagic planktonic-rich marls (the "*Orbulina* Marls") in the North-eastern sector. Both the "Bryozoan Limestones" and the "*Orbulina* Marls" are wedge-shaped units. Nannofossil assemblages with *Sphenolithus heteromorphus* were observed throughout the "*Orbulina* Marls" unit, indicating zones CNM6 and CNM7 p.p. that correspond to the upper Burdigalian-Langhian p.p. interval, from ~17.7 Ma to ~15 Ma in age. This result constrains the "*Lepidocyclina* Limestone II" to the upper Aquitanian-Burdigalian p.p. interval. The top of the "*Orbulina* Marls" is ascribed to uppermost Langhian-base of the Serravallian by Carnevale *et al*. (2011) and to the lower Tortonian by Merola (2007). The last shallow water unit, the "*Lithothamnium* Limestone", lies unconformably on the *Orbulina* Marls and comprises up to 30 m of limestones to marly limestones, characterized by abundant red algae nodules. This unit represents the Tortonian-early Messinian transgression identified over the entire Apulia Platform (Patacca et al., 2013). The topmost unit of the Bolognano Formation comprises, again, hemipelagic marls, the "*Turborotalia multiloba* Marls" that, according to Merola (2007), are representative of the lower Messinian.

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Review of conodonts across the Devonian/Carboniferous boundary: implication for the redefinition of the boundary and a proposal for an updated conodont zonation

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The Devonian/Carboniferous boundary definition is under revision because of problems recognized in the last few years in regard to the index taxon and the type section. The distribution of conodont species of *Bispathodus*, *Branmehla*, *Palmatolepis*, *Polygnathus*, *Protognathodus*, *Pseudopolygnathus,* and *Siphonodella* have been investigated in order to evaluate their stratigraphic potential for the redefinition of the Devonian/Carboniferous boundary and a revised biozonation of the uppermost Famennian and lowermost Tournaisian.

For the definition of the boundary it is necessary to find criteria that guarantee stability in the future, and do not significantly change the present stratigraphic position. Only a few conodont species first appear close to the present boundary and most of these do not have the characteristics of a stratigraphic index taxon, since all are quite rare. Only the FAD of *Protognathodus kockeli* and the FAD *Siphonodella bransoni* (= *S. duplicata* M1) can be considered as conodont markers, although both these possible positions for the DCB boundary have advantages and problems.

We propose an updated biozonation scheme across the boundary based on the FADs of *Bispathodus ac. aculeatus*, *Bispathodus costatus*, *Bispathodus ultimus*, *Protognathodus kockeli*, *Siphonodella bransoni* and *Siphonodella duplicata*.

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Lithostratigraphy of the Pre-Variscan sequence of the Carnic Alps (Austria-Italy)

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The pre-Variscan sequence of the Carnic Alps is one of the most complete and better known in the world. Several workers investigated the area since the XIX century and produced a huge amount of papers dealing with different topics in geological sciences (geology, palaeontology, stratigraphy, structural geology, etc.).
However, the different parts of this sequence were mainly denominated with informal names, that derivate either from facies or historical terms. Furthermore, being the region across the state border between Italy and Austria, different terminologies have been adopted on both sides of the mountain chain, which result in different subdivisions of the sequence and a high number of names indicating similar -if not the same- lithological units. Also, in a few cases, the same name was used to indicate different units. Moreover, almost none of these units was formalized according to the ICS rules.

A joint research project was carried on the last seven years: more than forty researchers from various European countries, mainly from Austria and Italy, were involved in four business meetings, three field workshops, and the (re)study of a huge amount of old and new data, in order to achieve a common but unified terminology.
As result the pre-Variscan sequence of the Carnic Alps is now subdivided in 36 formations, lithologically well characterized, with well-defined boundaries and designated stratotypes.
A volume on the revised lithostratigraphy will be published by the Geological Survey of Austria. It includes a rough characterization of each formation with illustrations of the type section, formation boundaries and typical macrofacies.

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Large benthic foraminifers as proxies of bathymetric changes in the middle to late Eocene Dinaric Foreland Basin (northern Dalmatia, Croatia)

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This combined micropalaeontological and sedimentological study is based on the middle to late Eocene deposits in the Novigrad sub-basin, one of several SE-trending narrow synclinal troughs within the evolving thrust wedge-top Dinaric foreland basin of northern Dalmatia. Deposits of the sub-basin SW limb indicate repetitive clastic and carbonate-ramp sedimentation, apparently driven by the emergence and submergence phases of the trough-bounding blind-thrust growth anticline. Phases of clastic sedimentation involved progradation of a wave-dominated gravelly shoreline (foreshore) facies over a sandy shoreface covering heterolithic sand-mud offshore transition and muddy offshore deposits. The offshore-transition and offshore deposits are commonly intercalated with foreshore-derived, gravelly debris-flow and slump deposits indicating pulses of gravitational resedimentation, probably triggered by an excessive uplift and/or normal faulting of the anticline flank. Phases of biogenic carbonate sedimentation, attributed to the anticline submergence, were dominated by the accumulation of large benthic foraminifers (nummulitids, operculinids, orthophragminids, aborescent foraminiferids, asterigerinids, rhapydionids and alveolinids) and their fragmented tests along with bryozoans, echinoids, corals and red-algae debris.

The composition of foraminifer assemblages, their detailed systematic and functional morphologic analysis, the preservation degree of their tests (varying from poor to good, including micritization and overgrowth by either foraminifers or algae) and the abundance of certain morphotypes (limestones, mostly wackestones and packstones, with a matrix composed of fine bioclastic hash) are thought to indicate a carbonate ramp depositional setting. The carbonate depositional system probably comprised an array of nummulite banks formed close to the fair-weather wave base, possibly with inner ramp lagoons and an open-marine middle/outer ramp zone. The foraminifers indicate a Priabonian age of the carbonate deposits in the Novigrad sub-basin, which highlights the high frequency of carbonate/clastic environmental changes. The demise of large benthic foraminifers in each carbonate unit seems to be a result of the environment shift from low-nutrient oligotrophic and euphotic conditions – favourable for shallow-water benthic foraminifera – to increasingly eutrophic conditions due to the increase of erosion and input of terrigenous nutrient associated with a relative sea-level fall. The carbonate units on the synclinal sub-basin flank are thus interpreted to be transient carbonate ramps developed during short-term relative sea-level rises and terminated by relative sea-level falls. The short-term changes between clastic and carbonate sedimentation on the sub-basin flank may be due to a combination of the 4th-order (Milankovitch) eustatic cycles and the tectonic pulses of structural evolution of the wedge-top foreland basin.

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A place for *Nummulites ptukhiani*? A new lineage of reticulate *Nummulites* from Kilwa District, Tanzania

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Reticulate *Nummulites* are a widespread and distinctive group of *Nummulites*, frequently used in biostratigraphy, but their evolution is poorly understood. Studies from the Western Tethys suggest they form a single lineage, the *Nummulites fabiani* lineage, with an increasing proloculus size over time. This has led to their use as one of the diagnostic taxa for larger benthic foraminiferal biostratigraphy. However, outside of this region additional taxa have been recorded. The most widely discussed example is *Nummulites ptukhiani,* which was described from Armenia, whose morphology does not fit with the *N. fabiani* lineage. This raises the question whether reticulate *Nummulites* are monophyletic, or the result of multiple independent convergent evolutionary lineages. Here we present data from three newly identified populations of Lutetian to Bartonian reticulate *Nummulites* from the stratigraphically well-constrained Tanzania Drilling Project records, which shed new light on the ancestry of these aberrant forms. These populations are characterized by extremely large proloculi and unusual morphology. We demonstrate that the populations are consistent with an evolutionary lineage that is morphologically distinct but contemporaneous with the *N. fabiani* lineage of the Tethys. These forms are remarkably similar in external and internal morphology to the Armenian *Nummulites ptukhiani.* We therefore refer to them as the *N. ptukhiani* lineage. The existence of a second lineage of reticulate *Nummulites* indicates that their evolution is more complex than previously thought and raises questions as to whether they evolved from a common ancestor, or independently. It also underlines the importance of carrying out thorough studies of larger benthic foraminifera with independent stratigraphic control from outside of the Tethyan region to more fully understand their evolution and to enable accurate biostratigraphy.

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Integrated stratigraphy of the Bartonian-Priabonian Urtsadzor section, Armenia

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The uppermost Bartonian to lowermost Priabonian transition is associated with several rapid extinctions across microfossil groups. However, the marker for the Bartonian-Priabonian boundary is not formally defined and currently under discussion. The planktonic foraminifera *Acarinina* and *Morozovelloides* suffer a rapid global extinction and calcareous nannofossils show several assemblage changes including the last occurrences of *Sphenolithus obtusus* and *Chiasmolithus grandis*, the acme of *Cribrocentrum erbae* and first occurrences of *Chiasmolithus oamaruensis, Isthmolithus recurvus* and *Cribrocentrum isabellae* around this interval. Within the shallow water, larger foraminifera also show an extinction of the large species of the genus *Nummulites*, as well as the first occurrences of important genera, such as *Spiroclypeus* and *Pellatispira* the upper middle Eocene. However, the exact correlation between shallow and deep water records remains uncertain, as do the mechanisms driving these extinction events.

Here we present the first results of a new integrated stratigraphical study (calcareous nannofossils, planktonic foraminifera, larger benthic foraminifera, and magnetostratigraphy) of the Urtsadzor section in south-western Armenia which appears to be continuous through this interval. The Urtsadzor section consists of marlstones rich in micro- and nannofossils, with interbedded limestones containing abundant larger foraminifera. Our new data enable us to correlate larger foraminiferal events with global planktonic biostratigraphy, in a section outside of southwest Europe where most previous correlations have been based. At Urtsadzor, the large *Nummulites* species *N. millecaput,* appear to decrease in abundance toward the top of the section. The first occurrence of *Spiroclypeus* occurs in the uppermost limestone bed. These larger foraminiferal events occur well above the planktonic foraminiferal extinction level and nannofossil assemblage changes indicating the event is not synchronous across all groups, and has important implications for biostratigraphy.

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Aims and results of correlating Mesozoic lithostratigraphic units between the Alps and the Pannonian Basin

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In the Alpine–Carpathian and Balkan area at the very beginning of the geological activity it was clear that the Mesozoic successions have many similar characters. The intensive research in the Eastern Alps preceded the rest of the area and several names (Dachstein Limestone, Hauptdolomite, Werfener Schichten, Pötschenkalk, Hallstätter Kalk, Hierlatzkalk, Adnet Limestone, Gault-Flysch etc.) have been overtaken by the CBGA countries from the Eastern Alps partly in translated form.
Since the establishment of the lithostratigraphic units in the neighbouring countries there is a desire to compare and correlate their units with each other in large areas of the Earth. This activity is promoted (supported) in the territory of the Carpathian–Balkan Geological Association as well, via establishing a Working Group with the same aims in the territory of the member countries. The similarity of the Lower Cretaceous clastic succession of the Salzburg and the Gerecse areas (North-eastern part of the Transdanubian Range in Hungary) was recognised already in 1868 by Hantken and later based on the fossil community by Somogyi (1914). The similarity of the Berriasian to Hauterivian part of the Lower Cretaceous succession has been recognised by Noszky in the thirties of the last century thanks to the co-occurrence of the South Alpine biancone (maiolica) facies in the South Bakony as well.
Several similar successions are found to have occurred since the geological activity became intensive. Thanks to the joint correlation between the most promising territories there are already a few unexpected results as well. The first surprising conclusion of the correlation activity was introduced in 2010 (Csaszar and Gawlick) saying that the Transdanubian Range is a unique tectonic unit in the Alpine–Carpathian system which has preserved up to this day its original connection to the North-Alpine and the South Alpine (SA) development. This conclusion verified the close relation between Upper Jurassic – Lower Cretaceous successions of the Salzburg area in the Northern Calcareous Alps (NCA) and the Gerecse Hills, but more formations and events became correlated such as the Member rank units of the Oxfordian breccia in the Gerecse and in the Eastern Alps and the Berriasian Felsővadács Breccia (Gerecse) and the Barmstein Breccia (Eastern and Southern Alp; Gorican 2012). The latter ones have an important aspect namely that the breccia grains are in parts green algae-bearing platform limestone origin (Plassen Carbonate Platform and equivalents) which derives from another tectonic unit. These breccias clearly indicate the same tectonic event. The overlying marl and sandstone formations are also found in both places including the very coarse-grained breccias and conglomerates bodies of varied lithology (e. g. rudisted and coral bearing limestones and black cherts).
The Transdanubian Range (TR) has a syncline structure of NE–SW orientation with Jurassic and Cretaceous formations in the axes. In the middle part of the syncline the uppermost Jurassic and Lower Cretaceous formations are missing because it was elevated towards which the break of sedimentation lasted longer from both NE and SW directions.
The correlation of Mesozoic formations of the broader Salzburg area and the Gerecse Hills and also the Bakony and Southern Alps has been emphasized, but an important step is still missing. We are still using original lithostratigraphic names of the NCA, the SA and the TR instead of agreeing in the key sections of the correlated formations and using their names for the relevant formations. It means this step is still ahead of us.
To decrease the number of lithostratigraphic names with special attention to the formation rank is a very important task at least from two points of view: (1) avoiding to use unnecessary names, (2) usage of the approved names is a clear indication for the close relationship of the relevant areas.

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Why isn't the lithostratigraphy for magmatic and metamorphic rocks valid?

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Definition of lithostratigraphy according to the International Stratigraphic Guide is "the element of stratigraphy that deals with the lithology of strata and with their organization into units based on lithologic character" (Hedberg 1976). There is a minor change in the 2nd edition made by A. Salvador (1994) "Lithostratigraphy. The element of stratigraphy that deals with the description and systematic organization of the rocks of the Earth's crust into distinctive named units based on the lithologic character of the rocks and their stratigraphic relations".
There are also minor differences in the definition of the lithostratigraphic units between the 1st and the 2nd editions "Lithostratigraphic unit – a body of rock strata that is unified by consisting dominantly of certain lithologic type or combination of lithologic types, or by possessing other impressive and unifying lithologic features. A lithostratigraphic unit may consist of sedimentary, or igneous, or metamorphic rocks, or of an association of two or more of these. Lithostratigraphic units are recognised and defined not by inferred geologic history or mode of genesis." "The critical requirement of the unit is a substantial degree of overall lithologic homogeneity." The homogeneity in broader sense may mean a great variety of different rock types, characteristic for the entire formation. In the Salvador's edition (1994): "Lithostratigraphic Unit. A body of rocks that is defined and recognized on the bases of its observable and distinctive lithologic properties or combination of lithologic properties and its stratigraphic relations." Salvador's explanation of the "lithologic homogeneity": "Diversity in detail may in itself constitute a form of overall lithologic unity." There are a few important statements in the 2nd (Salvador's) edition of the Guide. "Definition and recognition of lithostratigraphic units must be based on description of the lithologic composition" and not on geophysical properties. Fossils may also be important in the recognition of a lithostratigraphic unit either because of their distinctive constituents or because of their rock forming properties. There is another important statement about the laterally discontinuous rock bodies with the same lithologic properties and approximately the same stratigraphic position: They can also be a single lithostratigraphic unit. This is the case with the "series of genetically related but discontinuous igneous bodies or series of disconnected reef limestones or coal lenses lying at approximately the same stratigraphic position".
According to the North American Stratigraphic Code a *lithostratigraphic unit* is a geologic rock unit that conforms to the principles of superposition, while the lithodemic unit generally does not conform to the Law of Superposition. This definition is fundamentally different from that of the International Stratigraphic Guide (ISG – see above). According to the latter these kinds of units are based on the lithologic composition independently from their super- or subposition. If we look at the relation of the basic lithostratigraphic units (formations) of the sedimentary successions in the Alpine–Carpathian–Dinaridic system we have to recognize that many famous units are overlain or underlain by different lithostratigraphic units from place to place and also they are interfingering with different units of varied lithology. The Seefeld Fm. is situated within the Hauptdolomit Fm. in the Eastern and Southern Alps. It is not an exceptional situation in sedimentary successions.
What is the conclusion? Nevertheless the Law of Superposition usually can be recognized in the sedimentary successions but not obligatorily. Therefore it can't be considered as a definitive element of the lithostratigraphic classification. As the Formation is the primary unit of the lithostratigraphic classification to draw the boundary between the formations it is very important not only from the Law of Superposition but also from the lateral contact point of view. To draw a boundary between the varied types of sedimentary rocks is often more difficult than between sedimentary and magmatic rocks. The age determination of the different types of rocks is not more complicated if both of them have lithostratigraphic names. In columnar sections they are next to each other as similar rank units. Anyway it is high time to establish a working group to discuss the still open questions among experts of sedimentary, magmatic and metamorphic rocks.

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Correlation of Mesozoic lithostratigraphic units of the East-Alpine Bajuvaric and Tirolic units and the North Eastern part of the Transdanubian Range

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Although in the Transdanubian Range formations in the Lower and Middle Triassic are already similar to those in several East Alpine tectonic units but great similarities are found in the Upper Triassic, in particular in the Tirolic and Bajuvaric Zones. There were facies differences within the Transdanubian Range in northeast – southwest direction already in the Early Triassic. In the Middle and Late Triassic within the platform carbonates pelitic shallow basins developed locally. These differences are characteristic for the Tirolic and Bajuvaric nappes in Austria as well. From this time onwards several lithostratigraphic names have been taken over from the Eastern Alps: Hauptdolomite (in translated version: Fődolomit), Dachstein Limestone, Kössen Fm. At the same time some of the well correlated units have different names yet in Hungary (e.g., Raibl Fm. = Veszprem Marl). The Late Hettangian rifting and the Toarcian break-up in the Penninic Realm led to a completely new palaeotopography. The result is horst-and-graben topography on a large area of the rifting zone. Nevertheless the first signal of fundamental differences between the Bakony and the Gerecse occurred already during the Hettangian Age, when oncoidic Kardosret Limestone was deposited in the Bakony, while in the Gerecse, Vértes, Pilis and Buda-Hills area the Dachstein Limestone has an erosional surface. There is only one common lithostratigraphic name in the Eastern Alps and the Transdanubian Range in the Lower Jurassic Series (Hierlatz Limestone) while another one has different names (Adnet Lms. = Pisznice Lms.). Stronger altitude differentiation of the basement started in the Toarcian. There are no common lithostratigraphic names in the Middle Jurassic although the Klauskalk in the Tirolicum is similar to the Tölgyhat Limestone and the deep-water Ruhpolding Radiolarite is equal to the Lokut Radiolarite. The situation in the Upper Jurassic is the same. The "Oxfordian breccia" is the first signal of the increased tectonic activity in both areas. It is called „Rofanbrekzie" in the Eastern Alps within the Ruhpolding Radiolarite. The Ruhpolding Fm. in the Tirolic and Bajuvaric nappes is overlain by ammonitic marly limestone followed by the Oberalm Limestone. The „Oxfordian breccia" in the Gerecse called Pockő Chert Member is only 1-2 m in thickness and developed either in the Lokut Radiolarite or in the lower part of its overlying ammonitic Palihalas Limestone Fm. The latter one is red, nodular limestone and at least in colour it is different from the overlying bed of the Ruhpolding Radiolarite. The equivalent of the Oberalm Fm. in the Transdanubian Range is the Szentivanhegy Limestone. Radical change in the sedimentation started with the occurrence of the fine-grained flysch type Schrambach Fm in the Bajuvaric and Tirolic nappes and in the Bersek Marl Fm. in the Gerecse Hills. The sedimentation continued with deposition of the coarse-grained Rossfeld Fm. and the Labatlan Sandstone Fm. respectively. The uppermost part of the Labatlan Fm. is called Köszörűkőbanya Conglomerate Mb. of debris cone origin at the base of a steep submarine slope. Predominant component of the conglomerate and breccia grains are chert but it contains some fragments of basalt, gabbro, polycrystalline quartzite sandstone, lithic sandstone, phyllite and slate. In the uppermost beds there are limestone breccia beds with rudist bivalves, hydrozoans and even corals. The grain size of the flysch type Labatlan Fm is getting finer and finer southwest direction while the water depth is shallowing. As it can be seen the Mesozoic succession of the Bajuvaric and Tirolic part of the Eastern Alps and the north-eastern part of the Transdanubian Range are relatively well comparable from lithostratigraphic point of view while tectonic point of view there is a great difference between them. Nevertheless based on the occurrence of the flysch and its lithologic composition the presence of nappe structure in the broader environment of the Gerecse cannot be excluded but the sediment transport is supposed to be southward direction. The Upper Cretaceous is completely missing in the broader Gerecse area but it is developed in the Bakony Mts after a long break owing to the Middle and Late Alpine tectonic phases.

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Transient Calcareous Plankton and Environmental Perturbations Across Three Early Eocene Hyperthermals: The Terche Record (Northeastern Italy)

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In addition to the well-known Paleocene-Eocene Thermal Maximum (PETM ~55.9 Ma), a series of subsequent hyperthermals, punctuating the early Eocene long-term warming trend, were globally detected in the last decade. The early Paleogene hyperthermals are transient warming events linked to rapid injection of isotopically light carbon into the ocean-atmosphere system perturbing the global carbon cycle. These events have been widely characterized in terms of geochemical variations while the biotic response is still scarcely constrained.

We have investigated the middle Paleocene-lower Eocene Terche section (Venetian Southern Alps, north-eastern Italy) deposited in middle bathyal settings of the Belluno Basin, a key area in the central-western Tethys. The upper portion of the section encompasses three expanded lithological anomalies, the marly-clay units (MUs), characterized by marked decreases in $CaCO_3$ content associated with negative carbon isotope excursions (CIEs). Integrated biomagnetostratigraphy allows us to correlate the MUs to the three post-PETM hyperthermals Eocene Thermal Maximum 2 (ETM2 or H1; ~53.7 Ma), H2 (~53.6 Ma) and I1(~53.3 Ma). The age model adopted in this study has been derived by the correlation of the Terche $CaCO_3$ data with the ODP Site 1258 Fe XRF record (equatorial Atlantic Ocean).

Remarkable changes in the Terche calcareous plankton assemblages are observed across these hyperthermals. Within the MUs calcareous nannofossils record an increase in eutrophic taxa, such as *Toweius*, *Ericsonia* and *Coccolithus pelagicus*, corresponding to a drop in the oligotrophic indices, such as *Discoaster* and *Zygrablithus bijugatus.* These latter gradually recover in the upper part of the CIEs. Peaks of Cretaceous reworked calcareous nannofossils are recorded immediately above the CIEs onset, suggesting enhanced weathering and erosion on land as a consequence of improved rainfalls. These data are consistent with an improved eutrophy also documented by peaks in radiolarians. Fluctuations in planktic foraminiferal assemblages across the MUs highlight a dominance of warm-indices acarininids and a drastic decline of the cold-indices subbotinids. A sharp increase of the highly specialized warm-oligotrophic *Morozovella* is recorded in coincidence of the ETM2 and the I1 CIE peaks, slightly out of phase with respect to the maximum values of Cretaceous reworking.

These biotic modifications during hyperthermals documents abrupt, though temporary, episodes of environmental perturbations resulting in relative eutrophication of surface waters and intense warmth. The most intense changes occur during the ETM2. Higher nutrient availability in the surface waters might be related to an accelerated hydrological cycle and more intensive weathering in response to the stronger greenhouse effect in the hyperthermal event. We hypothesize that these conditions, detrimental for calcareous oligotrophic taxa, favoured acarininids that were enabled to migrate downward in the water column and temporarily colonize deeper and warmer waters previously occupied by subbotinids. Dissolution proxies based on planktic foraminifera (fragmentation index, plankton/benthos ratio, coarse fraction) do not display significant variations within these critical intervals. In particular, the fragmentation index at Terche, shows very low values in comparison with those observed during the PETM and the X-event in the nearby Valbelluna sections suggesting a genuine biotic response. The decrease in carbonate content can be therefore related to dilution, due to increase in terrigenous sediments supply, rather than dissolution.

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Carbon isotope stratigraphy of the Carnian Pluvial Event (early Late Triassic) in the northwestern Tethys

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In the Late Triassic (~230 Ma) a climate change from arid to markedly humid conditions, known as the Carnian Pluvial Event (CPE), is recorded in stratigraphic sections worldwide. In marine sedimentary basins, the arrival of huge amount of siliciclastic material, the establishment of anoxic conditions and a sudden change of the carbonate factory mark the CPE. Palaeobotanical analyses evidence a shift of floral associations towards more hygrophytic elements at different latitudes and massive resin production. The CPE is also closely associated with biological turnover among some marine groups and seems to be linked to major evolutionary innovations (e.g. dinosaurs radiation, nannoplankton appearance and gymnosperm turnover). Sedimentological and palynological data show that the CPE was multiphasic, with a least three humid pulses.
Organic $\delta^{13}C$ records from stratigraphic sections in the Dolomites (Italy), the Northern Calcareous Alps (Austria) and the Transdanubian Range (Hungary), which were located in the northwestern Tethys during the Carnian, show a 2–4‰ negative carbon isotope excursion (CIE) at the boundary between the *Trachyceras aonoides* and the *Austrotrachyceras austriacum* ammonoid zones, and the boundary between the *Concentricisporites bianulatus* and the *Aulisporites astigmosus* sporomorph assemblages. The negative CIE interrupts a long term positive Ladinian–Carnian trend that is a reproducible feature of the Triassic $\delta^{13}C$ curve and is recorded also by brachiopod calcite and bulk carbonates in other sections. The negative CIE is coincident with the expression of the CPE in the studied stratigraphic sections characterized by sudden change of sedimentation indicative of massive terrigenous input and oxygen depletion. The carbonate carbon isotope record from Dibona section in Italy does not show the negative CIE, which is on the contrary evident in the organic carbon isotope data. This suggests that carbonate diagenesis could have obliterated the original $\delta^{13}C$ signal.
We propose that intensification of Pangea megamonsoon activity linked to the injection of large amount of ^{13}C-depleted carbon into the atmosphere–ocean system caused a sudden increase of the continental runoff in the Carnian. Wrangellia LIP activity is the most likely “smoking gun” for the CPE.

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Integrated Biostratigraphy of the Coniacian/Santonian boundary in the El Kef area (northwestern Tunisia)

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The Upper Coniacian- Lower Santonian interval is studied in the Koudiat Ben Kamel section (KBK) of El Kef area (northwestern Tunisia) where the two holotypes of *Playceramus siccensis* and the planktonic foraminifer *Dicarinella asymetrica* were identified. The Coniacian/Santonian transition is marked by a ca. 20 m thick lim estone bed within an alternation of gray marls and beige limestones of the Kef formation. Planktonic foraminiferal assemblages of the upper Coniacian are dominated by large, keeled morphotypes of the genera *Globotruncana* (*G. angusticarinata)*, *Marginotruncana* (*M. coronata*, *M.marginata*, *M. pseudolinneiana*, *M.sinuosa*, *M. undulata*), *Dicarinella concavata, D. cyrenaica*, and *D. asymetrica* which reach large sizes in the lower Santonian. *Heterohelix globulosa* and *Laeviheterohelix pulchra* represent a minor part of the association. The benthic foraminiferal faunas are dominated by thick-walled calcareous forms. They are represented by *Frondicularia inversa*, *Lenticulina* sp., *Nodosaria* sp. and Miliolidea. The Coniacian/Santonian boundary is herein fixed on the top of a 120 cm beige limestone bend, rich in *Platyceramus cycloides* (which we consider a synonym of *Platyceramus siccensis*), *Protexanites bontanti* and *Protexanites bourgoisianus*. This boundary coincides also with the first occurences of the foraminifers *Contusotruncana fornicata* and the real "Pill Box Like" morphotypes of *Globotruncana linneiana*. Benthic foraminiferal assemblages from the lower Santonian marls are characterized by increasing numbers of small calcareous forms (*Bolivinopsis beaudouiniana*, *B praelonga*) and abundant agglutinated foraminifera (*Dorothia oxycona*, *D. turris*, *Gaudryina serrata*, *G. rugosa*). These results reflect an increase in paleodepth from an internal platform (inner shelf) to an external platform (outer shelf) during this interval.

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Eifelian Climatic and Environmental Change and Astronomical Forcing Inferred from Magnetic Susceptibility and Stable Isotope Records from the Subtropics of Western Laurussia: Southern Illinois Basin: Central North America

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Very little is known about Middle Devonian climate dynamics, and there is no consensus about the general state of the climate system (greenhouse versus icehouse) during the Middle Devonian. Oxygen isotope paleothermometery of Elrick et al. (2009) and Joachimski et al. (2009), suggests cool to temperate tropical sea surface temperatures, whereas the extensive reef constructions of the Middle Devonian suggest much warmer conditions as expected during super greenhouse climates (Copper 2002). In this study, we present proxy records that cover the entire Eifelian (Middle Devonian) Stage in order to assess climatic and environmental variability during that interval. We sampled the Grand Tower and St. Laurent Formations (southern Illinois) and measured bulk magnetic susceptibility, $\delta^{13}C$ and $\delta^{18}O$ values in carbonate, and the $\delta^{18}O$ values from icriodid P_1 elements.

Our investigation of the Lower and Middle Devonian strata in the southern Illinois Basin (Illinois, USA) yield diagnostic conodont faunas. The study of conodont samples of the Grand Tower and St. Laurent Formations provide biostratigraphic control on the position of the Emsian-Eifelian and Eifelian-Givetian stage boundaries in the Grand Tower type section along the Mississippi river (Jackson Co., SW Ill.) and in the Illinois State Geological Survey's White County core (White Co., SE Ill.). We are able to generate geophysical and $\delta^{13}C_{carbonate,}$ $\delta^{18}O_{carbonate}$, and $\delta^{18}O_{apatite}$ geochemical proxy records and place them within a robust biostratigraphic framework confirming the presence of the Kačák-*otomari* positive $\delta^{13}C_{carb}$ excursion beginning in the *hemiansatus* zonal interval (lower St. Laurent Formation). The Conodont $\delta^{18}O$ values of icriodid P_1 elements range between 17.4 and 21.2 ‰ through the section and suggest considerable changes in subtropical sea surface temperatures (SSTs) and/or changes in the isotopic composition of local seawater in the southern Illinois Basin during the Eifelian and Early Givetian. Within the upper Grand Tower, $\delta^{18}O_{apatite}$ values decrease by 4‰ then increase by 2.5‰. In the overlying St. Laurent Formation, values decrease by 1‰. If solely due to temperature, these changes suggest warming of up to 16°C during the mid-Eifelian followed by a 11°C cooling in the Late Eifelian and 4°C warming in the Early Givetian. Changes in local to regional moisture balance circulations patterns that could influence seawater $\delta^{18}O$ are also considered likely sources of variation. Finally, we evaluate a possible imprint of astronomical climate forcing and interpret low-frequency variations in the different proxy records as the imprint of 405-kyr eccentricity forcing.

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Astrochronological calibration of Late Frasnian Sea Level and Bioevents estimated from integrated bio-, chemo- and cyclostratgraphy: Iowa Basin, USA

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Cyclostratigraphy, spectral analysis and astronomical tuning of high-resolution magnetic susceptibility (MS) data provides unprecedented precision in estimating the timing of sea level and Kellwasser Extinction events during the Late Devonian. Identification of Milankovitch periodicities within the MS data permitted documentation of 16.5 long 405-kyr eccentricity cycles (Fr-LECs) within the Frasnian stage of the Upper Devonian of western Alberta (De Vleeschouwer et al., 2012) and Poland (De Vleeschouwer et al. 2013). To further test the cyclostratigraphic model for the Frasnian, we conducted an integrated biostratigraphic, chemostratigraphic, and paleomagnetic investigation to develop a comparative record for the Late Frasnian of the subtropical Iowa Basin.

The Late Frasnian Lime Creek Formation in Iowa was sampled in the Cerro Gordo Project Hole #1 (CG-1) from northern Iowa and the H-32 core from southeastern Iowa. Conodont biostratigraphy (CG-1 and H-32) and $\delta^{13}C_{carb}$ provide good initial Late Frasnian time control. For the cyclostratigraphic purposes of this study, we carried out bulk magnetic susceptibility (MS) measurements at high sampling resolution on both cores (10 cm resolution in CG-1; 4 cm resolution in H-32). The MS series of both cores display the imprint of 100-kyr and 405-kyr eccentricity. The cyclostratigraphic interpretation in terms of eccentricity cycles, allows the correlation of both records and suggests that the studied interval covers the last ~2.6 million years of the Frasnian. In other words, the base of the Lime Creek Formation corresponds to the base of Frasnian Long Eccentricity Cycle 11 (Fr-LEC 11). The pronounced shift in $\delta^{13}C_{carb}$ values from -1‰ to +2‰ in the upper Lime Creek is interpreted as an expanded record of the LKE $\delta^{13}C_{carb}$ excursion that spans two short eccentricity cycles within Fr-LEC 15 (200 ky duration). The onset of sea level rise that initiated Late Frasnian Sequence 7 in Alberta begins within Fr-LEC 10. In Iowa the transgression of Devonian T-R cycle IId-1 did not re-establish deposition across the deeply incised karst surface capping the emergent Middle Frasnian Shell Rock Platform for the duration of much of Fr-LEC 10 (minimal hiatus estimated 300-400 ky). The estimated duration of the prolonged high-stand interval of T-R cycle IId-1 in Iowa spans all of Fr-LEC 11 to 14 and lower short eccentricity cycle 1 of Fr-LEC 15. In accordance with previous cyclostratigraphic studies in Canada (De Vleeschouwer et al. 2012) and Poland (De Vleeschouwer et al. 2013), the Lower Kellwasser $\delta^{13}C_{carb}$ excursion occurs within Fr-LEC 15, approximately 800 thousand years before the Frasnian-Famennian boundary. These results thus confirm that it is possible to establish global cyclostratigraphic correlations, provided that a clear astronomical imprint can be identified in the studied records and represent the first steps towards a high-resolution chronology for the Frasnian - Famennian boundary interval.

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Investigation and Revision of the Pre- and Post-Hangenberg Extinction Shelly Faunas (Brachiopoda): Late-Latest Famennian and Early Tournaisian of the Illinois Basin of Central North America.

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Recent investigations by the Devonian-Carboniferous (D-C) Boundary working group are focused on revision of the D-C boundary and documenting faunal sequences through boundary intervals world-wide. The North American working group of the ICS-SDS is undertaking restudy of key boundary interval sections in the Illinois Basin, Great Basin-Western Utah and Alberta. Here we present initial results of investigation of the Late Famennian-to-Early Tournaisian brachiopod faunas from the Illinois Basin based on restudy of museum type collections illustrated in studies by Weller (1914), Huddle (1933), Williams (1943) and Carter (1988), and new field-based collections from the type areas of Late-Latest Famennian units in eastern Missouri and Iowa, and Huddle's collections from south-central Indiana.

The pre-Hangenberg fauna of the English River Formation is associated with conodonts spanning the interval of Upper *expansa*? to *costatus-kockeli* interregnum (formerly Lower-Middle *praesulcata* zones). The post-Hangenberg Extinction survivor and recovery fauna of the Louisiana shelly fauna is associated with conodonts of the *kockeli* Zone or Upper *praesulcata* Zone. The fauna of "Ellsworth" Member-New Albany Shale of Indiana (Huddle, 1933) is the assemblage associated with the holotype of *Siphonodella sulcata* and is very early Tournaisian (*sulcata* to *duplicata* zones) in age. The English River fauna consists of twenty species that include: *Chonopectus fischeri*, *Mesoplica mesacostalis, Ovatia nacens*, *Semiproductus curtirostris*, *Sentosia nummularis*, *Plicohonetes*? sp., *Leptagonia convexa*, *Schuchertella*? sp., *Schellwienella* n. sp. *Schizophoria* (*S.*) sp. cf. *S. williamsi*, *Paraphorhynhus transversum*, *Eudoxina subrotundus*, *E. maplensis*, *Syringothyris extenuatus*, *Hispidaria*? *biplicatus*, *Camarorphorella buckleyi*, *Composita corpulenta*, and *Eumetria altirostris*. Twenty or more brachiopod taxa have been described from the post-Hangenberg age Louisiana Limestone. These include: *Anthocrania spiculata*, *Petrocrania rowleyi*, *P. dodgei*, *Rhipidomella missouriensis*, *Schuchertella lens*, *S. louisianensis*, *Plicochonetes ornatus, Obinaria pyxidata, "Strophalosia" beecheri, Leptolosia scintilla, Paraphorhynchus striatocostatum, Cyrtina acutirostris, Tylothyris clarksvillensis, Acanthospirina aciclulifera, Syringothyris hannibalensis, Parallelora marionensis, Crurithyris minuta, C. louisianensis*, *Athyris lamellosa,* and *Camarorphorella buckleyi.* The early Tournaisian "Ellsworth" fauna of Indiana from outer shelf gray shales and includes: *Langella?* sp*., Orbiculoidea sp., Globosochonetes seymourensis, Schuchertella* sp*., Rhynchotrema* sp. cf. *R. prisca, Rhipidomella newalbanensis, Pseudosyrinx* sp. and *Tylothyris* sp. cf. *T. missouriensis* (Huddle specimen lost). Coeval faunas (up to 42 species) from platform facies with conodonts of the *sulcata-duplicata* zones were described by Carter (1988, Glen Park Formation) in the western Illinois Basin, and indicate major radiations of the post-Hangenberg Extinction survivor and recovery clades occurred rapidly in the subtropics during earliest Tournaisian.

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Basin-to-Platform Records of Kellwasser Extinctions: Iowa Basin: Central North America

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New high resolution faunal data document the Lower and Upper Kellwasser extinction intervals (LKE & UKE) in basinal, deep subtidal ramp and platform settings in core and surface exposures in the Iowa Basin of the central United States. Offshore-basinal conodont sequences in the Iowa Geological Survey (IGS) Sullivan and H-32 cores and Sweetland Creek type section (Over, 2002) fix the position of the LKE in the upper Sweetand Creek Shale in Frasnian Montagne Noire (MN) Zone 12, and the UKE beginning within MN Zone 13b in the lower Grassy Creek Shale in southeastern Iowa. Benthic and pelagic faunal sequences in deep-subtidal mid-ramp facies of the Amana Beds of the Lime Creek Formation record the LKE extinction demonstrated by the stepped extinctions of brachiopods and ammonoids within transgressive and maximum flooding intervals associated with Devonian Transgressive-Regressive (T-R) cycle IId-2 and onset of benthic hypoxia. There the LKE is recorded by three-fold stepped extinctions of ten known brachiopod taxa, all echinoderms, and two (*Manticoceras regulare*, *Sphaeromanticoceras rhynchostomum*) ammonoids just below the base of MN Zone 13a and maximum flooding of T-R cycle IId-2 coincident with organic-rich brown shale deposition. No benthic taxa range into the interval of MN Zone 13. New data from Lime Creek platform sections include high resolution stable isotope geochemical, magnetic susceptibility (MS), brachiopod and continuous conodont sampling in the IGS CG-1 core, conodont sampling from Bird Hill East sections of Day (1989, 1990), and near continuous sampling from new quarry exposures of the uppermost Cerro Gordo and Owen members in the Bruns Quarry south of the Lime Creek Formation type area. The $\delta^{13}C_{carb}$ stratigraphy in the CG-1 core records the onset of the LKE $\delta^{13}C_{carb}$ excursion within Frasnian Long Eccentricity Cycle 15 of De Vleeschouwer et al. (2012) within MN Zone 12 (upper part of brachiopod *Elita inconsueta* Zone). The brachiopod composite sequence in outcrop and quarry sections of the Lime Creek are shown here to record the LKE in northern Iowa. In the Owen Member section at the Bruns Quarry the LKE is recorded in deposits of the upper Cerro Gordo and Owen members of the Lime Creek deposited during the late highstand of T-R cycle IId-1, followed by the onset of transgression, maximum flooding, and early highstand interval of T-R cycle IId-2 in the remainder of the Owen Member. Diverse brachiopod faunas of the *Elita inconsueta* Zone with upper MN 12 conodonts in the upper Cerro Gordo and lower Owen are replaced up section by low diversity assemblages of the Iowatrypa owenensis Zone associated with MN Zone 13 conodonts. These assemblages are dominated by gastropods (*Floyda* & *Westerna*) and infaunal bivalves; low diversity brachiopod assemblages with *Iowatrypa owensis*, *Pseudoatrypa devoniana, Spinatrypa trulla, Cyrtospirifer whitneyi* (*owenensis* morphotype), *Conispirifer cyrtinaformis, Nervostrophia sp.* and *Strophonelloides reversa*; rugose corals *Tabulophyllum expansum* and *Pachyphyllum dumonti*.

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Palynostratigraphy of some Cretaceous rocks of the BB80-1 borehole, offshore Western Abu Darag Basin, Gulf of Suez, Egypt

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The current palynological investigation is based on 78 cutting samples from the poorly-dated (Jurassic to Cenomanian) clastic sequence of the unidentified unit, "Nubia A" unit, and Raha Formation of the BB80-1 borehole, offshore Western Gulf of Suez, Egypt. As earlier stratigraphic studies have largely ignored these clastic sediments in this area, a central objective was therefore to construct a biostratigraphic scheme of the investigated subsurface units, especially that "Nubia A" unit represents one of the important oil-producing horizons in the offshore Gulf of Suez region. Despite the borehole samples proved palynologically lean, it was possible to provide a fair age determination of the rock units under investigation. Index terrestrial palynomorphs (i.e. gymnosperm and angiosperm pollens) are the only useful biostratigraphical tools used in the palynological dating. In contrast, recovered phytoplankton taxa are found to be facies-controlled and of no biostratigraphic significance to this study. It was only possible to define part of the upper Malha Formation of the Albian age based on the presence of index gymnosperm pollen *Elaterosporites klaszii*, which is diagnostic for the mid Albian-mid Cenomanian in the Albian-Cenomanian Elaterate Province, and the complete absence of other late Albian-mid Cenomanian elaterate pollens (e.g., *Elaterocolpites castelainii, Elateroplicites africaensis*). The uppermost Malha and lower Raha formations were identified by the presence of the *Elaterocolpites castelainii-Elateroplicites africaensis-Afropollis kharamanensis* Assemblage Zone of the late Albian-early Cenomanian age and the co-occurrence of a regional acme bioevent of *Afropollis* of the mid Albian-early Cenomanian age in northern Egypt (Deaf et al., 2014). Sporomorphs characteristic of the Albian-Cenomanian Elaterate Phytogeographic Province were identified from the borehole.

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Small shelly fossils and recognition of the Lower Tommotian boundary

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The stratotype of the Tommotian Stage is the Dvortsy section on the Aldan River which is represented by light-colored dolomites of the Yudoma Fm. and red and white limestones of the Pestrotsvetnaya Fm. The deposits are characterized by mass appearances of hyoliths, molluscs, brachiopods, sponges, and SSF. The stage is underlain by the deposits of the Nemakit-Daldynian Stage with two SSF zones, i.e. *Anabarites trisulcatus* (lower) and *Purella antiqua* (upper). The Tommotian stage of the Siberian Stage Standard approximately corresponds to the Stage 2 of the International stratigraphic chart.

Siberian Platform. On the Siberian Platform the base of the Tommotian stage is easily recognizable by fossils of the *Nochoroicyathus sunnaginicus* assemblage zone. The most typical and widespread SSF are mollusks - *Aldanella attleborensis, Watsonella crosbyi, Bemella* spp., tommotiids - *Camenella* spp., and problematics - *Torellella lentiformis, Hyolithellus tortuosus*. The underlying *Purella antiqua* zone is characterized by FADs of widespread SSF: mollusks - *Purella antiqua, P. cristata, Barskovia* spp., *Anabarella plana, Latouchella korobkovi*, problematics - *Torellella curva, Halkieria longa, H. sacciformis, Hyolithellus tenuis, H. vladimirovae*. The overlying *Dokidocyathus regularis* zone, in addition to archaeocyaths, is characterized by FADs of the SSF taxa: mollusk - *Aldanella operosa*, tommotiid - *Lapworthella tortuosa*, problematic - *Hyolithellus insolitus*. Thus, on the Siberian Platform the recognition of the Tommotian base is insured by the first archaeocyaths and tommotiids, and several mollusk species. This level is bracketed by the first *Lapworthella* above, and *Purella – Barskovia* mollusks below.

China. The best studied sections of the Precambrian–Lower Cambrian transitional interval are situated in Yunnan province. The lower part of the Zhongyicun Mb. (lower *Anabarites trisulcatus – Protohertzina anabarica* Zone) can be correlated with the Siberian *Anabarites trisulcatus* Zone. The first mollusks in the middle of the Zhongyicun Mb. (upper *Anabarites trisulcatus – Protohertzina anabarica* Zone) can be correlated with the Siberian *Purella antiqua* zone, where the first mollusks appears as well. Dahai Mb. is undoubtedly Tommotian in age,due to typical mollusks, e.g. *Aldanella attleborensis, Watsonella crosbyi.* The age of the topmost part of the Zhongyicun Mb. is questionable. *A. attleborensis*, the general pattern of generic diversity and chemostratigraphic data favor a correlation with the Tommotian *Nochoroicyathus sunnaginicus* zone. The base of the Tommotian stage can be traced in other regions of China by the FADs of mollusks [*A. attleborensis (=A. yanjiaheensis*) and *Igorella maidipingensis*].

Mongolia. In Western Mongolia the Precambrian–Lower Cambrian transitional interval is represented by thick deposits of the Bayan-Gol Fm. with a series of biostratigraphic zones. In West Mongolia the base of the Tommotian stage lies approximately in the middle part of the *Halkieria amorpha/Ilsanella compessa* zone. However, no distinct change occurs in fossil composition at this level.

North America. Terrigenous deposits of a temperate zone correspond to the Precambrian–Cambrian interval. SSF assemblages are very poor compared with shallow water 'tropical' carbonate deposits of the Siberian or Chinese platforms. Three zones are recognized within the discussed interval: *"Ladatheca" cylindrica, Watsonella crosbyi,* and *Sunnaginia imbricata.* The base of the Tommotian can be recognized by the mollusks *Aldanella attleborensis* and *Watsonella crosbyi* in the middle part of the Chapel island Fm., so that the base of *Watsonella crosbyi* in Avalonia can be correlated with the base of *Nochoroicyathus sunnaginicus* zone of SSS. The tommotiid *Lapworthella ludvigseni* suggests correlation with the *Dokidocyathus regularis* zone. The presence of *Aldanella attleborensis* and *Watsonella crosbyi* at that level and in the upper *Sunnaginia imbricata* zone does not contradict this idea, since both species still occur in the *Dokidocyathus regularis* zone of Siberia. Thus, on the base of SSF the base of the Tommotian stage can be recognized in other regions of the world with more or less representative paleontological characteristics. The reliable position of this level can be indicated by FADs of two mollusk species, *Aldanella attleborensis* and *Watsonella crosbyi*, bracketed by the first *Lapworthella* above, and first mollusks (e.g., *Purella, Barskovia, Latouchella*) below.

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The Triassic floral assemblages and origin of Mesozoic flora in North China

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Since the sea water edged out of North China in the Middle Permian, the Upper Permian and the Mesozoic in North China are almost totally no-marine strata. The Triassic System in this region is divided ascendingly into the Liujiagou Formation and Heshanggou Formation of Lower Series, the Zhifang Formation and Tongchuan Formation of Middle Series and the Yanchang Formation of Upper Series. Plant fossils have been discovered from all these formations, based on which a series of floral assemblages of the Triassic has been proposed. The origin and evolution of the Mesozoic flora in North China are revealed based on these floral assemblages.

1. *Pleuromia*-*Neuropteridium*-*Voltia* Assemblage

This assemblage is preserved in the Liujiagouin and Heshanggou Formations of about the Induan-Olenekian in age. It consists of two types of plants. One is the survivals of the Paleozoic flora, including conifers and pteridosperms, such as *Yuccites*, *Neuropteridium*, *Voltia*, and etc.. The other one is new members, which is represented by the Lycopsida, including *Pleuromia* and *Annalepis*. All these taxa are characterized by small size, small leaves with thick cuticles, and thick sporangium walls, indicating they adapted to serious eco-environments.

2. *Pleuromeia*-*Aipteris* Assemblage

The assemblage is preserved in the Zhifang Formation, which is of early Middle Triassic age, about the Anisian. It is developed from the old assemblage mentioned above, but the Late Paleozoic residues elements decrease, and many new elements of ferns, Cycadopsida and Ginkgopsida appear.

3. *Neocalamites*-*Tongchuanophyllum*-*Symopteris* Assemblage

This assemblage yielded from the Tongchuan Formation of the Middle Triassic. The flora is characterized by marked increase of specific diversity, abundant Pteridosperms and new members of Sphenopsida and fern. It is interested that they are many Gondwana elements, such as *Glosssopteris* and *Linguifolium* in this assemblages.

4. *Thinnfeldia*-*Danaeopsis fecunda*-*Asterotheca* Assemblage

The specific diversity of the flora increases rapidly since the middle Ladinian. A large number of new species of Sphenopsida, Filicopsida and Cycadopsida emerge. The Pteridosperms decreased very much except *Thinnfeldia*. The Mesozoic type flora, which is dominated by Filicopsida and Gymnosperms (including chiefly Cycadopsida, Ginkgopsida and Coniferopsida), successfully occupied North China at the beginning of the Carnian. Tree forests consist of the gymnosperms living in the swamps, lower lands, slopes and high lands, and form the Late Triassic coal formations in North China.

The evolution of the Triassic floras in North China is synchronous with the climate changes. The flora in North China has evolved from the survivals flora stage in the Early Triassic, to a transition flora stage in the early Middle Triassic, and to typical Mesozoic flora in the early Late Triassic, about the Carnian.

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Closing the gaps in the Neogene interval of the Geological Time Scale: State of the Art

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Nowadays, all the Neogene stages have been formally ratified with the exception of the Burdigalian and Langhian ones. In the last few years, two projects granted by the Italian Ministry of University and Research, and supported by the Subcommission on Neogene Stratigraphy, have tried to close these gaps. The older project, coordinated by S.M. Iaccarino (University of Parma), focused on the Langhian Stage and allowed recognizing, through a bio-magnetostratigraphic approach, two sections in the Mediterranean region suitable to host the GSSP: the St. Peter's Pool Section, located in the Malta Island (Foresi et al., 2011) and the La Vedova Section, outcropping in the Italian Conero Riviera (Turco et al., 2011). These two sections together cover the time interval between ~16.05 Ma and ~15.1 Ma (Iaccarino et al., 2011). The recentmost project, coordinated by A. Di Stefano (University of Catania), focused on the Burdigalian Stage and, by using modern high-resolution methodologies (biostratigraphy, magnetostratigraphy, chemostratigraphy, cyclostratigraphy and astrochronology), aims investigating suitable sections in the Mediterranean region to host the GSSP. Preliminary investigations and literature data allowed the identification of very few well exposed and easy reachable sections that, based on their litho-micropaleontological and magnetic properties, are potentially suitable for our goal. One is the Maltese St. Thomas Section that has been chronologically framed by Foresi et al. (2014) between ~19.7 Ma and ~17.2 Ma. For the same purpose we have recently investigated the Lower Miocene deposits of the Marche Region (central Italy), near the S. Croce di Arcevia Section, already studied although with traditional methods and in low resolution (Coccioni et al., 1997), and the Gürpinar Section outcropping in the Cyprus Island (Hakeyemez and Toker, 2010). Additionally, the large-scale correlation with extra Mediterranean areas has been guaranteed by a new investigation of the Atlantic Ocean successions DSDP Site 608 (Di Stefano et al., 2011, 2015) and IODP sites 1405 and 1406 (in progress). The analyses of numerous Burdigalian and Langhian sections for chronostratigraphic purposes allowed to reconstruct for the first time an almost continuous bio-magnetostratigraphic framework for the Mediterranean area, which has been completed by the investigation of the lower part of the central Italy deposits of the Moria Section (Di Stefano et al., 2015), which ranges between ~17.7 Ma and ~16.4 Ma.

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Thermal evolution of sedimentary basins by fission track on apatite and zircon

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This study aims to determine the thermal system of sedimentary basins of The High Atlas (Imilchil), the eastern Anti-Atlas (Tafilalet) and the Western Anti-Atlas (Lower Draa). The purpose in this case is to illustrate the relationship between relief and their exhumation, erosion and accumulation in various basins.
To understand and to compel this project, we undertook a low-temperature thermo chronology on 50 samples of sedimentary rocks (red beds) and magmatic rocks. Dating was obtained by fission track on apatite and zircon (AFT and ZFT) and will clarify the extent of subsidence, and the age of exhumation of rocks that have been analysed.

The thermo chronology studies AFT and ZFT in Morocco have been increased recently especially in the Atlas-plateau area, these studies of thermo chronology on apatite fission track have recently been carried out on the Hercynian basement of the Meseta (Saddiqi et al., 2009; Ghorbal et al, 2009, El Aimer, 2014). This led to highlight the complex vertical movements, which were acquired from apatite of magmatic rocks of the Central High Atlas (Barbaro et al. 2009). The results indicate that the exhumation of the old blocks occurred during the Neogene, while in the eastern part an exhumation to 50 My was deduced.

Many of the thermo-chronology studies by the fission of uranium UT/He were conducted in the Anti-Atlas (Lower and Middle Draa) and in the Archean basement of the Moroccan Sahara (Sebti et al., 2009; Ruiz et al., 2011; Oukassou et al, 2013; Lepretre et al., 2014). The studies showed that these areas have experienced vertical movements during the Mesozoic and Cenozoic.

The purpose of this research is to put into perspective the results that we obtained and bring it in a global context, integrating the vertical evolution of the basins (subsidence) and their relationship with the surrounding areas.

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The position of the Emsian/Eifelian boundary in the SW Dra Valley (Morocco) reviewed by the biostratigraphical distribution of ostracodes

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Various sections of Devonian strata in the Dra Valley (Anti-Atlas, Morocco) have been investigated by different research groups from the Münster University and the Senckenberg Institute (Frankfurt). Ostracodes have been found by both and led to a joined investigation by the present authors.
The Emsian/Eifelian boundary can hitherto not be drawn exactly in the Dra Valley e.g. by means of conodonts or goniatites. By some authors it is thought to be within or at the top of the Rich 4 Sandstone Member, but as there are no macrofossils present it is no possible to establish this. Moreover, a newly found occurrence of large beyrichiids (*Zygobeyrichia subcylindrica*) within the overlying crinoid marls is currently questioning the position of the Emsian/Eifelian boundary within the Rich4.
The Crinoid Marl Member at the base of the Yeraifa-Formation is assumed to be Eifelian in age by the Münster group, as they found no conodonts but some brachiopods typical of the Eifelian (oral comm. R.T. Becker, 2012). G. Becker et al 2004 also regarded the marls as Eifelian in age due to conodonts (*costatus* Conodont Zone), but a recent reconsideration of the conodonts from sample Tork Giv1 by K. Weddige (SMF) lead to a latest Emsian age (*patulus* Conodont Zone). The following basal beds of the goniatite bearing *Pinacites* Limestone belong without doubt to the Eifelian *costatus* Conodont zone.
Therefore three different but age-equivalent samples with more than 35 ostracode taxa were considered in detail by means of biostratigraphy, as the come from the Crinoid Marl Member (about 1 m above the beyrichiids bearing bed), which is near the assumed Emsian/Eifelian boundary:

1) Sample FRA-TKZ 4c2 (coll. E. Schindler), which is incredible rich in silicified and well preserved ostracodes
2) Tor Eif-2d (collection Münster, section Hassi Mouf South)
3) Tork Giv1 (described in G. Becker et al., 2004) of which additional residue material was recently studied for conodonts and ostracodes.

Sample FRA-TKZ 4c2 yielded only one *Icriodus corniger rectirostratus*, which could not be exactly dated but could be compared with the Heisdorf and Lauch Fm. of the Stratotype section in the Eifel area, Germany. The highly diverse ostracode fauna with 32 taxa shows great similarities especially with late Early Devonian (late Emsian) European faunas especially from Thuringia and have only very rare middle Devonian aspects (e.g., *Polyzygia symmetrica*). Sample Tork Giv1 with rare conodonts of the *patulus* Zone has a very similar composition of ostracodes. And the same is due for sample Tor-Eif-2d, which is not nearly as rich in ostracodes as FRA-TKZ 4c2 and contained so far no conodonts.

Thus, the ostracode faunas favour the Early/Middle Devonian boundary within the Yeraifia Formation and not in or on top of the Rich 4 sandstone in the SW Dra Valley.

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The Maikhanuul Diamictite Formation in the Zavkhan Basin (Western Mongolia) is the Central Asian Model of the Neoproterozoic Glacial Facies Associations

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Neoproterozoic diamictites (tillites, tilloids) of glacial origin have been recognized on all continents more than 100 years ago (Coleman, 1908; Chumakov, 1978; Lindsay et al.,1996). Two relatively thin (220 m) diamictites in the Zavkhan basin of western Mongolia have been identified as being of glacial origin. The glacial marine deposits were recognized as a result of the work of the international team from different countries (Russia, Mongolia, UK, USA), organized by Russian-Mongolian Paleontological Expedition and IGCP Project 303 on Precambrian-Cambrian Event Stratigraphy in 1990s (Brasier et al.,1996; Lindsay et al., 1996; Serezhnikova et al., 2014). The Neoproterozoic and Lower Cambrian strata of the Zavkhan basin are divided into four formations: the Zavkhan, Maikhanuul, Tsagaanolom and Bayangol formations. The Maikhanuul formation which rests unconformably upon the Zavkhan volcanic sequence (732-777 Ma, Dorjnamjaa et al., 1991) consists of glaciogenic and other clastic deposits and comprises two units of diamictites separated by a section of flysch sediments. This formation is overlain by phosphate-bearing massive carbonate units of Ediacaran Tsagaanolom formation with the 632 ±14 Ma (1000-1500 thick). The early Cambrian clastic sediments of the Bayangol formation (900 m thick) rest conformably upon the limestones of the Tsagaanolom formation. Our study was focused on the glacial marine sediments of the Maikhanuul formation in the Tsagaangol and North Duulga sections ($95^{0}50'00''$E; $46^{\circ}50'00''$N). The lower unit (~50 m thick) of conglomerates contains a variety of clasts ranging in size from gravel to 20-30 m boulders with shapes varying from subangular to well rounded. The clasts are volcanic rocks of the underlying Zavkhan formation as well as granite, limestone, and quartzite derived from other sources. The upper part of the unit (~60 m thick) is a layer of alternating mudstones and thinly bedded sandstones. The clastic unit consists of massive gray - green, arkosic sandstones (~ 60 m thick). The top part of the upper diamictites consists almost entirely of limestones or dolostones about 105 m thick which are included within the overlying Tsagaanolom formation. The rocks of the two units contain highly angular boulders, bed penetrating dropstones, striated clasts that show evidence of glacial activity. The presence of two diamictite units, cap dolomites, radiometric dates of underlying volcanics, rock composition, shape and size of intraclasts all suggest correlation of the Maikhanuul diamictites with Central Australian Neoproterozoic glacial marine deposits. It have been suggested that the tillites could be of Sturtian age; however, $\delta^{13}C$ values from limestones of the overlaying Tsagaanolom formatiom ($+2.8^{0}/_{00}$) do not exclude of possibility of Varanger ice age (Lindsay et al., 1996). Serezhnikova et al. (2014) reports new findings of problematical circular imprints in intertillites beds of the Maikhanuul formation. These problematical cm-sized circular (star-shaped, rod-shaped, globular and filamentous-shaped) remains were found in sandstones and siltstones of the flysch unit of the diamictites of the Maikhanuul formation. These forms may owe their origin to the activity of bacteria as well as of chemical reactions. According to Lindsay et al. (1996) we argued that the two units of the Maikhanuul diamictites were formed during a major ice age, and that potential of the western Mongolian diamictites for global correlation is high, as Central Asian Model.

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Link between complex internal structures and stratigraphy: Xradia – ZEISS MicroXCT-400 of genus *Sphaerogypsina* Galloway 1933

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First, spherical to semi-spherical forms, ranging in diameter from 0.6 to 2 mm with a characteristic chess-board surface and common in Paleogene tropical shallow-water carbonates were described as bryozoans. Later, such forms were classified into the foraminiferal species *Sphaerogypsina globulus*. In a number of studies that followed, morphological variations of tests found in recent sediments and in rocks of different ages were reported (*i.e*. Miocene, Late Eocene and Recent). But, all globular gypsinids have been called *S. globulus sensu lato* because without detailed internal structural characterization, species identification of larger foraminifera is impossible. Without adequate test sections, making a link between *Sphaerogypsina* and stratigraphy was hampered, too. To obtain an oriented test section for the identification of *Sphaerogypsina*, which grows by adding chambers in alternated cycles, is difficult. Application of Xradia – ZEISS MicroXCT-400 on tests ranging from the Late Eocene (Hungary), Miocene (Austria) and Pliocene (Jamaica) to recent (Adriatic Sea, Red Sea and Atlantic) combined with studies of Middle Eocene (Jamaica, Venezuela) specimens performed by cathodoluminiscence and transmitted light microscope, document the complexity of test growth. Resolution on a micrometric scale displays the inner character such as the size and position of the embryonic chambers, size and shape of embryonic chambers, juvenile, adult and gerontic chamberlets, size of pores and radial stacked superimposed chamberlets. A biometric analysis of form reveals that: a) recent forms are smaller than fossil ones (Eocene A-forms attained up to 1.85 mm in diameter, Miocene 1.1 mm, recent ones vary from 0.56 to 0.9 mm); b) diameters of embryonic cycles have more or less constant values (Eocene of 0.21 mm, Miocene 0.21 mm and recent 0.19 to 0.28 mm); c) Miocene and Red Sea tests have the same values of protoconch and deuteroconch diameters, the Eocene test had the largest and the Adriatic form the smallest values; d) the number of inserted radial stacks, varies according to the diameters of adult cycles. The position of embryonic apparatus wanders, from being at the centre to way off centre (with a different transition off centre). This study proved that differences in internal structures between the examined specimens ranging in age from Eocene, Neogene to Recent are of taxonomic importance and therefore fall within forms known as *S. globulus* more than one species exist (different genera are not excluded, however).

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Ordovician sea-level changes: one global curve or two semi-global ones?

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Comparative analysis of the Ordovician successions of the Siberian and North American platforms demonstrates a striking similarity in the long-term lithological changes and sea-level curve interpretation. On both platforms, Ordovician succession starts with tropical stromatolite-bearing carbonates, which abruptly changes to siliciclastic deposits (Baykit Sandstone in Siberia and Eureka Sandstone in North America respectively) and terminates with cool-water carbonates (Ettensohn, 2010; Herrmann et al., 2004; Kanygin et al., 2010; Dronov, 2013). Numerous K-bentonite beds in the Upper Ordovician of North American and Siberian platforms stressed this similarity (Huff et al., 2010; Dronov et al., 2011; Huff et al., 2014). The sea-level curve for the Ordovician of North American platform assumes a prominent sea-level drop at the base of the Middle Ordovician and a long-term lowstand during all the Dapingian and Darriwilian (80-100 m lower than in the Lower and Upper Ordovician), (Vail et al., 1977; Ross and Ross, 1992; 1995). The sea-level curve for the Ordovician of Siberian platform looks roughly the same (Dronov et al., 2009; Kanygin et al., 2010).

On the other hand, sea level curves for the Ordovician of the Gondwanan platforms (North Africa, Yangtze platform, South America, Avalonia) seem to share different patterns (Videt et al., 2010; Su, 2007; Heredia and Beresi, 1995; Woodcock, 1990). The Middle Ordovician represents rather a highstand interval in these reconstructions. As for the Baltica, there are two different sea-level models for this palaeocontinent. The sea-level curve suggested by Nielsen (2004) demonstrates close similarity to the North American model while the sea-level curve presented by Dronov and Holmer (2002) seems to fit better to the platforms rifted from the Gondwana palaeocontinent (Munnecke et al., 2010). This contradiction reflects opposite opinions in the interpretation of limestone units within the deep-water setting of the Ordovician basin of Baltoscandia (Dronov, 2013). The invasion of carbonate facies into the black shale realm is interpreted as a shallowing event in the deep-water model, assuming that limestone represents more shallow-water facies than the black shale (Nielsen, 2004). On the other hand, the same episodes in shallow-water areas are characterized by the expansion of the relatively deep-water marine red bed facies into the shallow-water realm, suggesting deepening events. In our opinion, the invasion of limestone facies into the deep-water black shale environment could be explained through the mechanism of "highstand shedding" (Schlager, 2007). According to this view, carbonates were transported from a shallow-water environment into a deep-water setting only at the time of maximum carbonate production in the shallow-water environment, i.e. during sea-level highstand. Based on this interpretation we suggest that Baltica also follow the Gondwanan sea-level patterns.

As a result instead of one global sea-level curve for the Ordovician (Haq and Shutter, 2008; Cooper et al., 2012) it would be probably more correct to suggest two semi-global curves for two big tectonic regions one of which includes Siberian and North American platforms and the other combine Baltica and Gondwanan platforms. This subdivision probably reflects position of the main Ordovician lithosphere plates.

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Late Tortonian to Messinian (6 – 8 Ma) chemo- and magnetostratigraphy from equatorial Pacific IODP Sites U1337 and U1338: towards an accurate late Miocene orbital calibration

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The synchronisation of radio-isotopic and astronomical dating techniques (rock-clock synchronisation), and the late Tortonian to Messinian Geological Time Scale is mainly constructed using astronomical tuning of sedimentary cycles in Mediterranean outcrops. Recent studies utilising astronomically tuned deep-sea sedimentary successions challenge the Mediterranean tuning. To test the rock-clock synchronisation, it is crucial to obtain very accurate ages for magnetic polarity chrons between 6-8 Ma, particularly Chrons C3An.2n, C3.Ar and C3Bn, independent of the Mediterranean calibration. However, outside of the Mediterranean basin, a stand-alone high-quality, high-resolution chemo-, magneto-, and cyclostratigraphy covering 6-8 Ma at a single DSDP/ODP/IODP site does not currently exist.

The lack of appropriate records changed with retrieval of adjacent equatorial Pacific IODP Sites U1337 (4463 mbsl) and U1338 (4200 mbsl). In the interval of interest, both sites are carbonate-rich, characterised by cyclic Milankovitch-related variations in colour and lithology, have a basic magnetostratigraphy, ~2 cm/kyr sedimentation rates, and a complete sedimentary succession. These archives are ideal for generating an accurate astronomically calibrated high-resolution integrated chemo- and magneto-stratigraphy, which is required to successfully test the rock-clock synchronisation.

Here we present initial results of a high-quality benthic stable isotope and magnetic polarity record from IODP Site U1337. Despite low natural remanent magnetisation in the discrete sample data, a good magnetostratigraphy can be established at Site U1337 by combining inclination and declination data from ~400 palaeomagnetic cube samples with shipboard half-core measurements. At Site U1337, 14 polarity changes were identified between the top of Chron C3An.1n (6.033 Ma) to the base of Chron C4n.2n (8.1.08 Ma). Core images and well-defined metre-scale cycles in major elemental records from X-ray fluorescence (XRF) core scanning at Sites U1337 and U1338 enabled a high-resolution correlation between the sites from 0-10 Ma. This correlation is integral to combining the improved Site U1337 magnetostratigraphy with the Site U1338 magnetostratigraphy, and to integrating the Site U1337 and U1338 benthic isotope records to create a robust, high-resolution, late Miocene isotope stratigraphy that can be astronomically tuned with unprecedented accuracy.

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An end-Paleogene Flora of Angiosperms from Northeast Brazil: Testimony of the Initial Appearance of Modern Plant Biomes

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The short interval of warm climate that characterized the end of Oligocene had a great influence on the evolution of flowering plants, leading to the first appearance of elements that nowadays characterized the tropical forests and landscapes with a kind of hydric-restriction (savannah and grasslands). This time interval was recently considered also the moment to the first geological stresses that conducted to the Andean uplift and consequent appearing of land connections between the South and Central Americas. The angiosperm assemblage here informed comes from a bentonitic shale interval of a volcanic-sedimentary succession from Boa Vista Basin (Campos Novos Formation), in State of Paraiba, Northeast Brazil. ^{40}Ar/^{39}Ar age data from lower and upper lava flows constrain the plant fossil levels to the Late Oligocene. The taphoflora, composed exclusively by angiosperm remains shows to be dominated by Fabaceae related forms, including legumes and a little flower, accompanied by Lauraceae, Annonaceae, Burseraceae, Anacardiaceae, Myrtaceae and Malvaceae. The assemblage indicates an arboreal and pioneering vegetation which analogous grows today in distinct Brazilian and Mesoamerica Neotropical biomes. The leaf physiognomies supports the tropical condition of climate, but the microphyllic sizes of the laminas informs about a kind of stressing conditions (seasonal dry periods or volcanic activity). This well-dated floral assemblage, preserved in a restrict intracratonic (or pull-apart) basin, suggests that continuous lands exists between northern South America and the south of Central America and could be a good tool to test the balance between the auto-and allocyclic controls of biotic events.

To Every Plutonic, Metamorphic and Structural Rock, Its Proper Stratigraphic Name

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Although crystalline (non-stratified) rocks cover approximately 75% of the exposed surface area of the planet, the application of stratigraphic nomenclature to these rock units lags far behind that of stratified rocks. This is still the case, even though it has been over 30 years since the 1983 North American Stratigraphic Code (Articles 31-42) introduced the concept of lithodemic units which were specifically designed for stratigraphic analysis of intrusive and metamorphic rock bodies (NACSN 1983, 2005). The purpose of this presentation is to serve as a primer for the application of lithostratigraphic (*sensu lato*) nomenclature for crystalline rocks (in particular, Precambrian rocks). It includes examples from the literature to illustrate the application of both *formal* and *informal* stratigraphic nomenclature to crystalline rocks.

The familiar lithostratigraphic units include Formations, Groups and Supergroups (lithostratigraphic units, *sensu stricto*), which can and have been applied to low metamorphic grade rocks where the law of superposition applies. The equivalent lithodemic units - Lithodemes, Suites, Supersuites, Complexes and Structural Complexes - are applied to low to high metamorphic grade intrusive and/or metamorphic rocks where the law of superposition cannot be demonstrated (NACSN 1983, 2005). Most importantly, the basic rules that are applied to lithodemic units (plutonic and otherwise) are the same as those applied to standard lithostratigraphic units (*e.g.,* formations, groups, *etc.*). Key is declaring that you wish to formalize the nomenclature, that you provide type or reference sections for the unit, that you adequately describe as many properties of the unit as possible (mineralogy, grain size, nature of contacts with adjacent units), and that you publish your nomenclature in a form that is readily accessible to the geological community. Too often the unit names are created, but these other details are forgotten. However, it must be remembered that a unit is only formalized when all of these steps have been taken.

Examples of informal lithostratigraphic units can include all of the previous units when they are not formally defined, as well as units such as gneiss associations and tectonic assemblages (Easton 2009). A "gneiss association" is primarily based on rock type, but also may contain information with respect to plutonic history, metamorphism and/or mafic intrusions (*i.e.,* dikes). If formally named, it would correspond to a suite or an intrusive or metamorphic complex. In contrast, a "tectonic assemblage" consists of stratified volcanic and/or sedimentary rock units built during a discrete interval of time in a common depositional or volcanic setting. The rock units typically share a common lithofacies, but also can share additional attributes, such as structural, metamorphic, geochemical and geophysical features. A tectonic assemblage is typically bounded by faults, unconformities and/or younger intrusions. A tectonic assemblage may consist of one or more groups or formations, and one or more tectonic assemblages may constitute a terrane or a domain.

Areas of possible improvement in the existing formal and informal stratigraphic units include clarification of the definition of "intrusive complex", discussion of the need for additional lower and intermediate rank terms when it comes to describing igneous rocks, and the eventual transition of informally defined units (tectonic assemblages) to properly defined chronostratigraphic units.

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The dinoflagellate cyst *Labyrinthodinium truncatum* and the base of the Langhian: North American perspectives

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The Coastal Plain of eastern North America is a fascinating and challenging place to do biostratigraphy. The Miocene was a time of rapid sea level changes that resulted in episodes of erosion and non-deposition that now punctuate the stratigraphic record. Open-marine microfossils such as foraminfera and calcareous nannofossils are near their practical limits. There are few outcrops, but shallow core material is often available. The study of the occurrences of the dinoflagellate cyst *Labyrinthodinium truncatum* around potential stratigraphic positions for the base of the Langhian Stage is illustrative.

Since the early 1980s, the lowest occurrence of *Labyrinthodinium truncatum* has been used to approximate the base of the middle Miocene in Europe and, more recently, in North America. When this occurrence is used as a correlation point, it cannot also be used to examine regional variations in the details of its lowest occurrence.

There are two subspecies of *Labyrinthodinium truncatum*: *L. truncatum truncatum* and *L. truncatum modicum*. The subspecies are distinguished by morphological differences. *L. truncatum truncatum* has less numerous processes that are longer (≥ 4 µm) and typically have some sort of alignment into longitudinal series. *L. truncatum modicum* has more numerous processes that are shorter (< 4 µm) and cannot be separated into longitudinal series. From these specifications, it is clear that intermediate permutations are possible.

The two subspecies have different ranges. *L. truncatum modicum* is found stratigraphically lower than *L. truncatum truncatum* in sections from eastern North America. Forms that are intermediate between the two subspecies are present above the lowest occurrence of *L. truncatum modicum*; above that *L. truncatum truncatum* becomes dominant. The lowest occurrence of *L. truncatum modicum* is one biostratigraphic datum. The lowest occurrence of the clear presence and dominance of *L. truncatum truncatum* is another biostratigraphic datum.

A major challenge is integrating these datums with other chronostratigraphic datums. Based on both published and unpublished information, the lowest occurrence of *L. truncatum modicum* is at the approximate level of the lowest occurrence of the foraminifera *Globigerinoides sicanus* in eastern North America. The lowest occurrence of *L. truncatum truncatum* is below the base of the foraminifera *Orbulina suturalis* and may be approximately at the level of the base of *Praeorbulina glomerosa circularis* or may be above it.

By necessity, my correlations to magnetostratigraphic chrons and subchrons are indirect. The published literature has at least 4 different recent correlations o f magnetostratigraphy to these dinocyst and/or foraminifera datums. As pointed out by others, strontium isotope ratios in this time interval have large (up to ±1.5 m.y.) uncertainties associated with them and may show systematic offsets of expected dates.

The morphologic plasticity and taxonomic complexity of *Labyrinthodinium truncatum* are not unique to dinocysts, as evidenced by similar complexity in the foraminifera at this time (e.g. *Praeorbulina*). The stability provided by a Langhian GSSP, when a final decision is made, and the detailed studies that preceded it, can be expected to increase understanding of morphologic and evolutionary complexity.

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Extinction and recovery of plancktonic foraminifera across the Santonian-Campanian transition in northwestern Tunisia

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In order to study planktonic foraminiferal distribution and behavior across the upper Santonian-lower Campanian interval, several sections in northwestern Tunisia are studied in detail. In El Kef and Ellès sections this interval consists of marls gradually enriched in limestones belonging to the upper part of the Kef Formation and lower part of Abiod Formation, including the lower bed of indurated white limestone.

Quantitative analysis of foraminifera based on representative fraction containing at least 300 specimens from each sample show dominance and high diversification of planktonic foraminifera. Benthic foraminifera and Ostracoda are rare.

In the studied interval, the planktonic foraminiferal assemblages are diverse in terms of genera (*Heterohelix*, *Marginotruncana*, *Dicarinella*, *Sigalia*, *Ventilabrella*, *Planoglobulina*, *Globotruncana*, *Globotruncanita, ...*) and species dwelling intermediate and surface sea water of the upper bathyal zone.

Some species disappeared in the upper part of the Santonian Stage, especially those belonging to *Marginotruncana* (*M. tarfayaensis, M. schneegansi, M. coronata, M. renzi, M. paraconcavata*) and all of the genus *Dicarinella*.

Other species thrived such us *Globotruncana arca*, *G. orientalis, G. mariei*, *G. bulloides*, *G. linneiana*, and *Globotruncanita elevata.*

Among large Heterohelicidae, *Sigalia deflaensia* and *Sigalia carpatica* disappeared at the S/C boundary concurrently to *Ventilabrella decoratissima.* However, *Sigalia bejaouensis*, *Planoglobulina manuelensis*, *Ventilabrella eggeri*, and *V. alpina* appeared in the upper Santonian.

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The Liassic of the High Atlas, Morocco (Ait Bou Guemmez Area): Sedimentologic and Structural Pattern

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Stratigraphical studies carried out in the Aït Bou Guemmez area (Central High Atlas, Morocco), lead us to precise the nature and the spatial organisation of Liassic deposits. The series is composed of four sedimentary units: Hettangian - lower Sinemurian; upper Sinemurian - lower Carixian; middle Carixian - upper Domerian; late Domerian - Toarcian p.p. Each of these produces transgressive – regressive cycles. These units are limited by regional unconformities, coinciding with the main periods of accentuating the structuration in the axis of the central High Atlas belt.
The structural analysis undertaken at various sites along the Jbel Tizal - Jbel Azourki fault, shows a local extension during the entire Liassic, related to rifting, which marked the west-Tethyian margin. The NW-SE direction of the extension in the lower Liassic implies the continuity of the same mechanisms in the central High Atlas, responsible for the creation of the Upper Triassic basin în the Atlas domain. Those oriented NE - SW during the middle - upper Liassic implies a reorientation of the main axis in the region of Aït Bou Guemmez. This change induces a new geodynamic evolution.

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Magnetostratigraphy of Neogene continental series of Guercif Basin (Morocco)

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A multidisciplinary study based on paleontological, sedimentological and tectonic-sedimentary approaches was carried out in the Guercif basin in order to understand the phenomena that have contributed to the development of the Neogene formations characteristic of the Taza-Guercif Basin. The main structures of this basin consist of anticlines with a general orientation between N 20° and N 45° corresponding to the Messinian compression and normal faults generally oriented N 70° corresponding to the extensive period during the Tortonian. Four lithostratigraphic sections have fitted on which 136 samples have been taken for the magnetostratigraphic study. The magnetic characteristics of these rocks show that the magnetization usually results from the presence of magnetite, titanate-magnetite, goethite and hematite. The results demonstrate the presence of a single reverse polarity in the case of the Khendek El Ouaich section correlated with chron C3Br.2r (7.3-7.5 Ma) based on biochronological and radiometric data. However, Ain Guettara section shows a succession of at least three normal polarities and two opposite polarities. In the absence of a timing reference, the section could not be correlated with the geomagnetic scale. The Oued Lahmar section, situated in the south of Guettara section shows a succession of 4 normal polarities and 5 inverse polarities. The last section is a continental formation formed in the Safsafat anticline. The magnetostratigraphy applied on this section shows a succession of normal and inverse polarities.

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Submarine volcanism and deep-marine sedimentation in an intraarc basin of southern Chile: evidence of extension and crustal thinning in the Patagonian Andes during the Late Oligocene - Early Miocene

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The Chilean margin has been considered as the model of an ocean-continent convergent system dominated by compression and active mountain building as a consequence of the strong mechanical coupling between the upper and the lower plates. The Andes of southern Chile, however, have not been in a permanent state of compression throughout the Cenozoic as they show alternating phases of compressive and extensional deformation. Volcano-sedimentary marine strata in the Aysén region of southern Chile were investigated to better understand the extensional phases and crustal thinning that occurred in the Andean orogeny as these deposits constitute the only reliable record of submarine arc volcanism during the Cenozoic in southern South America. In order to discern the age and tectono-sedimentary setting of these strata, referred to as the Traiguén Formation, we integrate sedimentology, ichnology, petrography, geochemistry, structural geology, density distribution, foraminiferal micropaleontology, and U-Pb geochronology. Our results indicate that the Traiguén Formation was deposited in a deep-marine intraarc basin dominated by extensional tectonics during the Late Oligocene-earliest Miocene. The geochemistry and petrography of the pillow basalts suggest that they formed in a volcanic arc on a thinned crust rather than at an oceanic spreading center. We attribute the origin of the Traiguén basin to a transient period of slab rollback and invigorated asthenospheric wedge circulation that was caused by an increase in trench-normal convergence rate at ca. 26–28 Ma and which resulted in a regional event of extension and widespread volcanism.

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The Early Maastrichtian benthic meso- and macrofauna of Kronsmoor (northern Germany): an integrated ecosystem analysis of the Late Cretaceous Chalk Sea

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The relatively small modern shelf seas are characterized by high biological productivity, suggesting that primary productivity in shelf seas should have been even more important during much of the greenhouse world of the geological past when large, shallow epicontinental seas existed. However, the structure of marine fossil food chains in pre-Cenozoic oceans is poorly understood. This is also true for the food chains of the Cretaceous Chalk Sea due to the lack of high-resolution integrated palaeobiological, palaeoecological and geochemical data.

The Saturn quarry near Kronsmoor (Schleswig-Holstein, northern Germany) offers an undisturbed section of Upper Campian to Lower Maastrichtian Chalk (Kronsmoor and Hemmoor formations, Niebuhr 2006). This section is the target of the DFG Project "Biodiversity and plankton-benthos coupling: an integrated ecosystem analysis from the Late Cretaceous Chalk". The aim of this part of the study is the reconstruction of the benthic community with meso- and macrofossils. A 32m-thick detailed section of the Lower Maastrichtian *B. obtusa* and *B. sumensis* zones was logged and bulk samples of about 5kg each were retrieved in a distance of one meter. Several samples have already been washed, showing a diverse assemblage of bryozoans, benthic foraminifers, ostracods, fragments of brachiopods and bivalves, spines and corona plates of different echinid taxa, sponge debris and tiny serpulids. Furthermore, numerous macrofossils that have been collected in-situ bed-by-bed. The lower part of the section (*B. obtusa* Zone) is poorly macrofossiliferous and only about 100 benthic macrofossils were collected, mostly irregular and regular echinoids, brachiopods and crinoids. The upper part (*B. sumensis* Zone) yielded over 900 macrobenthic fossils with an overall much higher diversity. As a result, there are conspicuous changes of the macrobenthic community:

- a general increase in abundance of benthic macrofossils (e.g., the abundance of brachiopods increases from only 30 to over 500 specimens).
- the diversity of benthic macrofossils rises significantly (e.g., bivalves diversified from three genera to eight).

In addition to the fossil diversity, the feeding and living modes of the benthic macrofauna will be considered in the palaeoecological analysis. Irregular echinoids such as *Echinocorys* were infaunal detritivores. The other irregular echinoids (e.g. *Galerites*) lived epifaunally and were grazer-deposit feeders. The bivalves such as *Pycnodonte vesicularis* and *Spondylus spinosus* as well as the brachiopods (e.g., *Neoliothyrina obesa*), crinoids and corals were mostly suspension feeders and they lived either mobile or stationary epifaunally. Preliminary results indicate that most representatives of the Early Maastrichtian benthic community of Kronsmoor were dependent on the availability of particulate organic matter. In the absence of any indications for oxygen depletion and/or deviations from normal marine salinity, our present hypothesis is that the lower part of the section represents an oligotrophic phase with low productivity while the upper part reflects a more mesotrophic phase with consequently enhanced fluxes of organic carbon to the sea-floor. This interpretation is supported by the appearance of flint-bearing sediments (commonly assigned to high-productivity settings) at the transition into the Hemmoor Formation. During the forthcoming investigations, microfaunal and nannoplankton data as well as geochemical proxies will be integrated in order to comprehensively reconstruct the Chalk Sea ecosystem.

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Calcareous nannofossil biostratigraphy of the late Albian - early Turonian time interval: implications for global correlations

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Calcareous nannofossil biostratigraphy is proven to be a reliable tool for dating and correlating Cretaceous sequences at regional to global. However, assessment of nannofossil event reproducibility still demands detail investigations of different oceanic basins, paleolatitudes and settings.
In this study we present the revision of nannofossil biostratigraphic events across the late Albian – early Turonian time interval. We investigated pelagic and hemipelagic sections located in different sedimentary basins in order to estimate reproducibility and variability of nannofossil bioevents in different paleoceanographic regimes and/or latitudes and to evaluate the applicability of the three major nannofossil zonations available for the mid Cretaceous. The studied sections are located in the Tethys Ocean, Vocontian Trough, Moroccan basin, Western Interior Seaway, and Pacific Ocean and were selected on the basis of availability of chemo-bio-stratigraphic data to constrain the age of nannofossil events relative to stages, C-isotope anomalies and Oceanic Anoxic Events (OAEs).
Most of the observed taxa are unambiguously described in the literature, but some taxonomic revision has been applied to cases of potential misidentification and discrepant attribution. Each zonal and subzonal nannofossil event was evaluated for assessing the reproducibility, sinchroneity or diachroneity. Also, a few additional potential nannofossil events are discussed in comparison with zonal and subzonal markers. Nannofossil Biohorizons were also examined in the context of stage boundaries definition, namely the Albian/Cenomanian and the Cenomanian/Turonian boundary, to provide further information about the applicability of nannofossil events and the achievable resolution.
Moreover, our investigation proved nannofossil events to be extremely useful to biostratigraphically constrain paleoceanographic events of the late Albian – early Turonian interval, namely the latest Albian OAE 1d, the mid Cenomanian MCE I and the latest Cenomanian OAE 2, which were successfully characterized in all the studied sequences.

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Proposal to Reconsider an Ediacaran-Cambrian Boundary Stratotype Section and Point (GSSP) at the First Occurrence (FAD) of Mineral-Shelled Cloudinids

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Search for a suitable Ediacaran/Cambrian stratotype section is either handicapped by lack of body fossils as in the Fortune Bay section of eastern Newfoundland or by a major hiatus indicating discontinuity of depositional record as demonstrated in all shallow marine platformal sequences such as in China, Australia, Siberia, Morocco, Namibia, Paraguay Belt of western South America and other sections worldwide, which span the Precambrian-Cambrian stratigraphic interval. Apparently this hiatus and/or multiple hiati are due to a bipolar glacially induced regression. Evidence for such an extensive time gap in the depositional record is known both from the northern and southern hemisphere: The infra-Cambrian Baykonurian glacial diamictites of Siberia and the coeval Nomtsas glacial episodes of Namibia. According to new research results the high degree of similarity of the geological facies evolution with other parts of the world (e.g., Yangtze Platform, Siberia, Spain, Namibia and South America) can be demonstrated, where the fragmentation of the Rodinia super-continent and Neoproterozoic glaciations are also well documented. In the Corumbá region (Paraguay Belt) the sharp top contact of the shallow marine Tamengo Formation with the laminated black shales (containing rare angular dropstones) of the discordantly overlying Guaicurus Formation indicates that the latter represents a new transgressive glacially influenced marine onlap succession. A Cambrian age of the GuaicurusShales is not (yet) biostratigraphically verified; however, the underlying fossil record of cloudinids indicates a terminal Ediacaran age for the top of the Tamengo Formation. The microtubular cloudinids are interpreted as dysoxic analogues of recent tubeworms and are suggested to serve as first skeletonized "index fossils" worldwide to delineate the onset of a Phanerozoic-type body fossil vectorial evolutionary pathway. Based on the FAD of a cloudinid species as marker fossil a revision of the Precambrian/Cambrian boundary is here advocated. This would avoid placing this important GSSP into the virtually worldwide occurring Nomtsas-Baykonurian glacial hiatus or into the currently defined and re-advocated deeper-water clastic GSSP section at Fortune Bay, eastern Newfoundland, which is devoid of body fossils. This section currently represents the GSSP for the lower boundary of the Cambrian System and is biologically documented exclusively by trace fossils. These trace fossils (or any behaviorally mediated paleoecological signals) do not document a vectorial evolutionary trend and cannot be regarded to mark any intersystemic boundary according to the IUGS-ICS Code. The Ediacaran Subcommission encourage search for an alternative stratigraphic horizon, but they do not advocate that any alternative GSSP for the Ediacaran-Cambrian boundary should be considered to be placed at a level below the glacigenically induced Nomtsas-Baykonurianhiati. Such terminal Ediacaran sections for a new potential Cambrian GSSP are observed in the Paraguay Belt of SW Brazil, eastern Paraguay and in eastern Uruguay, and are also documented elsewhere.

In accordance with IUGS-ICS regulations it is here proposed to adopt a new Cambrian GSSP within a depositionally continuous section that is marked by the first occurrence of a taxonomically well defined cloudinid species and which has a widespread record from many parts of the world.

Ontogeny, morphological variability and taphonomy of *Oryctocephalus indicus* (Reed, 1910) from the Kaili Formation, South China

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The First Appearance Datum (FAD) of the oryctocephalid trilobite *Oryctocephalus indicus* (Reed, 1910) is one of the candidates to establish the base of the Cambrian Series 3, Stage 5. However, despite of the importance of this trilobite for intercontinental correlation its morphological variation has been briefly studied and its ontogeny is unknown.

Good stratigraphic and taphonomic control is essential for making an informed assessment of taxonomy and intraspecific variation. In addition to being based on small numbers of specimens, many oryctocephalid trilobites from USA, Himalaya or Siberia also lack adequate taphonomic control. Furthermore, ontogenetic studies are necessary in order to assess whether observed morphological differences might relate to differences among growth stages. The aim of this work is to assess the morphological variation and taphonomy in *Oryctocephalus indicus* from South China. During the last 30 years intensive and detailed sampling has been carried out at the Kaili Formation in the Wuliu-Zengjiayan Section, Guizhou Province, China and about 1000 specimens of *Oryctocephalus indicus* have been collected. Most of the specimens come from the Wuliu Zengjiayan Section but also other sections have been deeply worked (e.g. Miaobanpo, Jianshan, Pingzhai and Sanwan sections).

The high number of specimens allow us to describe the juvenile morphology and ontogeny of *Oryctocephalus indicus* from South China. The new material comprises a relatively complete meraspid ontogenetic series, which shows new details on their morphological changes such as the changes in the facial suture and the addition of the trunk segments. The trunk segmentation schedule of *Oryctocephalus indicus* is slightly different of other Cambrian oryctocephalid trilobites such as *Arthricocephalus*. Despite of the the boundary between thorax and pygidium migrated posteriorly as well as in other oryctocephalid, our sample shows a variability in the number of trunk segment among holaspid specimens.

Our study suggest that all specimens from these sections belong to a single, relatively variable, morphospecies; *Oryctocephalus indicus*. The previous defined subspecies seems to be related with ontogenetically patterns or taphonomy variation which produced a mosaic of morphotypes. For instance, the number of trunk segments (from 15 to 19) or the shape of the facial suture are close related with ontogeny changes. However some morphological features of the glabellar furrows such as transglabellar SO, S1 and S2 or the presence/absence of S4 are dependent of the taphonomy.

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The Cenomanian/Turonian Boundary Interval at Clot de Chevalier (Vocontian Basin, France): planktonic foraminiferal biostratigraphy and species diversification

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The Cenomanian/Turonian Boundary Interval has been object of a number of studies aimed to assess the causes of the Oceanic Anoxic Event 2 (OAE 2) and to constrain its consequences on the marine biota. Planktonic foraminifera were generally resilient to this environmental perturbation and only the single-keeled rotaliporids disappeared in the latest Cenomanian at the onset of the event, with the extinction of their last representative *Rotalipora cushmani*. However, several new lineages, including the double-keeled genera *Dicarinella* and *Marginotruncana* evolved in the late Cenomanian, survived to the OAE 2 and dominated the planktonic foraminiferal assemblages until the Santonian, possibly implying the acquisition of a new life strategy that resulted successful for several mys.

Despite several sections have been studied for planktonic foraminifera in the Vocontian Basin, none of these sections have been entirely studied in washed residues because of the compactness of the lithologies. Moreover, studies aimed to assess the planktonic foraminiferal response to the OAE 2 have often overlooked the remarkable morphological plasticity of specimens occurring in this stratigraphic interval.

The Clot de Chevalier section (Vocontian Basin, France) is 35 m thick and consists of alternated dark grey marlstones and light grey more indurated limestones spanning the uppermost Cenomanian–lowermost Turonian stratigraphic interval. The section includes a 15 m thick succession of alternated marlstones and laminated black shale layers, representing the lithological expression of the OAE 2. We present new biostratigraphic, taxonomic, and relative abundance data of planktonic foraminiferal species from Clot de Chevalier, with the aim to (1) document the morphological plasticity of planktonic foraminifera in this time interval (2) stabilize their taxonomy through the reconstruction of phyletic lineages and (3) possibly identify a promising secondary marker for the base of the Turonian, overcoming the problem of the unreliable lowest occurrence of *Helvetoglobotruncana helvetica*. For the purposes of this study we examined 37 samples that were processed with acetic acid to extract isolated planktonic foraminifera that were studied in washed residues. Planktonic foraminiferal bioevents and assemblage composition identified at Clot de Chevalier have been compared with the well-studied Pont d'Issole section (Grosheny et al., 2006; Jarvis et al., 2011) located ca. 15 km to the NE, highlighting a problematic correlation in some stratigraphic intervals.

Results of our study support the validity of several species that have been misidentified and/or overlooked in the literature (i.e., *Dicarinella roddai*, *Praeglobotruncana oraviensis*, *Marginotruncana caronae*), whose appearances represent promising bioevents to improve the current planktonic foraminiferal biozonation. In addition, we document the occurrence of three new trochospiral species never described and/or illustrated in the literature, whose occurrence and abundance in the assemblages might provide new information for paleoceanographic reconstructions. We also identified intermediate morphotypes between ancestor and descendant species (i.e., *Marginotruncana* cf. *schneegansi*, *Marginotruncana* cf. *sigali*) that are extremely useful to reconstruct phyletic lineages among double-keeled taxa that first evolved in the late Cenomanian to early Turonian time interval. Finally, our observations provide new insights on the evolution of planktonic foraminifera across the Cenomanian–Turonian Boundary Interval that appears as a time of evolutionary experimentation, rather than crisis, for several lineages.

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Stratigraphy and paleogeography of the Ordovician-Silurian Wufeng and Lungmachi black shales in South China

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The black shales of the Wufeng and Lungmachi formations are widely distributed in South China. Both of the formations are dominated by graptolites. The Wufeng Formation consists of black shales and cherts with an average thickness of about 6 meters. Four graptolite biozones from upper Katian to lower Hirnantian can be distinguished, including the *Dicellograptus complanatus* Biozone, the *Dicellograptus complexus* Biozone, the *Paraorthograptus pacificus* Biozone and the *Metabolograptus extraordinarius* Biozone in ascending order. Above the Wufeng Formation is the Kuanyinchiao Bed, which is generally less than half a meter in thickness and mostly composed of argillaceous limestones or mudstones. It contains the famous *Hirnantia* shelly fauna, which is mostly correlated to mid-Hirnantian in age. The Lungmachi Formation lies mostly on the Kuanyinchiao Bed. It can be recognized as two parts, black shales, silty shales and sandstones in the lower part, and gray and yellowish shales and mudstones in the upper part. The lower Lungmachi Formation black shales are generally 50-80 meters in thickness. Nine graptolite biozones from upper Hirnantian to lower Telychian can be recognized from the lower Lungmachi Formation, including the P*ersculptograptus persculptus* Biozone, the *Akidograptus ascensus* Biozone, the *Parakidograptus acuminatus* Biozone, the *Cystograptus vesiculosus* Biozone, the *Coronograptus cyphus* Biozone, the *Demirastrites triangulatus* Biozone, the *Lituigraptus convolutus* Biozone, the *Stimulograptus sedgwickii* Biozone and the *Spirograptus guerichi* Biozone.

The basal and upper contacts of both the Wufeng and Lungmachi black shales are diachronous. The Hirnantian glaciation and the associated sea-level fall, together with regional tectonic movement, the Kwangsian Orogeny, resulted in the significant hiatus between the two formations in many areas in South China.

The GSSP for the base of the Hirnantian Stage was set in the Wufeng Formation at Wangjiawan North, Yichang, Hubei Province in 2006. The Bajiaomiao section, Shennongjia, Hubei Province, which yields continuous sequence from the *P. persculptus* Biozone to the *Spirograptus turriculatus* Biozone, was proposed as the candidate section for the restudy of the GSSPs for the bases of the Aeronian and Telychian stages.

A big compilation of over 400 sections covering the Ordovician-Silurian transition has been used for the reconstruction of the temporal and spatial distribution of the Wufeng and Lungmachi black shales. The uneven distributions of both black shales can be recognized precisely.

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Conodonts from the Cambrian-Ordovician boundary interval in the Upper Yangtze region, South China

FAN, Ru[1,2,3,4], DENG, Sheng-Hui[1,2,3], LU, Yuan-Zheng[1,2,3], ZHANG, Xue-Lei[1], LI, Xin[1,2,3], ZHANG, Shi-Ben[1,2,3]

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Conodonts from the Cambrian-Ordovician transition at the Liangcun section in Xishui County, Guizhou and at the Huangcao section in Wulong County, Chongqing are examined for the first time. Both sections are located in the Upper Yangtze region. A total of 1367 specimens were recovered, representing 30 species and 15 genera. Based on the ranges of conodonts generalized from these two sections and another six sections previously studied in the same region, three conodont zones, *Cordylodus proavus*, *Monocostodus sevierensis* and *Cordylodus angulatus* zones are recognized. The index species of the Cambrian-Ordovician boundary at the global stratotype section and point (GSSP), *Iapetognathus fluctivagus* and its substitute in China *I. jilinensis* are not observed in the study sections, therefore it is impossible to determine the Cambrian-Ordovician boundary exactly. However, it probably lies within the lower part of *M. sevierensis* zone (the upper part of the Loushanguan Group), correlating with the GSSP in Canada and the Dayangcha section in China. Chronological sequences of the FAD (First Appearance Datum) of *C. angulatus*, *Chosonodina herfurthi* and *Rossodus manitouensis* are not obvious in the study, so the *C. angulatus* zone here is correlated with zones defined by *C. angulatus*, *Ch. herfurthi* and *R. manitouensis* in the Lower Yangtze region.

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Significant Carbon isotope excursions with implications for global correlations in the Cambrian

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The existing $\delta^{13}C$ data in the Cambrian from different regions of the world are analyzed in this research. It indicates that there are four carbon isotope excursions which have been well documented with global significance. In ascending order, they are: (1) a large negative excursion, comparable to "BACE" (BAsal Cambrian Carbon isotope Excursion) event, which occurs near the Precambrian-Cambrian boundary with a magnitude of 4‰–10‰ (PDB), (2) the "ZHUCE" (ZHUjiaqing Carbon isotope Excursion) event, a distinct positive excursion (over +5‰) that can be recognized at the Fortunian Stage to Stage 2 transition, (3) another strong negative one, so called "ROECE" (Redlichiid-Olenellid Extinction Carbon isotope Excursion) event, shifting at the interval between Series 2 and Series 3, peaking at -3‰ – -5‰ (PDB), (4) the famous Steptoean positive carbon isotope excursion (SPICE), which has been widely identified at the base of Furongian Series, Paibian Stage, with an amplitude about 4‰ (PDB). The four sharp $\delta^{13}C$ shifts correlate well with coeval paleoceanographic changes and bioevents. Besides, there are some $\delta^{13}C$ excursions from a few sections in previous studies, and more data are required to identify whether they are global or regional ones.

Reconstruction of Archaeological Landscape of Gobustan and the relationship with the Caspian Sea level changes at the end of Late Pleistocene and Early Holocene

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Gobustan as a geographical region in East Azerbaijan is a vast territory of ravines and gorges, which is located between the south-east foot of the Great Caucasus and the Caspian Sea. Orogenesis has taken place in Gobustan in the late Pleistocene. At that period the present mountains Beyukdash, Kichikdash, Jingirdag and Shongardag were washed up by the fresh Khvalyn Sea with didacnas.

Of special interest are the “Gaya arasi”and “Firuz-2” sites on Kichikdash mountain and “Ana zaga”, “Okuzler” and “Ovchular” caves on Beyukdash mountain. The study and dating of cultural layers of these sites let us reconstruct the archaeological landscape of Gobustan in the late Pleistocene and early Holocene. One of the interesting findings are 6 *Didacna* cockleshells that were revealed on the upper terrace of Beyukdash mountain from the cultural layer of Okuzler-2 site determining the Paleolithic age of the site.

Rock images of small boats were found on the high cave walls in the “Gaya arasi” site. The average layer in this cave was dated back to 13,660 years B.P. At present, work on testing and dating cultural layers of the given site are still going on.

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Condylopyge Hawle and Corda, 1847 in the Barrandian area (Czech Republic, agnostida): Biostratigraphical and palaeogeographical significance

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Condylopyge rex (Barrande, 1846), type species of the agnostid genus *Condylopyge* Hawle and Corda, 1847, was originally described from the *Paradoxides* (*Eccaparadoxides*) *pusillus* Zone of the Skryje–Týřovice Basin (early Drumian, Buchava Formation, Barrandian area, Czech Republic). *Condylopyge* has been only recently ascertained also in the Příbram–Jince Basin, where *C. rex* and *C. regia* (Sjögren, 1872) are present in two different levels of the Jince Formation.

Sixteen species and one subspecies have been assigned to the genus *Condylopyge*, namely: *C. amitina* Rushton, 1966; *C. antiqua* Elicki and Pilolla, 2004; *C. cambrensis* (Hicks, 1871); *C. carinata* Westergård, 1936; *C. carinata vicina* Jegorova, 1972; *C. cruzensis* Liñán and Gozalo, 1986; *C. eli* Geyer, 1998; *C. globosa* (Illing, 1916); *C. imperator* Howell, 1935; *C. matutina* Dean, 2005; *C. regia* (Sjögren, 1872); *C. rex* (Barrande, 1846); *C. regulus* (Matthew, 1886); *C. spinigera* Westergård, 1946; *C. transectus* (Matthew, 1896); two species are to be considered *nomina nuda*, *C. etaerus* Fletcher, 1972 and *C. ishensis* Perf.

Separate species show usually short stratigraphical ranges in the interval from upper levels of the Cambrian Series 2 (Stage 4; *C. amitina* from the *Orodes* Zone, Purley Shale Formation, Nuneaton, Wales) to middle levels of the Cambrian Series 3 (late Drumian; *C. rex* and *C. spinigera* from the *Ptychagnostus punctuosus* Zone in Sweden and Wales).

From point of view of exoskeletal morphology, three groups could be distinguished in *Condylopyge*:
(1) the older *aminitina – eli* group includes *C. aminitina*, *C. antiqua*, *C. cruzensis*, *C. eli* and *C. matutina*. All species are characterized by only slightly expanded anteroglabella; members this group are known in all major areas with the exception of Baltica,
(2) the most diverse and widely distributed is the *carinata – rex* group, which includes *C. carinata*, *C. globosa*, *C. regia*, *C. rex* and the poorly known species *C. cambrensis*, *C. imperator*, *C. regulus* and *C. transectus*. These species show a typically expanded anteroglabella; specimens belonging to this group are known in all major areas with the exception of Morocco and Turkey,
(3) the youngest species *C. spinigera* shows conspicuously angulate cephalic and pygidial outlines, this species survives in Baltica and eastern Newfoundland to the end of Drumian.

If plotted on a Cambrian palaeogeographic map, all known occurrences of *Condylopyge* show an apparently restricted palaeogeographical distribution, being known from Siberia (very rare), Baltica (Sweden, Norway and erratic boulders in northern Germany) and several regions in West Gondwana (Morocco; Armorican Terrane Assemblage – Spain, France, Italy, Germany, Czech Republic; Avalonia – British Isles, eastern Newfoundland and Massachusetts; Turkey).

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Middle Jurassic cycles of sea-level change in the central part of the Polish Basin

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The Polish Basin is located in Central Europe in the eastern part of the South-Permian Basin. The Middle Jurassic deposits in the central part of the Polish Basin exceed 1100 m, which is two times bigger in comparison to the marginal parts. Such thickness is due to the subsiding activity of the Mid-Polish Trough located along the Teisseyre-Tornquist Zone. This subsidence was compensated by sedimentation which developed the Middle Jurassic succession. Sedimentological studies based on investigation of cores from deep boreholes allowed distinguishing few environments spanning offshore to foreshore zones of a shallow epicontinental sea. Investigations of the vertical facies succession point out that the Middle Jurassic succession can be divided into 8 transgressive-regressive cycles. The age of four older cycles is documented by the presence of ammonites, foraminifera and ostracods. Younger cycles are documented by dinoflagellats, foraminifera and ostracods. The oldest cycle begins with estuarine sediments (lower Aalenian), sharply covered with offshore black shale facies. In some boreholes these shales pass into the shallower mudstones (upper Aalenian – *murchisonae* and ?*bradfordensis* zones). It is not yet sure if they mark a regressive phase of the first cycle or only a local fluctuation due to tectonic activity. The next three cycles are built of the transgressive offshore black shales and progradational regressive successions composed of mudstones and heteroliths and topped by shallow or middle shoreface sandstones. The first cycle include late Aalenian (?*bradfordensis*, *concavum* zones) and early Bajocian *(discites – humphresianum* zones). The middle cycle is late Bajocian (*subfurcatum – parkinsoni* zones), the last is early Bathonian (*zigzag – tenuiplicatus* zones). The middle and upper Bathonian cycles begin with transitional sediments or lower shoreface deposits. The uppermost parts of these cycles are built of the sandstones and limestones representing the upper shoreface, foreshore and lagoon environments. The age of cycle V is middle Bathonian (*prograciclis – subcontractus* zones), cycle IV is middle-late Bathonian (*morrissi* – early *orbis* zones) and of cycle VII is late Bathonian (*orbis* – early *discus* zones). The end of the middle Jurassic is correlated with the transgressive part of cycle VIII, which regressive part is upper Jurassic (Oxfordian). The transgressive part of this cycle spans the late *discus* zone (late Bathonian) and lower Callovian (*herveyi – calloviense* zones). It is documented by carbonate-siliciclastic shoreface deposits which pass upwards into upper Jurassic limestones. At the boundary between the Middle and the Upper Jurassic a condensed bed occurs. The age of this bed is middle and upper Callovian (*jason – lamberti* zones).

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Chattian larger foraminifera from the Benitatxell Range (Prebetic Domain, SE Spain). Comments on the biostratigraphical utility of certain species.

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Three sections were logged and sampled along a kilometre-scale continuous carbonate strata of Oligocene age with larger foraminifera and coralline algae in the north-western part of the Benitatxell Range (Prebetic Domain; SE Iberian Peninsula). The foraminiferal and red algal limestone beds overlay turbiditic levels and are capped by a Miocene marly succession with interbedded clays and sandy limestones with glauconite, both barren in larger foraminifera. The foraminiferal association identified in the limestones studied includes *Austrotrillina* cf. *striata, Heterostegina assilinoides, Spiroclypeus blankenhorni, Operculina complanata, Nummulites* aff. *vascus*, *Miogysinoides formosensis, Nephrolepidina praemarginata, N.morgani, Eulepidina dilatata, E. elefantina, Amphistegina* cf. *bohdanowiczi*, *Rotalia viennotti, Risananeiza* sp., and *Sphaerogypsina* sp. The foraminiferal assemblage is the same in the three sections, with vertical and lateral variations due to environmental factors. For example, large rotaliids dominate in the lower part of the sedimentary record, while porcellaneous *Austrotrillina* is found only in the middle part of the succession, and rotaliids and miogypsinids are more abundant in the upper part. The association corresponds to the Shallow Benthic Zone SBZ 22B of Cahuzac & Poignant (1997)[1], upper Chattian. Miogypsinids and lepidocyclinids are extensively used in Oligo-Miocene biostratigraphy. Biozones are defined from arbitrarily defined chronospecies in lineages showing a progressive increase in megalospheric embryo's size (*Nephrolepidina*) or reduction of spiral chamber (miogypsinids). However, the variability of these features within a single sample might be so great that different chronospecies are found together. In the studied section, the variability in the number of spiral chambers in *Miogypsinoides* includes three different chronospecies supposedly consecutive in time (*M.complanata, M. formoensis, M. bantamensis*). The phylogenetic interpretation of *Miogypsinoides* by Boudagher-Fadel & Price (2013)[2], with widely overlapping biostratigraphical ranges seems to be more realistic, and agrees with our results. Similarly, *Nephrolepidina* shows embryos corresponding to *N. praemarginata* and *N.morgani,* but also with specimens with smaller and larger embryos. With such a continuous variability, the definition of chronospecies appears to be too subjective, and statistical analysis is necessary. *Neorotalia* is frequent in Oligocene-Miocene foraminiferal associations. A typical species characterized by a thick, protruding ventral pilar is asigned by most authors to either *N. lithothamnica* or *N. viennoti*. The comparison with the original descriptions shows that it corresponds to *N. viennoti*. *Risananeiza* is characterized by an almost planispiral test, symmetrical in axial section, with large pilars and canals in both the dorsal and ventral side. Two Tethyan species have been described: *R. pustulosa* Boukhary et al. (2008)[3], and *R. crassaparies* Benedetti & Briguglio (2012)[4]. We could not assign our specimens to one of these two species because their diagnostic biometric parameters overlap considerably. *Risananeiza* is frequent in Oligo-Miocene rocks from the Western Tethys. It has often been reported as *Neorotalia* (e.g., *N. pustulosa* in Didon et al., 1961; *N. alicantina* in Brandano et al., 2009)[5,6]. Specimens from the Asmari Fm (Iran) assigned to *Bozorgniella qumiensis* (Daneshian et al., 2011)[7] probably belong also to *Risananeiza*. A detailed revision of this genus is called for, since it might reveal different species of biostratigraphical use in the Tethyan Oligocene-Miocene, as well as provide useful data of Tethyan Oligocene-Miocene paleogeography.

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Can facies act as a chronostratigraphical tool?

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Recent advances in chronostratigraphy are enabling global correlation of Silurian strata at a temporal resolution of 10-100 k.y. Comparative analysis of disparate localities at this resolution is yielding surprisingly similar peculiarities of facies. Facies analysis has been traditionally regarded as a tool to investigate local paleoenvironmental conditions and reconstruct past paleoecological settings. Less frequently are aspects of facies recognized as long-distance time-correlative markers. The concept of time-specific facies, originally proposed by Walliser (1986) and recently revised by Brett et al. (2012), challenges the "strictly local" facies paradigm by emphasizing that some aspects of facies are signatures of broader oceanic-climatic processes. Their synchronous occurrence, spanning major portions of sedimentary basins to globally, represents the key distinctive factor of time-specific facies. This aspect is combined with the significance of the ecostratigraphic analysis as a tool to identify bioevents and, therefore, for improving biostratigraphic subdivisions (e.g., Boucot, 1986).

Marine ironstones represent a prime example of time-specific facies. Silurian ironstones retaining microbial signatures are documented by Ferretti et al. (2012) in forms of Fe-rich oolitic horizons and ferruginous laminated structures for the Llandovery-Wenlock boundary interval (mid-late Telychian, *Pt. celloni* Superzone-*Pt. a. amorphognathoides* Zone and Sheinwoodian, *Oz. s. rhenana* Zone) in the Carnic Alps (Austria). Age-equivalent ironstones also occur in the Appalachian Basin of eastern North America (McLaughlin et al., 2012). Appalachian Basin ironstones collected from the New Point Stone quarry (Napoleon, Indiana) and Dawes Quarry Creek (Clinton, New York) were recently analyzed through combined analytical techniques (i.e., confocal laser Raman microscopy, X-ray diffraction, ESEM-EDX, and optical microscopy) for a geobiological characterization. Results demonstrate that the Appalachian ironstones seem to reflect the same microbially-mediated iron mineralization already documented in the Carnic Alps. Combined evidence of iron geochemistry and microbial interactions include i) the formation of planar laminated ironstones (late Telychian); ii) coeval ooidal pack- to grain-ironstones; iii) a wealth of other microbial-related morphostructures and mineralogies. The synchroneity of iron microbe activity on opposite ends of the Iapetus Ocean during the late Telychian and Sheinwoodian is inferred as a time-specific sea water redox signature associated with the Ireviken Event.

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ICDP proposal "Drilling over-deepened Alpine Valleys (DOVE)"

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A submitted International Continental Drilling Program (ICDP) proposal focuses on drilling of sedimentary sequences in the circum Alpine area. The goal of the intended project is to understand and to date the infill of overdeepened valleys. The sediments of past glaciations and interglacials are considered to be an important key to understand paleoclimate, paleoecology and landscape history in the Alpine region during the Quaternary.

The circum alpine initiative would be a perfect opportunity to bring scientists from several countries around the European Alps together. It would offer a new window of opportunity to understand Pleistocene glaciations of the European Alps in general. Implications for all kind of mountain glaciations would be possibly developed.

Additional to fundamental scientific questions about Earth history and glaciation, information about valley infills are of importance for several applied topics like, for example, shallow geothermal applications or seismic risks.

In case of successful application a new phase of Quaternary research on the Alpine glaciation will start.

Study of the Stratigraphy of the Volcanic Deposits of Mount Goma DR Congo and Its Implications for the Phreatomagmatic Hazard in Goma

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Mount Goma, located within the Nyiragongo volcanic fields, stands in the heart of the city of Goma, on the shoreline of Lake Kivu. Goma harbor shelters in the scalloped crater of Mount Goma. We report here the results of a morphological and stratigraphic study of the pyroclastic deposits of Mount Goma. The subaerial cone morphology suggests the existence of at least three, possibly four craters. Of these two are currently small depressions in the borders of the port. The largest crater is submerged and is currently occupied by the port.

Pyroclastic deposits are based on possibly old lava flows visible in the western part of the port. Pyroclastic deposits are generally rich in ash and small lapilli and show induration facies and palagonization variable in space. A well-marked contact separates strongly indurated hyalotuff deposits and palagonitized, characterized by a variable content of volcanic bombs, and indurated deposits of ash and lapilli of a similar color. Fine laminations, in places deformed by the impact of bombs, and cross-laminations at certain levels of these deposits shows it is formed in wet conditions and hence suggests a phreatomagmatic character of the eruption. No dating work has been carried out of the eruptive activity of Mount Goma, but the contrast in the degree of induration suggests that at least two eruptive phases, separated in time, have contributed to the building of this cone. It also follows from the nature of the deposits that Mount Goma was formed after Lake Kivu had reached its current level or higher. Deposits from Mount Goma are covered by recent lava at the current morphological base of the edifice. This implies that Mount Goma is larger under the lava and that such eruption has had an impact on an area of potentially a few kilometers radius around the eruptive vent. The possibility of base surge events during such phreatomagmatic eruption is a major hazard. The possibility of such a scenario to repeat itself in the future is undetermined to date.

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The 'Anthropocene' Epoch: scientific decision or political statement?

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The proposal of the 'Anthropocene' as a new epoch in the Geologic Time Scale has received greatly increasing attention in both scientific and public media (e.g., Nature, Scientific American, Science, Geoscientist, New York Times, Los Angeles Times, The Economist, National Geographic Magazine). The attention results from the recognition that humans have greatly impacted the Earth system, changing the rates of its surficial processes and leaving a clear impact in the stratigraphic record. Thus the proposal that the 'Anthropocene' should be ratified as a unit of the International Chronostratigraphic Chart/Geological Time Scale deserves serious consideration by the International Commission on Stratigraphy (ICS). However, that proposal must be examined critically with regard to the objective and procedures of ICS in establishing a single, hierarchal set of global chronostratigraphic units at the ranks of Stage, Series, and System, with regard to the nature of these units, and with regard to the utility of the concept of the 'Anthropocene'.

GSSPs, approved by ICS and ratified by the International Union of Geological Sciences (IUGS), are considered as defining the chronostratigraphic units that are the basis of the Geologic Time Scale. Accordingly, the drive to officially establish the 'Anthropocene' has focused on the criteria on which to define its beginning. However, this is a mistaken concept because the chronostratigraphic units are defined by their stratigraphic content, and the purpose of GSSPs is to establish specific definitions of stratigraphic horizons that set the limits, both upper and lower boundaries, of the chronostratigraphic units. Thus, although no GSSPs have yet been approved for the Cretaceous System, the Lower Cretaceous Series, and the Berriasian to Albian stages, these are official units of the ICS International Chronostratigraphic Chart. They are characterized by considerable stratigraphic content that allows them to be correlated worldwide and allows the corresponding geochronologic units (Cretaceous Period, Early Cretaceous Epoch, and Berriasian to Albian ages) to be used to express events in Earth history. This then raises the question of the stratigraphic content of the Anthropocene.

The stratigraphic content of the chronostratigraphic units and the stratigraphic criteria that define their boundaries are used to correlate strata worldwide and thus serve as the temporal framework for reconstructing Earth history. But, for many reasons, the stratigraphic record is not available nor would stratigraphic principles be used for reconstructing Earth history in the 'Anthropocene' for the simple reason that events of the 'Anthropocene' are directly observed by humans and are expressed in terms of human calendars and chronometers. In this sense, studies of the 'Anthropocene' are not stratigraphic. Furthermore, geologic events that are directly observed by humans are recorded in terms of human calendars, e.g. the 1906 San Francisco Earthquake, the 1980 eruption of Mt. St. Helens. What value would there be in referring to these events as 'Anthropocene'.

In its extreme expression, the concept of the 'Anthropocene' recognizes that humans are the controlling factor in Earth processes today. Yet, this ignores the tremendous impact of ongoing Earth processes on the Earth system (e.g., extreme magmatic events) and the potential impact of extra-terrestrial bodies.

As a product of human invention, the 'Anthropocene' is analogous to the Renaissance. Its entire history can be reconstructed from human observations and products. One can argue about the human event or product that began the Renaissance, but does that have any value. The term Renaissance conveys an exception meaning of revolutionary human endeavors that grew and spread over time. In the same way, human impact on the Earth system has grown and spread over time, and that history is recorded in great detail in human observations and records and not in the stratigraphic record.

The concept of the 'Anthropocene' is not consistent with the global chronostratigraphic units that ICS is charged with defining with GSSPs. Yet, when faced with this fact, many proponents of the 'Anthropocene' argue that the human impact on the Earth system must be officially recognized. In doing so, they are calling for ICS to make a political statement rather than a scientific decision.

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Field Testing the Proposed Bartonian Correlation Events: Case Studies from the Gulf Coastal Plain of the United States

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There are two proposed primary correlation events for the base of the Bartonian Stage: the base or the top of magnetic polarity chronozone C19n. Important biostratigraphic events associated with chronozone C19n may serve as secondary correlation criteria for the Bartonian. These events include the lowest occurrences of the planktonic foraminifera *Turborotalia pomeroli* and *T. cerroazulensis*, the lowest occurrence of the calcareous nannofossil *Reticulofenstra reticulata*, and the base of shallow benthic zone SBZ 17. These criteria are currently being evaluated for their utility in widespread correlation of the base of the Bartonian.

The Lutetian-Bartonian transition in the Gulf Coastal Plain occurs within a series of unconformity-bounded sequences deposited in a middle neritic setting. These sequences are recognized in outcrop and in the subsurface from Florida to Texas within the Avon Park, Lisbon, Cook Mountain, and Crockett Formations. Only spotty magnetostratigraphic data has been published on this interval making recognition of the primary guide event in the Gulf Coastal Plain a challenge. The rocks contain abundant and diverse calcareous nannofossils and benthic foraminifera. Planktonic foraminifera are present but are of low diversity.

There is broad agreement on the recognition of the Lutetian and Bartonian stages in the Gulf Coastal Plain. These correlations have been accomplished primarily by the macrofossil and microfossil content of the various formations. Identifying the boundary between the Lutetian and Bartonian in the Gulf Coastal Plain is more problematic. The planktonic foraminifera collected across this interval have only limited use for correlation. The most reliable correlation event for the base of the Bartonian in the Gulf Coastal Plain is the lowest stratigraphic occurrence of the calcareous nannofossil *Reticulofenestra reticulata*. This horizon is recognizable from Alabama to Texas. Closely associated with this event in the Lisbon, Cook Mountain, and Crockett Formations is the highest stratigraphic occurrence of the smaller benthic foraminiferan *Ceratobulimina exima*. This horizon has long been used for subsurface correlation in the Gulf Coastal Plain and can be used effectively with the lowest occurrence of *R. reticulata* to identify the Lutetian-Bartonian boundary in the region.

One regional correlation event, the lowest occurrence of the larger foraminiferal genus *Lepidocyclina,* has been re-evaluated in this study. This has been considered a solid biostratigraphic horizon for the base of the Bartonian in the Caribbean, Gulf Coastal Plain, and possibly Central America but its utility is now questionable. Specimens of *Lepidocyclina* were collected from the Cook Mountain Formation in Louisiana from just beneath the Upper Alabama Ferry ash. A high precision age of 41.84 ± 0.02 Ma for the Upper Alabama Ferry ash in Texas has recently been published. This age correlates with magnetic polarity chronozone C19r making the lowest stratigraphic occurrence of *Lepidocyclina* a late Lutetian biostratigraphic event.

The Gulf Coastal Plain represents a setting where correlation with deep marine magnetostratigraphic and biostratigraphic events is challenging. Through the use of secondary and local biostrtigraphic correlation horizons however, the base of the Bartonian can be recognized throughout the region.

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Giant microbial build-ups of earliest Triassic in Armenia

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After the end Permian mass extinction, about 252 Ma ago, microbial communities colonised the space left vacant after the extinction of skeletonised metazoans. These so called Permian-Triassic boundary microbialites (PTBMs) were abundant in low-latitude carbonate shelves in central Tethyan margins and occurred not only in shallow marine environments but also in deeper ones. These peculiar carbonate depositions occur at four main levels during the Early Triassic, but despite numerous researches the modes of microbialite formation are still vague. Together with the PTBMs calcium carbonate crystal fans (CCFs) occur also after the mass extinction.

Numerous samples from PTBMs and CCFs were taken from three different sites in southern Armenia and were microscopically and geochemically characterized. In Armenia, PTBMs and CCFs grew in a relative distal open marine setting on a pelagic carbonate ramp. The thickness of the predominantly thrombolitic PTBMs varies between 5 cm to 1.5 m. The synoptic relief of the thrombolite head is estimated at 40-60 cm above the muddy sea bottom. The overturned cone-shaped build-up geometry has a top head diameter up to 8 m width consisting of numerous thrombolite domes with a total height of up to 15 m. An asymmetrical growth indicates influence of a steady bottom current condition. The matrix of PTBMs and CCFs is a bioclastic wackestone which mainly contains ostracods, foraminifers, microgastropods and thin-shelled bivalves.

A "recipe" for the successful application of Sr-isotope stratigraphy (SIS) to shallow water carbonate successions

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The $^{87}Sr/^{86}Sr$ of marine water is controlled by the mixing of the isotopically different fluxes from two main reservoirs: erosion of the continental crust (with generally high $^{87}Sr/^{86}Sr$) and mid-ocean ridge hydrothermal activity (with low $^{87}Sr/^{86}Sr$).Therefore variations in $^{87}Sr/^{86}Sr$ are a very useful tool for investigating climatic and geodynamic processes. However in the last decades the use of $^{87}Sr/^{86}Sr$ for stratigraphic purposes, as a high-resolution tool of chronostratigraphic dating and correlation of marine sediment, has increased dramatically. The so called Strontium Isotope Stratigraphy (SIS), relies on the fact that the $^{87}Sr/^{86}Sr$ value of the ocean varied through geological time and that the composition of the ocean waters is homogeneous with regards to Sr isotopes at any time due to the long residence time of Sr in the oceans.

The most recent reference curve of marine strontium isotope ratio is that compiled, using a large database of well dated biogenic carbonates, by McArthur et al. (2001), covering the interval 0-509Ma. The use of the curve as a stratigraphic tool is facilitated by its conversion into a look-up table giving the numerical ages and the 95% confidence limits for any value of $^{87}Sr/^{86}Sr$ interpolated in steps of 0.000001. During the last two decades, SIS has been increasingly applied to shallow-water carbonate successions in order to solve the problems of low resolution and poor chronostratigraphic calibration often plaguing biostratigraphy in these facies. However, despite the high potential of SIS, some possible shortcomings may severely complicate its application. The accurate selection and diagenetic screening of the material to be used for SIS is the most crucial step, because diagenetically altered isotopic ratios produce false ages. Furthermore the intrinsic limits of the method must be taken into account: the numerical and chronostratigraphic ages derived by the Sr isotope ratio of pristine samples are only as good as the reference curve from which they are derived.

In this work the aforementioned caveats will be discussed in detail by means of several examples from Upper Cretaceous shallow water carbonates around the world where SIS has been applied successfully. A guideline for the correct use of SIS in shallow water carbonates will be presented showing that the rigid procedure proposed is mandatory to ensure that the ages obtained by this chemostratigraphic method are reliable.

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The Maar of Altenmarkt/Riegersburg – a type location to determine a lithostratigraphic unit for the volcaniclastic rocks in the Styrian monogenetic volcanic field

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Alkali basaltic volcanism was widespread in the Carpathian-Pannonian region from the early late Miocene to the middle Pleistocene times. Within the Pliocene a basaltic phase of volcanism started in the Styrian Basin which lasted until the early Pleistocene. All of these volcanic remnants are interbedded in Miocene sediments and have an explosive initial phase with phreatomagmatic eruptions. Most of the volcanoes show all indications of maar volcanoes even if at some locations only the diatremes are preserved. Only a few volcanoes produced after the initial explosive phase greater magma intrusions or extrusions.In literature this volcanic phase in the Styrian Basin is called “the second volcanic phase”, “the basaltic phase”, “the young volcanic phase” or “the Pliocene-Pleistocene volcanic phase”. Up today a formal lithostratigraphic unit for these volcanic rocks is not yet defined. In the volcanic area of Altenmarkt near Riegersburg all different variations of volcanic rocks (tuff breccia, layered ash, ash/lapilli, lapill and block tuffs and basalt) and maar lake sediments occur. This location is eminently suitable to be a reference profile to define a lithostratigraphic unit for the basaltic volcaniclastic rocks in the Styrian monogenetic volcanic field.

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A comparison of Interior Layer Deposits within Valles Marineris, Mars

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The Martian Valles Marineris, located on the eastern flank of the Tharsis region, is a 4000 km long linked system of troughs. The formation of the up-to-11 km deep chasmata of Valles Marineris is thought to have taken place during a two-stage process in which ancestral basins collapsed and were later linked by tectonism. Located within most chasmata are enigmatic layered deposits, referred to as interior layered deposits (ILDs), whose origin and mechanism of formation are uncertain. It has been estimated that ILDs cover 17% of the total area, representing 60% by volume of all deposits within Valles Marineris with several deposits nearly reaching the height of the surrounding plateau.

Here we present the results of an extensive study of most of the ILD mounds located within presumed ancestral basins. ILDs within Hebes, East and West Candor, Ophir, Juventae, Capri and Ganges chasmata were studied and layer thicknesses measured where possible. The data were collected over an elevation range of more than 6 km and indicate significant similarities between the mounds. Layering is generally sub-horizontal to shallow dipping. In many locations layering is parallel and can be traced for several hundreds of meters. Features that are interpreted as soft-sedimentary features appear to occur primarily in thinner layered material. No features attributable to aeolian activity could be identified within the stratigraphy of any mounds at the available image resolution. In multiple chasms individual identifiable units can exceed 1 km in stratigraphic thickness. Angular unconformities can be identified within some mounds; in those instances the overlying unit is thinner layered than the underlying unit. Overall, for identified units, mean observable layer thickness is in the range of 1 m to approximately 7 m. Two distinct units within Hebes and Juventae chasmata have thicknesses on the order of tens of meters.

The general similarities between ILDs suggest that the ancestral basins within Valles Marineris share a similar depositional history. We believe that the ILD morphology is most compatible with an environmental setting in which the ancestral basins were lakes which may have been periodically frozen. The source of the ILD material was most likely airborne dust or ash.

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Long-wavelength groundwater discharge in Arabia Terra (Mars)

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Presence of past or present water on Mars is the strongest evidence of a living planet and an incentive for the astrobiological research looking for life signatures potentially preserved in the water-related rocks. New models of Mars hydrology localized groundwater upwelling sites in the equatorial lowlands where huge thickness of water-related sediments accompanied by peculiar morphologies have been deposited. Conical mounds and furrows are widely interpreted as the morphological evidences of fluids expulsion on the martian surface. In the Crommelin crater (equatorial Arabia Terra) furrows and conical mounds are exhumed within light-toned equatorial layered deposits (ELDs). Aim of this work is to describe these landforms assessing their potential relations with long wave-length groundwater upwelling in Crommelin area. Are the aqueous morphologies in the exact place where groundwater rises to the surface?

A comparative approach of some of the morphologies identified in the Arabia Terra region provided new insights into the genetic interaction of water and Mars light-toned sediments. Particularly ELDs deposits from Firsoff and Crommelin craters have been mapped and described in detail. Where the groundwater reached the surface, arguably in the southern sectors of studied craters, the sediments package is thicker and peculiar morphologies have been described. Such morphologies include mounds, ridge-and-trough structures and furrows. Depressions such as Crommelin and Firsoff craters would have reached by water and sediments due to the migration of the groundwater flow from the martian highlands (south) to the lowlands (north). Such a geological record, with kilometer thick sediments package of ELDs dotted by fluid escape morphologies, developed during a major climate shift (Noachian–Hesperian) when the fluctuation of the water table fed with huge amount of sediments deep craters like Crommelin and Firsoff along the Mars equatorial region.

In this work the occurrence of ELDs is contextualized with a regional water upwelling scenario driven by the topography of Arabia Terra. We hypothesized a model of the groundwater discharge during the Late Noachian starting from previous model of Mars hydrology. In this reconstruction the aquifer recharge is confined at the high latitudes (greater than 45° North and South) and the subsurface was discretized to a mega-regolith with permeability and porosity comparable with terrestrial granular sediments.

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A Nomenclature Landslide: The "Stratigraphic Lexicon for Ontario" Project

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Summary. The aim of the Ontario Geological Survey (OGS) "Stratigraphic Lexicon for Ontario" project is to produce for the province of Ontario, in electronic formats, a lexicon of stratigraphic terms in current and past use complete with the references, type locality, history and description for each term; and to establish a framework for the introduction of new terms in the future.

Introduction. In recent years, a co-ordinated effort to develop a North American Data Model (NADM) for geologic map databases has been undertaken by agencies in Canada and the United States. Amongst the descriptive components forming any geologic model is stratigraphy, for which a standardized lexicon is required.

In the United States, the United States Geological Survey (USGS) is the gatekeeper for stratigraphic nomenclature. An online version of the National Geologic Map Database is provided through GeoLex (http://ngmdb.usgs.gov/Geolex/search). However, in Canada, there existed neither a centralized clearinghouse nor a single source of information for geological names. Historically, the Geological Survey of Canada (GSC) had created several different physical databases (i.e., card files); however, these were not widely known, were inconsistently maintained, and were generally inaccessible. Provincial surveys have regional or limited listings. In the 1980s, the Canadian Society of Petroleum Geologists began a project to compile and publish stratigraphic nomenclature by region. The "Lexicon of Canadian Stratigraphy" series was detailed, but incomplete: the Central Canada volume, which included Ontario, remained only a concept. Thus, nomenclature for Ontario was never compiled.

An initiative by the National Geological Surveys Committee (NGSC) to provide an Internet portal to Canadian geoscience information resulted in several partnerships with the federal, provincial, and territorial government agencies. The GSC began work on the Canadian Stratigraphic Lexicon as part of a project to create an "Integrated system for geological map, stratigraphic, paleontological and geochronological databases". The online version of the collection of known lexicons (or lexicon-like databases) is WebLex (http://weblex.nrcan.gc.ca/weblex_e.pl), which can be searched by name of the unit, region (province), or by age of the unit. WebLex is still a work-in-progress.

Ontario. For Ontario, there is no complete lexicon of stratigraphic names; what is available is not current and, for the most part, is represented only by a list of names, which is not comprehensive. Since 2005, the GSC has provided periodically their existing WebLex data (database = StratLex) for Ontario (initially as a spreadsheet; later, as a relational database) to OGS staff for evaluation. After combining the data from the GSC and the OGS, and eliminating duplication, approximately 4000 terms need to be examined; however, this list includes some geologic features (e.g., faults, greenstone belts), the names for which also require standardization.

The Stratigraphic Lexicon for Ontario project is envisioned to comprise several phases, including the next phase that will establish • a peer review (OGS internal) committee; • criteria for terminology review process and procedures; • criteria for priority setting; • data management procedures; and • monitoring and reporting processes. Evaluation by a peer review committee will be based on criteria such as current (approved) names, alternate (historical or invalid) names, location of type section, reference(s) for the publication in which the name was defined formally, etc.

By implementing the Lexicon project and provincial stratigraphic review committee, OGS will contribute to geoscience nationally and internationally and will provide stakeholders access to consistent terminology for use in map creation and databases.

Rhaetian duration: Astronomical calibration of Austrian key sections

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An accurate time scale does not yet exist for the entire Triassic, and much work is needed to improve it, especially for the Late Triassic. The total duration of the Late Triassic can be estimated at about 30 Myr, but the relative durations of Carnian, Norian and Rhaetian are still poorly known. This is particularly true for the Rhaetian which duration estimates vary from 3 to 9 Ma. These discrepancies result from numerous attempts to correlate the two main independent data sets used to construct the Late Triassic time scale : (1) the APTS (Astronomically calibrated geomagnetic Polarity Time Scale) from the Upper Carnian-Lower Jurassic continental sucession of the Newark rift basin (eastern North America), and (2) some magnetic polarity sequences from well biostratigraphically dated tethyan marine successions. The difficulty in unambiguously correlate these two data sets is due to the recurrent problem to biostratigraphically correlate marine and continental sections, and unambiguously correlate magnetic polarity sequences whose “black-white fingerprint” can be distorted by variations in sedimentation rate and hiatus. New Zircon U-Pb dates for volcanic ash beds within the Rhaetian Aramachay Formation in Northern Peru were very recently published pointing a duration of 4.14 Myr for the Rhaetian. To analyze the tempo and rate of the numerous biotic and environmental events occurring at the end of the Triassic, an accurate estimate of the duration of the Rhaetian is of paramount importance.

We addressed this issue by the astronomical calibration through cyclostratigraphic studies of some reference marine successions in the Northern Calcareous Alps of Austria. We analysed four key sections encompassing the whole Rhaetian: (1) the Steinbergkogel section proposed as the Norian-Rhaetian GSSP, (2) the Zlambach section which covers most of the Lower Rhaetian, the Middle Rhaetian and basal part of the Upper Rhaetian, (3) The Eiberg section, covering the Upper Rhaetian, was the subject of many stratigraphic studies, and finally (4) the Kuhjoch section, Rhaetian/Hettangian (Triassic/Jurassic) GSSP. Magnetic susceptibility (MS) was used as the proxy for the cyclostratigraphic analysis. MS was measured every 10 cm on samples from each studied section. Since the sections studied correlate perfectly we were able to construct a 150 m composite record of MS variations encompassing the whole Rhaetian. Our goal were to demonstrate the astronomical forcing recorded by these austrian sedimentary successions, and to astronomically calibrate the duration of the Rhaetian using 405 kyr orbital eccentricity cycle as a geochronometer. Following removal of a long-term trend, the data were analyzed using spectral analysis with the multitaper method (MTM). The MS variations have cyclic patterns across a wide range of frequencies. Milankovitch frequencies from precession to long eccentricity were recognized. Cycles with an average thickness of 8 m are interpreted to correspond to the 405 kyr orbital eccentricity term. After tuning we used these cycles to estimate the duration of the Rheatian. Our results rather go towards a relatively short duration of 5.6 Myr.

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SHRIMP Zircon U-Pb data of Cryogenian in South China Plate

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The Neoproterozoic Era consists of Tonian, Cryogenian and Ediacaran periods on the International Geologic Time Scale, which is based on U-Pb dating, C/O isotopes, Sr isotopes, geochemical stratigraphy and metazoan evolution. The three systems well developed in South China, however, some sections with three diamictite horizons, including the Chang'an (diamictite), Fulu, Gucheng (diamictite), Datangpo and Nantuo (diamictite) formations in Hunan, Guizhou and Guangxi provinces on the Yangtze Block. Now, four Neoproterozoic glaciations, including the Kaigas, Sturtian, Marinoan and Gaskiers, have been differentiated in the global strata and are known from several different continents. Three glaciations have been found in Cryogenian at about 750-635 Ma, which is the same as the Nanhuan System in China. The last one (Gaskiers) is equivalent to the Hankalchough diamictite in Xinjiang and to the Luoquan Formation (diamictite) on the North China Plate, both of which belong to the Ediacaran (Sinian System). Nonetheless, the age at the base of Cryogenian is still argued. Three different views of the age of this boundary are as follows: 1) the basal Cryogenian boundary occurs at the appearance of the earliest glacial episode; 2) the basal boundary is at the first sedimentary indication of cold events; and 3) the boundary occurs at the first well-developed glaciation across the globe. The first glaciation (Kaigas diamictite, about 770 Ma) is only well-developed in South Africa and generally lacking any development on other continents. Hence, some geologists proposed that the bottom of Cryogenian is better placed at the base of Sturtian in Australia, an episode that is well developed across the globe. Others hope to put the boundary of Cryogenian at the first depositional appearance of a cold event. However, the International Cryogenian Working Group proposed to set up the GSSP for the bottom of the Cryogenian in a section with four basic features: 1) the real appearance of diamictite; 2) the presence of C/O and Sr isotopic changes; 3) chemical index of alteration; and 4) available SHRIMP zircon dating. Since the "Snowball" hypothesis was proposed by Hoffman, the possibility of Neoproterozoic global glaciations provides yet another means of correlation, but equating the resulting diamictites in China and around the world may prove to be difficult. As already mentioned, four Neoproterozoic glaciagenic diamictites occur in one section in the Quruqtagh area, Xinjiang, and these diamictites may be equivalent to other already noted global episodes, in which case they may be able to provide robust correlations between Late Precambrian glaciations elsewhere and in China. The Nanhuan System is also changed on the CGTS, such that the bottom boundary is placed below the unmetamorphosed cover strata or glaciagenic diamictites; the age at the base is approximately <760 Ma. However, our interpretations of the age of the above Neoproterozoic strata have also been influenced by the zircon U-Pb dating of bentonites from the low-grade metamorphic rocks of the Jiangnan Old Land. Weighted mean $^{206}Pb/^{238}U$ ages of 814±6 Ma, 801±3 Ma, 799.8±4.7 Ma and 787±6 Ma were obtained from the Danzhou Group, and a weighted mean $^{206}Pb/^{238}U$ age of 778.4±5.2 Ma was obtained from just above the boundary of the Chang'an Formation in Guangxi Province. Others, 758.6±4.7 Ma and 744.4±4.1 Ma were achieved in the bottom of Chang'an Formation in Hunan Province, both of which will push forward many changes in the interpretation of age dates throughout the entirety of South China.

Development Characteristics and Geological Model of Ordovician KarstCarbonate Reservoir Space in Tahe Oilfield

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The development and distribution of fracture-cave system in Tahe Oilfield are limited by the carbonate epigenic karstification. The Ordovician formation has experienced two kaistification period in the early Caledonian and Hercynian, so that it has composed a badly heterogeneous reservoir. According to the research of the karst origin, evolution and growth mechanism of Tahe Oilfield, the Ordovician reservoir was vertically divided into surface karst zone, vertical percolation karst zone and horizontal subsurface flow karst zone, and horizontally can be departed into three karst paleo topography units as highlands, slopes and depressions. Based on the study of outcrop observations, cores, drilling, well logging, and seismic and production performance, it shows that karst caves, dissolved fractures and honeycomb-cave are effective reservoir space in the region, and matrix can block the fracture-cave system as the impermeable layer. Combined with the epigenic karstification theory and the control to the rock holes, according to different causes, the reservoir space of Tahe Oilfield can be divided into sinkhole, undercurrent cavity and small cave, according to the filling patterns, the reservoir space can be divided into collapse filling cavty, mechanical filling cavity and chemical filling cavity. Meanwhile, the geological model of different types of pore-cave systems has been formed. Combined with the development characteristics of carbonate reservoir of Tahe Oilfield and production practice, the final model of Tahe Oilfield karst reservoir space distribution has been built up.

Evidence of Mediterranean-Atlantic exchange immediately after the Miocene-Pliocene boundary in the Gulf of Cádiz

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Obtained records on IODP Site U1387C (Expedition 339) suggest that the onset of Mediterranean Outflow Water (MOW) after the Messinian Salinity Crisis was active immediately after the Miocene-Pliocene boundary in the Gulf of Cádiz. The Miocene-Pliocene boundary has been determined by a seismic correlation between the Algarve-2 borehole to the U1387C and is confirmed by the absence of *G. margaritae* acme and estimated sedimentation rates. During the latest Messinian, typical hemipelagic sediments exhibiting precession-induced climate variability were deposited. In contrast, earliest Pliocene sediments are dominated by along-slope bottom currents that also show evidence of winnowing and particle sorting, suggesting that MOW was initiated at or shortly after the Miocene-Pliocene boundary.

Benthic foraminiferal assemblages analyzed in the same interval support that idea, pointing to an important change at the time where the Miocene-Pliocene boundary has been positioned. Eutrophic, poorly ventilated conditions in the Gulf of Cadiz are indicated for the upper Messinian sediments of IODP Site U1387C when the Mediterranean basin was restricted. The opening of the Gibraltar Strait is reflected in a higher species richness and increasing abundances of oxic indicators. While the overall trend indicates improved ventilation potentially caused by MOW, appearances of benthic shelf foraminifers indicate episodic downslope processes on those intervals with coarser sediments.

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Diatom Biostratigraphy at the Miocene Sites of Cerro Colorado and Cerros Los Quesos, Pisco Formation, Peru

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The Pisco Formation is a Mio-Pliocene formation cropping out for 300 km along the coast of Peru. This mainly diatomaceous formation is famous worldwide for being a fossil marine vertebrates Lagerstätte. Diatom biostratigraphy was applied to date the Pisco Fm. in few previous works (Macharé and Fourtanier, 1987; Schrader and Ronning, 1988; Koizumi, 1992); those works applied species ranges used in both the Cenozoic middle- to high-latitude North Pacific zonation and Cenozoic low-latitude zonation of Barron (1985).

During recent fieldworks the stratigraphic sections at Cerro Colorado and Cerros Los Quesos (Ica desert, Peru) were measured and samples for biostratigraphy were collected ca. every 5 m.

Difficulties arose during the biostratigraphic investigations because of the paucity of index species: indeed, coastal and upwelling conditions, which characterized the two sites, lead to the proliferation of species with long stratigraphic ranges such as *Odontella aurita*, *Rhaphoneis* spp., *Delphineis* spp., *Coscinodiscus* spp., *Chaetoceros* spp., etc.

Results were obtained merging together ranges of species used both in the equatorial Pacific and in the North Tropical Pacific schemes.

Cerro Colorado is characterized by an angular discordance that divides it into a lower and an upper allomember (Di Celma et al., 2015). The co-occurrence of the diatom species *Denticulopsis hustedtii* and *Lithodesmium reynoldsii* allows the attribution of the lower allomember to the late Miocene, while the only index species present in the upper allomember is *Thalassiosira antiqua*, which has a stratigraphic range that goes from the late Miocene to the late Pliocene. Thus samples from the upper allomember alone do not permit an accurate dating of the post-discordance sediments. The base of the Cerros Los Quesos sequence is characterized by a younger form of *T. antiqua,* differring from that of Cerro Colorado by having a more regular central area. Therefore, speculations on the time-relationship between the two sites can be made based on differences in *T. antiqua*. The presence of many plicated *Thalassiosira* specimens ascribable to *Thalassiosira flexuosa*, suggest that Cerros Los Quesos, although younger than Cerro Colorado, is still late Miocene in age.

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Pleistocene vs. Holocene sediments of the Serbian segment of the Sava River

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Based on a multidisciplinary research the Pleistocene sediments of the (palaeo)Sava River are characterized by a constrative dynamic phase disturbed by neotectonic movements of the Sava fault. The lithology is quite heterogeneous, ranging from gravels to clays. The majority of the clastics was transported by the rivers and streams from the Bosnian mountains (the mineral composition of fluvial sediments originated from the serpentine zone in Bosnia). In the palaeontological record the warm/temperate stages (correlated with unpaired MIS) were identified by the Pleistocene *Corbicula* fauna (connected with the younger part of Lower- and Middle Pleistocene warm/temperate stages).
The analysis of the Holocene archives of the Sava river recognized a meandering river with its sources from the Julian Alps and Karavanke Mts. (Slovenia). The lithology is predominantly made of sand and silt. The younger Holocene sediments - based on its palaeontological content - are characterized by *Dreissena polymorpha* shells and the youngest (last about 35 years) by *Corbicula fluminea* shells.

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Recent advances in Quaternary fluvial stratigraphy of the Serbian segment of the Pannonian realm

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The geological mapping of Serbia (and former Yugoslavia) during the 1970-ies left a wealth of unsolved questions in regard to the Serbian Quaternary stratigraphy. The evident changes and advances in the last 5 years were the following:
1) The Penck and Brückner's morphostratigraphical model for the Alps is not allowed to be used in a geochronological/chonostratigraphical context (recommendations of the charts of the ICS-IUGS).
2) The Eoplesitocene cannot be used for the Serbian Quaternary formations, it should be renamed to Lower Pleistocene.
3) The Upper Paludina beds, based on its palaeontological record, should be correlated with the Lower Pleistocene.
4) The *Corbicula fluminalis* beds should be renamed to Pleistocene *Corbicula* beds and should be correlated with the warm/temperate stages (interglacials) of the younger part of the Lower- and Middle Pleistocene.
5) The *Viviparus boeckhi* Horizon should be a lower subunit of the Pleistocene *Corbicula* beds of the younger part of Early Pleistocene age.

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Middle Triassic radiolarites: Key rocks for Triassic-Jurassic geodynamic and palaeogeographic reconstructions of the western Tethyan realm? Derivation from lost oceanic domains and/or indicating ALCAPA or Dinaride/Hellenide provenance? New data from the Hallstatt Mélange (Northern Calcareous Alps, Austria)

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Triassic radiolarites are crucial sedimentary rocks for palaeogeographic and geodynamic reconstructions of the Tethyan realm. They were deposited on the Neo-tethys passive margin and as sedimentary cover of the Neotethys oceanic crust, which evolved since the late Anisian. Radiolarites, occasionally associated with volcanic, are typical of the late Anisian-Ladinian successions in the Dinaride-Hellenide mountain chain. They, however, have not been reported from the Triassic sedimentary successions of the Alpine-Carpathian mountain belt (ALCAPA). Their occurrence therefore is widely used for the reconstruction of the provenance of “exotic” tectonic units, either of Alpine-Carpathian or Dinaride-Hellenide derivation. This also resulted in contrasting palaeogeographic settings for Triassic times: e.g. an independent Meliata Ocean between the Alpine-Carpathian realm and tectonic units in the Pannonian realm or the Eastern Alps/Pannonian realm and Southern Alps/Dinarides, or in between the Dinarides. Alternatively, the radiolarite facies is used as an argument to interpret the palaeogeographic provenance of the “Pelso Composite Terrane” in the Southern Alps/Dinarides area, later displaced by strike-slip movements. In the ALCAPA region the Triassic radiolarites, occurring in the form of pebbles in Jurassic mélanges, are interpreted as remnants of the sedimentary cover of (Meliata) oceanic crust.

We present the microfacies and biostratigraphy of radiolarite and limestone components in mass-flow deposits from the upper Middle to lower Upper Jurassic Hallstatt Mélange. These radiolarites are late Anisian to early late Ladinian in age. The multi-colored limestones belong to the Late Triassic Hallstatt pelagics. All components are interpreted to be derived from the continental slope towards the Neotethys Ocean (Meliata facies zone). A comparison with preserved successions from the Carpathians, Pannonian realm, and Dinarides strengthens the above interpretation. Reworked oceanic crust is missing in mass-flow deposits. The Middle-Upper Triassic sedimentary succession indicates the existence of Triassic radiolarites in the distal passive margin setting of the Eastern Alps. Following conclusions can be drawn:

1. The Middle Triassic radiolarites are not an exclusive element of the Dinarides/Hellenides and thus cannot be used for palaeogeographic reconstructions. They also occur in the Eastern Alps and Western Carpathians, and their occurrence therefore cannot be used to attribute tectonically isolated units in the entire Circum-Pannonian realm to show either Alpine-Carpathian or Dinaride-Hellenide provenance.
2. Neotethys oceanic break-up started in late Anisian. The middle Anisian shallow-water carbonates indicate that the Middle Triassic radiolarites could be deposited in a continental slope of a passive continental margin. The latter are characteristics of a distal passive margin setting of the Neotethys realm.
3. The scenario of several independent Triassic oceans in the eastern Mediterranean mountain ranges is not supported by the identical sedimentological evolution of the Triassic outer shelf sequences in this region.
4. Middle Triassic radiolarites do not necessarily represent erosional products of original sedimentary cover of the Triassic Neotethys ocean floor. They were deposited over the distal passive continental margin of the Neotethys Ocean. Their finding cannot be used as an argument for an eroded oceanic domain. In contrast, The Upper Triassic radiolarites were exclusively deposited on the oceanic floor.

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Integrated planktic foraminifera, calcareous nannoplankton, and nummulitid biostratigraphy of a Maastrichtian to Priabonian deep-water sequence from the Sierra del Maigmo, SE-Spain

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The Sierra del Maigmo in the eastern Prebetic Zone (Betic Cordillera, Alicante Province, south-eastern Spain) provides a succession of marls and limestones deposited in a bathyal paleo-environment. The c. 500 m thick rocks are rich in distal to proximal turbidites and represents a shallowing upward sequence with thin and fine-grained turbidites at the base developing into thick and coarse-grained ones at the top. While most planktic foraminifera and calcareous nannofossil from marls can be considered to be autochthonous, the found nummulitids are components of the turbidites and thus transported from adjacent shelf settings (allochthonous). This setting gave the opportunity to study contemporaneously deposited shallow and deep-water fossil assemblages in combination. We present the biostratigraphic results for planktic foraminifera, calcareous nannofossils, and larger foraminifera (nummulitids) and compare the derived zonations. Although the sample density is relatively low, the planktic foraminiferal assemblages point to a nearly complete succession (except local erosional gaps), ranging from the *Pseudoguembelina palpebra*-Zone (Early Maastrichtian) to the Zone E14 (*G. semiinvoluta*-Zone, late Bartonian/early Priabonian). Nannofossil analyses show largely identical ages (Maastrichtian UC20 to late Bartonian/early Priabonian NP18), except for few cases with dominant reworked nannofossils. Sampled nummulitids indicate ages from Shallow Benthic Zone 11 (late Ypresian) to SBZ 18 (late Bartonian/early Priabonian. The combination of the investigated stratigraphically important fossil groups show time gaps ranging from nearly synchrony to about one planktic foraminiferal zone between the deposition of planktic foraminifera and calcareous nannofossils, and the benthic nummulitids. This points to differential transport or storage periods up to 1-2 My for the nummulitids on the shelf during the Eocene.

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Cambrian subdivisions' last chapter: examination of the Cambrian Stage 4 lower boundary candidates

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Subdivision of the Cambrian into stages progressed over the last two decades, but left the Stage 4 lower boundary more or less disregarded. Possible biological marker horizons are provided by trilobite, archaeocyath, mollusk, other small skeletal fossils and acritarch occurrences, with trilobites being favoured as indicators of a boundary level. Global biostratigraphic correlations are inherently difficult for the Cambrian because of the endemic nature of the trilobite-dominated faunas, and the Stage 4 lower boundary interval suffers additionally from distinct facies differentiations within and between the Cambrian continents. Globally distributed agnostines, extensively usable for the younger half of the Cambrian, are not available so that a GSSP for Stage 4 will have to be established on restricted species.

Complications result from the attempt to select stages of subequal durations so that the stratigraphic position of the Stage 4 lower boundary will be affected by the position of the not yet established Series 2/Stage 3 and Series 3/Stage 5 lower boundaries. Historic concepts are of minor interest because a boundary in about this position has never been used on global scales. The Siberian Early Cambrian subdivision, which was frequently transposed into an incorrect global left hand scale until recently, suffers from its definition by means of endemic Siberian species and is unsuitable for international use. This fact also sheds some light on the myth of the so-called end-Botoman mass extinction.

Prime candidates to indicate a correlatable boundary at a position suitable to define the Stage 3 Stage 4 boundary and a GSSP include the associations with such trilobites as *Serrodiscus bellimarginatus*, *Triangulaspis annio*, *T. schucherti* and *Hebediscus attleborensis*, which are known from Western Avalonia (southeastern Newfoundland), Eastern Avalonia (central England), the Taconic Allochthon of Laurentia, West Gondwana (Spain, Morocco, Sardinia), the Altay-Sayan Fold Belt, various parts of the Siberian Platform, and the Russian Far East region. They appear to be also recognizable, with some restrictions, in Laurentian Greenland and South Australia. This faunal band is generally amply fossiliferous and testifies a period prior to the globally detectable regression that masks the successions in most of the Cambrian continents by an immense input of clastic sediments. As a result, auxiliary trilobite taxa exist in this level and enable a correlation into other regions. In West Gondwana, this fauna includes other species of *Hebediscus* ("*Dipharus*"), *Triangulaspis*, *Mallagnostus llarenai*, other species of *Serrodiscus*, saukiandiids, and early ellipsocephalines. A correlation into the Avalonian *Callavia* Zone is possible. In the Taconic allochthon, the assemblage has been termed the *Elliptocephala asaphoides* fauna and includes such species as *Calodiscus meeki*, *C. schucherti*, and *Serrodiscus speciosus*. *Mallagnostus llarenai* brackets Western Gondwana with Eastern Avalonia. Elements of this fauna occur in Siberia in the *Bergeroniellus gurarii* to *B. asiaticus* zones of the Botoman Stage, in the West Sayan (Obruchev "horizon"), and in the Far East region.

Using this *Serrodiscus*-*Triangulaspis*-*Hebediscus* band would allow a reasonably precise global correlation and offer the opportunity to calibrate it by physical methods. However, the faunal band is distinctly affected by facies preferences of its constituents; the key taxa are known from relatively few Cambrian areas; the associations are often paucispecific; and its key species tend to be difficult to recognize so that a number of published identifications require careful reconsideration.

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Considerations on the Precambrian Phanerozoic and Ediacaran Cambrian boundary: a historic approach to an unresolvable dilemma

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The concept of the Precambrian Phanerozoic boundary is ruled by the idea that it divides an older period virtually without any vestiges of life from a younger period with a plethora of organisms of all different phyla. Traditionally, the boundary between the erathems and systems was drawn at a regional unconformity, and until the late 1940s it was assumed that the base of the Cambrian was marked by the lowest appearance of trilobites. By the end of the 1960s, the existence of a latest Precambrian fauna was widely acknowledged, primarily characterized by the Ediacara fauna of South Australia. In addition, the activities of geologists from the Soviet Union had demonstrated a pre-trilobitic succession of skeletal fossils on the Siberian Platform, which were referred to the Cambrian System. Activities of a Working-Group on the Precambrian-Cambrian Boundary to define the bottom line of the Cambrian's biostratigraphic scale led to the insight that most of the fossils from this pre-trilobitic Lower Cambrian interval (termed the 'Tommotian fauna') were not referable to well established groups. Subsequent discussions focused on the relationship between lithofacies and biofacies and the problem of correlating carbonate shelf facies with archaeocyathans (as in Siberia) with clastic shelf to basinal facies that dominate elsewhere. A WG meeting in 1978 recommended that "The Precambrian-Cambrian boundary should be placed as close as is practicable to the base of the oldest stratigraphic unit to yield Tommotian (sensu lato) fossil assemblages." Candidate sections selected during the following years included the Ulakhan-Sulugur section in Siberia; the Meishucun section in South China; and several sections on the Burin Peninsula, Newfoundland, all discussed on the Bristol meeting of the WG in 1983. Emphasis upon small skeletal fossils ('SSFs') stimulated research on the earliest hard part fossils, and led to a preliminary mandate of the Meishucun section. However, concerns about their biostratigraphic utility grew, and during a Workshop in Uppsala in 1986 it became apparent that correlation of the boundary successions in China into most other regions remained problematic. Small skeletal fossils were identified as long-ranging, highly variable and taxonomically difficult taxa that were facies-dependent and provincial in distribution, with a virtual restriction to shallow marine carbonate facies. Attempts to identify pandemic form failed.

A WG meeting in southeastern Newfoundland in 1987 stressed advantages of trace fossil assemblages illustrated in sections on the Burin Peninsula. Ichnofossils are common in siliciclastic facies in which skeletal fossils are typically rare, and some of them were less strongly restricted in terms of habitat than in later intervals of earth history. The ichnofossil assemblages at Fortune Head display the lowest Cambrian-aspect macrofauna in a sequence that preserves a particularly complete record of the earliest Cambrian evolutionary radiation and include some ichnotaxa with a limited stratigraphic range but broad geographic distribution. These features are exemplified worldwide by the upward replacement of the low-diversity, simple, subhorizontal, sediment-feeder traces of the uppermost Proterozoic, some of which are only known from this interval by complex feeding, escape, and dwelling burrows.

The GSSP for the base of the Phanerozoic and Cambrian at Fortune Head was accepted and ratified by the ISC in 1992 and has become the base of the previously unnamed global lowest Cambrian Terreneuvian Series and Fortunian Stage. This boundary had been defined as the onset of a diverse ichnoassemblage produced by advanced bilaterians, indicated by the lowest occurrence of *Phycodes pedum* (now *Trichophycus* or *Treptichnus pedum*) in the section. In 2013, the coterminous GSSPs for the Cambrian, Terreneuvian, and Fortunian were redefined (at the same horizon), but not at the FAD of the eurytopic and globally distributed ichnofossil *Trichophycus pedum* (and the base of a *T. pedum* Zone) but above the highest occurrence of characteristic Ediacaran problematica and at the base of the *T. pedum* Ichnofossil Assemblage Zone.

Key areas for demonstrating particular problems of the Ediacaran Cambrian boundary include Namibia, where the transition of Ediacaran- and Cambrian-type fossils can be studied. A radiometric dating from the Ediacaran Cambrian boundary interval in Oman, however, generally adopted for the boundary on a global scale, is of little use; its proposal disregards basic of biostratigraphy.

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Response of Fluvial Architecture and Vegetation with change in rainfall amount during the late Cenozoic time: Compound specific isotopic evidence from the NW Siwalik, India

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The collision between Indian and Eurasian continental landmass at ~ 55 Ma has resulted in the formation of the Himalayan mountain chain. At the late stage of Himalayan orogeny at ~ 20 Ma, flexural downwarping of overriding Indian plate has produced world largest terrestrial foreland basin in the foothill of Himalaya. During the late Miocene, rise of the Himalaya and Tibetan Plateau triggered the initiation of Indian Monsoon which enhanced the physical and chemical weathering of the Himalayan rocks. The eroded sediment deposited in the foreland basin gave rise to the Siwalik Group of rocks. Thus this foreland sediment is an excellent archive to unfold the late Cenozoic climatic condition existed over the northern part of India. However, previous reconstruction of timing of monsoon initiation and its effect on ecosystem and fluvial architecture using the Siwalik Group of rock is equivocal. The major goal of this study is to understand the effect of monsoon on vegetation using NW Indian Siwalik paleosol derived long chain *n*-alkane δD and $\delta^{13}C$ value along with fluvial architecture analysis. The *n*-alkane δD based rainfall reconstructions show variations in rainfall amount between 10.5 to 2 Ma with peak rainfall at ~9 Ma and 5 Ma. The foreland sedimentary record depicts varying degree of creation of accommodation space during this interval: high accommodation space and immature soil development during the higher rainfall compared to the low rainfall regime. The change in the amount of rainfall is also reflected in the varying abundance of C_4 plant reconstructed from the long chain *n*-alkane $\delta^{13}C$ value. However, rainfall amount and abundance of C_4 plant is not well correlated. The appearance and expansion of C_4 plant has earlier been documented from the different part of the globe and it shows timing of C_4 advent is not synchronous in basin scale. This asynchronous nature of C_4 plant appearance points towards the regional heterogeneity in climatic factors and soil morphology during the late Cenozoic time.

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Quaternary correlation charts: the last 2.7 Ma, the last 270 ka

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Two international stratigraphical correlation charts for the Quaternary will be presented. They differ by one order of magnitude in the time/depth represented and the resolution at which correlations are made. The first chart spans the last 2.7 Ma, resolved to the nearest 10,000 years, and has global coverage. This chart dates from 2004 and has since been revised semi-annually (e.g. Gibbard & Cohen, 2008). The second chart covers the last 270 Ka, resolved to the nearest 1,000 years. It illustrates the North Atlantic and Europe north of the Mediterranean. A prototype of the latter chart was first exhibited at the 2011 INQUA Congress, then further developed, and completed for release at STRATI2015 and at the 2015 INQUA Congress.

The differences in time/depth and resolution echo the difference in preservation with increasingly younger records. Directly related to this, the charts reflect the differences in detail of study and level of understanding attainable. Because different regions hosted different Quaternary environments, regional division schemes differ between countries and between land and sea. These divisions are therefore based on different criteria and definitions. The many environmental sequences shown in both emphasise the shared, dominant glacial-interglacial cyclicity.

The principal application of the charts is to provide a ready reference for the widely used stratigraphical terms for similar periods in different areas, environments and schemes. In addition, the 1,000-year resolution of the last 270,000 years chart also encourages cross-comparison and testing of alternative correlations between records for this critical interval, providing a vital tool for modern Quaternary science.

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Remarks on the planktonic foraminiferal record and integrated stratigraphy across the Upper Albian - Cenomanian interval at Monte Petrano (Umbria-Marche Basin)

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The Albian - Cenomanian time interval coincides with two major perturbations in the ocean-atmosphere system evidenced by positive $\delta^{13}C$ anomalies: the Oceanic Anoxic Event 1d (OAE 1d) and the Mid Cenomanian Event (MCE). The Monte Petrano section, located in the Umbria-Marche Basin (Italy), is a 65 m-thick stratigraphically complete sequence composed of limestone intercalated by marly limestone and chert layers belonging to the Scaglia Bianca Formation. The section spans the Upper Albian - Upper Cenomanian stratigraphic interval and contains abundant and highly diversified calcareous plankton assemblages. The section includes a distinctive regional marker, about 4 m-thick, characterized by 5 black marly levels with high organic content, known as Pialli Level, representing the lithological expression of the OAE 1d in the Umbria-Marche Basin. The $\delta^{13}C$ analysis showed the presence of both the OAE 1d and MCE positive excursions.
During the Late Albian – Cenomanian (~105-93 Ma) planktonic foraminifera experienced, for the first time in their evolutionary history, a major radiation with the appearance of biserial taxa and of single-keeled trochospiral taxa, informally called rotaliporids. At the same time, planispiral and trochospiral taxa developed new and more complex wall textures (macroperforate, muricate and costellate) that persisted until the end of the Cretaceous.
Planktonic foraminifera were studied in thin section and washed residues. Because of the compactness of the lithologies, they were isolated using an experimental technique with a solution of acetic acid at 80%. Biostratigraphic analysis was performed on the >38 μm size-fraction, while >125 μm size-fraction was used to quantify changes in the assemblage composition. The studied stratigraphic interval is assigned to 5 biozones, from base to top: *Pseudothalmanninella ticinensis*, *Thalmanninella appenninica*, *Th. globotruncanoides*, *Th. reicheli* and *Rotalipora cushmani*. Remarkable is the reliability of the appearance level of *Th. appenninica* and *Th. globotruncanoides* as both species are common and easily identifiable. On the contrary, the lowest occurrence of *Th. reicheli* is questionable because of its rarity and discontinuous stratigraphic distribution. Moreover, the appearance of *R. cushmani* could be easily misidentified owing to the occurrence of common transitional morphotypes between its ancestor *R. montsalvensis* and *R. cushmani*. The base of the Cenomanian is placed at 16 m from the base of the section according to the lowest occurrence of *Th. globotruncanoides* following the stratotype definition. The highest occurrence of *Hayesites irregularis* correlates with the Albian/Cenomanian boundary at Monte Petrano.
The biostratigraphic analysis of calcareous nannofossils was conducted in smear slides, through the semiquantitative characterization of nannofloral abundance and preservation as well as relative abundance of individual taxa. All zonal and most subzonal markers of the three standard zonations were recognized.
Integration between planktonic foraminiferal and calcareous nannofossil events provides a robust biostratigraphic framework to constrain the chemostratigraphic record and the position of OAE 1d and MCE. Our data show that the positive $\delta^{13}C$ shift associated to OAE 1d culminates in the lowermost Cenomanian *Th. globotruncanoides* Zone, while the MCE falls in the middle Cenomanian *Th. reicheli* Zone. As far as the nannofossil biostratigraphy is concerned, the OAE 1d isotopic anomaly is constrained by the lowest occurrences of *Crucicribrum stenostaurion* and *H. irregularis* at the base and by the highest occurrence of *C. stenostaurion* at the top, respectively.
Finally, the bio- and chemostratigraphic events observed at Monte Petrano section are compared with those documented across the Albian-Cenomanian transition at Mont Risou (Vocontian Basin, France) the Global Stratotype Section and Point for the base of the Cenomanian Stage.

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Biodiversity of marine diatom flora in detailed elaboration of the North Pacific Neogene diatom zonation

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Fossil diatoms occur widely in deep-sea and onshore Neogene stratigraphic sequences in the high to middle latitudes and are among the primary biostratigraphic tools for precise dating and correlation of marine sediments. It is particularly time of the North Pacific, where calcareous microfossils are lacking or rare in the Neogene deposits. During the past decades, the Neogene diatom stratigraphy has made significant progress and has developed rapidly. In many respects, this progress is connected with the study of Cenozoic sedimentary deep-sea cores in the North Pacific started in the 1970s. The documenting fossil floras of different age and tracing of diatom assemblages in nearly complete marine sections made it possible to propose first versions of a series of middle Miocene to Quaternary successive zones. Later, new materials allowed greatly refining and improving the diatom zonation. The study of these materials provided data on the stratigraphic ranges of numerous planktic diatom species (including described new taxa) and gave the possibility to evaluate their importance for biochronology and correlation. At present the North Pacific Neogene diatom zonation includes numerous biohorizons based on datum levels, which have been directly correlated to the magnetostratigraphy of the early Miocene to Quaternary.

The current knowledge on diatoms provides the high-resolution biostratigraphy in the North Pacific comparable with the zonations based on planktic foraminifera and calcareous nannoplankton. In this regard, diversification of diatom flora (in particular, the "flashes" of biodiversity within particular genera in the Neogene) provides a promising data set of great potential. First of all, the diversification concerns with appearance and rapid evolution of pennate raphid diatoms from genera *Nitzschia*, *Crucidenticula*, *Denticulopsis*, *Neodenticula*, and impetuous development and species diversity of centric diatom genus *Thalassiosira*. The results of detailed taxonomic studies revealed numerous species within these genera. A number of taxa among tens species occur widely within the North Pacific, and have definite and stable stratigraphic ranges. As it was shown, some levels of the first or last occurrences of species (often having a narrow age diapason of existence) are practically isochronous around the whole region. Such levels of are used as markers of zonal boundaries. The current North Pacific Neogene to Quaternary diatom zonation includes about 20 zones. Most of their boundaries are marked by datum levels of age-diagnostic species from genera *Crucidenticula*, *Denticulopsis*, and *Neodenticula* consist of typical marine planktic taxa. The mentioned genera appeared in the Neogene and originated from different species of genus *Nitzschia*. Biodiversity owing to rapid evolution also makes it possible to determine additional datum levels within the zones. Filling the zones these successive levels are important infrazonal biostratigraphic markers for analysis of assemblages and evaluation of their age. Some of them may be used to determine boundaries of subzones. Later on, a part of such datums may serve as markers for boundaries of new more detailed zones. However, their isochroneity should be checked and the possibility of their application for wide-ranging correlation should be approved. In other cases, subzonal assemblage may be traced relatively locally and changed within the region owing to facies, etc. For example, these markers are important for the study of relatively shallow marine facies where neritic taxa dominate. In this regard, biostratigrahic units based on diverse *Thalassiosira* species appearing at different age levels are valuable and helpful.

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Problems of Neogene stratigraphy of Russia - three paleoecosystems and their facial characteristics

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Neogene formations are widely spread mainly in three major regions of Russia. The regions correspond to certain paleoecosystem types (PE-1, PE-2, PE-3). These are: (PE-1) - the Black Sea-Caspian region (the south of the European part of Russia), (EC-2) - Siberia (with the North-East of Russia), and (PE-3) - Kamchatka-Sakhalin. Their specific characters are reflected in peculiarities of the regional stratigraphic schemes. The regions belong to different types of sedimentary basins. PE-1 is a semiclosed marine basin of Eastern Paratethys, PE-2 is a continental basin, PE-3 is an open oceanic basin. Specific regional stratigraphic schemes comprising suites (formations) and horizons (regiostages) have been constructed for every region.

Usually subdivision of marine strata is more refined than that of continental deposits. Neogene regiostages in marine sedimentary basins exceeds in number regiostages of continental basins. So, 12 or 13 regiostages were established in PE-1, seven regiostages and 15 zones in PE-3, seven regiostages in PE-2. The regions also differ in thickness of deposits: 200-300 m in PE-2, 2000-3000 m in PE-1, and 2500-300 up to 5000-8000 m in PE-3. In the PE-3 sections there are many volcanic formations along with the terrigenous ones. This region belongs mostly to the ocean-continent transitional zone with increased tectonic activity resulting in frequent facial changes. Leading paleontological groups for subdivision of the regional sections are also different: molluscs for PE-1, molluscs, benthic foraminifers, and diatoms for PE-3, large and small mammals and flora for PE-2. Beside the biostratigraphic method, magnetic, seismic, isotopic, climatic and other data are used for subdivision of the PE-1 and PE-3 sections. The regiostages in the specific sedimentary basins are characterized by different duration and location of boundaries. They are correlated to the International stratigraphic scale with different degree of reliability. The high reliability was achieved in correlation of units of the Kamchatka-Sakhalin region where diatom zonations are widely used. There all Neogene stage boundaries have been outlined. In spite of different latitudinal position and sedimentational peculiarities, the three ecosystems reflected some global climatic events (e.g., climatic optima of the middle Miocene and early Pliocene, pessimuma of late Miocene and late Pliocene, and others).

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Jurassic and Cretaceous radiolarian biostratigraphy of the Al Aridh Group (Hawasina Nappes, Oman Mountains)

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The Hawasina Nappes preserve remnants of a deep-water basin (the Hawasina Basin), its slopes and intrabasinal pelagic platforms (known as the Oman Exotics). These nappes are defined as a series of imbricates situated between the autochthonous sequences of the Arabian Platform below and the Samail Ophiolite Nappe above. From bottom to top (palaeogeographically from proximal to distal), the Hawasina Nappes are subdivided into four tectonostratigraphic units: the Hamrat Duru Group, the Al Aridh Group, the Kawr Group (Oman Exotics) and the Umar Group.

The Jurassic to Cretaceous Musallah Formation of the Al Aridh Group has been studied and dated with radiolarians. This formation overlies calcareous turbidites of the Buwaydah Formation and consists of bedded radiolarian cherts punctuated by coarse-grained breccias and conglomerates. Radiolarian analyses allowed us to establish the time span of chert-dominated intervals, to constrain the ages of the intervening mass-flow deposits and to provide evidence of considerable stratigraphic gaps.

The Musallah Formation starts with varicoloured thin-bedded radiolarian chert with shale interlayers and ranges in age from the early Pliensbachian to the middle-late Toarcian. This chert unit is overlain by up to several meters thick, generally channelized, debris-flow deposits, which contain clasts of underlying lithologies and include sub-rounded blocks of Permian and Triassic shallow-water limestones. A late Aalenian age has been documented in a chert bed between two conglomerate levels. Two superimposed units of bedded radiolarian chert then follow. The first unit of reddish and yellowish thin-bedded chert spans from the lower-middle Bajocian to the lower Bathonian, and is directly overlain by the second unit of thicker-bedded dark red chert that is assigned to the upper Tithonian-Berriasian to the lower Hauterivian. At least three stages are missing between these two chert units without any clear evidence of erosion. The long stratigraphic gap is considered as a "hidden discontinuity", which resulted from down-slope sliding of semi-consolidated siliceous ooze. Upper Aptian to Albian and Coniacian radiolarian cherts were also documented but occur in pervasively folded upper part of the Musallah Formation that has not been completely reconstructed yet.

The correlation with the Hamrat Duru Group reveals that the Pliensbachian to Toarcian chert unit was uniformly deposited over the entire Hawasina Basin. The onset of siliceous sedimentation is roughly correlative with a Pliensbachian marine transgression over siliciclastics on the Arabian Platform and approximately corresponds to formation of ferromanganese hardground on the drowned Oman Exotics. These facies changes were related to the regional rifting phase that is well documented from the Arabian Peninsula to the western Mediterranean. The debris-flow deposits around the Aalenian–Bajocian boundary record a rapid subsidence pulse and correlate to the Mid-Cimmerian unconformity that is also a Tethyan-wide phenomenon. The Al Aridh Group is higher in the succession composed almost exclusively of radiolarian cherts and lacks Bathonian oolitic carbonate gravity-flow deposits that are characteristic of the Hamrat Duru Group and were widely distributed in proximal settings of all platform-bounded Tethyan basins. The conspicuous pre-Tithonian stratigraphic gap was concomitant with major subsidence on the edge of the Arabian Platform and can be explained by sediment removal due to block tilting related to the final breakup between the Arabian and Indian plates. The effects of this tilting are well marked only in the eastern part of the Hawasina Basin. Further west, in the Sumeini Group (NW Oman Mountains) and in the Pichakun Nappes (Zagros, Iran), there is no evidence of a pre-Tithonian gap in basinal successions; Oxfordian and Kimmeridgian bedded cherts and shales occur in proximal as well as in distal settings.

Cambrian Series 2 (Upper Ovetian) trilobites from Los Barrios de Luna (North Spain) and their intercontinental correlation

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The Los Barrios de Luna area in the León province (N Spain) is the most classical locality for Cambrian studies in the Cantabrian region. The Cambrian succession is composed of La Herrería, Láncara, Oville and Barrios formations. Upper Ovetian (Cambrian Series 2) trilobites have been recorded in the upper part of La Herrería Formation. We have revised these faunae from a palaeontological and biostratigraphical point of view. Two stratigraphic sections have been studied including trilobites and ichnofossils. The ichnofossils assemblages have a high diversity characterising the *Cruziana* facies, suggesting a shallow sublittoral environment for the upper part of the La Herrería Formation. The previous trilobites identified and the new discoveries allow us to recognise five trilobite assemblages in stratigraphical order:

1) *Lunolenus*? *lotzei*
2) *Lunagraulos antiquus*
3) *Lunolenus prior* and *Lunagraulos antiquus*
4) *Lunolenus lunae*, *Dolerolenus formosus* and *Metadoxides richterorum*
5) *Lunolenus lunae*, *Dolerolenus formosus*, *Dolerolenus longioculatus*, *Metadoxides armatus* and *Sardaspis*? sp. indet.

The new trilobite discoveries allow us to propose a detailed intercontinental correlation of the upper Ovetian Substage of Spain and Sardinia with the base of the Tsanglangpuan Stage of South China.

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Palaeoenvironmental changes across the Oxfordian/Kimmeridgian transition (Upper Jurassic, Wieluń Upland, Central Poland): evidences from rock magnetism and inorganic geochemistry

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The results of an integrated magnetic and geochemical study of the Oxfordian/Kimmeridgian boundary interval in the Polish Jura Chain are presented. The deposits studied are bedded limestone-marly limestones of the sponge megafacies deposited in the deep neritic northern Tethyan shelf. The succession studied (two sections: Katarowa Góra and Bobrowniki), 24 m thick, is well dated based on ammonites mostly of Submediterranean affinity, with important contribution of Sub-Boreal and Boreal species at some levels. Magnetic susceptibility (MS), anhysteretic remanent magnetization (ARM) and isothermal remanent magnetization (IRM) were measured with high resolution along the succession. Additionally, contents of main, minor, trace elements and REE were determined. The study aimed to identify palaeoenvironmental perturbations related to Boreal ammonite excursions.
The content of non-carbonate material is very low. Al content typically varies between 0.04 – 0.15% only. The rocks studied are also extremely weakly magnetic. MS values are mostly negative (usually between -4 and -2 x 10^{-9} m^3/kg). Dominant magnetic mineral is magnetite, occasionally hematite and goethite are also present. MS correlates positively with lithogenic elements (Al, Ti, Zr and others), which indicates that it is mostly of detrital origin. Correlation of ARM and IRM with lithogenic proxies is a bit worse. This might account for authigenic origin of a part of magnetic minerals. Despite that a long term trend of decrease of detrital supply is clearly visible on both magnetic and geochemical curves. The trend is broken only at the Oxfordian/Kimmeridgian boundary represented by tectonically enhanced omission surface, with extremely high content of terrigenous elements and magnetic minerals.
Relatively high input of terrigenous material is observed in the intervals rich in Boreal and Subboreal ammonites (e.g. "*Amoeboceras* layer") which occur in the lower and upper part of the Hypselum Zone. These intervals reveal also relatively high values of ARM as well as Th/U and P/Al ratios, which points to oxic conditions of the bottom water and increased productivity. The observations are in good agreement with palaeoecological observations, which show mixed ammonite assemblage and suggest important influx of nutrient-rich waters. The latter resulted in the development of radiolarians. Within the upper part of the succession, in the uppermost part of the Hypselum and in the Bimammatum Zone, a marked decrease of detrital influx is observed. It is accompanied by lower values of magnetic indexes and stepwise oxygen depletion of bottom water (decrease of Th/U ratio). Productivity index (P/Al) reveals here high variations and attends its maximum values. It is concordant with the increased number of Submediterranean ammonites and abundance of Tethyan radiolaria. These phenomena might be related to diminished mixing of seawater and increased carbonate production either as a result of the long term warming trend, which is documented on the basis of belemnite $\delta^{18}O$ values, or local shallowing of the Polish Jura basin.

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Multi-proxy record of the Upper Berriasian palaeoenvironmental changes in the Barlya section (Western Balkan, Bulgaria): clastic input, redox and productivity variations, nannofossil response

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Upper Berriasian to basal Valanginian part of the Barlya section (West Balkan Mts, Bulgaria), of ca. 38 m thickness, is represented by a transition between the pure micritic calpionellid limestones of the Glozhene Formation towards the clayey limestone–marl alternation of Salash Formation. The section is adequately dated by calpionellids, calcareous dinoflagellate cysts, calcareous nannofossils and magnetostratigraphy. It covers the stratigraphical interval from the upper part of Calpionella elliptica Subzone, Stomiosphaerina proxima Zone and NK-1 (upper part of magnetozone M17r) up to the Berriasian/Valanginian boundary (Praecalpionellites murgeanui/Calpionellites darderi subzonal boundary, Colomisphaera conferta Zone, NK-3, magnetozone M14r).
Paleoenvironmental proxies such as clastic input, redox and productivity variations were determined using rock magnetic parameters and inorganic chemistry. Additionally carbon isotope stratigraphy and semi-quantitative study of calcareous nannofossil abundance and diversity were performed.
An increase of fine grained lithogenic influx is observed from the middle part of M16r magnetozone (Elliptica/Simplex zonal boundary) which continues up to the lowermost Valanginian. It correlates with well established long term eustatic sea-level fall and climate humidity increase in the Western Tethys. It is suggested that Mg/Al ratio might reflect a change of clay mineral assemblage towards more kaolinite reach. If so, the increased clastic influx might have been related to chemical weathering intensification. However, the long-term character of the phenomena (more than 3 My) is longer than that expected for climatic and/or glacieustatic trends. Therefore we suggest a tectonic phenomenon as a main driving force of the lithogenic influx.
Two peaks of nannofossil abundance and diversity are observed. They are generally supposed to reflect the stages of enhanced eutrofication of the surface waters. The first correlates with minimum of clastic influx in the lower portion of M16r. It is accompanied by relatively depleted oxygen conditions of bottom waters (high U/Th and Ni/Co ratios,), high production of biogenic phosphorus, increased productivity indicators (significant enrichment in Ni, Cd, Zn and Ba) and decreasing trend of $\delta^{13}C$. The second peak occurs in the uppermost Berriasian (M15n) and its geochemical characteristics is quite different. It coincides with relatively high clastic input, very low enrichment in P, only slightly elevated U/Th ratio and positive plateau of $\delta^{13}C$. A possible explanation may be fresh water runoff in the upper part of M16n (recorded in negative excursion in $\delta^{13}C$ and diminishing abundance and diversity of nannofossil association), which ventilated the oxygen-depleted bottom water. Subsequently, the normal marine conditions were restored in the basin with optimum in the uppermost Berriasian (M15n). Conversely, the oligotrophic conditions might be responsive for the diversity and abundance minima of nannofossil association within the lower and upper part of M16n magnetozone.

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Plea for a modern definition of the Jurassic-Cretaceous boundary (illustrated by the case study of the lowermost Cretaceous in Alicante, SE Spain)

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When looking for the best candidate for the JK system boundary, the experts should take their blinders off, leave their basinal settings and consider what was occurring on the surrounding platforms (PF). They would then acknowledge there is no obvious way to identify the Tithonian-Berriasian stage boundary in such settings! Currently, biostratigraphy cannot help much in such environments because there are no ammonites (unless very rare occurrences), nor calpionellids. Granier & Bucur (2011) discussed alternative micropaleontological indexes selected amongst benthic foraminifers and “calcareous algae”. Fourcade & Granier (1989) and Schlagintweit & Enos (2013), for instance, used them in an attempt to locate the stage boundary in cores from the DSDP site 392A, off the Florida coast, for instance. Though the Berriasian age of the upper part of the PF interval is proven and the Tithonian age of the lower part is rather likely (but not fully documented), the exact location of the stage boundary still remains highly uncertain there. Actually, most of the time, we are unable to define it in PF settings; as a consequence /worse than that/ we are also unable to define the JK system boundary. Is there an alternative? The answer is “Yes, obviously!”, but first we must agree that the current acception of this system boundary will be subject to endless discussions (probably because it was a poor choice from the beginning). Second, we must consider an alternative, *i.e.*, shifting the system boundary upward or downward to match a nearby boundary (should it fall into a regional hiatus, it would highlight its significance!). I did the exercice some years ago (Granier, 1993, 1994, 2007) considering both PF and basinal sections in the Tethyan realm, from the Central Atlantic Ocean to the Middle East. I noted that the demise of the Jurassic carbonate platforms did not occur at the end of the Tithonian times, nor in the Volgian, but at the end of the Berriasian or the Ryazanian, with the Early Valanginian transgression; the associated /dis-/ continuity [note: a discontinuity on the PF passes laterally to a continuity in the basin] is by far the best candidate because it is significant one and it is mappable worldwide. A first evidence is given by a figure illustrating the SB1 concept taken from the "Seismic stratigraphy and global changes of sea level" by Vail et al. (1977); a second seismic section taken from the Schlager's (1989) paper on "Drowning unconformities on carbonate platforms" provides another piece of evidence. Other examples from the Atlantic Ocean domain include DSDP sites 392A and 416A (a basinal section, off Morocco), as well as O&G exploration wells off Nova Scotia (Shell Demascota G32, Shell Oneida O25) and the Senegal onshore (Copetao N’diass DS1). On the opposite side of the Tethyan realm, more examples can be found in the Persian Gulf (Abu Dhabi and Oman). In the central part of the figure, in the Spanish Province of Alicante, outcrops document it in basin (Sierra de Fontcalent) to PF (Cabezon de Oro, Puig Campana, Sierra Helada) environments, even including transitional ones (*i.e.*, the slope at Busot). There, the earliest Valanginian transgression led to the sudden occurrence of coarse siliciclastics (silt, sand, gravel and cobble in the “calcarenites with *Pseudocyclammina*”) on top of the Tithonian-Berriasian carbonate PF; basinward the coarse fraction becomes lesser. Small coral heads, as well as foraminifers and “calcareous green algae”, are commonly found in the coarse calcarenitic facies (turbidity was probably null due to the absence of clay particles). HSC, SCS, and tubular worm burrows (*Skolithos*) are the common sedimentary structures preserved. At Cabezon de Oro and Puig Campana, the calcarenitic unit is followed by a triple bed set that corresponds to a condensed interval (c. 1 m thick) representing part of the Valanginian, the Hauterivian, the Barremian and part of the Bedoulian. At Sierra de Fontcalent, in a basinal setting, the silty lower Valanginian is more than 100 m thick, which contrasts with the 50 m of Berriasian marls and limestones below, the 15 m of glauconitic upper Valanginian – Hauterivian limestones followed by some 60 m of Barremian marls and limestones above it. Late early Valanginian block faulting is responsible for this condensation. In conclusion, the lowermost Valanginian transgressive event should be an obvious candidate for the JK boundary.

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Holostratigraphy in Lebanon (the case study of a regional stage)

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Lebanon landscapes provide a wide variety of exposures of shallow-water Jurassic and Cretaceous rocks. The stratigraphy of the country still bears the mark of the late Louis Dubertret (1904-1979), once the editor-in-chief of the "Asie" section of the "Lexique Stratigraphique International". Dubertret, who was based in Beirut, was the major contributor to the geological mapping of the country. His approach of lithostratigraphy was mostly facies-driven as documented hereafter by the case study of the Lower Cretaceous "Falaise de Blanche", a Cyclopean limestone wall that runs throughout the Mount Lebanon and Anti-Lebanon ranges. On the outcrops, whitish micritic facies are commonly found overlying yellowish grainy facies. Dubertret (1950, 1955) merged these grainy limestone facies, either oolitic or bioclastic (with wackestone to grainstone textures), with underlying siliciclastic facies under a label "C2a"; he ascribed a label "C2b" to the overlying micritic limestone facies (with mudstone to wackestone textures). However, one facies may locally be missing or interfinger with the other, suggesting that these areas represent transitional zones between a shoal barrier and its protected lagoon.This geometrical relationship is merely the signature of regular lateral changes in facies. The fossil assemblages, which are very similar in both facies, also plead for their grouping in a single unit. In view of working in a well-constrained stratigraphic framework and getting rid of the issue of the lateral changes in facies, we decided on a more modern approach of lithostratigraphy (Murphy & Salvador, 1999; see Granier, 2000, for a first use in the Middle East), that of the UBU, *i.e.*, Unconformity Bounded Unit (Wheeler, 1959), that of the Alloformation (NACSN, 1983), or that of the regional stage (Hedberg, 1976; Rey et al., 2008; see Granier et al., 2011, for a first use in the Middle East): we adopted the last category (Maksoud *et al.*, 2014). UBU and Alloformations are unconformity bounded "rock units" (sedimentary rocks for the first and all rocks for the second) whereas a regional stage is a "time-rock unit" bounded by isochrones (Hedberg, 1976). These proposals would appear to be irreconcilable; however, they are not if one consider a founding principle of sequence stratigraphy that states that any discontinuity on a shelf passes laterally to a continuity in the neighbouring basin. In conclusion, we introduced a new regional stage, the "Jezzinian". The type-section of which is sited in Jezzine, 70 km south from Beirut. There each bounding unconformity, either the lower or the upper, corresponds to a transgressive surface (TS) merged with a sequence boundary (SB). Regarding biostratigraphic data, due to the historical lack of ammonite finds, except for the Albian strata with the well-known *Knemiceras* sp. (with the first finds several tens of meters above the cliff sections studied), a direct calibration on the International Chronostratigraphic Chart was not feasible. However, our holostratigraphic approach, that is the integration of sedimentological data, sequence stratigraphic interpretation, macrofossils and microfossils, led us to: • correlate the Jezzinian with the upper Kharaibian of the Persian Gulf (South Tethys), • correlate the Jezzinian with the Urgonian sequences Ba5 - Bd1 (North Tethys), • ascribe it a latest Barremian - early Bedoulian age (equivalent at least to parts of the Giraudi - Oglanlensis ammonite zones), • estimate the duration of the upper hiatus to at least the duration of the Hawarian of the Persian Gulf (South Tethys) or the Urgonian sequences Bd2?-Bd3? (North Tethys), *i.e.*, parts of the Oglanlensis - Deshayesi ammonite zones.

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The room for the Vendian in the Standard Global Chronostratigraphic Chart

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The Vendian was proposed by B.S. Sokolov as a stratigraphic subdivision comprising the last of the Proterozoic glacial periods (Laplandian Glaciation) and the overlying strata with a full stratigraphic range of fossil soft-bodied organisms. For over three decades the Vendian had been an informal part of the Standard Global Chronostratigraphic Chart, until 2004 when it gave place to the Ediacaran System. Further research has shown that the Ediacaran System significantly exceeds the stratigraphic range of the Vendian in Sokolov's definition and includes stratigraphic analogues of the Laplandian Glaciation (600–580 Ma). In the Varanger Peninsula ((N Norway), the type area for the Laplandian Glaciation, diamictites of the Smalfjord Fm. are significantly younger than ~630 Ma, whereas diamictites of the Mortensnes Fm. are older than ~560 Ma. In the Central Urals, diamictites of the Tany and Koiva Fms. are younger than the U–Pb zircon date of 598.1 ± 6.0 Ma, but may be older than ~570 Ma. In the South Urals, the diamictites of the Asha Gr. are constrained by the Rb–Sr age of 593 ± 15 Ma of burial diagenesis. One of the Laplandian glaciations is represented in Newfoundland as diamictites of the Gaskiers Fm. bracketed between the U–Pb zircon dates of 583.7 ± 0.5 Ma and 582.1 ± 0.5 Ma. Diamictites of the Roxbury and Fauquier Fms. of North America could account for other episodes of the Laplandian Glaciation. Apart from North America, stratigraphic equivalents of the Laplandian Glaciation are present in the Ediacaran strata of Scotland and Ireland, as the MacDuff, Inishowen and Loch na Cille diamictites of the Southern Highland Group; in the Chinese Tien Shan, as the Hankalchough diamictites of the Quruqtagh Group; in Australia, as sedimentological evidence for ice-rafting in the Bunyerroo Fm of the Wilpena Group; and in Tasmania, as the Croles Hill diamictites.

C-isotope variations in carbonates provide criteria for subdivision of the Ediacaran into two series. Should a relationship be established between the Laplandian Glacial Period (600–580 Ma) and the negative excursions EN2 and EN3 on the $\delta^{13}C$ curve for the Doushantuo Formation of China, the Vendian might take its place in the Standard Global Chronostratigraphic Chart as a formal upper series of the Ediacaran System. The Vendian Series might be further subdivided into the Laplandian, Redkinian, Belomorian, and Kotlinian stages. These proposed stages correspond to major evolutionary and ecological transformations, and this is precisely why these units possess stratigraphic significance. The first transformation is associated with the evolution of frondomorphs and vendobionts of the Avalon biota in low-energy inner shelf settings during the Redkinian (580–559 Ma). The sudden appearance of macroscopic organisms and the emergence of Avalon-type communities could be a consequence of the oxygenation of the Ediacaran Ocean and/or the launch of new mechanisms of ecosystem functioning in connection with the appearance of bilaterians. The Belomorian stage (559–550 Ma) is marked by the diversification of frondomorphs, the migration of vendobionts from low-energy inner shelf to high-energy shoreface settings, and the appearance of tribrachiomorphs and bilateralomorphs. Benthic organisms formed ecological associations that coexisted in the low-energy inner shelf (Avalon-type communities), in the wave- and current-agitated shoreface (Ediacara-type communities), and in the high-energy distributary systems (Nama-type communities). Furthermore, bilaterians developed the ability to bioturbate the sediment in low-energy inner shelf settings, and this could also affect marine ecosystem structure and functioning. The Kotlinian stage (550–540 Ma) is associated with a drop in taxonomic diversity of Ediacara-type communities in wave- and current-agitated shoreface with the exclusion of vendobionts, tribrachiomorphs, and bilateralomorphs by metazoans. High-energy distributary channel systems of prodeltas served as refugia for a peculiar Nama-type biota of endobenthic organisms that survived until the end of the Ediacaran.

The Vendian is proposed as the upper series of the Ediacaran System. Criteria for establishing the lower boundary of the Vendian should be resolved from integrated biostratigraphic, sedimentological and chemostratigraphic studies. Uncertainties in correlation of the Ediacaran–Cambrian boundary interval shall not preclude the use of the term "Vendian" in the Standard Global Chronostratigraphic Scale. This term is scientifically substantiated and satisfies formal requirements.

Ostracod-based biostratigraphy of the Solimões Formation (Miocene; western Amazonia) – Status quo and perspectives

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Amazonia is famous for its present day biodiversity, which roots in pre-Quaternary times (e.g., Hoorn et al., 2010). Hence, the Neogene evolution of this vast region, mainly driven by Andean tectonics and climatic changes, remains an intensively discussed topic in earth and life sciences as well. However, an accurate chronology of abiotic and, in turn, biotic changeovers is crucial to resolve Amazonia's geological past. Up to now, palynostratigraphy (Hoorn 1993) is *the* backbone of any biostratigraphic attempt in western Amazonia – and beyond. Few geochronologic data and long-distance correlations of scattered vertebrate sites do not provide a sufficient time resolution so far. Conversely, the in-depth investigation of mollusc faunas furnished well-founded and detailed biozonations, which are, however, highly linked to the palynological concept. Similarly, Muñoz-Torres et al. (2006) proposed an ostracod biozonation for the Pebas/Solimões Formation. Again, these zones are chronologically calibrated to palynostratigraphic results.

The taxonomic appraisal of ostracod faunas from a ~400 m long sediment core (1AS-10-AM; ~62 km SW Benjamin Constant; Brazil) permitted the revision of ~2/3 of hitherto described species of the ostracod genus *Cyprideis* (Gross et al. 2014). First and last "appearances" of *Cyprideis* species form the base of the biozones of Muñoz-Torres et al. (2006). Our systematic evaluation affects the suggested phylogeny of *Cyprideis*' and, consequently, biozonations as well. For example: i) Some species turned out to be synonyms and are of ecostratigraphic value at the most (e.g., *C. aulakos* and *C. sulcosigmoidalis*, respectively). ii) Some "characteristic" species (e.g., *Cyprideis* sp. 3–5) have been never described or illustrated and are thus not available for biostratigraphic applications. iii) Other species, place together by Muñoz-Torres et al. (1998), have been revalidated. This necessitates a re-evaluation of the Muñoz-Torres material in order to explore their biostratigraphic potential.

Apparently, the existing ostracod biozonation of western Amazonia requires substantial adjustments. Nonetheless, a rough, ostracod-based stratigraphy is already possible, which underlines that these minute crustaceans can essentially contribute to advance the Miocene stratigraphy of western Amazonia.

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Upper Oligocene to Lower Miocene deposits of the North Alpine Foreland Basin: a testing ground for Central Paratethys stratigraphy

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The North Alpine Foreland Basin (NAFB) represents a key-area for Central Paratethys stratigraphy, harboring the holostratotype of the Ottnangian stage (middle Burdigalian) as well as numerous faciostratotypes of the Kiscellian (Rupelian - ?Chattian), Egerian (Chattian – Aquitanian), Eggenburgian (?Aquitanian - middle Burdigalian), Ottnangian and Karpatian (upper Burdigalian) stages. Over the past decade, many of these classical sites have been re-evaluated by introducing new and improved stratigraphic methods, making the basin an important testing ground for stratigraphic concepts of the Central Paratethys.

Two key-sites of recent investigations are drill-site Hochburg 1 and the outcrop Ottnang-Schanze, the Ottnangian holostratotype. New bio-, chemo-, and magnetostratigraphic data not only allow for a more precise correlation of the regional Egerian, Eggenburgian and Ottnangian deposits to the global time scale, they also provide new perspectives on Central Paratethys stratigraphy. A major concern is the Egerian/Eggenburgian boundary, commonly correlated with the Aquitanian/Burdigalian boundary and represented in the NAFB by the lithostratigraphic boundary of the Puchkirchen Group (Egerian) and the Hall Formation (Eggenburgian). This view is contrasted by new results from Hochburg 1 that indicate an extension of the Puchkirchen Group well into the lower Burdigalian (<20 Ma). The implications of this new correlation for analyses of sedimentary budget, subsidence rates, sequence stratigraphy and the regional stage concept challenge our understanding of the development of the NAFB as well as the Central Paratethys.

Mediterranean Outflow Water at the Pliocene/Pleistocene transition: New stratigraphic constraints from IODP Site U1389 (Gulf of Cadiz)

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IODP Hole U1389E, at present located in the lower core of the Mediterranean Outflow Water (MOW) at 640m water depth in the northern Gulf of Cadiz, represents a key-site for the understanding of changes in MOW contribution to the North Atlantic during the late Pliocene and the transition into the Pleistocene ice house climate. Integrated geophysical, micropaleontological and geochemical proxy records of the recovered sediments imply major changes in MOW strength over the studied interval. However, to consider these data in a broader paleoceanographic and paleoclimatic context, a well-constrained age model is essential. New data from calcareous nannoplankton and XRF core-scanning suggest that the shipboard age model for the site has to be reconsidered as major changes in the depositional environment have not been recognized in the original, comparably low resolution data-sets.

While the new, high-resolution biostratigraphic data confirm the overall time frame of 2.6 to 3.6 Myrs for the studied interval, they also indicate that the last occurrence of *Discoaster tamalis* in the succession should be reconsidered. Cyclic patterns are recognized in the $CaCO_3$ and TOC contents, the Ca/Ti- and Zr/Al-ratios. A preliminary cyclostratigraphic analysis of these records suggests an interplay of obliquity and precessional forcing reflected in a change from deposits strongly influenced by terrestrial input (3.0-2.8 Myrs) to deposits strongly affected by MOW (2.8-2.6 Myrs).

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High resolution geochemical stratigraphy on the Yangtze Platform, South China: Implications for the Cambrian Series 2 to Cambrian Series 3 transition

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The transition from Cambrian Series 2 to Cambrian Series 3 was a time of geological and environmental perturbations and biological evolutions.The Wuliu-Zengjiayan section, Guizhou Province, South China has been proposed as a potential Global Stratotype Section and Point (GSSP) for this boundary. Here, we show sulfide sulfur isotope values from Guizhou sections. High DOP as well as strongly positive $\delta^{34}S_{sulfide}$ values from sediments around the boundary of Cambrian 2 and 3 in Guizhou suggest the development of closed system conditions with regard to sulfate availability. Such high bacterial turnover of sulfate could well be a consequence of abundant organic matter, preserved under anoxic conditions. We also discuss $\delta^{13}C_{carb}$ values from Yangtze Platform as well as the world. Guizhou sections display a progressive decrease in $\delta^{13}C$ to a pronounced $\delta^{13}C$ minimum with values at the proposed boundary level. The $\delta^{13}C$ minimum is thought to be caused by a transgressive event, flooding the shelf area with ^{13}C depleted basinal anoxic bottom water. Our $\delta^{13}C$ data are in good agreement with carbon isotope profiles recorded elsewhere. Furthermore, the concentrations of trace element and rare-earth elements (REEs) are reported. The trace element and REE geochemical characteristics of the Kaili Formation at the Jianshan section show that trace element composition and REE distribution patterns across the section are covariant. These define the so called ROECE event (*Redlichiid-Oleneliid* Extinction Carbon Isotope Excursion) and may reflect the perturbation of the global carbon and sulfur cycle during the Cambrian Series 2 to Cambrian Series 3 transition.
This study has investigated the link between geochemical variations and geological and paleoenvironmental changes of global importance as well as to provide additional data for a global chemostratigraphic subdivision of the boundary from Cambrian Series 2 to Cambrian Series 3.

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The International Stratigraphic Chart: progress and problems related to its translation to Ibero-American languages and countries

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Following the recent policy of the International Commission on Stratigraphy to produce standardized translations of the International Stratigraphic Chart for different languages with active scientific application for geological studies and mapping production, the January 2015 version has been translated to the languages of Iberia. The translation to Spanish (Castilian) of the *Tabla Cronoestratigráfica Internacional* resulted from the collaborative work between the Geological Society of Spain, the Spanish Geological Survey (IGME), the Royal Academy of Sciences and the Institute of Geosciences of the Spanish Research Council. In the same way the *Tabela Cronoestratigráfica Internacional* was translated to Portuguese (PT) in a teamwork produced by the Portuguese National Committee for the IGCP/UNESCO and the former Portuguese Geological Survey (LNEG). This version is widely used in the Portuguese-speaking African countries. Concerning the remaining Iberian languages, the *Taula Cronostratigràfica Internacional* was presented in Catalan language by the Cartographic and Geological Institute of Catalonia, in collaboration with researches of the University of Barcelona, the Institute of Catalonian Studies and the Royal Academy of Sciences and Arts of Barcelona. The Basque version translated into Euskara language, *Nazioarteko Taula Kronoestratigrafikoa*, was realized by members of the University of the Basque Country.
In the other Spanish and Portuguese speaking countries in Latin America and the Caribbean, the national entities responsible for geological studies developed their own language, with differences relative to discrete or general nomenclature of formal chronostratigraphic units, such as the endings for systems, series or stages, which also enhanced intra-regional differences. A provisional *Tabela Cronoestratigráfica* has also been proposed for the Brazilian Portuguese (BR) language, but still a more standardized view is needed. A single American Spanish chart is here presented as a consensus-proposal to unify the traditional geological usages in all Spanish-speaking American countries, in the frame of the current nomenclature and global definition from the standard names of the International Stratigraphic Chart.

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Tremadocian (Lower Ordovician) sedimentary record from the Iberian peninsula (Spain and Portugal) – A reappraisal with new data

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Tremadocian rocks are poorly characterized and discontinuously recorded in the Iberian Peninsula, where the existence of major erosive unconformities and diachronic stratigraphic gaps around the Cambrian/Ordovician boundary, is mainly associated to the denudation of rift shoulders during a multistage rifting through the Furongian and the Lower Ordovician epochs. This rifting was connected to the opening of the Rheic Ocean, which also generated thick volcano-sedimentary sequences and plutonism related to the long-lived Ollo de Sapo Magmatic Event, ranging in age between *ca*. 490 and 465 Ma, with a maximum at about 477 Ma and a youngest age of approximately 479 Ma for the massive metavolcanic sequences. In the south-central part of the Central Iberian Zone, unfossiliferous stratigraphic units with volcaniclastic imput occur below the ubiquitous Armorican Quartzite and may be in part of a late Tremadocian age. In the West Asturian-Leonese Zone, the eastern Iberian Ranges and partly in the Cantabrian Zone of northern Spain, the Ordovician conformably overlies Cambrian sequences: the Lower Ordovician strata may reach up to 2,500 m in thickness and are always developed in shallow-water siliciclastic facies, almost devoid of shelly faunas but rich in trace fossils. The extent of Tremadocian rocks were mainly defined on the base of scarce acritarch data, due to the absence of a diagnostic chitinozoan record. However, the Lower Ordovician sequence of the Iberian Ranges yielded several Tremadocian trilobite assemblages that are represented in the upper half of the Borrachón Formation, near the top of the succeeding Dere Formation and also in the lower part of the Santed Formation, being representative of the middle and late Tremadocian. The first record of late Tremadocian graptolites is presented here for the lowermost part of the Dere Fm.
In the SW of the Iberian Peninsula, reworked Tremadocian conodonts occur in Middle Ordovician boulders within a Carboniferous olistostrome in the Obejo-Valsequillo parautochtonous domain. In the Ossa Morena Zone, the transgressive Barriga Shale yielded rich late Tremadocian acritarch and graptolite assemblages from the *Araneograptus murrayi* and *Hunnegraptus copiosus* biozones.
The trilobites and conodonts recorded from the Iberian Tremadocian show affinities with coeval records on the Montagne Noire of SE France, but strengthening some biogeographical links with South America, ?Bohemia and Avalonia, before latter lost all its faunal ties from Gondwana.

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Biostratigraphy, sequence stratigraphy, paleoecology and diagenesis history of the Rupelian-Chattian carbonates in Fars Province, Zagros Basin, SW Iran

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Oligocene carbonates are widespread in the Fars Province, Zagros Basin, SW Iran. The distribution of planktonic and benthic foraminfera, stratal patterns and facies architecture are used as a tool to define biostratigraphy, sequence stratigraphy, paleoenvironment and paleoecology of these strata at Kavar Section. The presence of *Nummulites* spp. indicates the age of the sequence as Rupelian-Chattian (*Nummulites vascus - Nummulites fichteli* and *Archaias asmaricus/hensoni - Miogypsinoides complanatus* assemblage zones).
The distribution of Oligocene foraminifera together with other constituents allowed to identify 3 third order sequences of these carbonates. The correlation of the analyzed sections through the Interior Fars sub-Basin reflects the development of a carbonate ramp with a deepening trend from SE to NW during the Rupelian/Chattian transition.
Four foraminiferal associations are recognised in the investigated ramp setting. They represent a salinity of 34-40 to 50 psu and higher than 50 psu in more restricted conditions. The depth ranges from 200 m to less than 30 m as evidenced by the presence of planktonic foraminifera (in the outer ramp) and *Austrotrillina* and *Peneroplis* in the more restricted inner ramp environment. Warm tropical and subtropical water with a temperature of 18-25 ºC is proposed.
Petrographic studies showed that the Asmari Formation has a complex diagenetic history. The following diagenetic events in the carbonates of this succession include: micritization (bahamite and micrite envelope), dissolution, cementation (equant spary cement, drusy cement, poikilotopic cement, syntaxial cement), compaction (mechanical and chemical), stylolitization and neomorphism (aggrading type). The diagenetic features observed petrographically in these carbonates represent changes which took place under three diagenetic environments (eogenic, mesogenic and telogenic) under three different marine, burial and meteoric conditions.

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The reconstruction of the paleo-environment of Albian-Aptian sediments of the massive El Hmaima, North Tébessa, North-Eastern Algeria

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This research work focusses on a correlation of Albian-Aptian sediments across North Africa focusing on sedimentological, tectonic and paleontological characteristics of massive formations El Hmaima - North of Algeria.

A systematic study was initiated including sampling and washing samples of some Albian levels and a careful sorting of microfossils and minerals under a binocular microscope. Hard Aptian samples were processed by making thin sections to help to determine as precisely as possible the characteristics of the studied levels. The material used is existing in the geology laboratory of Tébessa University, Algeria. The massive El Hmaima North Tébessa was located on the territory of the municipality of Boulhef Dyr, Daira of Morsott.

The Aptian-Albian is characterized by carbonate deposits rich in organic matter levels. This interval is marked by a large marine transgression typically connected to a eustatic rise in second order by tectonic events related to the opening of the western part of the Mediterranean sea and the rifting of the central Atlantic and resulting paleogeographic conditions.

The Cretaceous/Paleogene boundary: sea level change, sea grasses, foraminifera and sequence stratigraphy

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The tsunami generated by the Chicxulub impact eroded the uppermost Cretaceous surface of the Gulf Coast region of the USA (Texas and Alabama) forming a distinctive topography that was previously interpreted as a sequence boundary. At more distal sites, such as Stevns Klint (Denmark), there appears to be no sequence boundary at the Cretaceous/Paleogene boundary but there is a sequence boundary within the uppermost Maastrichtian, between the Sigerslev and Højerup members, and another in the earliest Paleocene (top of zone P1a). Both of these surfaces are identified by distinctive, phosphatised, incipient hardgrounds. The changes in sea level involved in the generation of latest Cretaceous sequences are thought to have been relatively small as, in the Gulpen and Maastricht formations of the Maastricht area (Netherlands) the presence of sea grasses and their associated foraminifera would indicate that the chalk sea floor remained within the range of water depth that would allow photosynthesis (<20 m), even across suggested sequence boundaries. The assemblages of foraminifera associated with the sea grass fossils in the latest Maastrichtian are comparable in morphology to those associated with modern sea grass meadows and indicate a relationship that may have existed since, at least, the latest Cretaceous. The problem with the interpretation of sea grass communities is whether the foraminifera were initially epiphytal, living on the fronds, or responding to geotropism (climbing the fronds). The association that inhabits the root systems of the sea grass are also distinctive, taking advantage of both the bacteria in that environment and the oxygen generated by the root systems.

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New middle Famennian conodont data and the *Annulata* Event at El Khraouia (Amessoui Syncline, southern Tafilalt, Morocco)

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El Khraouia is situated at the eastern end of the northern limb of the Amessoui Syncline, ca. 11 km NNW of Taouz and approximately 4 km to the east of the abandoned settlement El Atrous. The Lower to Upper Devonian sequence has been included in a cross-section by Wendt et al. (1984), who recognized its palaeogeographic position at the western margin of the Tafilalt Basin. Thus, El Khraouia represents a transition between condensed sections of the Tafilalt Platform (e.g., Jebel Ouaoufilal, Jebel Ouaoufilal Pass) and those of the adjacent basin (e.g., Hassi Nebech). Hartenfels et al. (2013) studied for the first time the Upper Devonian succession in detail and noted very thick Upper Frasnian beds and increasing condensation towards the middle Famennian, which suggests a sea-level controlled mid-Famennian progradation of the hemipelagic Tafilalt Platform.

The base of the Famennian is marked by the sudden proliferation of *Phoenixites frechi*, the only opportunistic goniatite survivor of the Upper Kellwasser Extinction. Subsequently, the sequence consists of dark grey marls with intercalated nodular siltstones and few dark bluish-grey, solid micritic limestones. With the entry of the index goniatite *Maeneceras meridionale* in a regional marker limestone unit (Beds Fa 11b-13b), the sedimentation suddenly changes to a rather cyclic succession of grey marls with intercalated grey nodular or solid micritic limestones. As elsewhere in the Tafilalt, the base of this “IIß Limestone” represents a sequence boundary (final phase of the Upper Condroz Event), followed by the global eustatic rise that characterizes the base of the middle Famennian (UD II-G). In the conodont scale, the *Maeneceras* Limestone falls in the lower part of the regionally undivided, extended *Palmatolepis marginifera marginifera* Zone. This is confirmed by a diverse fauna, including the zonally diagnostic subspecies *Pa. quadrantinodosa quadrantinodosa* and *Pa. quadrantinodosa inflexoidea* as well as the late morphotype of *Pa. glabra lepta*. *Pa. marginifera marginifera* first occurs two carbonate layers above (Bed Fa 15b) this marker limestone, together with the local oldest record of *Mehlina* and *Branmehla*. The middle part of the middle Famennian is poor in macrofauna. Moderately common *Bispathodus stabilis vulgaris* (= former *stabilis* M1) in Bed Fa $20b_2$ may indicate the Upper *marginifera* Zone (Ziegler & Sandberg 1984). So far, there is no record of *Pa. marginifera utahensis* from southern Morocco. The upper part of the middle Famennian is characterized by *Sporadoceras angustisellatum*, rare *Xenosporadoceras spiriferum*, and orthoconic cephalopodes (Beds Fa 28a and 29a). As an alternative index species of the regional *Planitornoceras euryomphalum* Zone, *Sp. angustisellatum* marks the UD III-B/C. Slightly below, *Scaphignathus velifer leptus* and *Sc. velifer velifer* in Bed Fa 26b prove the *Sc. velifer velifer* Zone (see Hartenfels 2011). The latter disappears in Bed Fa 33b. Subsequently, the succession is interrupted by reddish marls (basal part of Bed Fa 35a) yielding haematitic ammonoids. First *Platyclymenia annulata* associated with prionoceratids and *Erfoudites ungeri* represent the beginning of the UD IV-A and thus the *Annulata* Event Interval. Based on their distinction, the global *Annulata* Events are highly useful for international correlation and possibly for the chronostratigraphic definition of a future Upper Famennian substage (see Hartenfels et al. 2009). Approximately 3 m above, loose limestone slabs with *Procymaclymenia pudica* (Bed Fa 36b) document the higher part of UD IV-B.

Within the middle Famennian a total of six different conodont-biofacies-types can be recognized. The *Maeneceras* Limestone is dominated by elements of the *Pa. glabra* Group. Subsequently, the lower part of the middle Famennian is characterized by a *Pa. minuta*/*gracilis* peak, whereas the higher part shows a dominance of *Branmehla*/*Mehlina*. In the middle part, the middle Famennian suggests a deeper water association with *Bispathodus* and representatives of the *Pa. perlobata*/*rugosa*-Group followed by a shallower “*Polygnathus*” *diversus* facies at the beginning of the upper part of the middle Famennian. Above, the reinstallation of the *Pa. minuta*/*gracilis* biofacies is interrupted by a peak of *Alternognathus* and *Scaphignathus* in association with dominant *Branmehla* and *Mehlina*.

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Limits in detecting tsunamites in the stratigraphic record – an example from the Early Miocene

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Shell beds are frequently discussed as indicators for tsunamites. Studies on coastal tsunami versus storm deposits suggest that wedge-like bed-load dominated deposits are more typical for storms, whereas sheet-like, suspended-load dominated deposits with mudclasts point to tsunamis. Co-occurrence of shells from spatially distinctly separate environments is a further characteristic of some tsunamites. A potential tsunamite candidate from the Early Miocene of the Paratethys Sea is represented by an enormous accumulation of huge oyster shells in a thin layer in the Korneuburg Basin (Austria). To evaluate this shell bed, more than 10.300 shells were manually outlined and the data were stored in an ArcGIS-based database. The data are derived from a digital surface model based on high resolution Terrestrial Laser Scanning (TLS) and orthophotos obtained by photogrammetric survey, with a resolution of 1 mm and 0.5 mm, respectively.
Earthquakes as trigger of a high-energy hydrodynamic event are very likely to have occurred frequently during the late Early Miocene Styrian phase in the seismically active area at the junction between Alps and Carpathians. Tsunami deposits form as product of tsunami run-up or backwash, and may be deposited onshore or offshore. This process has a strong directional force and the elongate and large oyster shells are expected to be excellent indicators f currents. Our analyses, however, revealed complex and partly even contradicting local patterns suggesting considerable distortion of a potential original pattern. We document unorthodox mechanisms explaining high ratios of convex-up shell positions and local alignment of shells in “pseudo-directions”. Finally, we document the difficulties in detecting potential tsunami signatures even in exceptionally preserved shell beds due to taphonomic bias by post-event processes in shallow marine settings.

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Early Miocene depositional environments and tectonics in the northern Vienna Basin

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The Mistelbach Horst is an elongate rhombic, SW-NE oriented element along the north-western margin of the Vienna Basin with a maximum length of c. 60 km and a maximum width of c. 20 km. During the pioneer phase of Paratethys stratigraphy, the hydrocarbon exploration drillings of this area were the base for Foraminifera eco-zonations, proposed by Rudolf Grill in several papers. Although these zones are still in use and are common sense in Paratethys literature, they were never defined in a modern sense. Grill's concept rather tried to illustrate typical assemblages, which should help in prospection. Moreover, the exploration geologists of the 1940-1950s were not aware of the complex tectonic setting of the area, which was strongly shaped during the Styrian tectonic phase.
New high-resolution 3D-seismic data of the OMV-AG revealed spectacular insights into the tectonic setting of the highly structured area, clearly contradicting existing stratigraphic schemes. Strongly tilted Lower Miocene strata are separated from Middle Miocene formations by a major erosional phase and discordance, including canyon-like features. Micropalaeontological analyses on samples of 17 cores were performed for bio- and lithostratigraphic re-interpretation. Biostratigraphy is largely based on benthic and planktonic foraminifers, which went further into analyses to gain palaeoecological information. In combination with 2D- and 3D-seismic data correlative horizons were defined and interpreted. Thus, the study aims at a refined stratigraphic model for the Miocene depositional systems in the northern Vienna Basin and a renewed palaeogeographic reconstruction of the basin itself.

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Late Permian marine ecosystem collapse began in deeper waters: evidence from brachiopod diversity and body size changes

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Analysis of Permian-Triassic brachiopod diversity and body-size changes from different water depths spanning the continental shelf to basinal facies in South China provides insights into the process of environmental deterioration. Comparison of the temporal changes of brachiopod diversity between deep-water and shallow-water facies demonstrates that deep-water brachiopods disappeared earlier than shallow-water brachiopods. This indicates that high environmental stress commenced first in deep water settings and later extended to shallow waters. This environmental stress is attributed to major volcanic eruptions, which first led to formation of a stratified ocean and a chemocline in the outer shelf and deeper-water environments, causing the disappearance of deep marine benthos including brachiopods. The chemocline then rapidly migrated upward and extended to shallow waters, causing widespread mass extinction of shallow marine benthos. We predict that the spatial and temporal patterns of earlier onset of disappearance/extinction and ecological crisis in deeper water ecosystems will be recorded during other episodes of rapid global warming.

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Dinoflagellate cysts and acritarchs: their contributions to bio- and chronostratigraphy

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Dinoflagellates (Division Dinoflagellata) are protists found today in most freshwater, brackish, and oceanic environments from the equator to the polar latitudes. Most are free-living with a planktonic motile stage, and of these about 50% are heterotrophs. Autotrophic dinoflagellates are among the most important primary producers in the oceans. Of the ~2000 species of extant dinoflagellate, only about 15–20% produce a resting cyst (usually assumed to be a hypnozygote) that is geologically preservable, owing to an outer wall made of a resistant biopolymer. Hence, the fossil record of dinoflagellates, which extends back to the Triassic, is selective. Even so, with more than 4000 species of organic-walled dinoflagellate cyst (hereafter dinocysts) described from the fossil record, ample diversity exists for biostratigraphic application. In particular, dinocyst assemblages have relatively high species richness in cool waters and reduced salinities, allowing them to be used for high-latitude biostratigraphy in settings where mineralized microfossil groups are not preserved or reduced in diversity. On the other hand, cyst-producing dinoflagellates are under-represented in tropical and open-ocean environments: indeed the cyst stage seems largely an adaptation for overwintering on the continental shelf. Sea-surface temperature, salinity and nutrient levels are all known to influence dinocyst species distributions strongly, such that fossil assemblages are effective for paleoenvironmental reconstructions. However, these ecological sensitivities do not predispose the dinocyst record to yield globally synchronous events.

Biostratigraphic zonations based on dinocysts have been proposed from the Middle Triassic (Ladinian) to the Quaternary. These biozones usually have regional utility at best, and in the Cretaceous reflect strong provincialism. Nonetheless, an uppermost Oligocene–Miocene dinocyst biozonation proposed in 1996 by de Verteuil and Norris for the eastern USA is broadly applicable across the North Atlantic into Europe, with marker species recognized as far apart as the Norwegian–Greenland Sea and the Middle East. Ten zones were recognized by de Verteuil and Norris, and their widespread utility arises from their ease of recognition (mostly interval zones) and the low meridional temperature gradients that characterized the Miocene. Even so, diachroneity of up to 0.5 myr, or more, has been demonstrated in most Miocene and Pliocene dinocyst events across the North Atlantic region where magnetostratigraphy is available for independent age control. For the Pliocene, where marine isotope stratigraphy is also available, some species disappearances are synchronous within a single marine isotope stage, but such events are rare. Accordingly, dinocyst biostratigraphic events tend not to be expressed as regional/global datums, but simply as lowest and highest recorded occurrences for a given section. Even so, the prevalence of reworking in the dinocyst record has led to the use of "highest common occurrence" and "highest persistent occurrence" as descriptive terms that might represent the actual disappearance of a taxon.

Given the strong regional imprint on dinocyst assemblages, dinocyst events tend to be used in place of biozones, certainly for the pre-Quaternary Cenozoic. Because these events are often diachronous or diffuse, they represent age brackets rather than precise moments in time. For the Quaternary, dinocyst ecostratigraphy is becoming an increasing powerful method for regional correlation, with temporal resolution potentially in the order of hundreds of years or less.

In spite of the inherent limitations of dinocysts as chronostratigraphic tools, their distribution across the continental shelf and in higher latitudes renders them invaluable for biostratigraphy and age constraint; and no other microfossil group is as effective for integrating marine and terrestrial biostratigraphies, using spores, pollen and dinocysts from the same samples.

Acritarchs are by definition organic-walled microfossils of unknown biological affinity, although for the Cenozoic most are probably dinoflagellate cysts and prasinophyte algae. The small size and problematic affinity of Cenozoic acritarchs have hindered attempts both to classify them and use them for biostratigraphy. Recent studies of the Pliocene and Pleistocene have nonetheless revealed strong biostratigraphic potential at mid- to high northern latitudes, where acritarchs can have an abundant and diverse record.

The Quaternary Period: official subdivision and future challenges

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The Quaternary as a subdivision of geologic time was first introduced by Arduino in 1760. It was subsequently used formally for marine sediments in the Seine Basin by Desnoyers in 1829, and featured on most geological time scales for at least 120 years. Attempts by the International Commission on Stratigraphy (ICS) beginning in 2004 to suppress the Quaternary as an official term were resisted by the ICS's own Subcommission on Quaternary Stratigraphy (SQS) and by INQUA. The position of SQS and subsequently that of INQUA was that the Quaternary should bear the rank of system/period and begin at 2.6 Ma, taking advantage of the pre-existing Gelasian Stage Global Boundary Stratotype Section and Point (GSSP) at Monte San Nicola in Sicily which is conveniently close to the widely correlated Gauss–Matuyama Chron boundary. This was a pragmatic decision because the intensification of Northern Hemisphere glaciation (iNHG), with which the Quaternary is loosely associated, starts earlier, at ~2.74 Ma in the Piacenzian.

An obstacle to the demands of SQS and INQUA, that the Quaternary begin at 2.6 Ma, was the existing Pliocene–Pleistocene Series boundary already established at Vrica in Italy and dated at 1.8 Ma. To maintain both boundaries would have violated hierarchical requirements of the time scale. Following protracted, intense and sometimes acrimonious debate, the Quaternary was officially defined in June 2009 at the rank of system/period with a base at 2.6 Ma, and the Pliocene–Pleistocene boundary accordingly lowered to the same level (Gibbard and Head, 2010). These decisions cannot now be officially revisited until 2019. While the importance of iNHG at ~2.74 Ma is not disputed, new research has revealed an important shift in North Atlantic circulation at 2.6 Ma with concomitant and presumably related changes occurring elsewhere in the higher northern latitudes, all essentially coincident with the base of the Quaternary.

In 2011, the Calabrian was defined as the second lowest stage of the Quaternary (the lowest being the Gelasian Stage), utilizing the former Pleistocene GSSP at Vrica (Cita et al., 2012). The base of the Holocene Series had earlier, in 2008, been defined at 11,700 calendar years before AD 2000 in a Greenland ice core. The Early–Middle Pleistocene boundary is the most pressing boundary currently under consideration, with the Matuyama–Brunhes Chron boundary (~773 ka) serving as its primary guide. Three candidate GSSPs are under consideration: the Valle di Manche and Montalbano Jonico sections in Italy, and the Chiba section in Japan. The two Italian sections were visited during an AIQUA–INQUA–SQS field workshop in October 2014; and the Chiba section is the subject of a field trip during the XIX INQUA Congress in Nagoya, Japan, in the summer of 2015.

Future challenges include the definition of the Upper Pleistocene with a base near that of the last interglacial (~130 ka), a suggested tripartite subdivision of the Holocene (at 8.2 ka BP and 4.2 ka BP; Walker et al. 2012), and a decision on the status and rank of the Anthropocene, with a presently preferred onset at some time in the mid-20th century.

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Cretaceous-Tertiary Paleobathymetric Evolution of a Forearc Basin, Western Baja California

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From Cretaceous to early Tertiary times, southwestern North America accumulated >5 km of sediments in the fore-arc Vizcaino Basin. Micropaleontological, palynological and well log data from eight (A to H) exploratory wells drilled by the Mexican Oil Company (PEMEX) indicate that marine sedimentation started in the late Albian, and continued until middle Eocene times. These deposits overlie either Cretaceous granitic rocks (wells: B and H), or Albian volcanic and sedimentary calcareous rocks of the Alisitos Arc (wells B, C, D and E). The fore-arc basin fill includes at least three transgressive-regressive cycles. The initial transgresive cycle started in Cenomanian times, with deposition of continental conglomerates and reached bathyal depths by mid-Turonian time. Between late Turonian and Campanian, a tectonic event originated a general regressive trend and a hiatus in the wells B, C and E. The second transgressive cycle started in late Turonian to Campanian time, reached bathyal depths in Campanian to early Maastrichtian time, and switched to a regressive trend in early to middle Paleocene time. Five wells (C, D, F, G and H) show continuous sedimentation through the Cretaceous/Paleocene boundary, and an early Paleocene hiatus is evident in three wells. The intra-early Paleocene hiatus dated in wells D and F, suggests that the event causing it was also responsible for the K-T unconformity (wells A and E). The third transgression took place during Paleocene to mid-Eocene time. The basal unconformity, the intracretaceous hiatus, and the upper unconformity reflect tectonic compressive-uplift events in the sedimentary wedge and subsequent subsidence probably due to strain relaxation. We interpret the Cenomanian unconformity as related to the collision of the extinct Alisitos Arc against the Peninsular Batholith. The Turonian to Campanian hiatus is probably related to collision of the Kula-Farallon plate against southwestern North America, while the upper unconformity likely reflects the collision of the Farallon-Pacific ridge with North America. However, the transgressive-regressive cycles within these three major events are here interpreted as third order eustatic cycles. No evidence was found of the oceanic terrane located to the west in Cedros Island and the Sebastian Vizcaino Peninsula. The Campanian to Paleocene sequences were deposited between the Kula/Farallon and the Farallon/Pacific collisions, and are very similar to strata from the Rosario Group cropping out from western Baja California to southernmost California.

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Phacopid trilobites from the Daleje Event Interval (Emsian, Devonian) at El Khraouia (Amessoui Syncline, southern Tafilalt, Morocco)

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The locality El Khraouia is situated in the southern Tafilalt region of Morocco. It lies at the eastern end of the Amessoui syncline, 4 km E of the abandoned settlement El Atrous and ca. 11 km NNW of the small town Taouz. Other Devonian sections nearby are the Rich Tamirant, 2-3 km to the N, and the Filoun Douze section 4 km to the S. The section El Khraouia comprises sediments spanning from the Silurian – Devonian boundary to the upper Devonian (Fammenian, at least UD VI-B. An overview of the section was given by Becker et al. (2013). Hartenfels et al. (2013) described the upper part of the section in detail and Hartenfels & Becker (this volume) present new middle Famennian conodont data.

The trilobite bearing Unit K (sensu Becker et al., 2013) has a total thickness of 100-120 m. It consists of greenish-grey silty shales. Locally there are no conodonts or goniatites but elsewhere in the Tafilalt there are upper Emsian faunas (LD IV-A/B). It is underlain by the *Mimagoniatites* Limestone, with a typical fossil association of the *laticostatus* zone at the top (top of the lower Emsian, LD III-D). Above the unit there is the *Anarcestes* Limestone with the goniatite genera *Sellanarcestes*, *Anarcestes* and *Achguigites,* which give a higher upper Emsian (LD IV-D) age. The fossils weather out of the shale in the ca. middle part of Unit K and can be easily collected. Besides the trilobites crinoid stem parts and small rugose corals are common. Orthoconic cephalopods are also present but rare (three fragments), which is also true for tabulate (thamnoporid) corals (five fragments) and athyrid brachiopods (two specimens); the trilobites are the main faunal element.

Two different taxa can be distinguished. *Destombesina* aff. *tafilaltensis* Morzadec, 2001 (four specimens) is close to *D. tafilaltensis*, which was described from the Tafilalt (Hamar Laghdad, Bou Tchrafine) and from the Maider (Jbel Issoumour) together with the tentaculite *Nowakia cancellata* (Alberti 1980), the index fossil for the basal upper Emsian and the Daleje Event. There are some slight differences between the new material and the holotype of *D. tafilaltensis* such as one more dorsoventral lens file and one more lens per file. We suspect that the morphological differences reflects intraspecific variation although Bignon & Cornier (2014) restricted the genus to four lenses per row.

Apart from *D. tafilaltensis* the genus includes only a second species, the type species *D. ourgartensis* Morzadec, 1997 from Zerhamra in the Ourgarta chain of Algeria. It is also only known from basal upper Emsian strata, so that the genus is a good indicator for Daleje Event level.

Locally more frequent is *Barrandeops forteyi* McKellar & Chatterton, 2009, which occurs in masses, so that over 250 fragments were collected. It is originally known from the Talawirte section in the northeastern Tafilalt and from upper Emsian strata of the famous Jbel Issoumour and the Bou Dîb sections, both in the northern Maider (McKellar & Chatterton 2009). In contrast to the *Destombesina* specimens, which were found more or less as complete carapaces, not one complete *Barrandeops* was found. All body parts of the trilobites are present in different holaspid stages. It is striking that the pygidium is often fused to the thorax, which suggests Salter's type of moulting and embedding. Complete cephala are extremely rare in comparison to the thoracopygidia. Isolated frontal lobes, without the posterior part of the cranidium and the librigena, are common and in discrepancy with the lower number of isolated librigena and posterior cranidia parts. This taphonomic feature requires a palaeoecological explanation.

The new low diversity trilobite assemblage of Unit K shows that the Daleje Event interval was regionally dominated by medium-eyed phacopids, with a minor content of asteropygids. The complete lack of proetids and other trilobite groups reflects a significant end-lower Emsian crisis.

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Disparity of epiboles during maximum flooding - Examples from late Viséan basinal settings in Germany

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Epiboles are defined as thin intervals in stratigraphic successions characterized by an unusual abundance of fossil taxa that are normally rare or absent in the other parts of the succession. Vice versa, "anti-epiboles" (outages) are characterized by the rarity of normally common fossils. The mode of origin of such unusual fossil occurrences, or of outages, might be related to bioevents of different origin, but also to taphonomic processes. Herein we compare two mass occurrences from maximum flooding intervals within late Viséan basinal settings from Germany which result from different processes within almost identical basinal settings. The study, therefore, underlines the importance of thorough investigation and the need to avoid unreflected conclusions drawn by apparent analogies.

The Early Carboniferous (Mississippian) Rhenohercynian foreland basin of the Variscan Orogen in Germany is characterized by basinal muddy, siliceous and calciturbiditic sediments, overlain by synorogenic greywackes. This is the typical Kulm Facies of the Rhenish Massif and the Harz Mountains. The upper Viséan succession is punctuated by two major transgressive intervals, which culminate in maximum flooding bioevents. The well-studied late Asbian *crenistria* Event resulted in deposition of three goniatite limestone beds. They can be traced across the Rhenohercynian Zone from Germany (Harz Mountains, Rhenish Massif) to Southern Portugal and are characterized by the mass occurrence of *Goniatites crenistria* PHILLIPS, occuring in larval, juvenile and adult stages. The taxon appears below and disappears above the *crenistria* goniatite beds. The outburst, however, is herein regarded as an ecological epibole, probably due to fading of fine-grained terrigenous input and concomitant decrease in nutrient supply within a "marine desert".

The less studied mid-Brigantian *Actinopteria* Black Shale Event, the main topic of our contribution, is known from the Harz Mountains and the Rhenish Massif. It is named after the bivalve *Ptychopteria* (*Actinopteria*) *lepida* (GOLDFUSS). That taxon enters two ammonoid zones below the *Actinopteria* Event in the Brigantian and ranges through the Pendleian (early Serpukhovian). It forms "mass occurrences" within that black shale, which are restricted to few distinct bedding planes within a centimetric interval. Mud turbidites with erosive basal boundaries and of different microfacies predominate in the *Actinopteria* Shale. Various, but simple ichnofabrics and agglutinating foraminifers indicate mostly dysoxic conditions of the soupy sediment. However, episodic colonization of the substrate by *Ptychopteria* – a colonization epibole – is ruled out due to palaeobiological constraints of that epibyssate pterineid. This is deduced from missing particles for byssal attachment, from misfunction of the gills due to mud-clogging, and from missing morphological adaptions for resting on the unstable soupground; larval or juvenile shells are also missing. Therefore, a pseudoplanctic life style and settling after death is stressed. That seems to be incompatible with the layer-bound distribution in the *Actinopteria* Shale, but key is the microfacies. The flimsy shells of that "paper pecten"(sic!) were in most cases eroded by the mud turbidites. They were only preserved in the most fine-grained, parautochthonous sediment layers on top or in autochthonous basinal muds, providing sufficient time for accumulation. Remnants of such layers are preserved as dark, clay-rich muds within *Planolites* burrows, restricted to the *Ptychopteria*-bearing interval. Thus, the "mass occurrence" is a function of preservation by non-erosion in the interval with the most complete sedimentary record. This is a new variant of a taphonomic epibole termed "maximum completeness epibole". It differs fundamentally from known taphonomic epiboles caused by obrution and early diagenetic effects. In the case of the *Actinopteria* Shale, it is related to minimum sedimentary influx and minimum turbiditic redistribution during maximum flooding.

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Serpukhovian productid brachiopod buildups in the Carboniferous of Nötsch (Carinthia, Austria) – a response to rising sea level

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The Carboniferous of Nötsch, situated some 15 km west of Villach (Carinthia, southern Austria), is a small fault-bound Variscan slice at the southern margin of the Upper Austroalpine Drau Range, north of the Periadriatric line. In spite of extensive literature assembled during more than 200 years of research, unsolved, respectively controversely discussed topics include major issues like palaeogeographic rooting, depositional environment and even stratigraphic age of the formations from Nötsch.

The predominantly siliciclastic, more than 1000 m thick sedimentary succession consists of three formations, from below Erlachgraben Formation, Badstub Formation and Nötsch Formation. Published data on smaller foraminifers and calcareous algae indicate a Serpukhovian age of the complete succession. In the Jacomini Quarry, west of the road from Nötsch to Bleiberg, we studied the productid dominated facies of the "Zwischenschiefer", a shaly to marly to calcareous intercalation of about 15-20 m thickness within the upper third of the at least 350-400 m thick Badstub Formation, which consists of amphibolite-rich, polymictic breccias and conglomerates. The mostly dark gray "Zwischenschiefer" develops gradually from the breccia below by decrease of grain size and fading of clasts; gradual increase of grain size and renewed income of clasts is observed at the top of the horizon. The horizon consists of carbonate mudstone, bioclastic wackestone, packstone and floatstone yielding calcareous algae, smaller foraminifers, few rugose and tabulate corals, crinoid ossicles and rare gastropods, Most conspicuous, however, is the predominance of brachiopod shells which co-occur in very different sizes from millimetres to more than 160 mm in length and width. This coincides with the co-occurrence of shells of strongly varying thicknesses. In many cases articulated shells of strongly biconvex morphotypes are preserved. The abundance of brachiopod spines, in part still attached to the shell or abounding in immediate vicinity is most remarkable.

Macroscopic observation show that the brachiopods - the large ones preliminarily identified as *Semiplanella carinthica* Sarytcheva 1977 and *Latiproductus volgensis* Sarytcheva 1977 – are irregularily distributed. They form more than meter-sized agglomerates surrounded by fossil-poor sediments. Most probably all the big brachiopod-rich blocks removed by blasting from the quarry walls represent such agglomerates. Within the agglomerates, most brachiopods are orientated with their convex ventral valve downward, i.e. in life position. Smaller juveniles might nest within the shelter of the convex dorsal valve resulting in stapled growth of several individuals.

In conclusion, the co-occurrence of shells of different size and thickness, the occurrence of articulated shells, the astonishing abundance of brachiopod spines, and the existence of brachiopod agglomerates consisting of orientated, articulated biconvex shells demonstrates a not transported, autochthonous to parautochthonous nature of the brachiopods. This indicates the existence of productid brachiopod buildups in the "Zwischenschiefer" of the Badstub Formation, though the presence of intercalated lumachellic horizons is not denied. The predominance of heterotrophic filter feeders and the scarcity of calcareous algae and corals constrain an increased nutrient and siliciclastic supply, which is already seen in the impure limestone facies itself. The short duration of the brachiopod settlement is related to a sealevel rise (the eustatic rise in the lower Serpukhovian?), which for short time caused retreat of the coast line, thus diminishing and finally stopping the shedding of breccias and conglomerates from an actively rising, orogenic hinterland. Thus, the habitat of the brachiopods was a supposedly narrow, "dirty", shallow carbonate shelf adjacent to the coast. Similar intimate connections between reefal carbonates and siliclastics in a near-shore setting are; e.g.; known from the west coast of the Red Sea. We stress the fact that our interpretation is contradictory to a deeper marine fan or slope setting for the breccias of the Badstub Formation postulated by other authors.

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Biostratigraphy of the Albian-Cenomanian series of North-eastern Tunisia: the case of Ariana and Grombalia sections

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In several tunisian localities, the Albian series are considered to overlay the Aptian ones *via* a major discontinuity; all being overlain by transgressive Cenomanian deposits. Aiming to clarify the stratigraphic extent of the missing Albian intervall in north-eastern Tunisia and to follow a complete Albian-Cenomanian record, the present work deals with a detailed biostratigraphic analysis by means of planktonic foraminifera of two well outcropping sections at Jebel Nahli and Grombalia (Ariana and Morneg areas, respectively).
Referring to the usual standards, the Albian/Cenomanian boundary is traced on the basis of two major foraminiferal bioevents: the highest occurence (HO) of *Planomalina buxtorfi* and the lowest occurrence (LO) of *Rotalipora globotruncanoides*. Furthermore, the planktonic foraminiferal stratigraphic range allows to identify six zones encompassing the late Albian - mid Cenomanian interval: the *Biticinella breggiensis*, *Rotalipora ticinensis*, *Rotalipora appenninica* Zones (Albian) and the *Rotalipora globotruncanoides* Zone, *Rotalipora reicheli* Zone and *Rotalipora cushmani* Zones (Cenomanian).

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Progress and outlook of ATS2020

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A complete astronomical time scale for the Cenozoic is now within reach for incorporation in the next standard GTS, as geological uncertainties are being eliminated. Existing gaps such as the Lower Miocene and Eocene have been or are presently being closed, and issues such as the number of 405-kyr cycles and tuning of the early Paleogene have been solved, resulting in an age of ~66.0 Ma for the K/Pg boundary. The astronomically calibrated age of 28.201 Ma for the FCs has been confirmed by single crystal U/Pb zircon dating of the Fish Canyon tuff itself, by comparing astronomical and U/Pb ages of ash layers near Ancona, Italy, and by checking the tuning of the Messinian sections in the Mediterranean on which this astronomical FCs age was originally based. Completion of the Cenozoic ATS asks for the revival of unit stratotypes for stages and Milankovitch chronozones to bring the standard GTS in harmony with the progress in the ATS.
Astronomical limitations are intrinsic to the solution for the Solar System that is used for the tuning. They include the reliability of full eccentricity beyond 50 Ma, as a consequence of the chaotic behaviour of the Solar System, and unknown past values of Earth parameters, such as tidal dissipation and dynamical ellipticity. The latter limit the reliability of precession and obliquity to the last 5-10 million years. However, these uncertainties may well be overcome by taking the geological (cyclostratigraphic) record into account.
Based on the tuning to stable 405-kyr eccentricity, the ATS is extended into the Mesozoic and already includes the entire Maastrichtian. Two tuning options remain for the tuning of the Cenomanian-Turonian boundary interval marked by the OA2 event, if the full error in its age is taken into account. The completion of the Cenozoic and future Mesozoic ATS is critical for solving fundamental issues in Earth System history. Finally, examples of the application of the ATS will be presented, including the understanding of Eocene hyperthermals, the global carbon cycle and the Messinian salinity crisis.

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Unit Stratotypes and Milankovitch Chronozones

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The advent of astronomical dating as independent means to establish the numerical calibration of the geological time scale potentially has far-reaching consequences for formal global chronostratigraphy. The approach has convincingly shown that astronomically tuned deep marine sections are continuous on Milankovitch time scales and can serve as unit stratotypes for global stages, the current basic building blocks of chronostratigraphy. In this way not only stage boundaries can be defined, but also the body of the stage in the same section or core, thus combining conventional unit stratotypes with the Global Stratotype Section and Point (GSSP) approach. Examples of such unit stratotypes are the Rossello composite section for the Zanclean and Piacenzian stages of the Pliocene, the Monte dei Corvi section for the Tortonian stage of the Miocene, and the Zumaia section for the Danian stage of the Paleocene. However, deep-sea cores potentially offer an acceptable alternative as the most suitable archive should be used for this purpose.

In addition, Milankovitch cycles can be defined as chronozones, i.e. formal chronostratigraphic units that operate on a smaller scale than and that are independent of the stage, but underlie the age calibration of the standard Geological Time Scale. For the entire Cenozoic and Maastrichtian, such an approach is now well feasible on the scale of the 405-kyr eccentricity cycle, taking the intercalibration between astronomical and radioisotopic (U/Pb, $^{40}Ar/^{39}Ar$) dating into account; these cycles can be numbered from the recent back in time, using the newest astronomical solutions. For the (late) Neogene, Milankovitch chronozones can also be incorporated with a higher temporal resolution by including the ~21-kyr precession and 41-kyr obliquity related cyclicity. Well known examples of such chronozones are the Marine Isotope Stages (MIS) of the marine Pliocene-Pleistocene, which can easily be incorporated in a formal scheme.

The question that has to be answered is whether Milankovitch chronozones and unit stratotypes should be designated as formal chronostratigraphic units. Such a definition would bring the standard Geological Time Scale and associated Chronostratigraphic Scale in harmony with current practice in and status of astronomical dating.

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"INSPIRE", "GBA-Thesaurus" and "DataViewer" at the Geological Survey of Austria – an approach to deal with lithostratigraphic issues

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The accumulation of geoscientific data in earth sciences has grown enormously over the last decades, since new methods and technologies for investigation and analysis have evolved. The increase of spatial geodata and the growing demand for interoperability due to interdisciplinary usage needs a sophisticated knowledge management. An important step towards facing that challenge is the INSPIRE directive of the European Union (INfrastructure for SPatial InfoRmation in Europe, 2007) with the aim to create a standardized spatial geodata infrastructure for the European Union. Especially geology became a crucial theme in the world of geospatial data within INSPIRE. It can be considered as basis for further geoscientific topics e.g. mineral resources as we can see in Annex II of the directive. The INSPIRE directive was integrated into Austrian law in 2010 (Geodaten Infrastructurgesetz – GeoDIG). Therefore, we are legally bound to structure and harmonize our public digital spatial geodata according to a given standard. Concerning our management of geoscientific data, this was also an opportunity for us to use the INSPIRE core model of "Geology" (INSPIRE Data Specification on Geology – Technical Guidelines, 2013) as basic structure to rely on. However, as the data world is computerized and the World Wide Web is now the main platform to share data in a transnational way, it is essential to structure and define the concepts of data as well as their relations (controlled vocabulary) and provide them in a machine readable way (e.g. SKOS-RDF). The Thesaurus of the Geological Survey of Austria – the "GBA-Thesaurus" – represents our controlled vocabulary and fulfills this functional requirement. For the domain experts within the Geological Survey, the GBA-Thesaurus provides a source of consistent index terms that spans a comprehensive range of our activities in mapping and research. These concepts can be used to refine or clarify labels and definitions. Moreover, it's possible to adopt classification models such as proposed in the North American Stratigraphic Code (NACSN, 2005). The GBA-Thesaurus also supports internet search based on a SKOS ontology thesaurus management, as well as on semantic web technologies (Linked Data). Furthermore, it allows to develop applications and modules showing our georeferenced geological data, based on mapping and research, connected with all that information – e.g. a lithostratigraphic unit – which is structured and provided through the GBA-Thesaurus. In combination with the "DataViewer" module (beta version) it is possible to select and filter geological features according to lithostratigraphic units, their related lithology content or chronostratigraphic correlation. This facilitates reprocessing lithostratigraphic issues concerning classification, terminology such as homonyms, synonyms, errata, obsolete labels and concept definition, respectively. The presentation will demonstrate practical examples that point out the huge potential by using these new technologies. After all, it is increasingly important to improve a transnational communication to achieve common overall objectives within the geoscientific community.

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A late early to middle Miocene stack of high-resolution benthic stable isotope records from Ocean Drilling Program (ODP) and Integrated Ocean Drilling Program (IODP) sites

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We present a 17-13 Ma stack of seven high-resolution benthic stable isotope records aligned along a common orbitally-tuned timescale. The $\delta^{18}O$ stack displays high variance during the warmer “Miocene Climatic Optimum“ interval (16.9.14.7 Ma), implying that climate variations were primarily driven by global circulation changes rather than ice volume fluctuations. We identify nine prominent $\delta^{18}O$ warm events paced by 100 kyr eccentricity variations, which provide global correlative features between 15.7 and 14.7 Ma. Other characteristics of the $\delta^{18}O$ stack are the dominant obliquity signal between 14.6 and 14.1 Ma and the massive increase of ~1‰ at 13.9-13.8 Ma, marking a fundamental step in Cenozoic ice expansion and climate cooling. Comparison of $\delta^{13}C$ profiles reveals an increasing offset between deeper and shallower locations starting at 14.6 Ma and intensifying after 13.8 Ma, as $\delta^{13}C$ becomes increasingly depleted at the deeper Pacific ODP Site 1237 and IODP Site U1338. This divergence suggests that enhanced stratification promoted CO_2 storage in the deep ocean, thus fostering global cooling. Carbonate dissolution proxies additionally reveal that the carbonate compensation depth behaved in a highly dynamic manner and that fluctuations were intricately coupled to profound changes in ocean geochemistry ($\delta^{13}C$) and climate ($\delta^{18}O$), supporting a crucial role for the marine carbon cycle as climate regulator through the middle Miocene.

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A conceptual sequence stratigraphy model for continental rift basins based on the Recôncavo Basin, Cretaceous, Brazil

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Rift basins are caused by crustal stretching prior to continental break-up, at the crystalline basement. The crustal stretching, which has rates up to 20 mm/year, produces asymmetric half-grabens where subsidence is controlled by one major boundary fault zone, which may have an extension of tens of kilometers and a dip up to 70 degrees. These structures have alternating dips, hence tilting of adjacent half- grabens frequently go to opposite directions, separated by a transfer fault. Therefore, a rift basin is actually composed of a series of depressions forming a system with a very complex geometry. A continental rift system develops when one branch of a three arms rift system fails to open and does not reach the passive margin stage, developing a system of linked half-grabens infilled with continental systems, such as alluvial fans, eolian, fluvial, deltaic, lacustrine debrites and turbidites. Modern examples are the East African rift system (mainly the Tanganyika and Malawi rifts) and the Baikal Lake in Russia. Due to the asymmetry of the half-grabens and the subsidence controlled by on major fault zone, the accommodation space within a rift basin is variable, and zones with high accommodation develop close to zones with low accommodation or even erosion. This implies in a synchronous movement of subsidence and uplift hence synchronous increase and decrease in accommodation; hence, the popular passive-margin-based sequence stratigraphic scheme, where the lowstand, transgressive, highstand and forced regressive systems tracts develop following a predictable order during a complete cycle of base-level change, is not applicable. Therefore, the traditional analysis of stacking patterns and the development of the aforementioned geometric systems tracts as proxies for base level variations is not applicable in a rift basin, because regressive and transgressive systems tracts may form relatively synchronous and very close geographically. This is a pitfall for stratigraphic analysis of rift basins: within the same half-graben, on well may display a clear retrogradational pattern while in a well a few tens of kilometers apart a progradational pattern may be seen. For a practical and useful stratigraphic analysis of rift basins, conceptual and methodological adaptations are required in order to understand the basins sedimentary infill, especially concerning the prediction of specific economically important facies and depositional systems. The present paper discusses and exemplifies these adaptations, discusses the tectonic and stratigraphic aspects related to continental rift basins. It proposes an integrative sequence stratigraphic model with three tectono-stratigraphic phases: (1) the rift initiation phase, which is characterized by isolated and restricted fault which create incipient half-grabens, infilled with fluvial and deltaic facies; (2) the rift development phase, during which the initial rift faults tend to link and to form a larger and deeper depositional area, recording lacustrine facies with an overall retrogradational trend, and; (3) Rift fill-up phase, when the accommodation rate decreases, the sedimentation regime is progradational, and the rift basin is filled with deltaic, fluvial and eolian facies. The model was applied to the Recôncavo basin, a Cretaceous rift basin in northeastern Brazil with a sedimentary record from Late Jurassic to mid-Cretaceous, spanning a period of about 20 m.a.. The rift initiation phase is characterized by a “spotty” occurrence, reflecting the initial half-grabens, holding the record of fluvial-deltaic deposition, which occurs interfingered with shallow lacustrine facies. The ongoing and increasingly rapid subsidence overwhelms the sedimentation rate, leading to high accommodation (= dominance of lacustrine deposition, with gravity-flow deposits like sandy debrites and turbidites). The rift fill-up phase is characterized by decreasing accommodation recorded by deltaic and fluvio-eolian progradation.

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The Pufels/Bulla section: C-isotope curve, the problem of its interpretation and the current status of knowledge

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The Pufels/Bulla section is an important section for the Permian-Triassic boundary and the Early Triassic in the Dolomites, as it is well exposed over most of the interval and very easily accessible. It has been investigated for biostratigraphy, paleomagnetics sedimentology and also several times for its ^{13}C isotope curve. Different interpretation of the latter by the investigating research groups has resulted in significant differences with respect to age assignment of the upper part of the section.
We investigate neighbouring Early Triassic sections (Pufelsbach/Bulla torrent, Tschonadui) and St. Vigil/St. Vigilio, a section further to the east, and compare litho- and isotope evolution with the Pufels/Bulla section. Our results indicate a still Induan (or minimum very basal Olenekian) age for the top of the Pufels/Bulla section.

Design of Panoramic Display of Stratigraphic Sections in the Geobiodiverstiy Database (GBDB)

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Stratigraphic sections are the basis of geological studies. In the past several decades, a huge mass of information of Chinese stratigraphic sections has been accumulated by Chinese geologists. From 2007 to 2014, the GBDB online database (www.geobiodiversity.com), the official database of the International Commission on Stratigraphy, has over 10,000 Chinese sections compiled. Many of these sections are quite important, such as GSSP sections or regional standard sections. The traditional ways to display these sections, for example, freehand sketch, static photo, and composite column chart, are lacking of sense of reality. Panoramic display is a kind of virtual reality technology which can give users strong sense of reality and provide them with immersive experience. Not only the geologic outcrop, but also the geomorphologic information around the outcrop can be presented lively to the users.
The panoramic display function was integrated to the GBDB in 2014. It takes three major steps to prepare and upload the panoramic data to the GBDB. First, user need find one geographic position that can provide the best experience to view the outcrop and its surround geomorphology. Then user takes about 8 to 12 continuous photos in 360-degree horizontal direction through digital camera. Each picture must have enough overlaps with the neighboring ones. Second, user can use some free software to stitch and fuse those photos to create one panorama file in SWF format. Third, user uploads the panorama file to the GBDB by using the “Add Panorama” function and input the necessary information for the description of the panorama data, such as locality name, coordinate values, date of the photo captured, etc.
The panoramic data of geological outcrops are new but significant data source for the demonstration of sections to the public and long-term preservation them. The accumulations of the panoramic data need the effort of the whole geological community.

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LA-ICP-MS U-Pb dating of zircons and geological implication for Cenozoic volcanic rocks from the Lawula Formation in Mankang Basin

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This article selects volcanic rock samples with eruption rhythm in Lawula Formation from Mangkang Basin by LA-ICP-MS U-Pb zircon dating.Most zircons separated from the Lawula Formation volcanic rocks exhibit stripoped and obvious oscillatory zoning with Th/U ratios range from 0.23 to 2.58,indicating their magmatic origin.Zircon LA-ICPMS U-Pb dating for the Lawula Formation volcanic rocks yield consistent ages of 37.81 ± 0.6Ma,36.23 ± 0.29Ma,35.63 ± 0.58Ma, respectively, indicating that the volcanic rocks in the Lawula Formation was formed in Late Eocene rather than Oligocene as previously believed. Zircon LA-ICPMS U-Pb dating also gives a wide age range of inherited zircons (54.1-2631 Ma),which range from Late Archean to Cenozoic with evident stage characteristics and fall into ten groups: 2631~2427Ma, 1400~1100Ma, 826~715Ma, 553~490.5Ma, 443Ma, 334.7Ma~301.3Ma, 277.1~259.5Ma, 223~208Ma, 188~104Ma, 59.6~54.1Ma.These age groups record the tectonic thermal events of supercontinent Pan-African movement and Caledonian Movement,the development and evolution of the Paleo-Tethyan Ocean and Neo-Tethyan Ocean,and the magmatism related to collision between Eurasian plate and Indian plate.They imply that there is the record of the Precambrian age,and the existence of Archean basement in the east of Tibet.According to geochemical data,SiO_2 content ranges from 55.4%~83.5%,Na_2O from 0.2~2.2,K_2O from 1.1~6.9 and K_2O/ Na_2O ratio from 2.39~10.56.The volcanic rocks are furcher characterized by enrichment of light rare elements[$(La/Yb)_N$=7.3~30.4] and Large-ion Lithophile elements,slight negative Eu anomalies [Eu/Eu*=0.69~0.82] and depleted in high field strength elements(e.e.,Nb,Ta and Ti) relative to primitive mantle.Geochemical feature indicate the volcanic rocks are generated in the setting of continental subduction induced by transpression.

Early-Middle Triassic redox condition variations in ramp settings, South China

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Growing evidence shows that marine ecosystems have suffered a extremely protected recovery process during the Early Triassic and completed reestablishment some 8-9 Myr after the end-Permian biocrisis. The punctuated oceanic anoxia (euxinia) has been caused as an important reason for the much delayed recovery process. Here, high resolution structure and size variation analysis of pyrite framboids from 144 fresh samples of the Chaohu section (Lower Triassic, Lower Yangtze Platform) and Qingyan section (Middle Triassic, Upper Yangtze Platform) provides a complete reconstruction of palaeo-redox history during the Early and Middle Triassic.

The newly obtained results show a weaker manifestation of anoxia in Griesbachian unlike previous expected, anoxia/euxinia persisted through the entire Dienerian and occurred in early, middle and late Smithian. Being separated by two oxygenated periods, anoxia/euxinia predominated the middle to late Spathian followed by a well oxygenated Anisian expect a short anoxia/euxinia period in late early-Anisian. These anoxia episodes coincide with the emergence of microbialites, Smithian-Spathian boundary event, seafloor fans, and microgastropods facies, respectively. The redox variation excursions indicated by pyrite framboids did not match perfectly the redox condition changes indicated by isotopic proxies from South China, suggesting that different proxies have their own limitations. They all, however, show the frequently disturbed climatic and environmental conditions in the aftermath of the end-Permian Great Dying.

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Stasis and species turnover of planktonic foraminifera and calcareous nannofossils in Turonian hemipelagic sequences from southeast Tanzania

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Turonian marine sediments in southeast Tanzania have yielded some of the best preserved microfossils in the world, providing valuable new insights on species taxonomy, biostratigraphy, biodiversity, and phylogenetic relationships. This presentation highlights results of an integrated study of planktonic foraminifera and calcareous nannofossils species abundance distributions and stratigraphic ranges in shallow boreholes that were drilled within 20 km of the coast of southeast Tanzania during the Tanzania Drilling Project. The sediments cored are predominantly composed of silty marine claystone that was deposited in an outer shelf to upper slope setting at 35°S paleolatitude, from within 50 km of the paleoshoreline.

A complete Cenomanian/Turonian boundary interval was not obtained at any of the TDP boreholes because of a hiatus spanning from the mid-Cenomanian through most of the lower Turonian. The late early Turonian through latest Turonian interval (forams: upper *Whiteinella archaeocretacea* through *Dicarinella concavata* Zone; nannos: Zone CC11-CC12) that was recovered is estimated to be ~170 m in composite thickness. The lower ~140 m of this composite interval is marked by essentially no species turnover with one datum, the first appearance of the calcareous nannofossil *Eiffelithus perchnielseniae* (s.s.), documented as the only reliable means of correlating the lower-middle Turonian among the TDP boreholes. This marker species has been previously identified as *Ei. eximius* and is now used in place of the latter species to denote the base of Zone CC12.

Major species turnovers occur at different levels in the upper Turonian for the two calcareous plankton groups. The older of these occurs at the top of the *Hv. helvetica* Zone, where last occurrences of four planktonic foraminiferal species are immediately followed, within several meters, by first occurrences of five foraminiferal species. There is essentially no change in the calcareous nannofossil populations or sediment lithology across this interval, suggesting that if a hiatus were present, it was very brief. Instead, an accompanying increase in the abundance of dwarfed planktonic forms suggests that the foraminiferal turnover may have been at least partly influenced by a shift in environmental conditions of the surface mixed layer. The subsequent late Turonian turnover is marked by extinction of three calcareous nannofossil species with no co-occurring foraminiferal extinctions and is immediately followed by first appearances of four calcareous nannofossil and two planktic foraminifer species, an abrupt and dramatic increase in the relative abundance of biserial taxa, and a sudden diagenetic shift that results in calcareous infilling of all foraminiferal tests. Juxtaposition of the abrupt species turnover, relative abundance shift, and increased diagenesis indicates presence of a disconformity with some portion of the early late Turonian missing.

Despite the possible influence of regional environmental changes on the species distributions in the Turonian marine sections in Tanzania, taxonomic and integrated biostratigraphic study of the exquisitely preserved calcareous plankton assemblages from the TDP boreholes is significantly improving the framework for regional and global chronostratigraphic correlation of Turonian hemipelagic and pelagic sequences. However, age determinations for the Turonian calcareous plankton bioevents are still highly uncertain and await discovery of sections that can provide absolute age tie points using radiometric, chemostratigraphic, and/or cyclostratigraphic methods.

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Paleogene NW Adria block surrounded by deeper basins; study by plankton, small and larger foraminifera on the drowning time in Late Ilerdian, Late Cuisian and Middle Lutetian (N Italy, SW Slovenia, SW Croatia – Istria, Kvarner)

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On the NW part of the Paleogene Adriatic Carbonate Platform (PgAd CP), beds from Maastrichtian to late Bartonian were deposited. The sedimentary succession consists of limestone and flysch. Previous investigations confirm the ages from SBZ 1 to SBZ 15 and planktonic zones from P1b-c to E 13.
Regarding the Cretaceous paleogeographic basement drowning, three distinct sedimentary belts could be distinguished, delimited by faults or barriers of various origins. The purpose of the present contribution is the temporal definition based on foraminiferal assemblages. In each belt, the youngest assemblage of the shallow-water platform and the oldest assemblage of the deeper-water clastic deposits were determined. On the territory of PgAd CP this is the new attempt at defining the geologic boundaries by the successive appearance of benthic and planktonic foraminiferal groups.
The entire Paleogene sedimentary complex lies in the footwall of the Frontal Zone of External Dinaric Thrust belt (Trnovo thrust series), which was related to L. Placer's "*Hypothetic fault structure in the Adriatic-Dinaric Mesozoic Carbonate Platform in the continuation of the Budva Trough*". After the last rotation of the entire Adria block, at the end of the Miocene and in the latest Pliocene, tectogenetic units formed, arranged from NE towards SW. **1)** The Budva Trough with hemipelagic sediments at the Paleocene/Eocene boundary (P 5 - *Subbotina velascoensis*, *Morozovella acuta, M. occlusa*) and turbiditic deposits in the basin at the contact with the Dinarides from Goriška brda, Vipava/Pivka basin to Ilirska Bistrica, with numerous nummulites and *Alveolina violae; BiosZ 1*. **2)** Southwards follows the Kras – Brkini and Vinodol syncline with flora and fauna in lagoonal, shallow marine sediments from the K/T boundary to the Ilerdian/Cuisian passage (SBZ 8, 9). Typical are *Alveolina triestina*, *A. brassica*, *A. montanarii*, (SBZ 10) *A. canavarii*, *A. schwageri*. Among planktonic foraminifera appear (P 6/7, E 4/5) *Acarinina pseudotopilensis*, *Morozovella subbotinae; BiosZ 2.* **3)** Southward a narrow belt of limestones occurs in Ćićarija Imbricated zone with the same Paleocene and Ilerdian foraminifera, from Rosandra river to Voz peninsula (Island of Krk). Sedimentation continues without interruption from lower to upper Cuisian, extending in middle Cuisan southwards towards Istria. Larger foraminifera (SBZ 12) include the lineage of *A. histrica* with *A. rakoveci*, *A. cuspidata*. Marly and flysch beds of the lower Lutetian are characterized by (P 9/10, E 7/8) *A. praetopilensis, A. bullbrooki,* and *M. aragonensis; BiosZ 3/1, 2*. **4)** A parallel zone in the south, the **i**mbricated Adria, is synchronously limited by Istrian dryland, the Adria basin open to east, and the Venetian basin to west. During the middle Cuisian a first transgression covers the land with lagoons, coal seams and bauxite pits. Deposits (SBZ 13, 14) of Alveolina nummulitic limestones follow the lineage of *A. levantina*, *A. elliptica nuttalli*, *A. frumentiformi*s, *Glomalveolina delicatissima*, which pass into the youngest beds on the platform margin to nummulitic, assilina and orthofragmina limestones. They are overlain by Transitional beds and later by flysch, containing (E /10) *Turborotalia possagnoensis* and *Hantkenina dumblei; BiosZ 4/1, 2,* known as the *Dalmatian zone.* **5)** The boreholes of Istra more 5, 4 and 3 are located along the eastern rim of the Venetian basin. The hemipelagic sediments of Middle Eocene contain *Morozovelloides crassatus*, *Acarinina mcgowrani,* and in the Upper Eocene *Turborotalia cocoaensis; BiosZ 5.*
Fauna determined at the transition from the platform to flysch within the NW Paleogene tectogenetic units indicates a separated realm: a shallow carbonate platform with intraplatform barriers in the form of the archipelago extended across Friuli to the Trento platform, on the Lessini shelf, over the Venetian basin.

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Lithostratigraphy in low-grade metamorphic rocks – Examples from the Upper Austroalpine Stolzalpe Nappe and Bundschuh Nappe (Eastern Alps/Europe)

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The lower limits of metamorphism around 300° C, respectively the differences and transitions from diagenetic to metamorphic rocks are well approached (Frey, 1986; Arkai et al., 2003; Bucher & Grapes, 2011). More controversy is the terminology of lithostratigraphic units in (low-grade) metamorphic rocks and areas influenced by tectonics. In former works it was suggested to formalize irregular formed, lithologically mixed and structurally complicated rock assemblages as complexes (Murphy & Salvador, 1999; Steininger & Piller, 1999). However, the huge masses of intrusive igneous, metamorphic or mixed nonstratiform rocks need a more detailed subdivision and the lithodemic units proposed by the North American Commission on Stratigraphic Nomenclature (2005) seems to be a proper tool.

Some significant differences between traditional lithostratigraphic and lithodemic units are recognized: a) lithodemic units do not conform to the law of superposition; b) they are penetratively deformed with (highly) complicated structural relations; c) they have lost their primary structure of stratification and position within a stratified sequence through metamorphism or tectonic processes.

In addition, the varying applications of "historically grown" terms (series, zone), terminology (none or not specified use of geographic type localities), as well as the implementation of lithostratigraphic units without lateral extend and mapped areas are difficult to interpret in further improve- and development.

Especially work in polyphase overprinted metavolcanic-metasedimentary areas (sediments, pyroclastics) sometimes interbedded, intruded and interfingered with effusive and intrusive (volcanic) igneous rocks at (sub-) greenschist facies (low-grade metamorphic) conditions is challenging. In Austria such rock assemblages are recognized in several tectonic subunits of the Upper Austroalpine Unit (Koralpe-Wölz, Greywacke zone, Tirolic-Noric and Drauzug-Gurktal nappe systems).

In this contribution we present examples from the Stolzalpe Nappe (Gurktal nappes) and the Bundschuh Nappe. In the Stolzalpe Nappe the subdivision of an Ordovician to Permian succession in lithostratigraphic and lithodemic units is in progress. A challenging problem is the subdivision of rock series which developed from similar precursor material by variable structural and metamorphic overprint. In the Permo-mesozoic cover of the Bundschuh nappe, schists and phyllites have been recently formalized as Bockbühel Lithodeme (Weissenbacher, 2015). The Bockbühel Lithodeme is suggested to be the greenschist-facies metamorphosed equivalent of the diagenetic Partnach beds in the Northern Calcareous Alps of Carnian age.

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New biostratigraphic data on Anisian (Middle Triassic) miospores from Cape Tsvetkov section, Northern Middle Siberia, Russia

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The Cape Tsvetkov section is one of the most important key-sections of Anisian deposits in the Northern Middle Siberia independently dated by marine fauna. Detailed ammonoid zonation was presented by Dagys (2001) and Konstantinov in Kazakov et al. (2002). The revision of palynological data allowed to define four palynological assemblages (PA) calibrated by ammonoid scales and can be used for the long distance correlation. The base of all PA is composed of spores of ferns and lycopsids and teniate and non-teniate bisaccate pollen typical for the Anisian.

The main factor of their definition is the discrete appearance in the section of a large group of species, which first appearance in the palynological record out of Boreal realm is related to higher stratigraphic levels of the Triassic.

PA I is characteristic for Lower Anisian sediments in the volume of ammonoid zones Grambergia taimyrensis, Lenotropites solitarius and Lenotropites caurus. It is determined by the first appearance of pollen grains *Accinctisporites lignatus*, *Chasmatosporites* sp., *Ovalipollis* sp., *Samaropollenites speciosus* and *Succinctisporites grandior*.

PA II corresponds to Middle Anisian substage, which includes now ammonoid zones Czekanowskites decipiens, Arctohungarutes ventrolanus, Arctohungarites triformis, Arctohungarites laevigatus, Boreohungarites kharaulakhensis, Epiczekanowskites gastroplanus, Orientohungarites terminalis. It is determined by the first appearance of spores *Microreticulatisporites opacus* and pollen *Vallasporites* cf. *ignacii, Duplicisporites* cf. *granulatus, Praecirculina granifer, Brachysaccus neomundanus, Araucariacites australis, Eucommiidites microgranulatus, Chasmatosporites apertus*.

PA III and IV describe Upper Anisian substage. PA III characterizes ammonoid zone Gymnotoceras rotelliforme, and PA IV – zone Frechites nevadanus.

The spore part in PA III has been considerably renewed due to the first appearance of spore group in composition of *Retitriletes austroclavatidites*, *Taurocusporites* sp. A, *Annulispora cicatricosa*, *A. folliculosa* and pollen *Quadraeculina anellaeformis* in this level.

The independence of PA IV is controlled by the first appearance of isolated specimens of spores: *Lycopodiacidites rugulatus*, *Contignisporites* sp., *Densosporites fissus* in zone Frechites nevadanus.

Palynological assemblages of the Barents Sea area (Vigran et al., 1998; 2014; Hochuli, Vigran, 2010) are rather similar taxonomically to these four Siberian ones. PA I is comparable to the *Anapiculatisporites spiniger* Composite Assemblage Zone (CAZ). PA II correlates to *Triadispora obscura* CAZ. The age analogs are PA IV and *Echinitosporites iliacoides* CAZ.

On the base of the palynological data from the Barents Sea area the list of miospores which appearance is fixed for the first time in ammonoid-dated Anisian strata has been considerably supplemented. In Early Anisian they comprise *Convolutispora microfoveolata*, *C. rugulata*, *Uvaesporites argenteaeformis*, *Aulisporites astigmosus*, *Stereisporites radiatus*, *Accinctisporites circumdatus*, *Podosporites amicus*, *Heliosaccus dimorphus*. In Middle Anisian – *Leschikisporites aduncus*, *Kraeuselisporites cooksonae*, *Enzonalasporites* sp., *Cordaitina gunyalensis*. The development of all the above-stated species together with Anisian marine faunas changes the estimate of their stratigraphic range and sets them in the key taxon group for Anisian age in general.

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Impact of the Early Lutetian C21r-H6 carbon-cycle perturbation on calcareous nannofossils and ocean dynamics (Gorrondatxe, Western Pyrennees)

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The Eocene Epoch was characterized by overall warm temperatures and superimposed multiple hyperthermal events. The largest, such as the PETM, ETM2 and ETM3, have been thoroughly studied. Valuable as they may have been, the results obtained from such hyperthermals may not be the best analogues to forecast the consequences of current global warming, as the amount of carbon released was greater than 10^3 Gt, which exceeds the current rate of emissions. With the aim of modeling how our oceans could be affected by the ongoing global warming, smaller scale hyperthermals should be analyzed.

In this study, carried out at the Gorrondatxe Beach (Biscay, Western Pyrenees), we have studied the Middle Eocene (Lutetian) C21r-H6 hyperthermal event, which was first defined by Sexton et al. (2011) in the western Atlantic Ocean. Later, Payros et al. (2012) identified this hyperthermal in Gorrondatxe and determined that it was characterized by a >1‰ decline in $\delta^{13}C$ and that it lasted 226 kyr (47.44 - 47.214 Ma). Our new study focused on a 400 kyr interval extending from before the hyperthermal event to its aftermath. As a supplement to previous stable isotope, mineralogy and foraminifera information (Payros et al., 2012), calcareous nannofossil data are reported herein. We identified 98 autochthonous species and another 15 reworked genera in the succession. The proportion between the most representative genera was calculated for each part of the succession. In addition, the carbonate volume of some nannofossil shells was determined using an innovative technique that measures the quantity of light emitted by the shell when it is illuminated with polarized light. Thus, changes in shell volume can be attributed to different grades of calcification. Our data show that the volume of calcium carbonate of selected calcareous nannofossils species decreased during the C21r-H6 event, suggesting changes in calcification, although potential dissolution is also considered and anlyzed. The temperature of the environment increased, which probably contributed to raise the sea level. The proportion of reworked calcareous nannofossil taxa increased considerably, suggesting higher erosion of the hinterland. Finally, an increase in nutrient availability has also been deduced.

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Integrated ammonite-belemnite infrazonal scales as instrument for detailed stratigraphy (an example from the Lower Callovian of Russian platform)

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The concept of infrazonal stratigraphy, elaborated mostly by John Callomon in the last quarter of the XX century, is the most popular approach among Jurassic ammonite stratigraphers. The application of this concept to the lower Callovian of Eastern European platform resulted in elaboration of very detailed schemes, comprising up to 26 biohorizons. General principles and methods of describing biohorizons, used by different authors, are quite diverse and not unified. However, the highest degree of resolution was achieved by describing successive biohorizons on the base of chronospecies and chronosubspecies of certain ammonite lineages (*Paracadoceras→Cadochamoussetia→Chamoussetia* lineage for the lower part of Lower Callovian; *Kepplerites* (*Gowericeras*)*→Sigaloceras→ Catasigaloceras→Kosmoceras* lineage for the upper part of lower Callovian to upper Callovian). The resulting infrazonal ammonite scheme contains not only “index lineage”, but several parallel phyletic successions of biohorizons, drawing the evolutionary history of the group on the studied time interval. Additionally, short episodes of immigration of alien species can be used for justification of “immigrational” biohorizons. Principally, the approach described above for ammonites, is applicable to other fossil groups, for example, belemnites, which are not widely used for stratigraphy and characterized by relatively similar mode of life (nektonic and necto-benthic).

In 2012-2014 the authors have performed the study of all most important sections of the Lower Callovian at Russian platform, counting over 25 localities and sampled over 1500 belemnite rostra, collected level-by-level together with ammonites. As a result, the lower Callovian was subdivided by belemnites into 4 parallel series of successive phylogenetic biohorizons, based on 4 different phyletic lines inside the boreal family Cylindroteuthidae (*Pachyteuthis* s. str.; *Cylindroteuthis* s. str., “*Cylindroteuthis*” *kowalevi*; *Communicobelus* → *Lagonibelus* (*Holcobeloides*)). Each succession covers certain interval within lower Callovian and partly overlaps with other successions. The total number of successive units for the whole lower Callovian is up to 14 biohorizons, which can be grouped into 4 larger units (=zones), characterized by well-recognizable assemblages on generic level. It is also possible to select biohorizons based on immigration events of belemnites from Tethys. Resulting scheme in belemnites provides a new biostratigraphic chronometer, independent to ammonite succession and comparable with ammonites in biostratigraphic resolution. The following observations can be made:

1. in non-condensed sections, well-characterized by both groups, the positions of boundaries between belemnite biohorizons never match with those of ammonite sequence, thus allowing further detalization of ammonite subdivision by belemnites.
2. in cases, when boundary between two successive belemnite biohorizons was traced in several section, its position inside certain ammonite horizon is always the same. This means that “presumably isochronous” boundaries of ammonite biohorizons are really more or less isochronous.
3. large changes in belemnite biota, reflected in zonal boundaries, are not connected with zonal boundaries in ammonites, thus indicating relatively independent evolution and radiation within both groups.
4. Belemnite immigration events from Tethys always tied up with similar events in ammonites, however, ammonite events are more numerous in total.
5. lower boundaries of conventional belemnite units (zones), characterized by certain appearance of belemnite complex (different genera), are often immigrational and are evidently diachronous in very distant sections; while certain phylogenetic biohorizons, based on index species, often can be traced over the whole studied territory and thus have higher potential for precise correlation.

To conclude, integration of parallel ammonite and belemnite infrazonal scales provides outstandingly precise correlations even for distantly spaced sections. The investigation was supported by RFBR grants No. 15-05-03149 and 15-05-06183.

End Triassic regression: Triassic-Jurassic boundary from the Tethyan Salt Range, Pakistan

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The end Triassic regression is an event of global significance, well established worldwide. In the stratigraphic sections of different European basins, erosion and karstification is common at the top of the Triassic succession. Further, channels with erosive bases and reworked clasts of the underlying Triassic sediments are observed at the base of the Early Jurassic sediments in European basins. In the Tethyan Salt Range of Pakistan, abrupt emergence, erosion and associated facies dislocation, from dominantly marine succession of the Triassic Kingriali Formation (dolomite) to pure fluvial/continental succession in the lower part of the Jurassic Datta Formation is observed. The basal part of the Datta Formation consists of conglomerates and pebbly sandstones with channel fill features and erosive bases. Angular, poorly sorted clasts of dolomites derived from the underlying Kingriali Formation are common in the lower most beds. A thick laterite bed, having bohemite, kaolinite and similar minerals occurs at the contact of the two formations. This indicates weathering under continental and tropical conditions (i.e. emergence) and represents the Triassic-Jurassic boundary in the area. This stratigraphically significant sea-level event coincides closely with one of the five biggest mass extinction events in the Phanerozoic. Sedimentological evidences for the globally present Jurassic-Triassic boundary in the Salt Range of Pakistan encourage a detail work in this regard. This may establish the chronostatigraphic order of the Datta Formation with respect to the European time-equivalent successions.

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The Integrated Approach to the Palynozones Definition in the Carboniferous of the Volhynian-Podilian Margin of the East-European Platform (Western Ukraine)

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The basis of palynological studies of the Carboniferous of the Volhynian-Podilian margin of the East-European platform are complexes of microfossils of vegetable and problematic origin, buried under certain paleogeographical conditions and timed to the concrete facial type of the rocks. The microphytofossils, after their separation from the mother plants, are spread in the outer medium as sedimentary particles and after fossilization enter the sedimentary rocks as insoluble dispersed organic matter. The multivariable process of transferring phytoorganics into fossils include 4 stages: the formation of the initial material under the control of climate and evolutionary development of the plant kingdom, its transportation, burial and fossilization, which essentially change the initial composition and the ratio of microcomponents. The indices of the microphytoorganics complexes not only reflect the peculiarities of the mother plant development, but must be considered also as the indications of the rock. The deposits are formed in a certain paleogeographical situation. The dispersed plants remnants have specific features of this situation, which influence the composition of microfossils, their safety and timing certain types of the rocks. So the microorganics complexes must be considered as a complex natural system formed by a combined activity of the outer surrounding factors, with the complex of indices which may be divided into two groups: taphonomic and cenotic. The taphonomic group includes the indices of facial conditions; they reflect the processes of transportation, burial and fossilization of the vegetable material and the change and repetition of the sedimentation conditions in time. They include: the degree of DOM concentration, the saturation with miospores, the differentiation of components by size, the intact of palynomorph, the presence of acritarch, the cyclic ware–broken distribution of the DOM quantity and its separate components in the vertical section. The cenotic indices are stipulated by the evolution and migration of flora under the influence of paleobiological and paleoclimatic factors. They include: the interchange of miospore dominants in the vertical section, one–direction changes of the miospore qualitative and quantitative composition – the appearance of different taxa, the existence within the certain stratigraphic interval and the disappearance from the section. For correct palynological investigations and definition of palynozones cenotic signs must be distinguished from taphonomic and identified unique changes of microfossils complexes. For this palynological analysis should include taphonomic investigations with facial study containing rocks. To distinguish facial changes in palynocomplexis from evolutionary, it is desirable to use the palynological material of rocks of the same facies. Palynological study of the Carboniferous of Volhynian-Podilian margin of East-European platform showed that the best facies are transitional from continental to marine, which contain numerous, taxonomically diverse miospores that reflect vegetation of large paleobotanical land area. So the integrated systematic approach is the effective instrument of the palynostratigraphy and the definition of palynozones. It also enhances the informativity and trustworthiness of palynological analysis and shows the new ways of its application.

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Calpionellid biostratigraphy of the lowermost Cretaceous volcanogenic beds of the Kaminnyi Potik Unit (Ukrainian Carpathians)

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The studied area is located in the Ukrainian Carpathians, in the valleys near Rachiv city and in the massif of Chyvchynian Mountains. Studied sections represent the Kaminnyi Potik Nappe located in the frontal part of the Marmarosh Massif. Investigated rocks are represented by the volcano-sedimentary complex approximately 200 meter in thickness. In the Chyvchynian Mountains sequence starts with basaltic pillow lava flows (i), which are covered by volcano-sedimentary breccias (synsedimentary debris flows) with blocks of the limestones, basalts, small fragments of red cherts within volcanic/tuffitic matrix (ii), coral limestones with basalt fragments and pyroclastic intercalations (iii), and by thin-bedded micritic limestones with cherts interbedded by coarse/fine-grained calcareous and pyroclastic flysch turbidites (iv). In the stratotype of the unit (Kaminnyi Potik section) above the volcanic rocks we found biodetritic limestones full of corals, bryozoans and crinoids (subordinately containing remains of the other benthic fauna as bivalves and foraminifers), which are overlying by carbonate turbidites with several pyroclastic intercalations. Turbidite leyers yielded calpionellids, which documented Middle and Upper Berriasian age – Calpionella (probably *Calpionella elliptica* Subzone) and Calpionellopsis zones (*Calpionellopsis simplex* Subzone). Calpionella Zone has been determined based on the prevalence of such species as: *Remaniella ferasini* (Catalano), *R. catalanoi* Pop, *R. cadischiana* (Colom), *Crassicollaria parvula* Remane, *Calpionella elliptica* Cadisch, *C. alpina* Lorenz, *Tintinnopsella carpatica* (Murgeanu & Filipescu). Calpionellopsis simplex Subzone was defined on the basis of the appearance of indicator species *Calpionellopsis simplex* (Colom) which co-occur with: *Calpionella alpina* Lorenz, *C. minuta* Houša, *Tintinopsella carpatica* (Murgeanu & Filipescu), *Calpionella elliptica* Cadisch, *Remaniella colomi* Pop and *R. catalanoi* Pop.

Carbon isotope correlation markers of the Lower Devonian Emsian Stage in Zeravshan-Hissar Mountainous Region (Uzbekistan) and Salair (southern West Siberia, Russia)

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Carbon and oxygen isotope composition of the Emsian sedimentary successions in Salair and Zeravshan-Hissar Mountainous Region has been studied since 2009, following a decision of the International Subcommission on Devonian Stratigraphy to redefine the stratigraphic range of Pragian Stage and reestablish a new basal Emsian GSSP. The present GSSP of the Pragian–Emsian boundary is in the Kitab State Geological Reserve at the base of Zinzilban Beds of the Khodzha-Kurgan Fm. In the Zinzilban Gorge section, the Emsian Stage is represented by the full stratigraphic range of the Kitabian Regional Stage comprising Zinzilban (*kitabicus* Zone), Norbonak (*excavatus* Zone), Dzhaus and Obi-Safit (*nothoperbonus–patulus* zones) beds.
Detailed studies of carbon and oxygen isotope variations in the Zinzilban Beds demonstrated marked $\delta^{13}C$ and $\delta^{18}O$ perturbations at the base of the *kitabicus* Zone (Izokh, Izokh 2010; Izokh 2011). In particular, variations of the carbon isotopic composition in the Zinzilban section show a negative excursion just above the Pragian–Emsian boundary (base of *kitabicus* conodont Zone), where $\delta^{13}C$ values decrease from 2 to -0.7‰, followed by an increase up to 3‰. Relatively high (+2‰) $\delta^{13}C$ values characterise the entire *kitabicus* Zone. Additional carbon isotope fluctuations occur in the upper part of the *kitabicus* Zobe and basal *excavates* Zone; however, these perturbations are minor compared to the Pragian–Emsian boundary interval. A decrease in values from 1.9 to 0.8‰ is observed, followed by a rise to 2.7‰.
Emsian stratigraphy of the Salair has recently been revised (Izokh, Yazikov, 2014; Yazikov et al., 2015). Earlier in the study, the Salairka, Belovo, and Shanda regional stages were correlated with the Emsian Stage. In the revised stratigraphic scheme, the Belovo Regional Stage is synonymous with the Shanda Regional Stage. Furthermore, conodont assemblages suggest placement of the Pragian–Emsian boundary within the Salairka Regional Stage, specifically in the uppermost Middle Salairka Beds, as opposed to the traditional position at the base of the regional stage. The uppermost Middle Salairka interval is characterised by a transgressive anoxic Salairka Event coinciding with the lowermost stratigraphic occurrence of *Polygnathus kitabicus*, as well as a compositional turnover of brachiopod communities (Yazikov et al., 2015).
Preliminary carbon isotope study of the Salairka Regional Stage reveal that the $\delta^{13}C$ curve is characterised by a positive excursion, with values increasing from 0.3 to 2.7‰, followed by a decrease to 0.1‰ within the Lower to Middle Salairka Beds (Izokh, 2011). Subsequent studies have brought new carbon isotope data suggesting a short-term negative excursion (a decrease from 2.3 to 0.5‰) in the upper part of Middle Salairka Beds against relatively high values (2.4…3.1‰). This excursion could be coeval with carbon isotope fluctuations at the base of *kitabicus* Zone in Zinzilban Section.
The new isotope data from Salair support the position of the Pragian–Emsian boundary based on conodonts and brachiopods in the upper part of the Middle Salairka Beds, and disagree with the earlier placement of the boundary at the base of the Salairka Regional Stage (Yolkin et al., 2000).

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Short-term perturbations of marine $^{87}Sr/^{86}Sr$ near the Jurassic–Cretaceous boundary in the Maurynya Section, West Siberia: potential causes and correlative value

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The Cretaceous is the only Phanerozoic system that has not yet been defined by the GSSP, primarily because of the lack of any major faunal change near the Jurassic–Cretaceous (J–K) boundary and because of the pronounced provincialism of marine fauna. The latter accounts for existing problems with correlation between the Boreal and Tethyan uppermost Jurassic–lowermost Cretaceous successions. On another hand, $^{87}Sr/^{86}Sr$, $\delta^{13}C$ and $\delta^{18}O$ excursions reflecting global climatic and geodynamic changes have been effectively used as proxies for global correlation.

Until recently, only the J–K transition beds in Great Britain (Jones et al., 1994) and Russian Platform (Gröcke et al., 2003) had primary $^{87}Sr/^{86}Sr$ record, along with few other sections characterised by sporadic data. According to the available information, the Upper Jurassic – lowermost Lower Cretaceous record demonstrates a trend towards a global increase in $^{87}Sr/^{86}Sr$ values. Potential stratigraphic markers for the J–K boundary are being sought in the lowermost Berriasian; however, this interval has poor Sr isotope record.

We introduce new data on $^{87}Sr/^{86}Sr$ in the Maurynya Section (upper Volgian – lowermost Ryazanian) and their correlation with the previously established $\delta^{13}C$ and $\delta^{18}O$ perturbations (Dzyuba et al., 2013). The Maurynya Section is located approximately 125 km south of the West Siberian town of Saranpaul'. The continuous upper Volgian and lowermost Ryazanian shallow marine sedimentary succession cropping out along the right bank of the Maurynya River reaches 6 m in thickness. The section is extremely rich in fossils, including belemnites. The following cylindroteuthid belemnite zones and units have been established in the section: the *Lagonibelus napaensis* Zone, the *Simobelus compactus* Beds, the *Cylindroteuthis knoxvillensis* Zone, and the *Boreioteuthis explorata* Beds (Dzyuba, 2013). The uppermost 3.5 m of the section is well characterised by ammonites of the *Craspedites taimyrensis* Zone up to the lowermost *Hectoroceras kochi* Zone (Alifirov et al., 2008).

Strontium isotopic composition was analysed in the belemnite rostra notable for high degree of preservation of the carbonate material. The obtained $^{87}Sr/^{86}Sr$ variation curve shows a positive trend up the section. The $^{87}Sr/^{86}Sr$ values increase from 0.70717 in the lower part of the upper Volgian Substage to 0.70724 in the lowermost *kochi* ammonite Zone of the Ryazanian Stage. A short $^{87}Sr/^{86}Sr$ rise up to 0.70722, followed by a decrease to 0.70720 is recorded in the mid-section corresponding to the Volgian *Subcraspedites maurynijensis* ammonite Beds.

The obtained positive $^{87}Sr/^{86}Sr$ trend in the J–K boundary interval of West Siberia correspond to the global pattern (e.g., Jones et al., 1994; Gröcke et al., 2003; McArthur and Howarth, 2004) suggesting that the increase in radiogenic ^{87}Sr input to the ocean could had been caused by global factors.

The J–K boundary interval is characterised by significant $\delta^{13}C$ variation (Dzyuba et al., 2013). A positive $\delta^{13}C$ excursion followed by a decrease in $\delta^{13}C$ values was established on belemnites at the top of *taimyrensis* Zone in the Maurynya Section. This negative shift is coeval with a minimum in the $\delta^{18}O$ curve. A similar trend has been revealed based on the study of C and O isotope composition in oyster shells. Temperatures calculated using the oyster shell $\delta^{18}O$ values suggest significant warming during the J–K transition (Kosenko et al., in press). The established temperature rise, together with the increase in $^{87}Sr/^{86}Sr$ values, corroborate earlier findings of the global warming across the J–K boundary. Climate aridisation and sea level lowstand near the J–K boundary, in turn, could lead to an increase in weathering and continental runoff to the ocean (Föllmi, 2012).

The positive $^{87}Sr/^{86}Sr$ shift at the base of the *maurynijensis* Beds, together with the $\delta^{13}C$ excursion at the top of *taimyrensis* Zone, can be used for regional and global correlation of Boreal and Tethyan successions.

This is a contribution to the IGCP 608.

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Stratigraphic change in ichnofabrics as a response to substrate food availability: A case from the Lower-Middle Pleistocene Kokumoto Formation, Kazusa Group, central Japan

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The Chiba composite section of the Kokumoto Formation in central Japan is a remarkable, thick marine succession and is a candidate for formal recognition as the Global Boundary Stratotype Section and Point (GSSP) for the base of the Middle Pleistocene stage. Although there have been numerous studies of the Kokumoto Formation, the ichnology of the formation has been unclear. Thus, the present study focused on the ichnological feature of the formation, especially on the stratigraphic change in ichnofabrics, which may represent benthic response to substrate food availability.

The Kokumoto Formation is approximately 350 to 400 m in thickness, and comprises large-scale alternations of sandstones and siltstones. Studied interval is the middle part of the Kokumoto Formation (MIS 19), which is predominantly composed of intensely bioturbated silty beds. Twelve ichnogenera were identified from the silty beds, which are typical components of the *Zoophycos* ichnofacies. In addition, no graphoglyptid trace fossils, which generally occur in abyssal plain environments, were recognized. Such ichnoassemblage supports the sedimentological observations suggesting that the silty beds of the Kokumoto Formation were deposited in a continental slope setting. In addition, two types of ichnofabrics were identified from the studied interval; 1) *Phycosiphon*-dominated ichnofabric (*Phy* ichnofabric), and 2) *Chondrites*-*Planolites*-*Thalassinoides* ichnofabric (*Ch*-*Pl*-*Th* ichnofabric). With respect to stratigraphic changes in ichnofabrics, a distinctive pattern was recognized; namely, *Ch*-*Pl*-*Th* ichnofabric is exclusively observed in the middle part of the studied interval, whereas both *Phy* and *Ch*-*Pl*-*Th* ichnofabrics occur in the lower and upper parts. This pattern is not correlated with changes in sedimentation rate. Instead, the stratigraphic pattern of ichnofabrics is well correlated with changes in substrate food contents, which are estimated by the results of high-resolution geochemical analysis. The lower and upper parts of the studied interval, which are characterized by the presence of *Phy* ichnofabric, are synchronized with relatively food-poor intervals. Since the *Phycosiphon* trace-maker is interpreted as a grain-selective deposit feeder, which may have effectively ingested substrate organic matter, it is reasonable that *Phy* ichnofabric occurs only in food-poor intervals. Furthermore, during the food-poor intervals, the occurrence of *Phy* ichnofabric in relatively food-rich sub-intervals is significantly lesser than that in the relatively food-poor sub-intervals.

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Early Toarcian palaeoenvironmental changes in the northwestern Panthalassic margin: Lithostratigraphy, carbon-isotope stratigraphy, and multiproxy geochemical analysis of the Nishinakayama Formation, Japan

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The early Toarcian (Early Jurassic; ca. 182 Ma) oceanic anoxic event (T-OAE) was a significant environmental perturbation that led to marked changes in ocean chemistry and climate, and which also had a severe impact on marine ecosystems. In addition, this event is characterized by the widespread occurrence of a ~3–7‰ negative excursion in the carbon-isotope ($\delta^{13}C$) composition of both marine organic and inorganic matter, and terrestrial plant material. This feature of the T-OAE indicates a pronounced perturbation to the global carbon cycle. Despite such global impacts of the event, the precise palaeoenvironmental changes during the early Toarcian from sections outside of the Boreal and Tethys realms are uncertain. Therefore, to resolve this issue and further expand our understanding of the nature of the event, here we investigated the Nishinakayama Formation of the Toyora area, southwest Japan, which represents shallow-marine strata deposited at the northwestern margin of the Panthalassa.

First, we established high-resolution litho- and carbon-isotope stratigraphy. Dark grey to black-coloured mudstones are predominant in the Nishinakayama Formation, but a distinct sandstone-rich interval was recognized in the middle part of the studied succession. As a result of carbon-isotope analysis, a characteristic $\delta^{13}C$ negative excursion was recognized around the middle part of the Nishinakayama Formation, the most negative peak of which corresponds with the sandstone-rich interval. The established high-resolution carbon-isotope stratigraphy allows accurate international correlation. Then, we carried out multiproxy geochemical analysis to reconstruct palaeoenvironmental conditions at the northwestern Panthalassic margin. The results suggest that in the studied succession, organic-matter enrichment generally persisted through the early Toarcian, but elemental redox proxies and ichnofabrics do not support persistent bottom-water anoxia through the $\delta^{13}C$ excursion. In addition, a distinct oxic interval corresponds the sandstone-rich interval, which suggests the frequent sediment flows with oxic waters. Analysis of terrigenously derived major and trace element abundances and palynology, coupled with sedimentological observations, revealed an increase in coarse-grained sediment, phytoclast size, and terrestrial organic-matter close to the onset of the $\delta^{13}C$ negative excursion. These lines of evidence suggest a significant strengthening of detrital sediment flux and hence hydrological cycling and continental weathering. This is consistent with previously published evidence from Boreal and Tethys realms.

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The Pridolian to Eifelian succession of the Rhenish Massif (Rheinisches Schiefergebirge, Germany): brachiopod faunas, events and correlation

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Pridolian to early Eifelian strata in the Rhenish Massif (Germany) contain a succession of rhynchonelliformean brachiopod faunas reflecting palaeoenvironmental changes in a tropical epeiric sea, driven by regional and global forces during a time span of approximately 30 million years. These "faunas", sets of fossil assemblages named after characteristic spiriferide species, are separated by events discernible by facies change and faunal turnover (Jansen, submitted).

The first rhenotypic brachiopod assemblages of the Rhenish area belong to the earliest Gedinnian *Quadrifarius dumontianus* Fauna. Brachiopods in combination with chitinozoans and conodonts allow a correlation with the Pridolian in the Artois area (France), Podolia and Bohemia. Ecological effects of the transgressive Klonk Event may have caused the extinction of the *Qu. dumontianus* Fauna near the Silurian-Devonian boundary. With the Hüinghausen Event in the early Gedinnian (early Lochkovian), shallow marine conditions returned, which were suitable for the spread of the *Howellella mercurii* Fauna. This fauna went extinct still within Gedinnian (Lochkovian) time, with the onset of the "Rhenish Gap", a regressive interval during the late Gedinnian to early Siegenian with a duration of 6-8 m. a., only partly reflected by the global sea-level curve and presumably caused mainly by strong siliciclastic input from the Old Red Continent. The *Acrospirifer primaevus* Fauna widely spread with the Gensberg Event at the beginning of the middle Siegenian, documenting a transgression of supraregional importance (Zinzilban Event?). After a regressive trend during the late Siegenian, the latest Siegenian Saxler Event marks the beginning of a transgressive phase which may coincide with the onset of T-R Cycle I b of the global sea-level curve (Johnson *et al.* 1985). The succeeding early Emsian *Arduspirifer antecedens* Fauna shows a gradual evolution of the rhenotypic brachiopods. Peaks of marine influence are reached with the transgressive Spitznack and Stadtfeld events (Mittmeyer 2008) in the middle respectively late early Emsian allowing the immigration of the first ammonoids; finally there's a strong regressive phase in the latest early Emsian ("Klerf facies").

The rising sea-level in connection with the earliest late Emsian Berlé Event (Mittmeyer 2008; corresponding to Daleje Event?) provided a more continuous connection to the sea and allowed the immigration of taxa of the late Emsian *Euryspirifer paradoxus* Fauna. The overall transgressive trend during the late Emsian was accompanied by a modest, stepwise faunal change. One of the most conspicuous features is the radiation of the genus *Paraspirifer*. While the rhenotypic Kondel fauna died out in the central and eastern Rhenish Massif near the Emsian-Eifelian boundary, resulting from the onset of deep water, hercynotypic conditions, the rhenotypic *Paraspirifer cultrijugatus* Fauna lived on in the Eifel and Sauerland regions, survived into the Eifelian and went extinct with the (regressive?) Kirberg Event within the *Polygnathus costatus costatus* Biochron at the end of the Lauch time, following with some delay after the Basal Choteč Event.

To conclude, the Pridolian to early Eifelian sedimentary succession exemplifies the dependence of the faunal development on the interplay of rapid eustatic sea-level changes in combination with varying subsidence and sedimentation rates causing palaeoenvironmental changes. Extinction, habitat-tracking, emigration and immigration of brachiopod species in connection with major events governed the composition of faunas.

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Late Wenlock $\delta^{13}C_{carb}$ stratigraphy and its relationship with the relative sea-level changes in the central part of the Midland Platform, UK

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The Homerian (Wenlock, middle Silurian) has been proposed to be a time of rapid sea-level changes and perturbations in the global carbon cycle reflected in a double-peaked positive carbon isotope excursion (CIE) known as the Mulde CIE. The excursion is recorded upon many paleocontinents, but its timing with respect to the physical (sequence-stratigraphic) architecture and faunal turnover remains relatively poorly known. The sea-level changes associated with the Mulde CIE have been particularly well constrained in the English Midlands, allowing for precise linking of geochemical and sequence stratigraphic data. Two sections located in the central part of the Midland Platform have been sampled for high-resolution (5 to 20 cm intervals) $\delta^{13}C_{carb}$ stratigraphy, conodont biostratigraphy and microfacies analysis across the entire Mulde CIE. Whitman's Hill Quarry exposes an approximately 40 m thick Homerian succession, spanning the upper Coalbrookdale Formation and most of the Much Wenlock Limestone (MWL) Formation (Lower Quarried Limestone and Nodular Beds members). Bruff Business Park exposes the MWLF and its contact with the lower part of the Lower Elton Formation. Sequence stratigraphy in these sections has been previously documented, allowing for precise correlations across the Midland Platform and indicating two regressive episodes. The first of them coincides with the final extinction level of the *lundgreni* event. It is widely recorded and proposed to have a glacioeustatic origin. At Whitman's Hill Quarry, the onset of the regression is associated with a very rapid rise of $\delta^{13}C$ values from the baseline level (average 0.1‰, all values reported with respect to VPDB) to 2‰ within the uppermost 1.4 m of the Coalbrookdale Fm. Maximum values of the lower peak of the Mulde CIE, reaching 4.8‰, are recorded within the early transgressive systems tract (TST), corresponding to the Lower Quarried Limestone Member. Late TST is represented by the lower part of the Nodular Beds Mb. and associated with the declining limb of the first $\delta^{13}C$ peak. The second peak of the Mulde CIE begins in the upper part of the member and spans the Upper Quarried Limestone Mb. which records the second, end-Homerian regression. It reaches maximum $\delta^{13}C_{carb}$ values of 3‰ and declines towards the Wenlock/Ludlow boundary which is placed at the contact with the overlying transgressive calcareous mudstones of the Lower Elton Formation. However, $\delta^{13}C$ values remain constantly high (average 1.5‰) across the lowest 8 m of the formation. Our data shows good agreement with the $\delta^{13}C$ records across the lower peak of the Mulde CIE in the Midland Platform and in sections in Baltica. It also suggests larger variability in the position of the second peak as compared to the sequence-stratigraphic architecture. This variability even at the regional scale of the Midland Platform is reflected also in other sections in Baltica, where the upper peak is missing or extremely condensed in some sections. The declining limb of the peak falls within an interval of intensified erosion and rapid facies shifts at the contact between the MWLF and the Lower Elton Formation. This interval close to the Wenlock-Ludlow boundary is also poorly documented in terms of conodont biostratigraphy. Our preliminary conodont extractions yielded low-diversity faunas dominated by *Pseudooneotodus* and *Ozarkodina bohemica longa*, which did not allow so far for precise biostratigraphic control. Our observations highlight the need to integrate carbon isotope and sequence stratigraphy in $\delta^{13}C$-based correlations near the Wenlock/Ludlow boundary.

Lower Cretaceous olistolith occurrences in the bend region of the Romanian Carpathians

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In the inner part of the Romanian Carpathian Bend area, three depositional sequences were differentiated in the Berriasian-Albian interval; all of them are of second-order and show coarsening upward trends. The three units may be assigned to regressive-transgressive cycles, displaying a shallowing upward trend. In these sediments, olistoliths are accumulated at four stratigraphic levels: (i) Early Valanginian, (ii) Late Hauterivian-Early Barremian, (iii) Late Aptian-Early Albian and (iv) Late Albian. Made up mostly of limestone and crystalline rocks, the olistoliths size usually varies between 5 m and 200 m (seldom reaching 500 m up to 2,000 m). Originated from the margin of the uplifted crystalline basement from the inner (western) part of the Romanian Carpathian Bend area, the olistoliths moved down slope and embedded in debris flow-type rudites. Some of the exotic blocks have been transported up to 15 km from their source area.

Based on the gathered data, we estimated long-term sea level variations in the Lower Cretaceous basin of the Romanian Carpathian Bend. The recorded sea level changes are in general conformable to the long-term eustatic curve of Haq (2014). A trangressive event, recorded as eurybatic sea level variation, was observed within the Late Aptian. The Valanginian olistolith-bearing sediments are synchronous with the major global lowering sea level of the Early Cretaceous times, while the olistoliths occurring within the Late Hauterivian, Late Aptian-Early Albian and Late Albian intervals are related to trangressive events.

We conclude that sea level fluctuations are important controlling factor of the olistolith occurrence. The mid Cretaceous tectonic movements that significantly impacted the Romanian Carpathians also acted as an essential control element of the olistolith-bearing sediment accumulation. Dynamic topography may also play an important role in achieving the sedimentary architecture.

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Hyperthermal Influenced Flashy Water and Sediment Delivery to Fluvial Megafan and Fan Delta Systems on Opposing Shorelines of an Early Eocene Lake

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The effects of hyperthermal climate change events during the Early Eocene Climatic Optimum (EECO) and especially the Paleocene-Eocene Thermal Maximum (PETM) are recognized in the marine sedimentary and isotope record worldwide, but the nature of the response to transient greenhouse climate change in terrestrial depocenters is not as well constrained. While some marine proxies for climate change suggest a global increase in humidity and precipitation during the PETM, alluvial and lacustrine deposits in the Wasatch and Green River Formations in the Uinta Basin, Utah, U.S.A. instead show evidence of prolonged periods of drought punctuated by intense flooding events during hyperthermals. This flashy hydrologic regime was not unique to the Uinta Basin during Early Eocene, and has also been recognized in the neighboring Piceance Basin in Colorado as well as the Ebro Basin in Northern Spain.

Flashy delivery of water and sediment had distinct effects on the process of deposition in coeval fluvial megafan and fan delta deposits on opposing shorelines of a paleolake that occupied the Uinta Basin throughout the Eocene. The Tertiary Uinta Basin was an asymmetric continental interior basin with a steep northern margin, adjacent to the block uplift controlling basin subsidence, and a low gradient southern margin. A ~140 km wide fluvial megafan with catchments as far as ~750 km away occupied the southern margin of the lacustrine basin. Within this megafan system, fluvial deposits contain within-channel continental bioturbation and paleosol development on bar accretion surfaces that are evidence of prolonged periods of groundwater flow or channel abandonment. These are punctuated by channel fills exhibiting a suite of both high-deposition rate and upper flow regime sedimentary structures that were deposited by very rapid suspension-fallout during seasonal to episodic river flooding events. A series of small (~8 km wide) and proximally sourced fan deltas fed sediment into the steeper northern margin of the lacustrine basin. 35-50% of the deposits in the delta plain environment of these fan deltas are very sandy debris flows with as low as 5% clay and silt sized material. Detrital zircon geochronology shows that these fan deltas were tapping catchments where mostly unconsolidated Cretaceous sedimentary cover and thick Jurassic eolianites were being eroded. Studies of coeval paleosols and floodplain deposits in the neighboring Bighorn Basin, Wyoming, U.S.A. (Kraus and Riggins, 2007) suggest an overall arid climate and floral turnover in the region. This may have suppressed the chemical weathering in catchments in the region leading to less abundant generation of clay sized material. This combination of flashy precipitation, arid climate, catchments mantled by abundant loose sand-sized colluvium, and steep depositional gradients promoted generation of abundant very sandy (5-10% clay and silt sized material) debris flows. In this way, the Wasatch and Green River Formations in the Uinta Basin, Utah, U.S.A. gives us two very different examples of how routing flashy water and sediment delivery (associated with pulses of hyperthermal climate change during the Early Eocene) through different depositional systems produced unique processes of deposition, and also gives us an opportunity to isolate the effects of other variables (e.g. sediment caliber, system gradient, catchment size) that can modulate the flashy precipitation signal in stratigraphy.

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Events in the Northern Paleogene foreland basin of the Eastern Carpathians (Romania, Bucovina), at the Ypresian-Lutetian transition

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This study is focused on the biostratigraphical, sedimentological and chemostratigraphical events that took place in the Paleogene foreland basin of Bucovina (Eastern Carpathians) at the Ypresian (Yp) to Lutetian (Lu) transition. The analysed section is located on Voitinel Valley, Suceava Basin. The boundary interval was separated at the base of the Suceviţa Formation, being characterized by **petrofacial associations** of sandstone facies (AF1) and sandstone-lutitic facies (AF2). From AF2, 12 samples were biostratigraphically and chemostratigraphically analysed.
The **calcareous nannoplankton** content differs in every analysed sample. The abundance is very high in the lower part of the section, were discoasters dominate: *Discoaster lodoensis*, *D. septemradiatus*, a.o. (sample 2). In the middle part of the interval, the first occurrence of *Nannotetrina fulgens* (NP15a-NP15b; sample 6) was remarked. On top (sample 12), a high content of discoasters (*D. distinctus* (NP15), *D. barbadiensis*) and *Nannotetrina fulgens*, a.o. is present. Based on the calcareous nannofossils content, we located the Yp/Lu boundary in the first part of the turbidite succession of the Suceviţa Formation, in the 11.75 – 12.50 m interval from the base of the formation (between samples 2 and 6).
Agglutinated foraminifera dominate**,** while planktonic forms are scarce or even missing. Foraminifera show a good correlation with the calcareous nannoplankton. They belong to the "flysch type" group associations, characteristic for the turbidite systems of the marine deep environment. *Saccamminoides carpathicus* is considered a marker for the Ypresian. The first occurence of this species is at 11.50 m (in sample 2), and the last occurence at 12.75 m from the base of the Suceviţa Formation. Its last occurence can be correlated with the first occurence of the nannofossil *Nannotetrina fulgens*, characteristic of the biozones NP15a-NP15b. The dominance of tubular forms belonging to the morphogroup M1 (*Bathysiphon*, *Nothia*, *Rhabdammina*, *Rhizammina*, *Hyperammina*, *Psammosiphonella*) has been observed. They indicate a marine depositional environment at the base of the slope – basinal plane (lower bathial – abisal). The percentage distribution of the morphogroups in the section varies between 18% (sample 8) and 76% (sample 4). A maximum percentage was recorded in the 11.50-12.50 m interval, and a minimum in the 12.75–13.25 m interval. This depth variation is confirmed by the maximum developement of the morphogroup M4b (*Reophax, Karrerulina*) (lower shelf – upper bathial) in the 12.75–13.75 m interval.
For assessing the **chemostratigraphic registration** of the events at the Yp/Lu boundary, we have determined and analysed the following parameters along the section: the $CaCO_3$ content, the variation of organic (TOC), anorganic (TIC) and total (TC) carbon, and a series of stable isotopes (^{44}Ca, ^{85}Rb, ^{88}Sr, ^{238}U, ^{138}Ba, ^{27}Al, ^{23}Na, ^{24}Mg, and ^{39}K). Relevant variations at the boundary were remarked in the case of $CaCO_3$, TOC, TIC, TC and the $^{88}Sr/^{85}Rb$ ratio. The $CaCO_3$ curve shows a strong variation along the section in the 11.50–14.25 m interval (differences between minimum and maximum values up to 40%). This variation well correlated with the biostratigraphically established Yp/Lu boundary interval. The $CaCO_3$ and TOC curves present a negative correlation with the abundance of agglutinated foraminifera: this corresponds to the depth variations in the depositional environment, according to the distribution of the M1 and M4b morphogroups. The $^{88}Sr/^{85}Rb$ ratio describes a trend similar to that of the $CaCO_3$ curve, registering a variation of 26.56% (10.82% - 37.33%) in the boundary interval.
In conclusion, the events recorded at the Yp/Lu boundary interval in the Paleogene East Carpathian foreland from Bucovina can be correlated with those described from the deep marine from the Western Pyrenees.

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Shallow marine paleoenvironments from the Oligocene Molasse deposits of the Albanian-Thessalian Basin (Albania)

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The Albanian-Thessalian (=Mesohellenic) Basin represents a narrow, SE-NW striking intramontane basin, filled by marine molassic deposits. It extends from Thessaly (Greece) in the South through Devolli, Korça, Gora, Mokra, up to Librazhdi (Albania) in the North. The studied region around Korça includes Oligocene to Lower Miocene formations dominated by siliciclastic sediments.

Quantitative analyses of the calcareous nannofossils and foraminifera were performed on several samples collected from marlstones/siltstones. The assemblages contain moderate to poorly preserved calcareous nannofossils, dominated by *Cycligargolithus floridanus* and *Reticulofenestra minuta* (representing more than 60% of the assemblage), occurring continuously and in high amount through the section. In lower amounts are present: *Sphenolithus* spp., *Coccolithus pelagicus, Reticulofenestra scripssae, Reticulofenestra* sp. Rare and discontinuous are *Helicosphaera* spp., *Cycligargolithus abisectus*, *Zyghrablithus bijugatus* etc., while Discoasterids and *Postosphaera* are very rare. High amount of *Cycligargolithus floridanus* and small reticulofenestrids suggest nearshore, warm well stratified column water and stable paleoenvironment conditions. Benthic foraminifera are present in significant amounts, but with a low diversity. The assemblages are dominated by large *Operculina complanata* and some rotaliids, characteristic to marine shallow environments. Biostratigraphycally, the calcareous nannofossils suggest that the material belongs to the *Sphenolithus distentus* Zone - NP24 (Upper Rupelian – Lower Chattian age) according to standard zonation of Martini (1971). The foraminifera are common for the Oligocene, but their stratigraphic range is wider.

The mollusk assemblage is characteristic for the Tethyan mid-Oligocene and corresponds to that of the southern Mesohellenic Basin as well as of the Northern Italy. Bivalve composition is dominated by shallow burrowing dwellers, followed by epibenthic dwellers, including also scattered deep burrowing representatives. Abundant throughout the investigated succession is *Chama tongriana* Roveretto, 1898, whereas locally masses of minute *Corbula subspisum* (d'Orbigny, 1852) shells are present. The faunal composition points to fully marine conditions and a shallow subtidal water depth. Generally soft, muddy and sandy bottom provided plentiful primary or secondary hard ground needed for settlement of epibiontic dwellers. The gastropod composition suggests shallow to moderately deep sublittoral soft bottom environments in which carnivorous, sediment and filter feeding species occur.

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Paleoenvironments in the Oligocene from the NW Transylvanian Basin (Romania) revealed by calcareous nannofossils and foraminifera

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Paleoenvironmental analyses based on calcareous nannofossils and foraminifera were carried out on samples collected from the Fântânele section (Vima Formation), located in the southern part of Preluca Masif, in north-western Transylvanian Basin. The studied area is characterized by continuous marine sedimentation for the whole Oligocene - Early Miocene interval (Popescu 1972, 1975, Melinte & Brustur, 2008).
The calcareous nannofossils assemblages suggest middle-upper Rupelian – Chattian age, respectively upper part of *Sphenolithus predistentus* Zone (NP23) to lower part of *Sphenolithus ciperoensis* Zone (NP25) according to standard zonation of Martini (1971). No Miocene taxa have been observed. The foraminiferal assemblage suggests the Early Oligocene (Rupelian) O4 Zone to Late Oligocene (Chattian) O5 Zone according to Wade et al. (2011).
The low diversity and low abundance benthic communities contain calcareous benthic forms (species of *Bolivina* and *Cibicidoides*) and agglutinated foraminifera (mainly tubular forms and *Reophax* species) possibly suggesting shallower environments. These alternate with high diversity assemblages from deeper environments mostly comprising calcareous benthic species of *Lenticulina, Alabamina, Epistominella, Gyroidina, Globocassidulina,* low-oxygen tolerant taxa such as *Bolivina, Fursenkoina* and species of *Uvigerina* suggesting high organic matter flux to the sea-floor. The overall shallowing trend of the upper part of the studied section is reflected in the composition of benthic foraminiferal assemblages. Additionally, calcareous nannofossils abundance patterns suggest relatively shallow environments, generally characterized by well-stratified column water, fluctuations in water salinity, temperature, nutrient supply and increased fresh-water input.

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The Eocene-Oligocene turnover of Deep-Water Agglutinated Foraminifera at ODP Site 647, Southern Labrador Sea (North Atlantic)

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We present a new record of deep-water agglutinated foraminifera (DWAF) across the Eocene-Oligocene Transition (EOT) in the southern Labrador Sea (ODP Site 647). We studied 82 samples from Cores 647A-37R to -27R, and recovered over 100 species and generic groups. The EOT represents an interval of rapid climatic change connected with global cooling, Antarctic glaciation, a substantial decrease in atmospheric CO2, and concurrent changes in the composition of deep waters in the world ocean. Our high-resolution quantitative study of the DWAF faunal succession in abyssal Hole 647A confirms earlier findings that the EOT was an interval of significant faunal turnover.

The faunal succession in Hole 647A is subdivided into two assemblages based on the stratigraphic ranges of characteristic benthic foraminiferal species: late Eocene *Spiroplectammina trinitatensis*-*Reticulophragmium amplectens* Zone and early Oligocene *Ammodiscus latus*-*Turrilina alsatica* Zone. The boundary between these zones, i.e., the Eocene/Oligocene (E/O) boundary, is characterized by the disappearance of 11 DWAF taxa, most of them organically-cemented taxa. The boundary interval was also characterized by a striking sharp decrease in DWAF abundance and diversity. Organically-cemented DWAF taxa increased in abundance in the early Oligocene, but their diversity and abundance never recovered to Eocene values. These data suggest a deepening of the calcite compensation depth and associated changes, such as more vigorous ocean circulation in coincidence with the E/O boundary interval.

The analysis of DWAF morphogroups reveals an acme in robust suspension-feeding tubular forms previous to the extinction, suggesting increased bottom water activity. The E/O boundary interval is characterized by an increase in DWAF infaunal taxa and *Spiroplectammina* species, probably related to increased productivity, as already suggested by the analysis of benthic elongate-cylindrical foraminifera at the same locality.

The faunal turnover across the EOT at Hole 647A suggests more vigorous deep-ocean circulation in the latest Eocene and across the E/O boundary interval in the Labrador Sea. It seems reasonable to link the disappearance of DWAF at the E/O boundary at Site 647 to more than one mechanism, including inferred higher productivity, possible competition from calcareous benthic foraminifera, changes in the CO2 content of the atmosphere and ocean, the deepening of the calcite compensation depth, and concurrent changes in taphonomic conditions caused by changes in the water masses in the North Atlantic.

New advances in the conodont biostratigraphy of the Upper Triassic successions in Csővár and the Buda Mts., Transdanubian Range, Hungary

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In the last ten years, the necessity to establish the Global Boundary Stratotype Section and Point (GSSP) of the Norian and Rhaetian stages, made the Upper Triassic an actively studied interval from a stratigraphic and biostratigraphic point of view. Given the worldwide diffusion and abundance of conodonts in the Upper Triassic, this fossil group represents one of the most suitable tools for the definition of these stages. Nevertheless, the debate concerning the actual usefulness of a conodont first appearing datum (FAD) as marker event for the definition of the Norian and Rhaetian stages is still in progress. Thus, every new data from different stratigraphic successions are fundamental to come to a suitable decision. In this perspective, the conodont successions of the Csővár Block and the Buda Mts. (eastern part of the Transdanubian Range, Hungary), may give a precious contribute.

In the Csővár area, nearly 600 m thick succession of dolomites and pelagic cherty limestones belonging to the Csővár borehole was recently investigated for conodonts, revealing rich faunas of uppermost Carnian to upper Rhaetian age. The uppermost Tuvalian is characterised by the dominance of carnepigondolellids (e.g., *Carnepigondolella tuvalica*), with few metapolygnathids (e.g. *Metapolygnathus praecommunisti*) and early epigondolellids (e.g. *Epigondolella heinzi*). At the Carnian/Norian boundary interval, a sudden turnover from carnepigondolellids to metapolygnathids (e.g., *M. communisti*) is observed, followed by the reappearance of the genera *Carnepigondolella* (*C. gulloae*) and *Epigondolella* (e.g., *E. rigoi*) and the occurrence of the genus *Norigondolella* (e.g. *N. navicula*) in the Lacian. The Alaunian is not well represented by conodonts, while the Sevatian is documented by the diversification of a rich record of species belonging to the genus *Mockina* (e.g., *Mo. englandi*, *Mo. mosheri*). The Rhaetian forms mostly belong to the genus *Misikella* (e.g., *Mi. posthernsteini*, *Mi. ultima*).

The Buda Mts. are characterised by Upper Triassic successions of basinal carbonates and are known for the large number of outcrops, but their biostratigraphic record is still in large part unknown, due to their poorly preserved macrofossils and the lack of microfaunistic investigations. In order to define better the age of these successions, plentiful sparse samples for conodonts were collected from the southern and the northern ranges. Samples were productive and revealed that the two areas differ in age. The southern range is dominated by the genera *Paragondolella* (e.g., *P. noah*), *Carnepigondolella* (e.g., *C. pseudodiebeli*) and *Epigondolella* (e.g., *E. quadrata*) with the presence of some methapolygnathids (e.g., *M. mersinensis*) and early norigondolellids indicating upper Carnian to lower Norian. The northern range yielded middle and upper Norian conodonts belonging to the genera *Epigondolella* (e.g., *E. triangularis*), *Norigondolella* and *Mockina* (e.g., *Mo. tozeri*, *Mo.bidentata*).

Covering the entire stratigraphic interval from the Upper Carnian to the Rheatian, the conodont records of the eastern part of the Transdanubian Range gives a rare opportunity for investigating the biostratigraphic value of several important Upper Triassic conodont species. Furthermore, these records are largely comparable to the conodont faunas of the Pizzo Mondello section (Western Sicily, Italy), GSSP candidate for the Norian stage. Consequently, the Csővár Block and the Buda Mts. represent potential tools to improve the definition of the Upper Triassic biostratigraphic scale and the knowledge of the conodonts phylogenesis, in the perspective of the establishment of the Norian and Rhaetian GSSPs.

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New data on the northern Aegean late Miocene marine gateway (Strymon basin, Greece)

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The Strymon basin (northern Greece) is a key region for establishing the Mediterranean-Paratethys connection during the Neogene. It constituted the marine gateway through the Balkans before and after the Messinian salinity crisis (MSC). The Akropotamos locality, in the eastern part of the Strymon basin, exposes Neogene clastic sediments with gypsum intercalations. Four subsections in the Akropotamos area are presented here. The base of the composite section consists of the pre-evaporitic sequence, several hundred meters of predominantly coarse fluviatile conglomerates. The uppermost part is marked by marine intercalations, which pass to clearly open marine facies at the top. The evaporitic unit begins with four meters massive saccharoidal gypsum followed by: one meter gypsilimestone with fenestrae, microbialite, and clayey carbonates with serpulids; four meters gypsirudite to gypsarenite, limestones with saccharoidal gypsum nodules, and laminated limestone with resedimented gypsum beds; two meters laminites and sandy limestones with serpulids and bivalves, as well as rare gypsum lenses; five meters laminites, silty clay with ripple marks, and silt to limestone beds with hummocky cross-stratification and decimeter intercalation of laminated, cherty sandstone before the last meter of the succession (bivalves, serpulids, plants, and coal are observed in this term of the sequence in one of the area's subsection); 1.5 meters dark clays; 1.5 meters massive to porous fine-grained limestone; two meters laminated marls with 0.5 meters ferruginous limestone at their base. The lower half of the above sequence is rich in ostracods indicating an estuarine environment. Changes in the faunal composition reflect mainly salinity fluctuations (mesohaline to hypersaline). In the upper part of the evaporitic unit, abundant nannofossil are identified, namely *Helicosphaera* spp., *Syracosphaera* spp., *Coronosphaera* spp., and *Lithostromation perdurum*. The contemporaneous presence of *D. bergrenii, A. primus, H. sellii* supports the biostratigraphic assignment of the studied samples within NN11 biozone, in particular NN11b, pointing to a Messinian age. The evaporitic unit is capped by three meters travertinous limestones. Indications of the Messinian erosional surface, separating this sequence from the overlying clastic sediments probably correspond to a Gilbert-type fan delta.

The Akropotamos deposits are correlated with those in the offshore Prinos-Kavala basin. The Prinos-Kavala basin was tectonically formed during the upper Paleogene by NE-SW and NW-SE faults. Borehole and seismic profile data from the Kavala-Prinos oil field show that the basin's sequence comprises a thick clastic pre-evaporitic sequence, deposited above the metamorphic basement of the Rhodope massif. This is followed by an evaporitic unit, 700 to 1000 m thick, deposited during the late Miocene (Messinian) and consisting of seven to eight anhydrite-marl cycles. Toward the depocenter of the basin, the anhydrite is replaced by halite layers, usually a few meters thick. The sequence is completed by post-evaporitic deposits (average thickness 1800 m) consisting of sands, silts, and clays (Pliocene-present). Thus, the Prinos-Kavala sequence corresponds to the S-SE offshore prolongation of the Strymon basin sequence. The northern Aegean Sea, during the MSC 1st stage, was a peripheral shallow-water basin. In the Pliocene-Pleistocene it subsided rapidly, filled mainly by Gilbert-delta fan turbidites onlapping the underlying evaporitic unit of the Prinos-Kavala basin. The onlapping sediments originated from the same northern continental source area that fed the Strymon basin.

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High potential part of liquefaction-fluidization in man-made strata of reclaimed land around Tokyo bay, central Japan: based on the geological survey on damaged part on the 2011 off the Pacific coast of Tohoku Earthquake

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Terrible liquefaction-fluidization phenomena happened partially, 10-50 m width and 20-100 m length, with subsidence less than 1m heigh on the reclaimed land of northern Tokyo bay at the 2011 off the Pacific coast of Tohoku Earthquake. Large amount of sand and groundwater spouted out in the terrible subsided parts. But there are little subsidence and no jetted sand outside the terrible subsided part.
Continuous box core samples by ACE Liner from surface to 5-8 m depth could be taken at the each 3-5 m lateral length from little subsided part to terrible subsided part on the damaged part. Continuous core samples were taken by triple core tube from surface to 15m depth near the damaged part. Detailed litho-stratigraphy, sedimentary structure, density and hardness of strata were observed on the core samples and large relief peels were taken from the box cores. These data indicate that: (1) The thickness of man-made strata is about 12 m; (2) Man-made strata is composed of Dumped Association (silty sand with grabel), Upper filling Association and Lower filling Association (dense sand). The two filling Associations were made by sand pump method from bottom sediments in the Tokyo bay; and (3) Upper filling Association, 3-6m thick, is composed of silt, medium-coarse sand and shell fragment beds. The association consists of lowermost, lower, middle, upper and uppermost bundle. Uppermost bundle consists of mainly loose-medium sand bed. Upper and lowermost bundle consist of mainly loose-medium sand bed and shell fragment bed. Middle bundle consists of dence-medium sand with shell fragment. Lower bundle consists of very soft silt bed. Liquefaction-fluidization parts at the 2011 earthquake are observed in loose sand beds of mainly upper and lowermost bundle. Thick silt, lower bundle, distribute on little subsided part. On subsided part, total thickness of liquefaction-fluidization part in the upper bundle is thick and very soft mud bed, lower bundle, change laterally to thin down. The above show that those lateral and vertical facies changed part have high potential of liquefaction-fluidization.

A potential Lower–Middle Pleistocene GSSP with detailed lithostratigraphy on tephra, sedimentary environment and magnetostratigraphy along the west Pacific margin: the Chiba section, Central Japan

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The Lower – Middle Pleistocene Kazusa Group, deposited on mainly bathyal – shelf in the Pacific Ocean with many kind of fossils, distributes widely in Boso peninsula. The Kazusa Group exposes continuously along Yoro river, Chiba section, type section of the group. The Kazusa Group consists of Kurotaki Formation (mainly tuffaceous gravelly sandstone), Katsuura F. (mainly alternation of sandstone with slump bed), Namihana F. (mainly siltstone with slump bed), Ohara F. (muddy alternation of sandstone and siltstone), Kiwada F. (muddy alternation of sandstone and siltstone with slump bed), Otadai F. (alternation of sandy alternation and muddy alternation of sandstone and siltstone), Umegase F. (mainly sandy alternation of sandstone and siltstone), Kokumoto F. (alternation of thick siltstone and sandy alternation of sandstone and siltstone), Kakinokidai F. (sandysiltstone with sandstone) and Chonan F. (alternation of thin sandstone and thin siltstone) in ascending order. Total thickness of the Kazusa Group is over 2,000 meters with over 50 marker tephra beds. Trapid depositional rates of 2.0-2.5 m/ky are obtained for the Kazusa Group. Therefore the Chiba section have high potential for international stratotype section.
Kokumoto Formation, about 350 meter thick, is composed of the lowermost part, the lower part, the upper part and the uppermost part in ascending order. The lowermost part, about 60 meter thick, consists of thick siltstone with thin sandstone bed and marker tephra, Ku6 and ku5. The lower part, about 120 meter thick, consists of sandy alternation of sandstone and siltstone with Ku3 tephra. The upper part, about 80 meter thick, consists of thick siltstone with thin sandstone and marker tephra (Byakubi zone (Byk-E, Byk-D, Byk-C, Byk-B and Byk-A), Kos-S2, Kos-S1, Kos-P, Tap-B, Tap-A, Tas-C, Tas-B, Tas-A, Ku2 and Ku1). Especially maker tephra are interbeded every 0.1-7.0 ky in the thick siltstone from Byk-E to Ku2 horizon. The Matuyama–Brunhes boundary is between Byk-C and Byk-B. Uppermost part, about 90 meter thick, consists of sandy alternation of sandstone and siltstone with Ku0.1 tephra.
On the lower part in the upper part of the Kokumoto Formation, thin bioturbated sandstone bed, 1-3cm thick, interbedded in bioturbated thick siltstone every 0.3-3 m. Thin bioturbated sandysiltstone bed, 1-5 cm thick, interbedded in bioturbated thick siltstone every 0.1-0.25 m thick. Sandstone beds , 3-100 cm thick, without biotabation are sometimes interbedded in the thick siltstone. This shows that life activity was about 3 cm depth on the sea bottom. No massive siltstone bed is interbeded in the thick bioturbated siltstone. The thick siltstone have bathyal and sublittoral benthic foraminifera and many bathyal trace fossils. Grain size distribution in the siltstone have bimodal grain group. Main grain group is composed of fine silt and sub group consists of very fine sand. These characteristics show that the sedimentary environment of the thick siltstone is hemipelagic in deep sea and sand flow often influx, namely deep sea slope.

Distribution and Paleobiogeography of Devonian Corals of Iran

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The Devonian platform of Iran consists of limestones rich in fossils, the main part of which is composed of solitary and compound rugose corals. The geographical distribution of Devonian corals in Iran was studied. These corals are Rugosa and Tabulata associated with brachiopods, conodonts, stromatoporids, crinoids and mollusks. The age of the corals range from Middle (Givetian) to Late Devonian (Famennian).

Up to 29 genera of rugose and tabulate corals have been distinguished. The coral assemblages of the Iranian Devonian platform have been compared with the corals of the same age of the other provinces of the world.

The Iranian assemblages show higher similarity with Western Europa with 25, Australia with 20, and North America with 19 common genera.

Skeleton found at Tehran alluvium Formation and analysis of its possible age, Iran

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A female skeleton has been found in a construction site of the urban water and waste water system located around Tehran Grand Bazaar in Molavi Street, one of the southern streets of the Iranian capital. This skeleton occurs in the Tehran alluvium Formation.
The Tehran alluvium Formation includes younger alluvial fans coming from southern pediments of the Alborz Mountains, continue to the south and spread over parts of Tehran city, which is been built on it. In general, this formation is created by alluvial and stream sedimentation. Its thickness is up to 50 m. The sediments are composed of gravel, sand, silt and boulders. Stratification has been seen in unconsolidated sediments. The layers of this formation are horizontally arranged and have not distorted by tectonic movements. The Tehran alluvium Formation overlies the Kahrizak Formation (1-5 m of thickness).
The method of burying of the discovered skeleton, the position of the sedimentary layers and archeological materials found in the site mentioned above, show that the skeleton dates back to 7000 years.

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New geochemical constraints on the Paleocene-Eocene thermal maximum: Dababiya GSSP, Egypt

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The Paleocene-Eocene Thermal Maximum (PETM) shows an extraordinary drop in the $\delta^{13}C$ of carbonate and organic matter across the globe, suggesting massive release of ^{13}C-depleted carbon dioxide into the ocean and atmosphere over a very short time interval (probably <20 ky). We report a geochemical and mineralogical study of 106 samples spanning the most expanded PETM at the Dababiya Global Stratotype Standard section and Point (GSSP) near Luxor, Egypt. The field and laboratory observations reveal that the deposition occurred in a submarine channel extended laterally about 200 m with the deepest part (~0.88 m) at the designated GSSP, although all bio-zones are present. At the GSSP, the Paleocene-Eocene boundary (PEB) coincides therefore with a sequence boundary (SB) and erosional surface, which can be traced over hundreds of km. $\delta^{13}C_{Carb}$ and $\delta^{13}C_{org}$ profiles show gradual decrease during the latest Paleocene reaching the CIE-minimum above the SB. This interval represents the initiation of the PETM, and may be explained by the onset of the North Atlantic volcanism activity. The CIE- minimum in $\delta^{13}C_{Carb}$ coincides with the SB (base of bed 1), but $\delta^{13}C_{org}$ minimum values are reached higher up in the top third of bed 2, which marks the onset of the recovery. The delayed recovery in $\delta^{13}C_{org}$ may be due to variable rate of carbon cycle (e.g. continental silicate weathering, increased rate of organic carbon burial, and increased ocean productivity). Above the middle of bed 3, $\delta^{13}C_{Carb}$ and $\delta^{13}C_{org}$ and the bulk rock composition return to background values observed below the PETM. A persistent shift in $\delta^{15}N_{org}$ values to near zero reflects a gradual increase in bacterial activity. High Ti, K and Zr and low Si contents at the PEB coincide with increased kaolinite contents, which suggests intense chemical weathering under more humid conditions at the PETM onset. Two negative Ce-anomalies indicate intervals of anoxic conditions during the lower and middle PETM (base and top of zone E1). The first anoxic event is represented by a negative Ce-anomaly, high V/C rand V/V+Ni ratios, negative Mn* and an abundance of idiomorphic pyrite crystals that indicate anoxic to euxinic conditions. The second anoxic event (middle PETM) is marked by high U, Mo, V, Fe and abundant small sized (2–5 µm) pyrite framboids, increased Cu, Ni, and Cd at the same level suggesting anoxic conditions linked to high surface water productivity. Above this interval, oxic conditions returned as indicated by the precipitation of phosphorus and barium. These data reveal an expanded PETM interval marked by intense weathering as a crucial parameter during the recovery phase.

Multidisciplinary approach for the identification of Middle Devonian biotic crisis in the Carnic Alps: results of the Project FWF P23775-B17

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The FWF (The Austrian Science Fund) Project P23775-B17 focuses on the Middle Devonian climate perturbation and their effects on the tropical coral communities. In order to identify intervals related to climate change, sections of three different paleoenvironmental settings (shallow water platform, distal slope and pelagic) in the Carnic Alps (Austria-Italy) were investigated in detail. Methods used include microfacies analysis, conodont biostratigraphy and the application of geochemistry (carbon and oxygen isotopes, TOC and sulfur content, major and trace elements) and geophysics (magnetic susceptibility and gamma-ray spectrometry).

The shallow water facies of the Kellergrat Reef Limestone (Givetian - ?Frasnian) exposed between Forcella Monumenz and Val di Collina (abandoned quarry) which is located at trail #149 to the Rifugio Marinelli (Italy) is characterized by the massive limestone composed of the fore-reef breccia. Within the Kellergrat Reef Limestone of the abandoned quarry abundant reef organisms are found. The Hoher Trieb Formation (Eifelian - Frasnian) of Zuc di Malaseit Basso section (Mt. Zermula, Lanza, Italy) consists of gray to dark gray platy limestone beds with the intercalation of black shale and chert, which are accumulated at the distal slop. The Valentin Limestone (Eifelian - Givetian) in the Wolayer Glacier section (Central Carnic Alps, Austria) is characterized by highly condensed but rhythmically deposited sediments, which show pelagic facies. Except for one thin layer (70a middle) below the Eifelian - Givetian boundary, which shows fine grained peloidal packstone with rare tentaculites, the dominant facies is composed of tentaculitid wackestone.

Within the *kockelianus – hemiansatus* conodont zones of the Hoher Trieb Formation, three remarkable depressions of $\delta^{13}C_{carb}$, which correspond with increasing values of TOC and sulfur are observed. The second depression of $\delta^{13}C_{carb}$ between the beds ZMB23 to ZMB20 starts with the largest negative shift of carbon isotope values in the section, ranging from 2.2 to 0.1 ‰. Within these beds, a positive spike of MS value is observed just after a minor negative shift. Such a minor negative shift is also found in the Th/U values (GRS) of the same interval. We considered that the shifts observed in the carbon isotope, TOC and sulfur content, MS and GRS in beds ZMB23 to ZMB20 are related to paleoenvironmental changes which were associated with the late Eifelian Kačák Event.

In the Valentin Limestone, a pronounced negative excursion of MS from 43.39 to 27.71 (10^{-9} [$m^3.kg^{-1}$]) is observed between beds 70a base and 70 top across the layer 70a middle. TOC and sulfur content show increased values within the bed 70a. Although $\delta^{13}C_{carb}$ values show only a slight negative shift across the layer 70a middle, it is suggested that the layer 70a middle is associated with the Kačák Event.

The corals found in the Hoher Trieb Formation and the Valentin Limestone are assigned to the re-deposited materials derived from the Eifelian or Givetian shallow water limestone. In the Carnic Alps, the Eifelian and Givetian shallow water deposits are known in the Spinotti Limestone, *Amphipora* Limestone and the Kellergrat Limestone. The succession from the Spinotti Limestone to the Kellergrat Limestone shows the change in sediments which was deposited in peritidal setting that was followed by dark bituminous limestone rich in *Amphipora* and later succeeded by a well-developed reef communities. The Spinotti and Kellergrat limestones yields diverse frame building organisms like tabulate, rugose corals and stromatoporoids, whereas the *Amphipora* Limestone yields rugose corals predominately of *Dendrostella*. The change in the sediments and in the coral community might link to the changing environmental conditions which were resulted from the Middle Devonian climate perturbations.

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The Triassic Marine Fauna of Northern Turkey

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The Pontids of Northern Turkey encompass a Triassic sequence overlying continuous Ordovician to Carboniferous sediments, deformed by the Late Carboniferous Variscan orogeny. The Pontids were amalgamated during the Cretaceous and consist of the Strandja, Istanbul and Sakarya terranes, the Istanbul Unit, along the south-western Black Sea coast, having a Precambrian crystalline basement. The Central Pontid basement consists of pre–Permian low-grade meta-clastic rocks with latest Permian – Early Carboniferous (305–290 Ma) granitoid intrusions. Hallstatt-type hemi-pelagic limestone olistoliths of Anisian – Carnian (Middle – Late Triassic) conodont and foraminifer ages (Okay et al., 2015), float in deformed siliciclastic turbidites that yield the Norian (Late Triassic) *Monotis salinaria,* a bivalve also found in the Tauric series of Crimea. The Istanbul Unit, back in Triassic times, was part of the northernmost Tethys branch, edging Eurasia. It is separated from the Sakarya Zone, South of it, by the Intra–Pontid suture, and from the Strandja Massif, North of it, by the Western Black Sea right–lateral strike–slip Fault. The late Early Anisian Bithynian type section in the Istanbul Zone Kocaeli Peninsula thus represents a part of the North Tethyan Intra–Pontid Ocean, in contrast to the subjacent Earliest Anisian Aegean type section, chosen in the island of Chios that, together with the Karaburun Peninsula, belongs to the South Tethyan Taurid Block. The well dated "Kocaeli Triassic" covers transgressively a Palaeozoic basement. Terrestrial at first, the sediments become increasingly transgressive, ending with regressive terms. The Triassic Kocaeli conodonts show faunal affinity with Bulgaria. This study encompasses Triassic marine faunas consisting of foraminifers, radiolaria, ostracods, crinoids, holothurian sclerites, scolecodonts, radulae, conodonts, fish teeth and plates, shark teeth, and Ichthyosaurus pelvic remains, collected South of Gebze (Kocaeli Peninsula) and in the Central Pontids Kayabaşı Limestone, both stratigraphical important.

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Triassic Climatic - Eustatic Links in Conodont Evolution

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The phylogeny and distribution of Triassic conodonts reveals aspects of their natural history. Conodonts incorporate the morphologic riposte to temperature as well as to eustatic cycles. Speciation, radiation and extinction are not fortuitous and evolution uses heterochrony (progenesis and neoteny) in response to stress generating events. Proteromorphosis (reappearance of ancestral morphs) and paedomorphosis (retention of juvenile traits) is a reaction to sublethal environmental stress. Often follows radiation of fully developed forms, in the recovery stage after extinction, timely matching transgressions. Evolutionary retrogradation (neoteny) during eustatic high stands often precedes extinction. The 51 MA long Triassic Period consists for the Induan – Olenekian first 5 MA of a post Permian extinction recovery rate of 13 speciations/MA. The next 10 MA of the Anisian – Ladinian (Dinarian) saw a drop in speciations to 8 S/MA, but during the remaining Carnian – Rhaetian 36 MA, the rate was down to below 2 S/MA, until the end Triassic final extinction. The dozen Permian survivors got extinct during the Induan. Gondolellidae saw a revival with the *Neospathodus* – *Chiosella* lineage, from which emerged, in the Aegean (Early Anisian), the *Paragondolella - Misikella* lineage that dominated the Triassic scene for the next 45 MA until total conodont extinction. Gladigondolellidae populated, from Late Spathian until Mid–Carnian, the pelagic environments. By Late Ladinian, *Neogondolella* became extinct, while *Paragondolella* was gradually replaced by *Metapolygnathus* during Julian times. The evolutionary trends of free blade, platform adornment, widening of the posterior end and furcation of the basal cavity, initiated sporadically during Late Ladinian, became the norm, reaching their peak in Early Norian *Ancyrogondolella*. Strongly ornamented *Mazzaella* and *Carnepigondolella* marked respectively the Julian Pluvial Event and the Late Tuvalian LST (Lowstand Systems Tract). The atavistic (neotenic) *Norigondolella* came in around the Tuvalian - Lacian boundary and a generalised posterior acumination set in with Alaunian (Middle Norian) *Mockina.* Catastrophes of various origin, such as global LST events and temperature rises, precipitated retrogradation with Dienerian *Neospathodus,* Pelsonian *Nicoraella*, Illyrian, Cordevolian *Mosherella*, Tuvalian *Neocavitella* and Sevatian – Rhaetian *Misikella.* Local Bithynian *Kamuellerella-Ketinella-Gedikella* affected the Istanbul Zone and Late Anisian *Pseudofurnishius priscus - shagami* the Gondwanian shelf. Summing up, climatic – eustatic events linked Triassic Conodont evolution, in unison with a stepwise decrease in speciation.

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The Extinction of *Chiloguembelina cubensis* in the Pacific Ocean (Sites U1334 and 1237): Implications for Defining the base of the Chattian

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Chiloguembelina is a distinctive biserial planktonic foraminifera genus ranging in the Eocene and Oligocene. The extinction of *Chiloguembelina cubensis* has been proposed as a marker for the base of the Chattian (~28 Ma) and thus the early/late Oligocene boundary. However, the event remains controversial, as some authors have found a well-defined bioevent, while others have found a decline in abundance with continuation of *C. cubensis* into the late Oligocene.

We conducted morphometric and quantitative biostratigraphic studies at two sites in the Pacific Ocean to investigate these bioevents. *Chiloguembelina cubensis* is a common and consistent component of early Oligocene planktonic foraminifera assemblages at Ocean Drilling Program Leg 202 Site 1237 (south-east Pacific) and Integrated Ocean Drilling Program Expedition 320 Site U1334 (equatorial Pacific). The two sites show extremely contrasting results with an abrupt extinction in magnetic polarity Chron C10n.1n at Site 1237. However, Site U1334 indicates peak abundances of this species in the upper Oligocene in Chron 9n. Therefore the biostratigraphic utility of the species in defining the boundary remains unclear, as the findings at Site U1334 question the legitimacy of the biostratigraphic utility of *Chiloguembelina cubensis* as a reliable boundary marker for the early/late Oligocene boundary.

Morphometric analysis of specimen size at the two sites shows a markedly smaller test size at Site 1237 compared with Site U1334. The reduced test size may be linked to surface water productivity. Site 1237 was positioned in an oligotrophic gyre, in comparison with Site U1334 which is positioned within the equatorial upwelling belt. This therefore demonstrates that nutrient availability is an important control on *C. cubensis* test size.

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The New Magnetostratigraphic Framework for the Lower Miocene (Burdigalian) in the North Alpine Foreland Basin

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There is still a considerable controversy about the Oligocene-Miocene chronostratigraphic correlation within the Paratethys domain. Especially in the German and Swiss Molasse basins a robust correlation framework is missing for the late Early Miocene, represented by the lithostratigraphic units of the Upper Marine Molasse (OMM), Upper Brackish Molasse (Kirchberg and Grimmelfingen Fm) and (older) Upper Freshwater Molasse (OSM). Even in several recent papers there is a misfit of about 1 Ma in the chronostratigraphic interpretations between the Swiss and German Molasse Basins concerning the base of the Upper Freshwater Molasse. Despite the existence of a huge number of biostratigraphic studies, magnetostratigraphic constraints are rare. In 2013, Reichenbacher et al. proposed an alternative correlation of the Upper Brackish and Upper Freshwater Molasse in the North Alpine Foreland Basin, which would solve the present controversy. This study was based on an integrated magneto-biostratigraphic study on four sections and three boreholes. However, the data coverage, especially of the three drill cores, was not sufficient to unambiguously justify the modification in the chronostratigraphy. We enlarged the magnetostratigraphic framework by resampling these drill cores in high resolution and sampled eight additional cores. We obtained magnetostratigraphic results from a total of 530 individual samples, which were analysed using alternating field and thermal demagnetization techniques. Additionally, we performed detailed rock magnetic analysis and identified magnetite as the main carrier of the magnetic remanence. Less abundant hematite and greigite are present in the studied material. Basically, we confirmed the results of Reichenbacher et. al (2013), where the Upper Freshwater Molasse (OSM) is almost entirely of normal polarity and the underlying lower Kirchberg Fm and the upper part of the Grimmelfingen Fm are of reverse polarity. However, we found evidence for an additional short normal polarity interval at the top of the Grimmelfingen Fm. Based on these results and adding biostratigraphic arguments we conclude that the Kirchberg Fm represent the rather short reverse polarity interval C5Cn.2r and the main hiatus at the base of the Grimmelfingen Fm is located within chron C5Cr. By this, the beginning of the German and Swiss OSM are perfectly coeval and start at about 16.5 Ma.

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Early to middle Miocene integrated stratigraphy at IODP Site U1335 (eastern equatorial Pacific)

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The lower to middle Miocene sedimentary archive at Integrated Ocean Drilling Program (IODP) Site U1335 (PEAT Expedition 320/321) enables us to directly compare orbitally-tuned isotope and geomagnetic chronologies over an interval of the geomagnetic polarity time scale (GPTS) still requiring refinements. IODP Site U1335 recovered a continuous, carbonate-rich lower to middle Miocene (20 to 13 Ma) sedimentary succession, deposited within the narrow zone of high-productivity upwelling in the eastern equatorial Pacific Ocean. We generated high-resolution (~5-10 kyr) orbitally-tuned benthic stable oxygen ($\delta^{18}O$) and carbon ($\delta^{13}C$) isotope records, spanning the onset and development of the Miocene Climatic Optimum (MCO) and the transition to a colder climate mode after 13.8 Ma. Between 18 and 15 Ma, our orbitally-tuned isotope records show good agreement with the succession of geomagnetic polarity chrons identified at IODP Site U1335 (Channell et al., 2013). Astronomically calibrated ages for the onsets of polarity chrons C5Dr.2r to C5Cn.1n are close to Neogene time scale (ATNTS2012) ages, except for a few exceptions that are ~100-200 kyr younger. The age assignments of chrons at IODP Site U1335 is supported by the good match of XRF-scanner data between Sites U1335 and U1336 and the placement of polarity chrons identified at IODP Site U1336 by Ohneiser et al. (2013). Further refinements in our age model, as well as correlation to other records and seafloor spreading rates, will help to constrain the timing of middle Miocene climatic events and assess the implications of different tuning approaches.

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Kotlinian biogeocoenotic crisis and the final stage of the Ediacaran System

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The Kotlinian Regional Stage of the East European Platform is suggested as a candidate for the final stage of the Ediacaran System. It was originally proposed based on the stratigraphic distribution of carbonaceous compression micro- and macrofossils, but was later redefined as a stratigraphic interval bracketed between the last occurrence of Ediacara-type fossil assemblage in wave- and current agitated shoreface and prodelta settings and the first appearance of trace fossils *Treptichnus pedum*. The Kotlinian Regional Stage contains low-diversity fossil assemblages confined primarily to high-energy distributary channel depositional systems (the Nama-type fossil assemblage). Wave- and current-agitated shoreface and prodelta, as well as adjacent low-energy inner shelf depositional systems were represented by palaeopascichnids and frondomorphs. Ichnocoenoses of the wave- and current-agitated shoreface and prodelta settings, to the contrary, demonstrate an increase in size and behavioral diversity of trace fossils. Volcanic zircons near the base of the Kotlinian Regional Stage in a section along the Zimnyaya Zolotitsa River, Southeast White Sea area yielded a U–Pb zircon date of 550.2 ± 4.6 Ma (Iglesia Llanos et al., 2005). The age of the lower boundary of the Kotlinian Regional Stage, therefore, can be estimated as ~550 Ma.

The lower boundary of the Kotlinian Regional Stage is defined by the onset of the Kotlinian global biogeocoenotic crisis, the first in a series of events leading to the Early Tommotian 'explosion' in morphological disparity and ecological complexity. The Kotlinian Crisis is characterised by a sudden diversity drop of soft-bodied organisms, followed by the advent of biologically controlled mineralisation and reef-building and burrowing activity in shoreface depositional systems. It primarily affected wave- and current-agitated shoreface deposits wiping out dickinsoniomorphs, tribrachiomorphs and bilateralomorphs in Ediacara-type communities. Contemporaneous low-energy inner shelf settings suffered from the loss of rangeomorphs, whereas frondomorphs remained unaffected. High-energy distributary channel systems served as refugia for Nama-type communities that survived until the end of the Ediacaran. The Kuibis and Schwartzrand subgroups (Namibia), the Kanilovka Group (Ukraine), the Chapel Island Formation (Newfoundland), the Blueflower Formation (NW Canada), the Dengying Formation (S China), the Turkut and Syhargalakh formations (Siberia), and the Asha Group (S Urals) each offers insight into the history of the Kotlinian Crisis.

The Asha Group is dominated by laminated shales and thin siltstone–sandstone alternations interpreted as a prograding low-energy inner shelf depositional system. The succession includes several thick sharp-based sandstone bodies comprising fine- to medium-grained, planar-laminated, hummocky-, convolute- and wave-bedded, planar and trough cross-bedded sandstones, occasionally pebble- to boulder conglomerates, regarded as tidal, deltaic and shoreface depositios. Although palaeoecological and taphonomic context of the Asha Group is favourable for the Ediacara-type biofacies, the associated fossil assemblages are depauperate and consist of frondomorph holdfasts, palaeopascichnids, microbial colonies, arumberiamorph structures, as well as lithified microbial substrates. In terms of fidelity and fossil completeness, preservation of Ediacaran fossils in the Asha Group is by no means inferior to that seen in other Ediacaran macrofossil localities. The low biodiversity of Ediacaran macrofossils is attributed to a relatively young Ediacaran age of the Asha Group (U–Pb zircon date of 547.6 ± 3.8 Ma from an ash bed in the lower part). The uppermost part of the Asha Group has yielded bilobed burrows with a backfill structure suggesting an affinity with the ichnogenus *Didymaulichnus* from the Ediacaran–Cambrian boundary.

Palaeopascichnids were not significantly affected by the extinction of dickinsoniomorphs, tribrachiomorphs, and bilateralomorphs. The observed dominance and numerical abundance of palaeopascichnids in the Kanilovka Group in Podolia and in the Asha Group in the South Urals cannot be coincidental and suggest a marked degree of resilience of this group of Ediacaran macroorganisms in the changing ecosystem. The widespread occurrence of palaeopascichnids during the Kotlinian Crisis resembles an opportunistic ecological strategy in the aftermath of an extinction event.

Palaeoceanographic influence on the Late Albian-Maastrichtian planktonic foraminiferal assemblages of the Crimea-Caucasus area and Russian Platform

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For the Cretaceous reconstructions we suggest to use the extinction of planktonic foraminifers (PF) which lived in the water column like their modern representatives and were controlled by similar environmental factors: water temperature, water-mass structure, amount of nutrients, and stability or instability of oceanographic conditions.
The climate during the Cretaceous had been globally warm, although from low to high latitudes it was less contrasted than in modern oceans. During the important Cretaceous radiations PF increased in size and acquired very special morphologies. PF evolved rapidly in some intervals (punctualism), slower in others (gradualism), allowing to construct a biostratigraphic scale at high resolution especially at low latitudes (Crimea-Caucasus area). Biostratigraphic scales for high latitudes have very low resolution (Russian Platform).
The early PF assemblages consisted of small-sized opportunistic taxa (*r*-strategists); *r/k* intermediate taxa started to evolve in the Aptian, while specialized, morphologically complex keeled taxa evolved in the late Albian and persisted, although with different genera, until the end of the Cretaceous (*k*-strategists). These general evolutionary trends were interrupted in the Late Cretaceous by one minor event at the C/T boundary (rotaliporids extinction). The other feature, obvious for this interval, is the prevalence of non-keeled small forms belonging to *Whiteinella*, *Hedbergella, Schackoina* and *Heterohelix (r*-strategists). The perforate, elongated chambers and tubulspinines schakoinids may represent the best survivorship tool to achieve better oxygen and nutrient uptake (Coccioni et al., 2007). The next turnover coincides with the Santonian-Campanian boundary when replacement of marginotruncanids by globotruncanids was related to a cooling episode (Petrizzo, 2002; Huber et al., 2002).
These events were parallel to palaeoenvironmental changes. All these changes are clearly recorded in the Crimea-Caucasus area. Low taxonomic diversity of planktonic foraminifers in the Russian Platform's epicontinental basins does not allow them to date exactly. However, the cold boreal water influence is recognized along the north-eastern margin of the Russian Platform (Baraboshkin et al., 2002; Naidin et al., 2007). Late Maastrichtian warming is also well recognized.
PF diversity decreases from the tropics to high latitudes, from the Crimea-Caucasus area to the Russian Platform sedimentary basins. Species disappearance toward high latitudes affects the larger-sized, more-ornamented *k*-strategists. All *k*-strategists taxa are practically absent in the Russian Platform. Intermediate morphotypes occupy intermediate habitats, the most ornamented ones are closer to the tropics and subtropics (Ukrainian and Polish-Lithuanian depressions). The occurrence of *k* or *k/r*-strategists at higher latitudes indicates the expansion of warmer conditions at a given time, for example, "elegans transgression" in the late Maastrichtian on the Russian Platform. Increases in diversity, size and morphological complexity through time identify an increasing number of trophic niches within the mixed layer and the onset of at least a weak thermocline.

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Inoceramid and foraminiferal record and biozonation of the Turonian and Coniacian (Upper Cretaceous) of the Mangyshlak Mts., western Kazakchstan

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The Mangyshlak Mountains, western Kazakhstan, is one of the key area for inoceramid and foraminiferal records of the Turonian and Coniacian (Upper Cretaceous) of the south-eastern margin of the Russian Platform. The Turonian-Coniacian succession in Mangyshlak is distinctly two-fold in its facies development. The lower, sandy siliciclastic unit of the Early and earliest Middle Turonian; and the upper, carbonate unit, of the Late Turonian-Coniacian. The units contact along a distinct unconformity, developed usually as a composite hardground with phosphatic horizon and associated stratigraphic gaps (short sea level chamges).

The Turonian and Coniacian of the Mangyshlak Mts. yielded rich and, in intervals, relatively complete inoceramid record. The faunas and their revealed succession correspond to what is known from central and eastern Europe, allowing the zonation as worked out in the latter areas, to be applied in virtually identical form (Walaszczyk, Peryt, 1989; Walaszczyk et al., 1999; Walaszczyk et al., 2010).

The (PF) occur throughout the succession, however, with remarkable bed-to-bed fluctuations in quantity and taxonomic richness. They are rare to absent in the Cenomanian–Lower Turonian siliciclastics; abundant across the Turonian–Coniacian boundary interval [with distinct increase of the P/B (planktonic/benthic) ratio]; and common in the rest of the interval studied. The first occurrences of PF and/or benthic (BF) taxa are referred herein to as the foraminiferal events. All recognized events correspond well to chronostratigraphic boundaries as defined by inoceramids.

(1) *Whiteinella archaeocretacea* (PF) event coincides with the *plenus* event, right below the Cenomanian-Turonian boundary. It is documented in a single section.

(2) *Dicarinalla elata* (PF) event is similarly located at the Cenomanian-Lower Turonian boundary, and documented in a single section.

(3) *Marginotruncana pseudolinneiana* (PF) and *Gavelinella moniliformis* (BF) events are dated for the late Middle Turonian.

(4) *Marginotruncana coronata* event (PF) coincides with the *Mytiloides striatoconcentricus* event of the early Late Turonian.

(5) *Archaeoglobigerina cretacea* (PF) and *Gavelinella kelleri/Stensioeina emsherica* (BF) events are associated with the earliest Coniacian *Cremnoceramus waltersdorfensis* event.

(6) *Concavatotruncana concavata* event (PF) is dated for the middle Early Coniacian *Cremnoceramus deformis deformis* event.

(5) *Archaeoglobigerina blowi* (PF) and *Gavelinella thalmanni/Stensioeina emsherica* (BF) events are of Middle Coniacian age (at the level of the first appearance of *Volviceramus involutus*).

Two peaks in P/B ratio are recognized in the Mangyshlak succession. The lower peak, which coincides with the *Whiteinalla* event, is dominated by *Hedbergella* and *Whiteinella* accounting for 90–92% of the population. The associated benthos, poor and monotonous (Kopaevich, 1996). The higher peak coincides with the Turonian-Coniacian boundary interval. In this peak, PF account for only 55–75% of the population, and moreover, associated BFare taxonomically diverse.

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Pedostratigraphy of pre-Quaternary/Quaternary red clays from Central Europe based on geochemical, clay mineralogical proxies and fossil assemblages

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Geochemical and mineralogical studies of paleosols provide essential information for paleoclimatic and paleoenvironmental interpretation of continental deposits and can present a high-resolution proxy for paleoclimate. Consequently, paleosols can help to interpret the history of sediment deposition and the autogenic and allogenic processes that influenced a sedimentary basin. Paleosols are also helpful in stratigraphic studies, including sequence stratigraphic analyses. They are used for stratigraphic correlations at the local and basinal scale, and some workers have calculated sediment accumulation rates based on the degree of paleosol development. The horizons of paleosols are widely used as key horizons for the stratigraphic subdivision of continental sedimentary series.

The reliability of usage of paleopedologic data has increased, especially with the development of methods of absolute and relative dating: radiocarbon, luminescent, paleomagnetic, amino acid, and paleontological (palynological and paleofaunistic) with geochemical and clay mineralogical data. The use of paleosols as components of the stratigraphic record has increased, especially after paleosols morphotypical features of different ages were studied. Paleosols in various sediment sections were once compound units of soil covers of different ages.

Results from geochemical climofunctions applied to Upper Pliocene–Lower Pleistocene red clays and paleosols located in East-Central Europe (Austria, Slovakia, Hungary, Serbia and Romania) together with other geochemical data, clay mineralogy and fossil record, indicate that there were three major periods of their development.

1. The older type red clay/paleosol (age ~4.2–3.2 Ma) is red kaolinitic clay containing typically disordered kaolinite, mixed-layer smectite/kaolinite, smectite and little gibbsite. It was formed in the local subaerial weathering crust in warm, humid, subtropical or monsoon climate.
2. The younger type (age ~3.2–2.5 Ma) contains red (or “reddish”) clay beds. It contains relatively fresh material (illite, chlorite), the weathering products are predominantly smectite and goethite formed under warm and drier climate in environmental conditions of savannah and steppe or forest steppe.
3. The basal red paleosol layer of the loess-paleosol series (age ~1.0–0.5 Ma) contain similar material as the 2nd type. The slightly but significantly lesser degree of weathering (more illite and chlorite, less smectite) indicates cooling of the climate.

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Lithotectonic Units as Classification Element in Lithostratigraphy at the Geological Survey of Austria

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Lithostratigraphic (as well as lithodemic and lithogenetic) units within legends of geological maps (as well as sections, stratigraphic charts, 3D-Models, etc.) can be classified by employing many different categories, like stratigraphic age, rock type, occurrence in particular geographical regions, tectonic units or sedimentary cycles. Generally, a mixture of such categories can be observed in most geological/lithostratigraphical maps, reflecting the theoretical framework, concepts and models applied by the authors. Such mixtures of categories appear unproblematic, as long as those maps and their legends remain to be used in printed formats. However problems are quickly arising, when geologic information of maps and legends is to be transferred into (GIS-)databases. This is especially true in areas or countries with a complicated tectonic setting. Therefore a group of geologists at the Geological Survey of Austria developed a hierarchic classification scheme for the “Lithotectonic Units” of Austria (and the relevant neighborhood, in the sense of this very topic). The uppermost hierarchical level discriminates between the “Alpine Orogen”, the “Adriatic Plate”, the “Eurasian Plate”, and “Upper Pliocene to Quaternary Sediments”. The latter item demonstrates, that by definition also certain depositional cycles are regarded as “Lithotectonic Units“, which is also the case for syn- and postorogenic igneous rock-bodies. The “Alpine Orogen”, for example, includes twelfe “Superunits”, in particular the “Internal Western Carpathians”, “South Alpine Superunit”, “Meliatic Superunit”, “Austroalpine Superunit”, “Intramontane basins“, “Allochthonous Molasse”, “Penninic Superunit”, “Sub Penninic Superunit”, “Parautochthonous Molasse”, “External Massifs”, “Helvetic Superunit”, and “Ceonozoic igeneus rocks in the Alpine Orogen”. All these concepts and terms are administrated in an Online-Thesaurus of the Geological Survey of Austria, using the SKOS-RDF ontology data model for machine-readability and semantic web technology (Linked Open Data) (http://resource.geolba.ac.at/). Huge efforts have already been invested to visualise the spatial representation of all defined lithotectonic units, stored and structured in a GIS dataset, based on a topographic map of the scale 1:200.000. The multilayer structure of this GIS model allows to display the respective lithotectonic units of all hierarchic levels in variable combinations. Further efforts aim to implement also lithostratigraphic, lithodemic and lithogenetic units successively into the GIS dataset. In addition, for the legends of printed geological maps of the Geological Survey of Austria the concept of “Lithotectonic units” is used as the basic classification scheme since several years. However, for reasons of better readability not all hierarchical levels of the tectonic GIS dataset structure are necessarily reflected in the headline-hierarchy of the printed geological maps.

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The Upper Jurassic–lowermost Cretaceous biostratigraphy and facial development of the pelagic limestones of the Niedzica Succession (Pieniny Klippen Belt) in Poland

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The Pieniny Klippen Belt (PKB) is situated at the boundary between Outer (Flysch) Carpathians and Inner Carpathians, forming strongly tectonized zone about 600 km long (from Vienna to the West up to Romania to the East) and 1-20 km wide, giving the present-day melange character of the PKB, where individual tectonic units are hard to distinguish. Palinspastic reconstruction of the PKB Basin indicates occurrence of submarine ridge (so-called Czorsztyn Ridge) during the whole Jurassic and Cretaceous times, which subdivided the Pieniny and Magura basins within the Carpathian part of the northernmost western Tethyan Ocean. Its SW-NE orientation is interpreted by means of palaeomagnetic data and relationship of sedimentary sequences/successions. The basins divided by the Czorsztyn Ridge were dominated by a pelagic type of sedimentation. The shallowest zone is the so-called Czorsztyn Succession, which primary occupied SE slope of the Czorsztyn Ridge. The transitional, deeper sequences, which primary occupied slope between deepest basinal units and the Czorsztyn Ridge are known as Niedzica and Czertezik successions, while the deepest part of the PKB Basin have been represented by the so-called Branisko and Pieniny successions, which are very well documented by deep-water Jurassic–Early Cretaceous deposits (radiolarites and pelagic *Maiolica*-type cherty limestones). The origin of the Czorsztyn Ridge was connected with Early Bajocian post-rift geotectonic reorganization of the western Tethys (effect of Meso-Cimmerian vertical movements) which a little bit later subsided and simultaneously originated of sedimentation (since latest Bajocian) of red nodular *Ammonitico Rosso*-type limestones. In the same time first episode of radiolarite sedimentation took place in the axial, basinal sequences. This episode marked beginning of the great facial differentiation between shallowest and deepest successions. The main phase of this facial differentiation involving, among the others, mixed siliceous-carbonate sedimentation took place later, mainly during Oxfordian times. Oxfordian radiolarites are typical for transitional (Niedzica and Czertezik) successions and strictly basinal parts of the basin (Branisko and Pieniny successions). In the Niedzica Succession of the PKB the Upper Jurassic–earliest Cretaceous (Kimmeridgian–Berriasian) carbonates are represented by two types of pelagic limestones: red nodular *Ammonitico Rosso*-type limestones (Kimmeridgian–Tithonian) and white-creamy micritic *Calpionella*-bearing limestones (Berriasian) (in local nomenclature so-called Czorsztyn Limestone Formation and Dursztyn Limestones Formation – respectively). By reason of lack of macrofossils (sporadic, indeterminable ammonites) the biostratigraphy of these units is based on micropaleontological investigations. Numerous samples have been taken bed by bed from three outcrops of the Jurassic–Cretaceous transition of this succession (Niedzica-Podmajerz, Czajakowa Skała and Zaskalskie-Bodnarówka) and were analyzed micropaleontologicaly/microfacialy. A rich stomiospherids (e.g., *Carpistomiosphaera borzai*, *Colomisphaera carpathica*, *C. fortis*, *Stomiosphaera moluccana*, *Parastomiosphaera malmica*) within red nodular limestones documented Borzai Zone of the Late Kimmeridgian and Moluccana, Malmica and Carpathica-Cieszynica zones of the Tithonian, respectively. On the other hand, in the overlying limestones calpionellids are very rich (mainly *Calpionella alpina*, *C. elliptica*, *Tintinnopsella carpathica* and *Calpionellopsis simplex*) which documented Calpionella and Calpionellopsis zones of the Berriasian in age. Such results indicate that boundary between Kimmeridgian and Tithonian occur within lower/middle (it depends on section) *Ammonitico Rosso*-type limestones and Tithonian/Berriasian between this limestones and *Calpionella*-bearing limestones. Generally, from microfacies point of view, the Kimmeridgian biomicritic and *Globochaete*-*Saccocoma*/*Saccocoma* microfacies are changed by *Saccocoma*/*Globochaetae* of the Tithonian microfacies and calpionellid-*Globuligerina* of the Berriasian one.

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Geological events of Pleistocene and fossil small mammals: unite time and place – index-sections

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Geohistorical significant events occurred in the Quaternary. They have left traces in sedimentary rocks and determine the nature of landscapes of south of eastern Europe. The events include the stages of soil formation, accumulation of glacial deposits, formation of sediments of marine transgressive-regressive cycles, inversions of the geomagnetic field, polarity subzones, etc. In some cases in these sediments the remains of small mammals are found. This allows correlating the landmark events of the Pleistocene with complexes of small mammals and the level of evolutionary development of its separate elements – orthostratigraphic species - and contributes to the direct correlation of continental and marine sediments. Therefore it is necessary to allocate sections in which the isochronism of two constituents – geological event and fauna - are represented in the sediments. We propose to call of these sections – index-section.

An index-section is a section - either unitary or duple - in which the rocks with diagnostic remains of orthostratigraphic fossils reflect the geological landmark event of the history of the region. The name of the index-section is given by the type of sedimentary rock or its particular physical properties, for example, the index-section of limnic-marine sediments (Chauda) or the index-section of rocks with magnetic characteristics (Korotoyak).

Index-sections of loess-soil deposits. Arapovichi: Vitashev (Bryansk) paleosol (24-32 ka, *Dicrostonyx* aff. *gulielmi*, *Lagurus lagurus, M. gregalis*). Index-sections Gadyach and Mikhailovka 5: Pryluki (Mezin, Eem) paleosol (*Microtus arvalis, M. agrestis, M. gregalis, M. subterraneus, Arvicola terrestris, Lagurus lagurus, Clethrionomys glareolus*). In index-sections Posevkino and Perevoz from the Zavadovka paleosol described *Microtus arvalis, M. gregalis, M. oeconomus, M. gregaloides, M. arvaloides, Arvicola* sp., *Lagurus lagurus*. Index-section Rasskazovo: Zavadovka (Lihvin, Holstein) paleosol (*Microtus arvalis-agrestis, M. gregalis, Arvicola* aff. *mosbachensis, Lagurus lagurus, Clethrionomys* sp.). Index-section Kolkotova balka: Lubny (Rosmalen) paleosol (*Lagurus transiens, Eolagurus luteus, M. gregalis, Cricetus cricetus*). In index-section Troitskoye from the Shirokino (Late Bavel) paleosol *Mimomys intermedius, Prolagurus pannonicus, Microtus hintoni, Eolagurus luteus, Allophaiomys* sp. identified. Index-section Nogaysk: from Shirokino (Early Bavel) paleosol *P. pannonicus, Allophaiomys pliocaenicus, M intermedius, M. pusillus, M. reidi* described.

Index-sections of limnic-marine deposits. Index-section Chauda (stratotype of Chauda horizon, Kerch Peninsula). Remains of small mammals (*Prolagurus posterius, Microtus arvalidens, Microtus arvalinus, Spermophilus* sp) were obtained from limnic-marine sediments. Index-section Ozernoye (lectostratotype of ancient euxin horizon, Holstein). The fauna *Arvicola mosbachensis, Lagurus lagurus, Clethrionomys glareolus, Microtus gregaloides, M. arvalinus, M. arvalidens* was described. Index-section Uzunlar (stratotype of Uzunlar horizon, Kerch Peninsula). Species *Arvicola chosaricus, Microtus gregalis, Microtus* ex gr. *arvalis-socialis, Lagurus* sp., *Spermophilus* sp. have been described. Index-section Karangat (stratotype of Karangat horizon, Eem). *Arvicola terrestris, Lagurus lagurus, Microtus gregalis, M. arvalis, M. agrestis* were identified.

Index-sections of rocks with magnetic characteristics. Index-section Korotoyak (point 253): fossiliferous layer with *Mimomys pusillus, M. savini, Clethrionomys* ex gr. *sokolovi, Eolagurus argyropuloi, P. pannonicus, A. pliocaenicus* contains the subzone Jaramillo. Duple index-section Shamin/Litvin: below and above the Matuyama/Brunhes boundary the identical fauna of small mammals with *Prolagurus pannonicus, Microtus hintoni, M. arvalinus, M. protoeconomus, Mimomys intermedius, M. pusillus, Eolagurus simplicidens gromovi, A. pliocaenicus* occurs.

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Carbon isotopy as major chronostratigraphic correlation tool: the Early Triassic case

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The marine carbon isotope curve has been found stratigraphically very valuable and applied successfully for the last 20 years for the correlation of Early Triassic marine sedimentary successions worldwide. Otherwise, Triassic and in general Mesozoic chronostratigraphic units are usually based on biotic events such as the first appaerances of ammonoids or conodonts. The Early Triassic is presently divided into 2 stages (Induan, Olenekian) each of them with two substages (Griensbachian, Dienerian and Smithian, Spathian respectively). This subdivision is still unsatisfying in that only the base of the Triassic is internationally defined by a GSSP which, as is meanwhile known, rests disconformably on latest Permian strata.

Since for most of the Lower Triassic substages no internationally agreed boundaries exist, we see this as a chance to propose their definition with close tie to distinct events in the marine $\delta^{13}C$ curve. For the Dienerian there is a distinctive event with a turning point in the curve towards positive values which we could date in Guryul ravine (Kashmir/India) to the base of the *Neospathodus dieneri* conodont zone. The same change is contemporanously identified in well-dated sections from China. As *Neospathodus dieneri* is the most widespread conodont during that interval and even found in shallow water facies (e.g. Iran, Italy), it thus seems a very reasonable candidate. A previous proposal by the Smithian boundary working group to base the Smithian substage with the first appearance of the conodont *Neospathodus waageni s. l.* has turned out unsatisfyingly because forms of this group appear much earlier than previously thought. Judging from the $\delta^{13}C$ curve a very suıtable event would be wıthın the large positive excursion before the long Smithian low/negative isotope interval. This peak has been dated in Spiti (Himalaya/India) closely to the FO of *Neospathodus waageni s. str.* and to the FO of the conodont *Eurygnathodus costatus*. The latter has a comparably short range within to slightly above the excursion wıth a nearly worldwide distribution in both basinal and shallow marine environments. The base of the Spathian finally should be constrained to the positive $\delta^{13}C$ excursion after the long Smithian low/negative carbon isotope interval, as already done in many carbon ısotope related Early Triassic papers. We found the positive peak in the Werfen Formation in close connection with the entry of the worldwide distributed ammonoid *Tirolites* and the conodont *Neospathodus hungaricus*. In the pelagics, this boundary corresponds the LO of *Scythogondolella milleri*, a very widespread conodont. Recent Chinese authors favour a slightly lower boundary at the Fo of *Neospathodus pındıngshanensis* which corresponds approximately to the onset of the positive excursion.

Proposal for a candidate GSSP for the base of the Rhaetian stage at Steinbergkogel (Salzkammergut, Austria)

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The Steinbergkogel section near Hallstatt, Salzkammergut, Austria is proposed as candidate GSSP for the Norian-Rhaetian boundary (NRB) with the boundary defined in bed 111 of section A, 2m20 above section base by the FAD of *Misikella posthernsteini*. This definition follows the boundary recommendation of the NRB Task Force of the Subcommission on Triassic Stratigraphy. The Steinbergkogel exposes a pelagic basin facies of red and gray Middle Norian to Lower Rhaetian Hallstatt Limestone with a rich ammonoid and conodont fauna. Accompanying biostratigraphic boundary markers are the FA of *Misikella koessensis,* the FA of the ammonoids *Paracochloceras suessi* and of *Sagenites* s.str.

Despite the overall rare occurrence of *Misikella posthernsteini* in the early Rhaetian, Bed 111 further shows a distinct conodonts frequency change from *Epigondolella* to *Misikella* dominance as a valuable proxy for the boundary. An identical, time-correlative shift in conodont biofacies is seen in the Steinbergkogel quarry sections B and C and in various Tethyan sections from Germany (Berchtesgaden), Austria (Hallstatt, Dachstein, Hernstein), Slovakia (S. Brezova), Turkey (Oyuklu; Mersin), Oman (Musandam; Sumeini, Baid and Al Aqil) and Indonesia (Timor).

The FAD of *M. posthernsteini* occurs 40 cm higher up than the FA of *Misikella hernsteini*. Just below the FO of *Misikella hernsteini* is the LO of *Metasibirites*, a widespread late Norian ammonoid genus and the worldwide disappearance of *Monotis* (*M. salinaria/subcircularis* in low palaeolatitudes and *M. ochotica* group in the Boreal). Very rare coccolith spp were observed below the Norian-Rhaetian boundary. They increase in abundance just above the FAD of *Misikella posthernsteini* where the first *Crucirhabdus minutus* was also recorded. Above the FAD of *M. posthernsteini* is also the FA of the dinoflagellate cyst *Rhaetogonyaulax rhaetica,* which can be here lithologically controlled, followed by the disappearance of the "Norian" palynomorphs.

Between the FA of *M. hernsteini* and the FAD of M. *posthernsteini* lies a magnetic polarity reversal, ending a relatively long normal polarity interval, which can be recognized in other Tethyan magnetostratigraphies whereas, unfortunately, a clear correlation with the lacustrine Newark magnetochronology remains ambiguous. The delta$^{13}C_{carb}$ record is well preserved and shows no significant variations around the boundary.

The Austrian Salzkammergut region fulfills essential requirements for a Rhaetian GSSP: i) A lithologically uniform boundary interval, good exposure conditions in an old abandoned quarry and location on public land in a mountainous forested area in an UNESCO world heritage site assure long-time preservation and accessibility, ii) the area is well known for diverse Norian-Rhaetian low palaeolatitude invertebrate faunas (cephalopods, bivalves, gastropods, brachiopods, reefal organisms) found in different bathymetric and facial environments; iii) knowledge of their temporal and spatial distribution is now well advanced and a high-resolution correlation framework of the relevant pelagic biomarkers (ammonoids, conodonts) linked to abiotic stratigraphic tools such as stable isotopes and magnetostratigraphy has been achieved; iv) the multistratigraphical approach allows a correlation with the geochronologically constrained Pucara Group in northern Peru where the NRB is dated to around 205,5 my, and in the future hopefully with the astrochronologically tuned time scale of the Newark basin.

Vertebrate stratigraphy approach of Miocene Ouedhref deposits in southeast Tunisia: El Hamma Area

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The study of the sandstone deposit Ouedhref in the area of El Hamma in southeastern Tunisia has revealed a collection of vertebrate fossils that give an age to this formation.
The paleontological study uncovered three big taxa: fishes, reptiles and mammals.
The fishes of El Hamma are represented by four freshwater taxa: *Lates niloticus*, *Clarias* sp, *Arius* sp. and *Bagrus* sp.
The representative of reptiles are *Trionyx* sp and *Diplocynodon* sp.
The mammals are present in this deposit by *Hipparion primigenium*, *Palaeotragus robinsoni*, *Tetralophodon longirostris*, *Samotherium* sp., *Gazella* sp., and an unknown feline taxon.
As a result of this study, a Burdigalian-Messinian age has been attributed to this sediment and seven MN zones (Neogene mammals zones) were identified (MN3-MN5, MN9-MN13). Besides that a reconstruction of the paleoenvironment and paleoclimate were carried out.

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Marine and continental quaternary deposits of the southeastern coast of the Caspian Sea

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The south-east coast of the Caspian Sea remains poorly studied, despite the presence of numerous anticlinal structures, revealing sections of Quaternary sediments, widespread marine terraces and interstratification of Caspian deposits with continental, represented by Uzboi and Paleo-Amu-Darya alluvium (Karakum formation), lake and aeolian sediments.

Geomorphologically, the southeastern section of the Caspian coast corresponds to the Western Turkmen lowland, characterized by a flat relief with a number of small anticlinal uplifts. Quaternary deposits of considerable thickness are hidden under aeolian sands and proluvial fans of Western Kopetdag, Uly and Kichi Balkhan and can be studied in a limited number of sections at the anticlinal uplifts (Cheleken, Monjukly, Boyadag, Syrtlanly, Nebitdag).

Deposits of the Akchagyl Stage are widespread within the Western Turkmen lowland. A complete section of these deposits is exposed in the Balkhan area (Chelek, Monzhukly), as well as in Western Kopetdag and southern slope of the Kichi Balkhan. These deposits show great facies changes. The Akchagyl Stage corresponds with rare strata of continental deposits with footprints and bones and teeth of camels, predators and small rodents (S Krasnovodsk Peninsula). The existing paleomagnetic data for the Akchagyl deposits in Western Turkmenistan indicate the Gauss-Matuyama inversion related to the boundary of the middle and upper Akchagyl. The correlation of the Pleistocene of Caspian region with the international chronostratigraphic chart is debatable. The Apsheron Stage (Eopleistocene of Russian Plain Stages) (400-600 m thick) overlies the late Akchagyl with a sharp unconformity. The sedimentation gaps occur between the middle and upper part and between the Bakinian and Apsheronian stages. Apsheronian clays with signs of erosion overlie continental coarse-grained alluvial sands of the Turkyanian formation. Its thickness is insignificant, fragmentary to mostly eroded. The deposits of the Bakinian stage occur in almost all anticlinal structures. They are represented by the lower and middle substages with the molluscs *Didacna parvula* Na1., *D. catillus* Eichw. The Khazar marine stage is widespread in the northern part of the Western Turkmen lowland. In the east it gradually passes intoto alluvial sediments of the Karakum formation with a mammal fauna, such as *Elephas wüsti* M. Pavl. The upper part of this continental formation contains remnants of vertebrates, many of which occur in the paleo-valley of the Amu Darya. From the Karakum formation *Palaeoloxodon turkmenikus* at Hudaydag, Uzboi and Urundzhik, *Archidiskodon* at Uzboi valley near Yazhan lake and *Trogontherii chosaricus* at Southern Urundzhik were described (Dubrova et al., 1996).

Deposits of Khvalynian age are well developed morphologically in the form of marine terraces: Lower Khvalynian terraces, at altitudes from 9 (37) to 45 (73) m usually with *Didacna praetrigonoides* Na1. and *D. delenda* Bog. and Upper Khvalynian from -2 (26) to -12 (16) m, with *Didacna praetrigonoides* Na1. and Anis (Kurbanov et al., 2013).

Data on the structure of Quaternary sediments at the south-east coast of the Caspian Sea allows to distinguish seven complexes of marine sediments corresponding to the stages of the Caspian Sea area (Akchagyl, Apsheron, Bakinian, Urundzhik, Khazar, Khvalynian, Novocaspian). The continental deposits are poorly studied but contain Akchagylian and Apsheronian deposits and Turkyanian sands and widespread Karakum formation. Lithologic homogeneity of Karakum formation shows a significant meandering of Paleo-Amu-Darya, which often changed its course from the modern delta of the Amu Darya River to the Caspian Sea and had a significant streamflow. The end of the Paleo-Amu-Darya streamflow refers to the beginning of Khvalynian era, which correlates with the onset of Uzboy confirmed by lithological and petrographic analysis of sediments in the Western Cheleken section (Kurbanov, 2013). Findings of mammals in Western Turkmenistan are confined to aquatic deposits: in the early Pleistocene (Akchagyl, Apsheron) to river and marine, in the middle and late Pleistocene sometimes to the river and lake facies.

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The correlation of Devonian deposits of Eastern and Western Transbaikal (eastern Russia)

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The Transbaikal in the south of Russia stretches from Lake Baikal as far as the upper reaches of the Amur River. Devonian deposits of Eastern Transbaikal are widely distributed in the Onon, Argun and Upper Amur terranes. **C**arbonate-volcanogenic-terrigenous lithofacies characterizes the Onon terrane and terrigenous-carbonate lithofacies the Argun and Upper Amur terranes. The Argun and Upper Amur terranes are composed of rocks which were deposited in the shelf zone of a paleobasin. All strata are characterized by abundant fossils. Crinoids and brachiopods are very numerous. The Devonian deposits of the Onon terrane are widely distributed, lithologically homogenuous and poor in fossils. Some sections are faunistically characterized. The lower and upper boundary of the Devonian are missing in this region. In addition these rocks are very badly exposed. The up-to-date stratigraphic scheme was based on the rythmostratigraphic principle. For the first time we dated the deposits from the Givetian to Famennian by numerous miospores (det. L. Nebericutina). They were discovered in all parts of the sections. We distinguish two formations and each of them has their own miospore assemblage. We date the first suite (Ustborzya Suite) as Givetian to Frasnian. Besides them the tetracorals (det. Yu. Onoprienko) *Xistriphyllum* ex gr. *spinulosum* (Soshkina), *Betanyphyllum* cf. *soetenicum* (Schluter), *Vasticrinus vastus* (Yeltyshewa & J. Dubatolova) crinoid stems (det. A. Kurilenko), *Rothpletzella devonica* (Maslov) algae (det. V. Luchinina), *Moravammina*? foraminifers (det. R. Ivanova), tetractines and pentactines silicious sponge spicules (det. O. Obut), *Trilonche davidi* (Hinde), *T.* cf. *obtusa* Hinde radiolaria (det. O. Obut), and *Icriodus* ex gr. *symmetricus* Branson & Mehl, *Ancyrognathus* cf. *triangularis* Young., *Mesotaxis* sp., *Panderodus* sp., *Polygnathus* sp., *Palmatolepis* sp.) conodonts (det. V. Aristov, N. Izoch) were found in these deposits also. The overlying Suite named Tsagan-Nor contains abundant miospores of the Famennian. The Devonian deposits of Western Transbaikal were not known until 2003. They were identified by O. Minina, S. Ruzhentsev in deposits, which were considered to represent Riphean-Ordovician. The Baikal-Vitim fold system includes the Vitimkan-Tsipa, Uda-Vitim and Turka-Kurba structural-formational zones. Flyshoid greywacke sediments of Givetian - Tournaisian time were found in these zones. The most well studied Devonian deposits are in the Vitimkan-Tsipa zone. Their age was determined by miospore assemblages and rare faunal and floral remains. Miospores are rich in the Lower Yaksha Subsuite. They are characteristic for Givetian – early Frasnian deposits of numerous regions of Russia. In addition, corals (det. L. Ulitina, T. Sharkova) *Graciolopora* sp., *Pachypora* sp., *Chaetetes* sp., bryozoans (det. R. Gorjunova) *Geramopora* sp., algae (det. V. Luchinina) *Rothpletzella devonica* (Maslov), conodonts (det. V. Aristov) *Spathognathodus* sp., *Mesotaxis asymmetricus* Bischoff & Ziegler co-occur with spores in the Subsuite. The Upper Yaksha Subsuite contains the stromatoporoid (det. V. Chromych) *Actinostroma* cf. *guasifenestratum* Khromych and palynomorphs of Famennian age. The overlying Tocher Suite contains in its lower part theconodonts *Palmatolepis* cf. *triangularis* San., *Pa. perlobata schindewolfi* Mull., *Pa.* cf. *marginifera* Helms, *Polygnathus glaber* Ulrich & Bassler and others, tentaculites of the order Nowakiida and palynomorphs. The general interval of their distribution is early and middle Famennian. The Middle Subsuite of the Tocher Suite is characterized by a miospore association of the Famennian. The Upper Tocher Subsuite contains Tournaisian palynomorphs, the conodonts *Neopolygnathus communis* Branson & Mehl, *Pseudopolygnathus triangulus* Voges and stromatoporoids *Kyklopora* sp. The same deposits were found in the Uda-Vitim and Turka-Kurba structural-formational zones.

Thus the Lower Yaksha Subsuite of the Vitimkan-Tsipa zone (Western Transbaikal) corresponds well with the Ustborzya Suite of the Onon terrane (Eastern Transbaikal) in lithological composition and age. The Upper Yaksha Subsuite, Lower Tocher and Middle Tocher subsuites of Western Transbaikal correlate with the Tsagan-Nor Suite of Eastern Transbaikal.

Spatial and Temporal distribution of the Ediacara Biota

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The Ediacara biota represent a globally distributed yet temporally restricted assemblage of stem and crown group animals in addition to extinct clades of multicellular life. The oldest forms appear in post-Gaskiers sections from southeastern Newfoundland and England some 579 Ma, which is followed by a major radiation in diversity and disparity in sections from Australia, Russia, Siberia, northwestern Canada, and China. The youngest assemblages from Namibia, Siberia, and southwestern USA preserve relatively depauperate communities dominated by a handful of Ediacaran species, as well as putative metazoans. Reports of Cambrian-aged Ediacara biota are exceedingly rare, suggesting that the Ediacaran-Cambrian transition marks a fundamental restructuring of ecosystems following the advent and proliferation of predation, vertical burrowing, and effective filter feeding.

Initially designed as a biogeographic exercise, Waggoner (2003) showed that the diversity of Ediacara biota could be statistically binned into three ‘assemblages’ (termed the ‘Avalon’, ‘White Sea’, and ‘Nama’), which occur in approximate ascending stratigraphic order. Following over a decade of dedicated studies, the controlling factor(s) behind the grouping of these assemblages is the topic of much debate; recent studies suggest that they may represent temporal (i.e., evolutionary), environmental, and/or preservational trends. Determining to what extent these assemblages represent temporal and/or evolutionary trends would represent a huge advance in developing a robust biostratigraphy for the Neoproterozoic. Here, we present the results of global scale meta-analysis of all known Ediacaran sites, which integrates fossil occurrences, detailed paleoenvironmental (i.e. facies) descriptions, modes of preservation, and high-precision geochronology. Analyses reveal that the three ‘assemblages’ remain robust statistical groupings. Moreover, our investigation supports previous studies that identify the importance of bathymetry and paleoecology in controlling Ediacaran organismal distributions, and downplays the influence of sediment type, preservational regimes, and temporal/evolutionary trends. Despite this, our ongoing work aims to identify biostratigraphically important taxa that can be used to subdivide the Ediacaran Period.

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Demonstrated Long-Term Utility of the Basal Cambrian GSSP at Fortune Head, Eastern Newfoundland

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The global standard section and point (GSSP) for the base of the Cambrian was proposed at a horizon in the lower Chapel Island Formation at Fortune Head, eastern Newfoundland (1987). Subsequently (1992), this proposal was accepted and ratified by the International Commission on Stratigraphy (ICS), and as the GSSP for the base of the global lowest Cambrian Terreneuvian Series and Fortunian Stage (2007). This basal Cambrian GSSP has a demonstrated utility as a global chronostratigraphic standard over the last 23 on almost all Cambrian paleocontinents from higher south latitude Avalonia and Baltica to tropical Gondwana (e.g., Namibia, Iberia, China, Australia). More recently (2013), the coterminous GSSPs for the Cambrian, Terreneuvian, and Fortunian have been redefined. The redefined GSSPs lie at the same horizon as the 1992 GSSP at Fortune Head, but are regarded not as being defined by the FAD, or first (actually "lowest") appearance datum, of the eurytopic and globally distributed ichnofossil *Trichophycus pedum* (whose FAD defined the base of a *T. pedum* Zone by the 1987 proposal). Simple "FADs" of a fossil without additional geochronologically important brackets should not define global chronostratigraphic units. A FAD reflects temporal biases that accompany an organism's dispersal history, as well as local effects that relate to habitat suitability, fossilization potential, and completeness of collecting. Thus, it was not surprising that incomplete collecting in the 1987 report was followed in 2001 by the report of *T. pedum* several meters below the *T. pedum* "Zone". A statement that this discovery "cast(s) doubt on the international utility" of the Fortune Head GSSP is countered by an understanding of confidence intervals in the stratigraphic distribution of fossil remains and that a "FAD" underestimates the lowest local range of a fossil taxon. In addition, the recognition of the wide environmental tolerance of the *T. pedum* producer reinforces the biostratigraphic utility of this ichnotaxon, having significant implications for the position of the Ediacaran-Cambrian boundary at the Fortune Head section and its correlation worldwide. In any case, to counter any seeming problems involving use of *T. pedum* assemblages in correlation, the base of a renamed *T. pedum* Ichnofossil Assemblage Zone (IAZ) was defined to lie above the highest occurrence of characteristic Ediacaran problematica (e.g., *Harlaniella podolica*, *Palaeopascichnus delicatus*) and at the base of a Phanerozoic-aspect *T. pedum* ichnofossil assemblage with forms such as *Gyrolithes*, *Allocotichnus*, and *Diplichnites* at Fortune Head and *Streptichnus* and other ichnogenera elsewhere. The *T. pedum* IAZ has a number of lower brackets useful in global correlation. These include a strong carbon excursion in fossiliferous South China sections that is recognizable in the unfossiliferous south Moroccan succession. Furthermore, the *T. pedum* IAZ is bracketed by the base of an *A. tornatum-C. velvatum* Zone (acritarchs) in Baltica and the LAD (last, actually "highest," appearance datum) of Ediacaran mineralized taxa (e.g., *Cloudina, Namacalanthus*) in tropical Gondwana and west Laurentia. Particularly useful in setting the Fortune Head GSSP into a geochronologic perspective is the bracketing of the *T. pedum* IAZ's base and the terminal Ediacaran carbon isotope excursion by precise U-Pb zircon dates in Oman and Namibia. As noted by the late Martin Brasier in 2013, his preliminary work also suggests that additional correlation aids based on carbon excursions based on carbonate nodules and organic carbon through the Fortune Head succession. The fundamental utility of the Fortune Head GSSP is that it marks a correlatable and precisely bracketed and dated horizon within the "modernization" of substrate communities of the Cambrian Evolutionary Radiation.

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Cenomanian - Turonian environments and diagenetic events of a neritic platform, Constantine mountains (Northeastern Algeria)

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The carbonate mounds of Djebel Kellal - Constantine Rock, constitute one of the mid-Cretaceous outcrops (Cenomanian-Turonian) observed in the Constantine area. These geological deposits within a mainly neritic setting show rimmed shelf paleoenvironments. The Cenomanian transgression has been recorded by the onset of reef building represented by bioclastic packstones, rudist floastones and echinoderm grainstones. During the Turonian, a moderate regression induced the development of a proximal facies, starting with benthic foraminiferal wackestones and ostracod grainstones (indicative of a well-protected environment) with large benthic foraminifera and oncoids (indication a depositional system close to the reef flat) and ends with dolomitic mudstones and calcisphere wackestones (supratidal-intertidal facies). Burial of these neritic sediments and their post diagenetic uplift have generated textural and mineralogical changes, remarkable in the Cenomanian microfacies of the area.

Stratigraphy and structuring of the Pliocene/Quaternary of Hamma Bouziaine Basin, Constantine Region (Northeastern Algeria)

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Hamma Bouziane Basin is the lowest point of the hydrogeological system of the Constantine area. It is characterized by a plain topography (elevation between 450 - 550 m) and by the presence of a very karstified (neritic) carbonate substratum. The later is associated with thermal events having caused the development of Quaternary travertine limestone or newly emerging hot sources of Hamma Bouziaine. This basin is clearly visible on the morphostructural map of the North Constantine region. The overall structural unit (N30°E) is recorded in a section at the paleogeographic boundary of the Constantine platform. This structure with an at least Cretaceous heritage (Dj Bergli) was remobilized during the Pliocene/Quaternary. The best argument for this is the migration of hydrothermal paleosources. A geological section (G. Durozoy, 1960) shows their interpretation on the deep structure of this basin.

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Constraining the chemical composition of the sedimentary record in Gale Crater, Mars, using the ChemCam instrument onboard the MSL Curiosity rover

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The Mars Science Laboratory rover Curiosity landed in Gale Crater in August 2012. Formed around the Late Noachian/Early Hesperian Epochs at ~3.6 Ga, Gale is a 150 km diameter impact crater filled by sedimentary rocks including a crescent-shaped mound up to 5 km high, Aeolis Mons (= Mount Sharp) standing in the crater center. Orbital studies revealed a significant morphological and mineralogical diversity highlighting varied paleoenvironments. Gale has been selected for investigating the potential past and present habitability of the planet Mars. The ChemCam instrument onboard Curiosity combines a Laser-Induced Breakdown Spectroscopy instrument (Maurice et al., Space Sci. Rev., 2012; Wiens et al., Space Sci. Rev., 2012) and a Remote Micro-Imager that enables to determine the elemental composition of rocks located up to 7 m from the rover. Along with the Mastcam and MAHLI cameras, ChemCam allows us to examine the chemostratigraphy of the sedimentary record at an outcrop scale. Over the last Martian year, the Curiosity rover has travelled more than 10 km, analyzing outcrop exposures and soils of the plain between the NW rim of Gale and Mt. Sharp. It encountered varied (chemistry, texture) sedimentary rocks pointing to fluvial, lacustrine, or fluvio-deltaic environments (Grotzinger et al., Science, 2013; Stack et al., LPSC, 2015). The primary phase of the mission has already provided significant constraints on the past conditions at Gale. Shortly after landing, Curiosity analyzed the fine-clastic sedimentary rocks of the 5 meter-thick Yellowknife Bay Formation (YKB). Ranging from mudstones at the base to sandstones at the top, this formation represents an ancient fluvio-lacustrine system that would have been habitable (Grotzinger et al., 2013). YKB rocks derive from basalt sources and appear to be essentially unweathered, suggesting arid, possibly cold, paleoclimates and relatively rapid erosion/deposition (McLennan et al., Science, 2013). On its way to Mt. Sharp, Curiosity encountered isolated outcrops of fine to coarse-grained massive or cross-bedded sandstones and conglomerates at the Darwin, Cooperstown, and Kimberley waypoints. Conglomerate bulk chemistry displays a more felsic composition than the Martian average crust as defined by meteorites and orbital data, implying that the Gale crater rim is enriched in felsic rocks. The sedimentary rocks at Cooperstown and Kimberley show a significantly enhanced K content suggesting a potassic source. All those rocks display rather low CIA (Chemical Index of Alteration) suggesting limited chemical weathering prior to deposition. At Parhump Hills, Curiosity reached the base of Mt. Sharp. The fine-grained sediments display a major-element composition similar to that of the conglomerates at Darwin, suggesting a fluvial deposition from a similar source, likely the Gale crater rim (Forni et al., LPSC, 2015). Overall, the Pahrump Hills rocks have a higher CIA than the rocks previously found, suggesting significant chemical weathering that may be the signal of more clement climatic conditions (McLennan et al., 2015).

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Supposed trans-Atlantic migration of *Heterostegina* around the Eocene/Oligocene boundary

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The larger foraminiferal genus *Heterostegina* is abundant and widespread in tropical seas since late Bartonian to Recent. The short ranges of its species/subspecies permits high-resolution stratigraphical subdivision in certain time-intervals. In the former Neotethys, *Heterostegina* is very common towards the end of the Eocene (*H. reticulata* in the late Bartonian and Priabonian) and also in the Late Oligocene (*H. assilinoides* in the Chattian). These taxa, however, are not in direct phylogenetic relationship with each other, hence the absence of the genus in the entire Rupelian of the Neotethys was hypothesized (LESS et al. 2008). Since then, we discovered a new species of *Heterostegina* in the Rupelian of Sicily and NW Aquitaine (here provisionally referred to as *H.* n. sp.), which cannot, however, be considered as either the offspring of *H. reticulata* or the ancestor of *H. assilinoides*.
Although the embryo of this new species is rather small, the very early appearance of subdivided (heterosteginid) chambers during the ontogeny marks quite an advanced stage in the nepionic acceleration. This suggests the presence of ancestral heterosteginid forms outside the Neotethys. Such forms – with even smaller embryo and with later ontogenetic appearance of heterosteginid chambers – were found in the Caribbean–Central American realm. They are described from the Upper Eocene of Florida, Cuba and Panama as *Heterostegina ocalana* but not yet reported from the Lower Oligocene of Central America.
According to our hypothesis, *H. ocalana* migrated eastward through the previously much narrower Atlantic Ocean around the Eocene/Oligocene boundary. Sporadic populations of *H.* n. sp., its phylogenetic successor, survived in the western part of the Neotethys until the end of the Rupelian, when they became extinct.
Results of strontium isotope stratigraphy (SIS) are consistent with our hypothesis: Floridian samples with *H. ocalana* indicate 33.8–34.4 Ma (late Priabonian), whereas NW Aquitanian ones with *H.* n. sp. show 28.9–30.2 Ma (late Rupelian). The SIS-age of *Heterostegina*-free samples from Florida (supposed to be Lower Oligocene) is 31.3–32.5 Ma (early Rupelian).
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New Sr-isotope stratigraphy (SIS) age-data from the Central Paratethys

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The Central Paratethys (CPT) was formed primarily as an inland sea of the Neotethys in the early Oligocene (covering the actual Carpathian and Eastern Alpine regions). It existed with mostly normal salinity roughly until the middle Serravallian and is characterized by rather endemic biota. Therefore, regional stages were introduced in the 60-70s of the 20th century. Their correlation to the global stages based on bio-, magneto- and sequence stratigraphy is in some cases still problematic and contradictory. A direct correlation of most important CPT sites to the numerical time scale is in progress by using SIS data, which can lead to a better correlation of the CPT regional stages to the global stages. Another outcome should be a detailed comparison between the interpretations of regional stages in different countries. Results listed below are the first data of our research.

The age of samples assigned to the basal and lower part of the Egerian CPT stage [Novaj (H), lower boundary stratotype: 24.6–24.0 Ma; Eger, Wind brickyard (H), holostratotype: 24.3–23.2 Ma; Csókás (H): 24.9–23.7 Ma; Budikovany (SK): 24.0–22.9 Ma] appeared to correspond to the late and terminal Chattian. These data are at least 2 Ma younger than expected (PILLER et al. 2007) and necessitate recorrelating the lower boundary of the Egerian within the late Chattian. SIS-data from sites with most primitive miogypsinids (whose FO defines the lower boundary of the Egerian) outside the CPT mark late Chattian, too [P. Badisco (I): 24.3–23.8 Ma; Escornebéou (F): 24.6–24.0 Ma]. The Bretka (SK) samples assigned to the upper, Miocene part of the Egerian mark 22.4–21.9 Ma (early Aquitanian).

Of the localities believed traditionally Eggenburgian the SIS-age of the Darnó Conglomerate from Szajla (H) appeared to be between 21.4 and 20.9 Ma corresponding both to late Aquitanian in accord with the newly found *Miogypsina tani* and to basal Eggenburgian in the CPT subdivision. The Coruşu (RO) sample with large pectinids marks 19.9–19.2 Ma (early Burdigalian). A younger (18.5–17.9 Ma) SIS-age (corresponding to about the Eggenburgian/Ottnangian boundary) has been obtained from the Budafok Sand from Budapest, Pacsirta Hill. Samples from the upper part of the Pétervására (Fiľakovo) Sandstone from Parád, Ilona Valley (H) and Lipovany (SK) gave even younger Sr-isotope ages (18.2–17.6 and 18.3–17.7 Ma, respectively), which correspond rather to the early Ottnangian. These data are; however, in accord with the Ottnangian character of mollusks and also with the revised (17.5–16.9 Ma) age of the overlying lower rhyolitic tuff from Ipolytarnóc (PÁLFY et al. 2007).

In the case of the Várpalota, Bánta-puszta (H) localities similar SIS-ages have been obtained from both sides of the locally assigned Ottnangian/Karpatian boundary (16.1–15.3 and 15.9–15.1 Ma, respectively) corresponding to the early Badenian and early Langhian. Similar (16.1–15.3 Ma) SIS-ages came out from the Egyházasgerge Sand from Csernely (H) and also from the schlier deposits of Cerová-Lieskové (SK) both thought to be Karpatian. The SIS-age (15.7–14.9 Ma) from the Szabó quarry in Várpalota (H) confirms the early Badenian biostratigraphic age of this site.

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New Sr-isotope stratigraphy (SIS) age-data from some European Oligo-Miocene larger benthic foraminiferal sites

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The Oligo-Miocene larger benthic foraminiferal (LBF) biozonation for European basins introduced by CAHUZAC & POIGNANT (1997) is successfully applied to the Rupelian to Burdigalian deposits of a large territory extending from Spain to W India. The zonation containing five (SBZ 21–25) biozones in the above time-span is largely based on data from isolated localities, and its correlation with the standard geological time scale is performed mainly by using planktonic data. A direct correlation of well-documented LBF sites to the numerical time scale covering the above interval is in progress by using SIS data from the W Tethys (including W Asia), which can lead to an increased resolution of the zonation, too. In the first results listed below we focus on European localities.

Four samples in younging stratigraphic order from the Biarritz (SW France) sequence resulted in the following SIS-ages: Lou Cachaou with rich Late Eocene (SBZ 20) LBF assemblage gave 37.0–35.0 Ma (Priabonian in general), whereas Villa Belza, Rocher de la Vierge and Phare-St-Martin in succession, all belonging to the early Rupelian SBZ 21 Zone (with *Nummulites fichteli*, *N. vascus*, *N. bouillei* and *Operculina complanata* – this latter only appears in the highest sample), gave 34.0–33.3, 33.2–32.8 and 32.5–31.7 Ma (all early Rupelian), respectively.

The only sample of the SBZ 22 Zone from Tuc de Saumon (SW France) belonging to its lower (SBZ 22A – late Rupelian) part with *N. fichteli* and primitive *Lepidocyclina* gave a SIS-age of 30.2–29.2 Ma in accord with the biostratigraphic data.

The first appearance of miogypsinids marks the lower boundary of the SBZ 23 Zone. Samples with most primitive forms (*Miogypsinoides complanatus* and *Miogypsina septentrionalis*) gave older ages (Escornebéou – SW France: 24.6–24.0 Ma, Porto Badisco – S Italy: 24.3–23.8 Ma, Novaj – Hungary: 24.6–24.0 Ma and Csókás – Hungary with no miogypsinids but otherwise containing very similar LBF-assemblage: 24.9–23.7 Ma) than samples with slightly more advanced miogypsinids (*Ms. formosensis* and/or *M. basraensis* in Estoti – SW France: 23.7–22.6 Ma and Budikovany – S Slovakia: 24.0–22.9 Ma). These late and terminal Chattian data are, however, younger than those reported by CAHUZAC & POIGNANT (1997) who placed the lower boundary of SBZ 23 at about 27.0 Ma.

Uni-spiralled species of *Miogypsina* define the SBZ 24 Zone of the Aquitanian. Sample from Bretka (Slovakia) with the more primitive *M. gunteri* gave a SIS-age of 22.4–21.9 Ma; sample Augey (SW France) with transitional *M. gunteri-tani* gave 21.6–21.0 Ma whereas samples L'ariey (SW France) and Szajla (Hungary) with the more advanced *M. tani* showed 21.5–20.6 Ma and 21.4–20.9 Ma, respectively. Thus, our new SIS-ages are in accord with the biostratigraphic data.

The Burdigalian age of the SBZ 25 Zone characterized by plurispiralled *Miogypsina* is also confirmed by our SIS data from SW France. Samples Mimbaste and Leognan with less advanced *M. globulina* gave 20.6–20.0 Ma and 19.5–19.0 Ma (both early Burdigalian) whereas sample Pont-Pourquey with more advanced *M. intermedia* resulted in 18.6–18.2 Ma (middle Burdigalian).

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How to subdivide the Terreneuvian Series: a biostratigraphic marker or a geochemical one?

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Cambrian chronostratigraphy has been progressing with the adoption of four series-level and ten stage-level subdivisions, though the Cambrian is the only Phanerozoic system for which half of its series and stages have not been formally defined and named. The lowest Cambrian Terreneuvian Series includes two stages (Fortunian and unnamed Stage 2), but how to subdivide the Terreneuvian is still on the way and an urgent task for the Cambrian colleagues.

Small skeletal (or shelly) fossils have been one of the important biostratigraphic tools for correlation and subdivision of the pre-trilobitic Cambrian strata. Some SSFs have a worldwide distribution and are useful index fossils for correlating the lower Cambrian sequences between different blocks. Amongst, the micromollusc *Watsonella crosbyi* is a widely occurring small skeletal fossil, and has been recovered from South China, Siberia, Mongolia, North America, France, South Australia, etc. It mainly occurs in the late Terreneuvian (late Meishucunian in South China, Tommotian in the Siberian Platform, late Placentian in North America) and has been taken as a nominal fossil for biozonation in these areas. Especially the occurrence of *W. crosbyi* in southern France was recently proven to be in the Stage 2 (Devaere et al., 2013). But it is doubtful that *W. crosbyi* occurs in the lower Botomian Sellick Hill Formation in South Australia (Gravestock et al., 2001). Its wide occurrence in both carbonate and siliciclastic environments indicates that *Watsonella crosbyi* was an important fossil for global correlation of the pre-trilobitic strata. The FAD of *Watsonella crosbyi* can be suggested as a candidate GSSP marker for defining the base of the Stage 2. This potential GSSP candidate marker could be calibrated with other fossils. The FADs of *Anabarella plana* and *Purella* spp. are below this marker, while the FADs of *Lapworthella* spp. are usually above it (except in Mongolia). The FAD of *Aldanella attleborensis* approximates to or is a little above this marker and could be also a potential biomarker for defining the base of the Cambrian Stage 2 since it is especially widely distributed in the Tommotian over the Siberian Platform (Parkhaev and Karlova, 2011). But in South China, the occurrence of this fossil is not widespread and its FAD is higher than that of *W. crosbyi* in eastern Yunnan.

Besides the SSFs, acritarchs are useful microfossils for the Cambrian biostratigraphy. The FAD of *Skiagia* plexus as a global recognizable level is a little higher than that of *Watsonella crosbyi* (Moczydlowska and Zang, 2006), and it can be complementary for making the base of the Cambrian Stage 2.This biomarker could also be calibrated with chemostratigraphic data. In northeastern Yunnan, South China, the FAD of *W. crosbyi* is near the base of the Dahai Member of the Zhujiaqing Formation, and it is below the major positive $\delta^{13}C$ excursion [dubbed ZHUCE by Zhu et al. (2007)] in the Terreneuvian. But it needs to be cautious to use a peak of carbon isotope excursion for defining the base of the Stage 2.

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The Bio- and Chronostratigraphic History of the Givetian (Middle Devonian): From one Subzone to three substages

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The Givetian Stage (Middle Devonian) has a long and complicated history of definition and subdivisions that thanks to the work carried out in the last 40 years, mostly by conodont workers, has officially been subdivided into three substages, Lower, Middle and Upper Givetian.

Initial subdivision in the mid 1950's placed most of the Givetian in just one conodont subzone, the *varcus* Subzone. Subsequent studies provided an early subdivision of the Givetian Stage into seven conodont zones, which are still mostly applicable for the lower and middle parts; the upper part has strongly been changed. Within this scheme the beginning of the Givetian was placed within the conodont *ensensis* Zone; above followed the *varcus* Zone with a threefold subdivision into lower, middle and upper *varcus* Subzones. Then, follows the *hermanni-cristatus* Zone, which was informally subdivided into lower and upper on the basis of the sequential entries of *Schmitognathus hermanni* and *Polygnathus cristatus*. The lowermost *asymmetricus* was the uppermost Givetian conodont Zone in this scheme.

Detailed conodont studies worldwide and refinement in correlations by means of this group helped the International Subcommisssion on Devonian Stratigraphy in deliberations on the definition and stabilization of the Givetian boundaries and in the discussions on its further subdivision into substages. Currently the Givetian is composed of ten conodont zones, which are the basis for the proposed subdivision into three substages.

The entry of *P. hemianasatus* defines the lower boundary of the Givetian Stage and of the Lower Givetian Substage. This entry also defines the base of the lowest Givetian conodont zone, the *hemiansatus* Zone. Above follows the *timorensis*, *rhenanus/varcus*, *ansatus*, *semialternans/ latifossatus*, lower and upper *hermanni*, lower and upper *disparilis* and *norrisi* Zones. The bases of these zones are defined by the entry of the name-giving taxa. The entry of *P. cristatus* defines the base of the upper *hermanni* Zone. The entry of *P. dengleris* defines the base of the upper *disparilis* Zone.

After thorough discussion the base of the Middle Givetian is traced at the base of the *rhenanus/varcus* Zone, i.e. at the first occurrence of either *P. varcus* or *P. rhenanus*.

The base of the Upper Givetian coincides with the base of the lower *hermanni* Zone, which is defined with the entry of *Sch. hermanni*.

In brief, the progress in detailed conodont studies has allowed a finer subdivision of the Givetian Stage into ten globally applied conodont zones that, in turn, enable further subdivision of the Givetian into three substages, Lower, Middle and Upper.

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Givetian (Middle Devonian) Event in the Spanish Central Pyrenees

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Two main "Events" are globally recognized in the Givetian (Middle Devonian): Pumillo Event and Taghanic Event. The Pumilio Event comprises two events that probably are related to a transgressive pulse, Lower and Upper Pumilio and are characterized by dark (black) limestones with mass occurrence of a tiny brachiopod, "*Terebratula pumilio*". Both are Middle Givetian in age; the Lower Pumilio happened within the *rhenanus/varcus* and the Upper Pumilio in the lower part of the *ansatus* Zone. The Taghanic Event is a multiphasic one that has recently been referred to rather as Taghanic Crisis. This Event spans a long time from the upper part of the *ansatus* Zone and all the *semialternans/latifossatus* Zone, i.e approximately the upper third of the Middle Givetian, lasting for several hundreds thousand years (400-800) and having different regional features.
The Spanish Central Pyrenees has resulted to be a key area for studying in detail the Devonian marine rocks and for constructing one of the finest conodont-based bio- and chronostrtigraphic scale. However, no Global Events had been detected in the Pyrenean strata.
The Pyrenean Villech section (54 m thick) reveals the signature of one of these events. In Bed 29 a 7 cm thin layer of black shales and limestones with shelly accumulations within a dominant variegated carbonate sequence is recorded. The combination of microfacies and faunal studies above and below this level do not indicate a change in the environment, suggesting that it might represent a hypoxic interval within a short and sudden deepening. Conodonts above and below this level belong to the *semialternans* Zone and suggest that this episode took place in the middle part of the *semialternans* Zone. Thus, it happened during the upper phase of the Thaganic Event that according to previous work was related to a transgressive pulse.
This new and contrasting data from the Pyrenees add complexity to the Taghanic Event and suggest the need for re-evaluating many sections and levels and testing, as accurate as possible, the age of the different phases/pulses within the Taghanic Crisis.
In brief, the Taghanic Event may be more complex that initially though, and local, accurate, signatures may improve palaeogeographical relations and geological histories of nearby and far away basins and continents.

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Geochemical markers of environmental changes observed in estuarine Holocene sedimentation on the Alagoas and Pernambuco states, Northeast Brazil

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Chemical analyzes were performed to determine the heavy metals (HM) contamination and C-N-H-S on organic matter (OM) in estuarine sediments of Botafogo and Jaboatão rivers in Pernambuco and Manguaba river in the State of Alagoas, northeast Brazil. The comparison of the contents found on the core profiles samples, allowed the characterization of the evolutionary vertical distribution in these Holocene sediments. The analyzed chemical species (As, Cr, Pb, Hg, Ni and Zn) generally had an increase in their concentration from the range of 30 to 35 cm in all profiles. This scenario indicates that there are two well differentiated compartments separated by this horizon, which functions as a geochemical marker. The results are marked by a dichotomy with respect to the C / N ratio specifying increasing evolution signature of trace metals, following a lower energy hydrodynamic, with the predominance of pelitic sedimentation. The organic matter present in the sediments indicates a progressive evolution of continental environment conditions at the bottom, to more estuarine conditions at the top. This behavior is probably related to sea level rise (SLR) base in the range considered and sufficiently significant in Brazilian Northeast coast at last 150 years, so that the balance of MO contributions of marine origin has become increasingly important towards more recent sedimentation. Sea level rise is one of the key problems that is taken into consideration in climate change impacts related to Northeast Brazil. Thus, it is in line with the evolution of the world greenhouse previously confirmed in the considered period of time, which gives the overall picture of a discreet and progressive drowning estuary by sea. It can be concluded that the estuary systems do not show industrial pollution, except Cr in Jaboatão River and Hg in Botafogo River, and that there was evolutionary installation estuaries recorded in sediments of the mouths of the rivers considered.

Mediterranean Neogene planktonic foraminifer biozonation and biochronology

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Planktonic foraminifera are widely used for biostratigraphy and correlation of Mediterranean Neogene marine sediments, and are a fundamental component in the astronomical tuning of the Neogene Time Scale.
Recent developments in high-resolution studies focused on the astronomical calibration of cyclically marine sediments cropping out in land based sections and in deep-sea records, increased the accuracy of distribution ranges of planktonic foraminiferal species improving the biostratigraphic resolution and biochronology.
The large amount of data on planktonic foraminifera obtained through quantitative methods, published in the recent years, allowed many biohorizons of the Neogene to be revised, and their calibrations to be reassessed.
We incorporate these developments and amendments into the existing Mediterranean planktonic foraminiferal biozonation. Therefore, we present an emended Standard Mediterranean planktonic foraminiferal biozonation with a detailed description of zones and subzones within the framework of the Astronomical Tuned Neogene Time Scale 2004 and 2012 (ATNTS2004, ATNTS2012) combined with the quantitative distribution pattern of the planktonic foraminiferal marker species.
Twenty-two biozones and thirty-one subzones have been identified that span the past 23 million years. We distinguished them using the following code system: MMi1 to MMi13: Mediterranean Miocene biozones, MPl1 to MPl6: Mediterranean Pliocene biozones, and MPle1 to MPle2: Mediterranean Pleistocene biozones. The subzones are indicated with alphabetic letters.
We assembled 113 Neogene planktonic foraminiferal biohorizons from multiple datasets, and incorporated the calibration of these bioevents into a revised Neogene planktonic foraminiferal biochronology. The revised and recalibrated data provide a major advance in biostratigraphic and biochronologic resolution and a template for future progress of the Neogene time scale.
Unfortunately, two main gaps of planktonic foraminiferal quantitative data occur in the late Burdigalian, between 16.50 Ma and 17.24 Ma, and at Aquitanian/Burdigalian boundary, between 19.74 Ma and 20.63 Ma, due to the absence of high-resolution Mediterranean deep marine records.

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Stable isotope stratigraphy and chronology of Langhian marine records from St. Peter Pool section (central Mediterranean, Malta Island)

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The St. Peter's Pool section, which outcrops in the Delimara Peninsula (south-eastern coast of the Malta island) and belongs to the Upper Globigerina Limestone member, presents a continuous and well preserved deep marine record for the Langhian time interval (Foresi et al., 2011). The 31 meter thick sedimentary record is characterized by cyclic alternations of calcareous marl, marly limestone and jutting bioturbated hardened limestone and lies on the well-known C2 (Pedley, 1975) phosphate-rich bed.

Biostratigraphic data (Foresi et al., 2011) suggest that the St. Peter's Pool sedimentary record spans a time interval of about 1.2 My (from 15.3 to 16.5 Ma). Oxygen and carbon stable isotope analyses performed on planktonic foraminifera *Globigerinoides quadrilobatus* (surface water proxy) and on benthic foraminifera *Cibicidoides dutemplei* (deep water proxy), show a good correlation with amplitude oscillation of the astronomical parameter of eccentricity. In particular, $\delta^{18}O$ *G. quadrilobatus* light values are in phase with eccentricity maxima and $\delta^{13}C$ *G. quadrilobatus* maxima are in phase with 400-kyr eccentricity minima.

Major increases in $\delta^{13}C$ *C. dutemplei* record document the onset of the carbon isotope events CM3a, CM3b and CM4. In addition, the strong shift if $\delta^{13}C$ benthic data from open ocean ODP-site 1146, dated about 15.6 Ma, is also documented in the St. Peter's Pool sedimentary record.

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New data of *Isoxys* from Balang Formation (Cambrian Series 2) of Eastern Guizhou, China

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Isoxys, one of the groups of large bivalved arthropods, is restricted in Cambrian, which is widely distributed in North America, Europe, Siberia, Australia and China. 17 species and some unidentified species of this taxon have been described from Cambrian Series 2 to Series 3. The Balang Fauna from the Balang Formation (Cambrian Series 2) contains fossil assemblage of *Isoxys*. The characters of *Isoxys* from the assemblage exhibit three morphological types in outline, one is similar to that of *Isoxys auritus* Jiang, 1982, other both are different from those of all species of *Isoxys*. Based on distinction of morphology of valve, the latter both are described separately as two new species of *Isoxys*, *I. jianheensis* sp. nov. and *I. grobulus* sp. nov. Carapace of *I. jianheensis* sp. nov. is small and sub-ellipse (less than 20mm) in outline, dorsal line slightly convex in the middle; maximum height generally in the 2/5 of anterior part, the L:H about 1.7; anterior margin more swollen than posterior margin; anterior spine very short and upwards; posterior spine longer, stronger and upcurved, small irregular reticulate pattern over the whole carapace. Valves of *I. grobulus* sp. nov. are medium-sized (20mm - 60mm in length), sub-semicircle in outline, dorsal line straight; maximum height generally in the 1/3 of anterior part, the L:H about 1.5; anterior margin more swollen and expand than posterior margin; anterior spine longer, stronger and relatively straight, posterior spine is similar with the anterior one; valve smooth, ornament absent. The *Isoxys* assemblage of the Balang Formation includes three species, *I. auritus*, *I. jianheensis* sp. nov. and *I. grobulus* sp. nov. Although the Balang Formation the Balang Fauna contained is widely distributed in eastern Guizhou, *Isoxys* only occurs in two sections of this formation near Jianhe County. Especially the Lazizhai section exposed along mountain ridges of northern Lazizhai village 7 kilometers away from Jianhe County, 203 specimens of *Isoxys* were collected in interval away from base of the Balang Formation 170 to 175 m. In addition, large bivalve arthropods *Tuzoia*, *Occacaris* and *Combinivalvula* also occur in the section. The Balang Fauna composited by 27 species of 8 phyla occurs in the middle and upper parts of the formation (above 150m) and is characterized by abundant large bivalve arthropods and trilobite, including trilobite juveniles different from that of other localities of the Balang Fauna. These associated characters result from deeper water environment and autochthonous burial of the fauna. Abundant *Isoxys* specimens provide important proofs for taxon of this group, taphnomy and expand this group geographic distribution.

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Mediterranean-Paratethys connection across the Meotian/Pontian boundary: insights from the *Braarudosphaera bigelowi* spike in the Tokhni section (Cyprus)

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A great effort has been made in recent years in precisely correlating and dating the Meotian/Pontian boundary (lower Messinian), marked by the record of a Paratethyan-wide marine flooding (Odessian Transgression) and recently recognized as predating the magnetic reversal at the base of chron C3r, dated at 6.04 (Grothe et al., 2014; Chang et al., 2014; Vasiliev et al., 2015). The influx of marine waters into the fresh water Paratethys Sea has been recorded by means of integrated paleontological analyses and is based on: i) the occurrence of peculiar ostracod and foraminifera assemblages (Stoica et al., 2013), ii) the first common occurrence of dinocyst marker species and, iii) the strong increase in relative abundance of aquatic palynomorphs in Pontian sediments in the Black Sea (Grothe et al., 2014), iiii) the occurrence of marine microfossil assemblages (Radionova et al., 2012). Moreover, the migration of mollusc and ostracod taxa from the Pannonian Basin and the Aegean Basin into the Black Sea (Popov et al., 2006; Grothe et al., 2014) also demonstrate the temporary connection of the marine water body of the Eagean Sea with the different Pannonian sub-basins and the existence of a brackish water column.
Among other data, the sharp signal of the open connection between the Paratethys and a marine water body corresponds to the high abundance of calcareous nannofossil *Braarudosphaera bigelowii* at several locations in the Black Sea (DSDP Hole 380A and 379A: Percival et al., 1978; Zhelezny Rog, Taman peninsula, Russia: Popov et al., 2006; Radionova et al., 2012). *B. bigelowii* is a well known stress tolerant taxon, very rare in normal marine waters, but common to abundant in brackish surface waters, like the modern Black Sea (Bukry, 1974).
Recently, the stratigraphy and age model of the previously published Tokhni section (Cyprus; Orszag-Sperber et al., 2009) has been revised on the basis of a new calcareous plankton biostratigraphy validated by new magnetostratigraphic data (Manzi et al., 2015; Gennari et al., in progress). The integrated micropaleontological data (Calcareous Nannofossils and Foraminifers) allowed a direct cycle-by-cycle correlation to the other Mediterranean reference sections and revealed that *B. bigelowii* is also abundant, thought not dominant, in a discrete stratigraphic interval at Tokhni. Conversely *B. bigelowii* is very rare (or absent) in coeval Messinian sediments of the Mediterranean Basin.
This episodic occurrence suggests an occasional and transient supply of fresher waters, either from enhanced runoff or from the connection to a brackish/fresh water body. The stratigraphic position of this peak abundance, three cycles below the 2nd influx of *Globorotalia scitula*, dated at 6.102 Ma (and correlated to cycle UA27 in the Abad composite; Sierro et al., 2001), suggests that these low salinity waters could have been sourced from the paleo-Black Sea, during the transient connection between the Paratethys and Mediterranean Seas at the Meotian/Pontian boundary. The geographic position of the Tokhni section on Cyprus and its relative proximity to the possible fresh water source area (the Paratethys, across the Dardanelles strait) possibly justifies the fact that the *B. bigelowii* peak abundance was never recorded in other Mediterranean sections.
These new data corroborate, strenghten and detail the recently proposed age model for the Meotian/Pontian boundary (Chang et al., 2014; Grothe et al., 2014; Vasiliev et al., 2015) and demonstrate the need of integrated calibration for the precise age dating of episodes of transient connection among the Eastern Mediterranean and the Paratethys basins.

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Paleocene and Lower Eocene Biostratigraphy (Foraminifera and Ostracods) from Jebel Serj, Central Tunisia

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Sedimentologic, paleontological and biostratigraphic studies were carried out on the Upper Cretaceous- lower Eocene succession of Khanguet Zalga in the Jebel Serj area, central Tunisia.
Lithostratigraphic investigations led to the recognition of three formations, from base to top: the limestone Abiod Formation; El Haria shale Formation which includes three members: a lower shale member (middle Paleocene, Selandian), a chalky upper member (late Paleocene, Thanetian) overlain by phosphates beds; the succession ends with the limestone Bou Dabbous Formation of early Eocene (Ypresian).
Paleontological analysis shows the occurrence of about 300 species in these formations: 200 of benthic foraminifers, 45 planktonic species and 55 ostracods. The Velasco type benthic foraminifers (*Nuttalloides truempyi*, *Osangularia velascoensis*, *Bulimina trinidadensis*,…) show a middle bathyal depositional environment, with a paleobathymetry between 500 - 600 m.
Based on the abundance and stratigraphic distribution of planktonic foraminiferal species, six planktonic zones are recognized: *Gansserina gansseri* zone of Late Cretaceous (lower Maastrichtian); *Morozovella angulata* (P3) zone of middle Paleocene (Selandian); *Globanomalina pseudomenardii* (P4) and *Morozovella velascoensis* (P5) zones of late Paleocene (Thanetian), *Morozovella edgari* (P6) and *Morozovella subbotinae* (P7) zones of early Eocene (Ypresian).
The sedimentological results show the presence of a hiatus in the studied sequence indicating the instability of this area during the Late Cretaceous - early Eocene time. The hiatus is placed at the top of upper Campanian and located between the Abiod Formation and the El Haria Formation via a hard ground. It is accompanied by a paleontological gap indicated by the absence of the upper Maastrichtian and lower Paleocene: *Abathomphalus mayaroensis* and *Plummerita hantkeninoides* zones of Late Cretaceous (Maastrichtian), *Guembelitria cretacea* (=Po), *Parvularugoglobigerina eugubina* zone (=P1a), *Parasubbotina pseudobulloides* (P1b) and *Praemurica trinidadensis* (P2) zone of early Paleocene (Danian) and finally *Praemurica uncinata* zone of middle Paleocene (earliest Selandian).

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Messinian Salinity Crisis in the Aegean Sea - new data from alluvial and marginal marine deposits of the Kassandra Peninsula in NE Greece

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Aegean Sea is a young back arc basin between the Balkan Peninsula and the Asia Minor. Its origin during the Late Miocene allowed communication of the Black Sea with the Mediterranean via the Marmara Sea environs. Black Sea is a remnant of a huge epicontinental sea that existed during the Oligocene to Miocene between the Alpine Foredeep in the West and the Aral Sea in the East. Apparently, the Aegean Sea represented since its opening its only gateway to the open ocean. During the Messinian Salinity Crisis leaking of the Paratethys waters into the Mediterranean has been proposed based on the Paratethys-related endemic mollusks and ostracods found in the topmost evaporite series. The biofacies characterized by the presence of latter fauna is termed in the Mediterranean as Lago Mare. We found marginal marine, Paratethys-rooted mollusk fauna at the Kassandra Peninsula south of Thessaloniki and investigated its relation with the Lago Mare.

Two sections of the outcrop area near Kryopigi on the Kassandra Peninsula have been investigated in detail. The southern one represents one extraordinary rich mammal site with at least twenty species recorded. It belongs to the Triglia Formation of the regional lithostratigraphic classification. The composite section is ~7-m-thick. It starts with ~1-m-thick reddish gravel and sand with channel structures. A prominent caliche horizon follows, overlain by a ~3-m-thick reddish sandy silt with channels filled by sand and gravel, and bearing richly mammal remains. The latter appear articulated as well as disarticulated pointing to a relative fast burial processes. On top, a ~4-m-thick reddish silt without bone remains is present. The latter two units are characterized by the presence of massive caliche and ferromanganese crusts pointing to paleosoil building under semi-arid conditions. The succession represents a braided-river deposit in its very base, switching in the second unit to the alluvial flood-plain facies. Based on the occurrence of diverse Hipparionine horse species accompanied by the remains of primate *Mesopithecus pentelicus*, the fauna supports correlation of the succession with the Late Miocene mammal stage Turolian (8.9 to 5.3 Ma).

The lower part of the northern outcrop exposes the same continental series. There, even ~8-m-thick braided river deposits are followed by a ~8-m-thick alluvial floodplain interval, bearing here only scattered mammal bones. Above, a ~50-cm-thick sand horizon is followed by a ~5-m-thick carbonate interval extremely rich in mollusk remains, indicating marginal-marine, shallow-water conditions close to a river-inlet. The upper part of the carbonate interval is affected by horizons of caliche pointing to reoccurring emersions. Its topmost meter is heavily affected by caliche crust paleosoil building suggesting a long-term emersion, resulting apparently from the final retreat of the sea. The mollusk fauna with diverse lymnocardiid representatives combined with the presence of *Timoclea wildhalmi* allows a direct correlation with the basal transgression of the Paratethys regional stage Pontian, dated in the Dacian as well as in the Black Sea basins to ~6 Ma. One radiometric datum from the ash intercalated in the upper part of the carbonate interval at Kryopigi supported fully this correlation. These data imply that the suggested leaking of the Paratethys into the Mediterranean is not necessarily needed for a trigger of the Lago Mare event, because the related fauna already dwelt in the marginal marine settings there at times predating the Messinian Salinity Crisis.

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Calcareous nannofossils of Djebel Meni upper Miocene (Chelif Basin, NW Algeria)

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The djebel Meni deposits, located at the south-western border of the Dahra Massif (Chelif basin), consists of three geological formations that outcrop in unconformity on a thixotropic sandstone bank. They consist of blue marls, diatomitic marl alternations with slump structures on its upper part, and finally by a gypsum facies.

A detailed analysis of calcareous nannofossils performed on 119 samples allows to recognize 10 families of 14 genera and 52 species. The presence of some of them (*Discoaster quinqueramus, D. neohamatus, D. neorectus, D. surculus*, *Amaurolithus primus, A. amplificus*) is indicative of five biozones (NN10a, NN10b, NN11a, NN11b, NN11c) assigned to the Upper Miocene period (upper Tortonian and Messinian). The Tortono-Messinian boundary is marked by the first occurrence of *Amaurolithus delicatus* and *Reticulofenestra rotaria*, corroborated by the first occurrence of the planktonic foraminifer *Globorotalia mediterranea*.

The analysis of the nanofossil assemblages and the fluctuations of relative abundance of *Coccolithus pelagicus* and *Reticulofenestra pseudoumbilicus* show evidence of seven successive phases characterized by alternating cold and warm marine water masses, variations in light intensity, and/or nutrient availability.

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Biostratigraphy and provenance data from Modino Unit Succession: new insights from the Northern Apennine inner-foredeep sequence

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In the Northern Apennine fold and thrust belt, the post-collisional stages are characterized by the Oligocene–Pliocene progressive shortening and shifting of the foredeep basins, resulting from the eastward migration of the orogenic front toward the belt foreland represented by the Adria plate continental margin. The foredeep deposits were involved in the tectonic stack as thrust sheets detached from their substrate and overthrust by the Ligurian Units derived from the Jurassic Ligure-Piemontese oceanic basin.
The Eocene-Oligocene succession of the Modino Unit (Tuscan Domain of the Northern Apennine) is composed by turbidites deposited on top of the Apenninic prism during the early collisional and post-collisional stages. The biostratigraphical, and petrographycal analysis of different stratigraphic sections of the Modino Unit Succession enables us to give a paleotectonic reconstruction of the evolution of this part of the foredeep. The use of calcareous nannofossils help us recognize most of the biostratigraphic units using the Chronostratigraphic Global Chart with the biohorizons developed for the Mediterranean region by Catanzariti *et al.,* 1997, and this data was integrated with the new bio-events reported in Agnini *et al.,* 2014 for the Lutetian and Bartonian part of the succession. The biostratigraphycal analysis suggest that the age of the Modino Unit succession is comprised between Lutetian and Aquitanian,
The petrographycal analysis on arenites show a change in sandstone compositions from the basal to the upper part of the sequence. This change is underlined by the significant presence of ophiolitic rock fragments (serpentinites, basalts and cherts) only in the oldest arenites of the succession (Lutetian and Rupelian).
Moreover, this data suggests that the sedimentation of the lower part of the Modino Unit succession is influenced by sediment failures and submarine landslides from a proximal and intermittent source composed by oceanic crust successions. Probably this source can be localized in the Apenninic wedge.
We think that the Rupelian-Chattian interval for this Unit, represents the link between the stage of dominant Apenninic sedimentation influenced by a high tectonic activity and the stage with dominant Alpine sedimentation.

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Proposal for a regional chronostratigraphical stage-division of the Middle Pleistocene in SE Europe, based on glacigenic sediments in the Croatian Dinarides

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Quaternary sediments have been studied for the past 20 years in the area of the Croatian Dinarides, specifically the northeast Adriatic coast and islands, the Velebit Mt. and northern Dalmatia. The sedimentological research yielded a glacigenic and periglacial origin of the studied sediments, which are attributed to several glacial and interglacial stages in the Croatian Dinarides.
Glacial sediments are diamicts (tills or tillites) interpreted as ground, medial and lateral moraines. Clasts with glacial striae, ice-shaped (faceted, bullet-shape and conical) and ice-shattered clasts are the main evidence of their glacial origin. The ground moraines are identified as Rujno, Paklenica and Novigrad Members. The Paklenica Mb., found also on Krk and Rab Islands, documents the furthest seawards extent of glaciation. Another characteristic landform of ice-marginal zone are kame-terraces which are well-preserved on the Krk and Pag Islands built of stratified slopeward dipping supraglacial debris and glaciofluvial sediments.
Glacifluvial sediments comprise both glacial outwash deposits of braided streams and flood plains, and fluvial deposits of meandering rivers, represented by sand and gravel deposits. Their glacigenic origin is based on facies association, since they occur with tills or tillites, and contain glacially derived boulders and blocks, sometimes also lithologically exotic debris. The proglacial glacifluvial sediments are found on Krk and Pag Islands (kame-terraces) and are widespread in Northern Dalmatia.
Glacilacustrine sediments comprise a) clay-silt sediments with complex clastic varves, and b) varve-like calcisiltites with drop-stones, being the main diagnostic feature for their proglacial character. Varved sediments with abundant plant macrofossils, ostracods and small bivalves are found at Ždrilo coast. The fossil macroflora indicates transition to cold stage and ice-advance documented by the Paklenica Mb. moraines. Varved-like sediments with dropstones are exposed at Novigrad Sea and Seline coastal sections. Subglacial hydrofractures, ice-contact subglacial sedimentary features and ice-wedge casts at the Novigrad Sea coastal section document the most southwards glacial extent and periglacial palaeoenvironment.
Glacideltaic sediments are an alternation of conglomerates, calcarenites and calcisiltites. Significant characteristics for glacial attribution are ice-striated clasts in conglomerates, and their association with glacilacustrine sediments, all exposed along the Seline coast and named Starigrad Unit. The sediment succession documents a subglacial deltaic environment of the ice terminal zone.

The sedimentary record revealed three phases of extensive glacial advance and retreat during the Middle Pleistocene. Seven allo-morpho-lithostratigraphic members were defined within the studied sedimentary successions. Three are represented by glacial deposits: the Starigrad Mb. as the oldest but with no ages available yet, the Paklenica Mb. as the most extensive one and older than 350 ka, and Novigrad Mb. older than 145.4 ± 6.2 ka (both dates are calibrated U-series ages of calcite cements in a moraine). Their characteristics correspond to glacial sediments in Montenegro and Greece, so the preliminary use of Pindus Mt. chronostratigraphy is the most suitable. Thereafter, the Paklenica Mb. that correlates well with the Ninkovići Mb. in Montenegro is ascribed to the Skamnellian Stage, and the Novigrad Mb. appends to the Vlasian Stage. The Seline Mb., Nozret Mb. and Karin Mb. are represented by lacustrine systems, whereas the Paljuv Mb. is represented by fluvial systems. Despite of only a few U-series minimum ages, we propose a partial regional stage-division by naming three cold stages: Starigradian Stage as tentative equivalent to one of the Cromerian glacials of Western Europe (MIS 14 or 16), Paklenician Stage as time-equivalent of the Skamnellian Stage (MIS 12) and Novigradian Stage as time-equivalent of the Vlasian Stage (MIS 6) in Greece. Further dating of sediments is crucial to complete the proposed regional division.

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The correlation of the Early Euxinian deposits of the Black Sea and the Likhvin continental deposits based on small mammalian faunas of Eastern Europe

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Numerous small mammal localities correlated with the Likhvin (=Holsteinian = Hoxnian) Interglacial are known on the Russian Plain. Most of them were found in fluvial deposits of the main rivers of Eastern Europe: the Dnieper, Oka, Don, Zapadnaya Dvina, Volga, Kama, Kuma et al. In many localities fluvial deposits underlie the loess-paleosol series with several widely distributed Middle Pleistocene paleosols (Kamenka paleosol – MIS 9; Romny paleosol –MIS 7) and the Dnieper till or Dnieper loess above them. In many localities the Dnieper till or loess are overlain by Mikulino (Eemian) paleosol and Valdai (=Weichselian) till or loess (Markova, 2006). The northernmost localities were found at approximately 57°N and the southernmost in the Kuma drainage basin in the Northern Caucasus (44°N).

Small mammal composition of Likhvin faunas includes *Arvicola cantianus*, *Lagurus* ex gr. *lagurus, Eolagurus luteus, Microtus gregalis, M. arvalis, M. oeconomus.* Steppe lemming remains include some morphotypes resembling *L. transiens*, but their quantity is lower than *L. Lagurus* morphotypes. The *Mimomys, Pliomys, Borsodia, Microtus (Terricola) arvalidens* and *M. (Stenocranius) gregaloides* remains are absent in these faunas.

A unique small mammal locality was found in the sea-liman deposits of the Black Sea in the SW of Eastern Europe in the Danube basin on the east coast of Yalpug lake (the liman of Danube river) near Ozernoe (Babel') village (Mikhailesku, Markova, 1992). The locality is confined to the deposits of terrace IV of Danube river. The fluvial sequence includes the alternation of the alluvial, lake and sea-liman deposits. The fluvial deposits are overlain by the loess-paleosol sequence with 4 fossil soils (the Late Pleistocene Briansk and Mikulino soils, and also the late Middle Pleistocene Romny and Kamenka soils).

The composition of the Ozernoe small mammal fauna includes such diagnostic species as *Arvicola cantiana, Microtus (Stenocranius) gregalis, Lagurus* ex gr. *transiens-lagurus, Eolagurus luteus volgensis* and others. The complex of brackish-water mollusks with *Didacna pontocaspia*, *D.* cf. *nalivkini, Monodacna caspia, Corbicula fluminalis* et al. was recovered from the same deposits (Mikhailesku, 1990)*. Didacna pontocaspia* is the most characteristic species for the Early Euxinian deposits of the Black Sea (Pavlov, 1925).

The high degree of similarity of the small mammal composition from the liman deposits of the Ozernoe locality with the composition of small mammals from the localities situated on the Russian Plain permits to correlate the Early Euxinian transgression of the Black Sea with the Likhvin Interglacial of the Russian Plain (MIS 11).

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Did 'Devonian' fish become extinct at the D-C boundary

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The compilation by Sallan & Coates (2010) of Devonian fish diversity has highlighted fish fauna collapse at the D-C boundary. Inevitably, this has focused attention on the earliest Carboniferous placoderm occurrences including key records from East Greenland. Previously these occurrences were largely irrelevant as the sections were so badly dated. However, the recognition that a precise D-C boundary can be palynologically defined emphasises these anomalous ranges. In one sense these records are unimportant representing dead clades walking, i.e. short-lived post-extinction survivors. But as these earliest Carboniferous records are often cited and used to demonstrate range extensions and stratigraphically date rocks it is important to confirm their veracity. It is also important to confirm the records from direct field knowledge as access to these remote and challenging sections is difficult with first-hand information rapidly passing into just written and generally unpublished records.
The main Carboniferous fish records are from Celsius Bjerg where the D-C boundary is coincident with the Obrutschew Fm and overlain the Harderbjerg Fm (90 m). Both *Holoptychius* and *Groenlandaspis* have been recorded from these sections (e.g. Bütler, 1954) and subsequently illustrated (Miles, 1964) and continually re-cited (e.g. Olsen and Larsen, 1993). Three of us (JM, HB, SF together with Dupret i.e. 3 specialist fish palaeontologists) visited this summit section on three occasions. Importantly in 2012 we made a temporary summit bivouac at 1100m which considerably increased our working time. We recovered no fish fossils from the Harderberg Formation, despite searching a considerable area with 100% exposure of frost-split bedding planes.
There are two specimens of *Groenlandaspis* identified as from the Harderbjerg Formation that are available in museum collection. The specimen figured by Miles (1964) from Celsius Bjerg, was at an altitude of 1300m, which appears to place it well within the Carboniferous. However, notes made by Bütler coupled with our field observations show it to comefrom the very base of the Harderbjerg Formation. As these represent a fluvial system that immediately overlies the deep wide stratified lacustrine sediments of the Obrutschew Fm there was a high potential for reworking. If *in situ* it is very earliest Carboniferous and post-dates the terrestrial plant extinctions.
The second specimen is from a thin sandstone sequence deposited onto the Precambrian basement of La Cours Bjerg. Although attributed by Säve-Söderbergh (1934) to the now Harderbjerg Fm, Bütler (1954) noted there was insufficient evidence for this assignment and it cannot be used as evidence for post Devonian *Groenlandaspis*.

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Geochemical analysis of three astronomically influenced Eocene deep-sea sections in the Basque-Cantabrian Basin (western Pyrenees): insights into climatic and environmental controls on hemipelagic sedimentation

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The formation of hemipelagic limestone-marl alternations is commonly related to cyclic environmental changes in sedimentary basins. Although several potential forcing mechanisms can produce such calcareous couplets, they have mostly been related to changes in the orbital parameters of the Earth (Milankovitch Cycles). The aim of this work is to cast light on the factors that affected the environmental evolution of a deep-sea basin greatly influenced by Milankovitch cycles. To this end, three successions (Sopelana, Gorrondatxe and Oyambre) were studied, which were formed in the Basque-Cantabrian Basin (western Pyrenees) at water depths of between 500 and 1500 m during different stages of the Eocene greenhouse interval. Six couplets were selected from each succession with the aim of identifying the influence of Milankovitch cycles of different duration. A high-resolution (1 sample/1000-1500 years) analysis of some environmental proxies ($CaCO_3$, $\delta^{13}C$ and $\delta^{18}O$) was carried out in each succession in order to determine the main forcing mechanisms that controlled the sedimentation during all orbital cycles.

Diagenetic processes could have altered the original geochemical features of the rocks, especially the oxygen isotope values, which are very sensitive to diagenesis. However, the results show that such processes were not very strong. Consequently, the environmental proxies are thought to reflect the conditions that prevailed in the basin while sedimentation was occurring. The influence of precessional and eccentricity cycles can be readily identified in the geochemical records of the three successions. However, the manifestation of each cycle type differs between the successions, suggesting that the main depositional controls were time and location dependent. In Sopelana, the precessional cycles mainly affected water temperature ($\delta^{18}O$), which in turn controlled summertime planktonic carbonate production ($CaCO_3$). Consequently, limestones can be interpreted as formed when summer occurred at perihelion, whereas marls represent summer occurring at aphelion. Accordingly, the couplets with the greatest carbonate contrast are related to maximum eccentricity. Surprisingly, the limestones that were formed at such times show slightly reduced temperatures, maybe as a consequence of the reactivation of cold oceanic currents. In Gorrondatxe, where turbidites are interbedded within the pelagic succession, the model is rather different, as the precessional cycles mainly affected rainfall, continental run-off and terrigenous input to the sea. Thus, at times of high precessional seasonality, terrigenous input increased and marls were accumulated. The $\delta^{13}C$ and $\delta^{18}O$ records varied in line with the $CaCO_3$ content, suggesting that turbidity currents may have included terrestrially derived, isotopically light fresh water. In Oyambre, precessional cycles also affected rainfall and continental run-off, which determined biological carbonate production though salinity variations. Thus, marls represent reduced summertime carbonate production due to increased rainfall and fresh water input and reduced salinity (low $\delta^{13}C$ and $\delta^{18}O$), whereas limestones represent increased carbonate production when the influence of fresh water decreased.

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The Fortunian and Cambrian Stage 2 as seen from arctic Siberia

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The uppermost Ediacaran to lowermost Cambrian Kessyusa Group in the northwestern slope of the Olenek Uplift, arctic Siberia, represents a mixed, carbonate and aluminosiliciclastic succession of up to 145 m thickness divided into the Syhargalakh, Mattaia and Chuskuna formations. The Syhargalakh Formation is intruded by diatremes of the Tas-Yuryakh Volcanic Complex. Tuff breccias interfinger with the upper member of the Syhargalakh Fm. A U–Pb zircon date of 543.9 ± 0.24 Ma from the tuff breccia (Bowring et al., 1993) provides the best age constraint of the Syhargalakh Fm. The upper member of the Syhargalakh Formation contains the boundary between the *Anabarites trisulcatus* and *Purella antiqua* assemblage zones of the Nemakit-Daldynian Regional Stage of Siberia and also yielded the lowermost stratigraphic occurrence of the trace fossil *Treptichnus pedum*, an index-taxon for the base of the Cambrian Fortunian Stage in the Standard Global Chronostratigraphic Chart. The lowest stratigraphic occurrence of both *Aldanella attleborensis* and *Watsonella crosbyi*, candidates for the index-species to define the base of the Cambrian Stage 2, are confined to the same stratigraphic horizon in the upper part of the overlying Mattaia Formation. A volcanic tuff immediately above the first appearance of *Aldanella attleborensis* yielded a U–Pb zircon date of 529.7 ± 0.3 Ma (Kaufman et al., 2012). High resolution sampling and C isotope analysis of Mattaia Formation carbonates (SOM) define a positive excursion up to +5‰ associated with $^{87}Sr/^{86}Sr$ composition of well-preserved limestone as low as 0.70818 (Kaufman et al., 2012).

Diverse small skeletal fossils are recorded in the mid-section of the Mattaia Formation ~16 m below the first appearance of *Aldanella attleborensis*. The sudden increase in diversity and abundance of trace fossils occurs just 5.5 meters higher in the section. There is no physical evidence of any significant change in sedimentation rate, hiatuses or local facies at this stratigraphic level. The increase in ichnodisparity and behavioural complexity in the Mattaia Formation therefore is part of a major rapid body-plan diversification event of the Cambrian explosion. Among trace fossils abundant vertical simple and U-shaped burrows (*Skolithos*, *Arenicolites*, *Diplocraterion*) occur representing perhaps the oldest deep-tier suspension feeders. Furthermore, the rise of suspension feeders coincides with the appearance of new behaviours of deposit feeders (e.g., *Heimdallia*, *Nereites*, *Rhizocorallium*, *Zoophycos*). All these behavioural changes and evolutionary innovations are accompanied by a conspicuous increase in bioturbation depth. The ichnocoenoses of the Kessyusa Group, in addition of being taxonomically and numerically abundant, appear to be ecologically far more complex compared to other Fortunian shallow-marine trace fossil assemblages. Trace fossils of the Kessuysa Group represent the oldest known archetypal *Cruziana* ichnofacies. In addition to a diversity of horizontal traces attributed to feeding activities at or slightly below the sediment-water interface, it contains vertical dwelling structures of suspension feeders. Complex ichnofabrics suggest the presence of multiple trophic guilds and a well-established tiered structure of the infaunal community. The *Cruziana* ichnofacies of the Kessyusa Group is the evidence of a Palaeozoic-type, if not modern infaunal ecological structure, established in the Terreneuvian.

At least in the northwestern slope of the Olenek Uplift of Siberia, the ichnospecies *Treptichnus pedum* appears to be older than the currently accepted age (541.0 ± 1.0 Ma) of the lower boundary of the Fortunian Stage. The U–Pb zircon date of 529.7 ± 0.3 Ma can be applied to constrain the base of the Cambrian Stage 2, regardless of the ultimate choice of primary correlation criterion for defining the boundary. In any case, the Fortunian is broadly coeval with, if not shorter than the *Purella antiqua* Assemblage Zone of the Nemakit-Dalnynian. The combined bio- and chronostratigraphic data from the Mattaia Fm. indicate that the last of the three positive carbon isotope excursions recorded in the Terreneuvian Series (the ZHUCE excursion) is within Tommotian strata defined by the first appearance of *Aldanella attleborensis*, and the base of the Tommotian Stage coincides with the lower boundary of a “Laolinian Stage” defined by the peak of the ZHUCE carbon isotope excursion.

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An integrated multiproxy stratigraphic analysis as a tool for recognition of the Devonian/Carboniferous boundary in a relatively shallow carbonate ramp environment: some Polish examples

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The uppermost part of the Famennian and lowermost part of the Tournaisian in the Pomerania area (NW Poland) (between Upper *expansa* and *sandbergi* conodont zones) is a very thick monotonous succession with up to several hundred meters of open-marine marls and claystones, formed below wave base and corresponding to a relatively shallow carbonate ramp environment. The Devonian/Carboniferous boundary falls in thin-bedded, dark grey marls, marly claystones and claystones, with only thin marly limestone intercalations or it is missing at an unconformity in some sections. Significant faunal remains are relatively rare in the uppermost part of Famennian and restricted to coral, brachiopod and crinoid debris, and to entomozoacean fragments, rare foraminifers and individual conodonts.

The study of the Pomeranian sections reveals numerous problems associated with the application of conodont biostratigraphy in the D/C boundary definition. Conodont analysis permitted recognition of the Upper *expansa*-Lower *praesulcata* zones, dominated by the bispathodid and polygnathid fauna. Owing to the extremely rare occurrence of the early siphonodellids in the uppermost Famennian and absence of the biostratigraphically valuable genus *Protognathodus*, the base of the *praesulcata* Zone cannot be fixed precisely. The recognition of the Middle *praesulcata* Zone *sensu* Ziegler and Sandberg (1984), defined by the last occurrence of *Palmatolepis gracilis gonioclymeniae*, is impossible owing to the absence of this index taxon (it is worth of note that definitive retreat of the offshore genus *Palmatolepis* from the Pomeranian Basin took part much earlier, at the end of the *marginifera* Chron). Apart from conodonts, used in the correlations of deep marine facies, foraminifers and miospores represent groups that are used in the correlations of shallow marine facies. Plurilocular foraminifers are present in some Pomeranian sections. The uppermost Famennian foraminiferal association corresponds to the *Quasiendothyra kobeitusana–Quasiendothyra konensis* Zone which falls in the interval between the Middle *expansa*–Middle *praesulcata* conodont zones. Higher up, two standard western European miospore zones were recognized close to the D/C boundary: the uppermost Famennian *Retispora lepidophyta–Verrucosisporites nitidus* (LN) Zone, and the lowermost Tournaisian *Vallatisporites verrucosus–Retusotriletes incohatus* (VI) Zone. The Hangenberg Event took place close to the *lepidophyta-nitidus* Chron.

The obtained results indicate that only an integrated approach, combining biostratigraphy based on conodonts, foraminifers, and miospores, provide more precise age determinations for those parts of the uppermost Famennian shallow-water succession which were hitherto unfavourable for individual fossil group.

Petrophysical and geochemical changes across the D/C boundary in the Pomerania area also provide a useful proxy for the determination of the Hangenberg Event, although the Hangenberg Black Shale horizon is not developed in some Pomeranian sections. The sedimentary succession and specific phenomena recognized close to the D/C boundary, such as fluctuations in water column euxinia, wildfire evidence, relative sea-level changes and perturbations of the carbon cycle reflected by positive carbon excursions, display a pattern partly similar to that observed in many areas in Europe during the Hangenberg Event. The significant potential of these proxies for regional correlation is high and capable of refining the biostratigraphic division of the D/C boundary interval.

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The revised Upper Triassic conodont record of the Tethys: a new step towards a better definition of the conodont bioevents around the base of the Norian stage

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In the last ten years, the studies on the systematic of the Upper Triassic conodonts have been progressively intensified. The main reason of this renewed interest towards the Late Triassic conodonts is that the Global Boundary Stratotype Section and Points (GSSPs) of the Norian and Rhaetian stages have still to be established and conodonts, being a very common fossil group in the Triassic, represent a possible tool for their definition. Actually, in 2004, the Tethyan Upper Carnian-Lower Norian conodont record was represented by 22 species, many of which established in the '70s and resembling in a single species a large variety of morphologies. A taxonomic revision thus appeared necessary to refresh an outdated systematic, and it led to almost redouble the number of conodont species, which became 40.
Large part of this taxonomic revision was conducted on the conodont faunas of the Pizzo Mondello section (Western Sicily, Italy), which is one of the two GSSP candidates for the base of the Norian, together with Black Bear Ridge (Northern British Columbia, Canada). The section is a 450 meters succession of pelagic cherty limestones (Scillato Formation), spanning from the Upper Carnian to the Rhaetian, and it provides the most continuous and valuable conodont record for the Tethys. Of the 40 species now identified in the Tethys around the Carnian/Norian boundary, seven new species were defined in this section.
Since the record of Pizzo Mondello could become the world reference for the Late Triassic conodont biostratigraphic record, its correlation potential with other sections is fundamental. For this purpose, recently we revised the conodont faunas of the Tethyan key sections Silická Brezová (Slovakia), Bölücektasi Tepe and Erenkolu Mezarlik (Turkey).
This revision allowed recording the occurrence of the newly established species in large part of the Tethys. Species that are potentially useful for the definition of the C/N boundary were also recognized in all the sections: *Epigondolella quadrata* Orchard, *Epigondolella rigoi* Noyan & Kozur, *Carnepigondolella gulloae* Mazza & Rigo and species belonging to the *Metapolygnathus communisti* group. The same succession of conodont bioevents was also identified in all the investigated sections, confirming that the Pizzo Mondello conodont record is actually representative for the entire Tethys.
These results open the possibility of new correlation options throughout the Teathyan realm, solving some biostratigraphic discrepancies raised in the past years and preparing the ground for the establishment of a truly reliable biovent for the definition of the Carnian/Norian bundary.

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Integrated stratigraphy of the Upper Cretaceous high productivity sequence of the Southern Tethys, Israel

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In this study we established a detailed and updated chronostratigraphic framework for the Upper Cretaceous high productivity sequence deposited in central and southern Israel based on eight different sections, covering a N-S transect of ~150 km. The Shefela basin (central Israel) is the largest and thickest of the oil shale basins in Israel and represents the broadest penetrated stratigraphic interval of the organic-rich section. We used a continues core from the Aderet borehole drilled in the Shefela basin by IEI ltd in order to construct a ‘type-section’ and detailed chronostratigraphic scheme for the high productivity (Si-P-C rich) sequence.

The N-S transect extends between the distal Shefela basin in central Israel (Aderet), Tel-Shoket (NS17), Biqat Beer-Sheva (NS23), Nevatim (M8), Mishor Rotem (PAMA outcrop and Bit68), Ein Mor (NS 20) and the inner-shelf Saraf/ZS28 core in the Zin basin. A total of twenty-four local correlatable datum levels were recognized using planktic foraminiferal biozones, benthic foraminiferal datums, lithostratigraphy and gamma-ray well log markers.

The base of the Aderet core is dated as upper Santonian *Dicarinella asymetrica* Zone, older than 83.5 Ma, shortly under the Santonian-Campanian boundary. This age correlates with that of the upper part of the lower Menuha Fm. The upper part of the Chert Mbr (Mishash Fm) in the Negev is represented by the ~7 m ‘Mishash Tongue’ in the Shefela. Biostratigraphy has tied peaks in the P_2O_5 content and corresponding gamma-ray signals throughout the transect with those of the Phosphate Mbr in the Negev. The entire Oil Shale Mbr (OSM) of the Ghareb Fm in the Negev correlates with the TOC-rich zone of 100 m thickness, at the middle part of Aderet core, between 350-450 m depth with an average of 15.2 wt.% TOC. Moderate sedimentation rates recorded during the lower and mid-Campanian are considerably elevated at the base of the *Pseudoguembelina palpebra* Zone, following a regional unconformity. Sedimentation rates decrease towards the southern sections yet are also dependent on the depth and architecture of the different basins. Moreover, the organic rich fraction within the pelagic sediments diminished at the upper part of the high productivity sequence in a step-like manner: first at the proximal southern localities (PAMA, Negev), then further offshore (M8, Nevatim) and later still in the distal northern basins (Aderet, Shefela). The top of the Aderet core is dated as mid-Maastrichtian *Abathomphalus mayaroensis* Zone implying an age of ~68.3 Ma. This indicates that the full duration of oil shale accumulation in the Aderet core spans ~17 Ma.

Arabian Plate-wide maximum flooding surfaces (MFS) recorded during the Tectonic Mega-Sequence (TMS) AP9 time frame (*Marginotruncana schneegansi* to *Pseudogumbelina hariaensis* zones; 92 to 63 Ma) are identified here in the local sedimentary system of the Levant: K160 signifying the onset of organic-rich carbonate deposition; K170 at the upper part of the massive and brecciated Chert Member, signifying also a regional productivity peak; and K180 marking the diminishing phase of the high productivity sequence in Israel.

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Integrating biostratigraphic and chemostratigraphic data: evaluation of two Upper Ordovician-lower Silurian GSSPs using Horizon Annealing for high-resolution correlation

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Global boundary Stratotype Sections and Points (GSSPs) should contain a range of marker horizons or other data points relevant for long-distance correlation, including as wide a diversity of fossil occurrences, chemostratigraphic events and geomagnetic reversals as possible. The best practice is to use the totality of the evidence through the entire continuous section that contains the boundary and correlate with the GSSP based on the sum of this evidence. Although there are several methods available for integrating multidisciplinary data into a correlation project (e.g., graphic correlation (GC) and constrained optimization (CONOP)), relatively few studies have employed these methods specifically for correlation with GSSPs and fewer still have used these methods as part of the process of selecting GSSPs. Horizon Annealing (HA) is a recently developed method similar to CONOP. Like CONOP, HA simultaneously integrates data from multiple stratigraphic successions and uses a simulated annealing algorithm to find a correlation between all of the sections (a multidimensional line of correlation) that minimizes the misfit between the composite succession and these individual sections. CONOP does this by ordering events that occur in these sections, such as first and last appearances of taxa or other kinds of marker events, whereas HA orders sample horizons, each sample horizon being characterized by all of data marking that level. Since GSSPs are, by definition, particular sample horizons, HA is well suited to the task of correlation of the GSSPs with correlative levels in other sections.

We have examined the correlation of the GSSPs for the bases of the Hirnantian Stage and the Silurian System using 27 relatively graptolite-rich sections on four paleo-continents spanning the upper Katian into mid-Rhuddanian using HA. An analysis conducted using only graptolite occurrence data permitted construction of what appears to be a reliable composite graptolite range chart, but graptolite data alone did not provide sufficient constraints for high-resolution correlation of individual levels between sections, such as the GSSP levels. We tested several approaches to integration of stable isotope data and regional lithostratigraphic marker beds into the HA composite, and these appear to have improved the correlation of key levels related to these GSSPs.

We have used two independent methods within HA to investigate the level of precision with which particular horizons can be constrained within the composite succession. Jackknife analysis, replicate analyses with individual sections randomly omitted from the dataset, provides a measure of the range of uncertainty in the placement of sample levels within the composite. Relaxed fit analysis, which assesses the range of variation recorded as the optimality-of-fit criteria are slightly relaxed, allows for a second assessment of the degree of constraint of each sample level within the composite.

Our preliminary conclusions suggest that the chosen GSSPs for these boundaries are relatively well-constrained in the HA composite relative to other sections and levels that were considered for these GSSPs. Thus, they represent good horizons for high-resolution correlation through these time intervals, at least for strata that yield good graptolite and/or carbon isotope data. In addition, if we make the assumption that the sample scale of the HA composite can be regarded as an approximation of a temporal scale, we can infer that the mean temporal resolution for individual sample horizons in the composite is approximately +/- 160 Ka. Correlation into a wider range of facies will require incorporation of data from other fossil groups, such as conodonts, chitinozoans, and shelly fossils.

Valanginian to Cenomanian Oceanic Dysoxia/Anoxia in the Eastern Carpathian Nappes

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The nappes of the outer part of the Eastern Carpathians, the Moldavides, derived from a continental rift, opened in the Late Triassic. Within the Cretaceous, the Moldavides situated in an oceanic remnant basin, with thinned continental crust. These nappes were involved in mid Cretaceous compression, subduction and shortening, being finally structured at the end of the Cretaceous, during the Laramian tectonic movements.

The Moldavide oldest sediments are Upper Valanginian to Albian black to grey shales that accumulated in a basin with restricted circulation, i.e., the Moldavian Trough. The Total Organic Carbon (TOC) content of the black shales significantly varies, between 0.3 and almost 4%, indicative for a kerogen types II and III.

At the end of the Late Cretaceous, in the Late Albian, i.e. within the Stoliczkaia dispar ammonite zone, this anoxic/dysoxic setting shifted to an oxic one, mirrored in the deposition of variegated (red, green and grey) shales. Regional factors, such as the intense tectonic activity that took place within the Eastern Carpathians during mid-Cretaceous times, could have been responsible for the environmental changes by modifying the circulation pattern in the Moldavian trough, from a restricted circulation to a more open one, along with global factors, including sea level fluctuations (Haq, 2014).

Since the Late Albian, the red shales are the dominant lithology and include thin cm up do dm black to grey shales depositional intervals; some of these black shales, located in the Albian/Cenomanian boundary interval, show a positive excursion of $\delta^{13}C$ with 1.5 ‰, indicative for the setting of the Oceanic Anoxic Event 1d. This interval contains poorly preserved nannofloras, with low species richness, and highly diversified benthic foraminifers of the Plectorecurvoides alternans and Haplophragmoides falcatosuturalis zones, suggestive for a deep-marine setting, probably a lower bathyal one (Melinte-Dobrinescu et al., 2015).

The variegated shally deposition lasted within the Cenomanian and Turonian stages and includes, within the Cenomanian/Turonian boundary interval, black shales containing the positive excursion of $\delta^{13}C$ of the Oceanic Anoxic Event 2, and significant fluctuation in the nannofloral composition.

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The singular Barremian series in the Lansarin Chain (Northeast Tunisia): Stratigraphic and Sedimentologic characteristics

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The present study aims at throwing light on stratigraphy and sedimentology of an uncommon Barremian outcrop exposed in the Lansarin Chain, in northeastern Tunisia.

The Lansarin section is distinguished by its exceptional thickness, compared to what is known in southern Tunisia (Jebel Oust; 900 m, Jbel Rhazouane; 840m), since it attains 3000 meters.

Above the Late Hauterivian bed marked by the *Pseudothurmannia angulicostata* Zone, the Barremian deposits of the Lansarin chain are well exposed in the Boulahouajeb section. At the base of the section they are formed by blue nodular limestone beds and dark fossiliferous marls and clay. Above, the limestone beds become more frequent, topped by a group of nodular and gray limestones (fifty beds) which produce a relief. The basal marls are characterized by the planktonic foraminifer *Gorbachikella kugleri;* which characterizes the lower Barremian, associated with benthic foraminifera (*Ammodiscus siliceus, Spirillina neocomiana, Lenticulina eichenbergi, Lenticulina ouachensis*). In the middle part of this section, we notice the first occurrence of *Praehedbergella sigali*. It terminates with *Gavelinella barremiana, Epistomina* sp., *Lenticulina crepidularis, Conorotalites barteinsteini barteinsteini and Conorotalites barteinsteini intercedens* which mark the upper Barremian.
The fifty beds of limestone that make the relief are rich in ammonites which enable a further subdivision of the Barremian. Thus, this subdivision will be used to establish a correlation with the standard biozonation of the Tethys.
This Barremian series finishes with a massive sequence of marls, which begins with four sandstones lenses of decametric thickness. These sedimentary facies successions contain three deep-sea ichnogenera of *Nereites* ichnofacies: *Nereites, Paleodictyon* and *Ophiomorpha*. The integration of ichnological and sedimentary facies suggests a deep marine paleoenvironment for the Barremian deposits in the Lansarin section, which has been confirmed by biostratigraphic analysis as well.
This significant thickness of the unusual Barremian series, which marks a deepening of the environment, is related to the activity of normal faults with NE-SW direction, reflecting extension during the Early Cretaceous. This movement follows the Jurassic rifting.

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Benthic microfossils, geochemistry and cyclicity of Rhaetian deep neritic to basinal sediments of the Northern Calcareous Alps

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The Rhaetian Zlambach Formation was previously suggested to have accumulated under stable normal marine conditions in a pelagic environment bordering to the so-called Meliata Ocean. Slumping structures and turbiditic beds are suggestive of a toe-of-slope to basin environment. Previous estimations of the maximum water depth of the Zlambach Formation vary between 50m and 500m. Preliminary results of the present study, particularly the absence of deep marine (bathyal) ostracods are suggestive of less than 200m water depth. A high resolution micropalaeontological and geochemical analysis of the Zlambach Formation at the Rossmoosgraben section (near to Bad Goisern, Austria) has proved significant environmental changes which were controlled by sedimentary cyclicity and changing water depth. The lower and middle part of the Zlambach Formation at the Rossmoosgraben section (Rhaetian 2-3) shows 4 to 6 meters thick depositional cycles consisting of thick clayey and silty marls in the lower parts and intercalated thickening-upwards micritic limestones in the upper parts. Intercalations of detritical limestones with abundant shallow-water foraminifera, geochemical proxies for the input of terrigenous clastics as well as the carbonate content prove turbiditic activity at the top of the cycles, probably caused by sea level fluctuations. Short-term sea level changes are also recorded in age-equivalent intraplatform basin deposits of the Northern Calcareous Alps (Kössen Formation). The microfossil assemblages of the Zlambach Formation also display cyclic changes. The ostracods show increasing total abundance and species diversity from the base to the top of each cycle and changes in the relative proportion of taxa. Relative small, smooth and thin-shelled healdiids and bairdiids are abundant in the lower part of each cycle. Larger thick-shelled and sculptured healdiids and bairdiids occur preferentially in the upper part of the cycles. Very distinct changes are recorded by the foraminifera assemblages and bioturbation patterns. In the lower parts of the cycles occur predominantly primitive agglutinated forms together with smaller nodosariid taxa while the relative abundance of other lagenids increases significantly towards the top. Laminated shales in the lowest parts of the cycles point to oxygen-poor conditions while the middle and upper parts show trace fossil associations indicating higher oxygen concentrations. Preliminary foraminifera and carbon isotope data as well as intervals with millimeter-scale laminations in the upper Zlambach Formation (Rhaetian 3) point to major environmental disturbance in the late Rhaetian.

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Triassic/Jurassic boundary change record in the West Carpathian sections

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A slight Upper Triassic transgression and humidification affected sedimentation in the Central Western Carpathian part of the N-Tethyan shelf margin. Terrigenous Carpathian Keuper deposits were covered by black silty mudstones and quartz sandstones of the Tomanova Fm. with iron ores, dinosaur footprints, Rhaetian fern macroflora, pollen associations (*Classopollis*, *Gliscopollis*) and sporomorphs (*Taeniasporites*, *Protohaploxypinus*). Sediment provenience was detected by total chemical and quantitative mineral analyses, C isotope study of organic matter (OM) and carbonates. Sandstone and shale mineralogy and chemistry proves for their identical source. Kaolinite decreases upwards being substituted by illite (6 to 41 %). The shape and size of kaolinite crystals indicates their detrital origin. More than 50 % of the clay mineral fraction including kaolinite (forming >30 % of the rock: 30-46% in claystone; 20-41% in sandstone), quartz and mica indicate intensive weathering of granites, and kaolinite formation by acid leaching in humid and warm Rhaetian climate. Acidity increased due to OM decomposition in wetland-like conditions. Although the residual OM content is relatively low (C_{org} 0.1 - 1.5%), its local increase (2.5 % or 8.12%) indicates humid periods with water table level rise, increased production and input of plant debris. $^{13}C_{org}$ isotope ratio (-27 to -25‰ V-PDB) demonstrates that OM is derived mostly from terrigenous plants, probably mixed with limnic OM. High content (39%) of siderite (pelosiderite) with Fe^{2}+ and other redox-sensitive elements in mud ore indicates temporary reduction and acidification of the lacustrine mud. Highly negative $^{13}C_{sid}$ isotope ratio (-12 to -17 ‰ PDB) in siderite suggest that pH and dissolved iron oxide and other mineral phases were probable changed by “biogenic” CO_2. Fe was mobilized during diagenesis as illustrated by chamosite distribution: it generally forms >5 % and ≤ 16 % in siderite free samples. Red Fe oxides (goethite, lepidocrockite) represent weathering products of these Fe^{2}+ minerals. High kaolinite content indicates start of the T/J Boundary humid event. C isotope data of OM from the Tomanova Fm are comparable with these from marginal/proximal marine zones, characterized by mixed terrigeneous and marine/limnic OM composition.

The adjacent Zliechov Basin farther to the south was inundated by a shallow sea. The kaolinite content in neritic carbonates of the Rhaetian Fatra Fm is low (<10%), being reduced by diagenesis and transformed to chlorite and I/S. The sequence is characterised by bioclastic limestones. The fauna comprises important index bivalve mollusks (*Rhaetavicula contorta*, *Placunopsis alpina*, *Chlamys valoniensis*), brachiopods (*Rhaetina gregaria*, *Austrirhynchia cornigera*) , corals and foraminifers (*Triasina hantkeni*, etc.). The palynofacies is dominated by terrestrial components, numerous *Ricciisporites tuberculatus* , dinoflagellate *Rhaetogonyaulax rhaetica* and by high amount of phytoclasts. Benthic diversity decreases upwards. The upper boundary of the Fatra Fm is sharp, stressed by a sudden termination of carbonate sedimentation and followed by non-carbonate “Boundary Claystone” and “Cardinia Sandstone” members of the Kopieniec Fm. The major $\delta^{13}C_{org}$ excursion within the T/J boundary interval documents perturbation of the global C cycle due to MORB volcanism peak during this time. Two smaller negative $\delta^{13}C_{org}$ excursions correspond to variations in the sedimentary OM content, decreasing carbonate content, as well as to changes in clay mineralogy, accompanying the major climatic change. Palynomorph assemblage is characterised by a significant increase of trilete laevigate spores, mainly *Deltoispora* spp., *Concavisporites* spp. and dinoflagellate *Dapcodinium priscum* caused by an important fresh water input.

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Calcareous micro-/nannoplankton and stable C and O isotopes in J/K boundary sections in Western Carpathians, Slovakia

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The most complete and well preserved Jurassic /Cretaceous sequences occur in the Pieniny Klippen Belt (Outer Carpathians) and in the Krížna Unit of the Central Carpathians. Plankton (calpionellid-, calcareous dinocyst- and nannoplankton) and O and C isotope fluctuations were studied in three selected (Brodno, Strapková and Hlboča) J/K boundary key sections. Nannofossil assemblages of Tithonian Rosso Ammonitico are dominated by *Conusphaera*. *Polycostella* abundance increased during start of the calpionellid Chitinoidella Zone and decreased towards the Crassicollaria Zone. *Helenea chiastia* accompanied by first small nannoconids appeared during latest Early Tithonian. Cadosinid cysts abundance in the Semiradiata Zone indicates surface water warming.
Start of Late Tithonian Crassicollaria Zone is correlable with the reverse magnetic Kysuca Subzone. Small nannoconids, *Hexalithus noeliae* and *Litraphidites carniolensis* appeared within the Microstaurus chiastius Zone. Stable isotopes ($\delta^{18}O$, $\delta^{13}C$) and low C_{org} indicate colder period, disturbed by warmer latest Tithonian episode.
The J/K boundary is defined by morphological change of *Calpionella alpina* tests. The standard Calpionella Zone base is located below the reverse Brodno magneto-Subzone in the Brodno section, and in half of the M19 Zone in the Strapková and Hlboča sections. Poorly diversified nannofossils (*Watznaueria*, *Cyclagelosphaera*, *Conusphaera*, *Polycostella)* are relatively abundant. Boundary interval is designated by the *Nannoconus wintereri* FO together with small nannoconids at the base, and the *Nannoconus steinmanni minor* FO at the top. Temperature increase indicated by oxygen isotopes followed Late Tithonian cooling. Nannoconids bloomed due to temperature/salinity changes associated with earliest Berriasian warm water influx. Correlation of calcareous microplankton and of C and O stable isotope and TOC/$CaCO_3$ data distribution was used in the characterization of the J/K boundary interval. The $\delta^{13}C$ values ranging from 1.1 to 1.4‰ (PDB) in limestone with minimum of residual C_{org} indicate balanced C regime in sea water column during the boundary interval (Michalík et al., 2009). Small $\delta^{18}O$ changes (from -1.5 to -2.5‰ PDB) are correlable with radiolarians concentrations in cycles reflecting fluctuation of basinal currents activity. The more negative $\delta^{18}O$ excursion near the J/K boundary could indicate temperature rise and salinity changes reflected by calcareous microorganism production.

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The paleogeographic model of the Cenomnian - early Turonian of Western Georgia based on planktonic foraminifera and cephalopods

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On the territory of Georgia three sedimentary cycles characterized by transgressions and regressions are present during the Cretaceous based on the analysis of sediment distribution and Cretaceous foraminifera. Among the three large sedimentation cycles the first cycle is related to the transgression of the early Cenomanian. Along the northern edge of the Georgian block, in the sediments of the Abkhazian-Rachian area, there was an abrupt rise of glauconitic sandstones heavily enriched in quartz material. The complex of planktonic foraminifera and belemnites (genera *Neohibolites* and *Parahibolites*) indicate the palaeo-water depth of the basin was at 100-120 m. In the west to east direction the number of deep sea taxa decreases indicating a decrease in water depth to marginal shelf areas (to 50m). Shallowing of the basin took place during mid Cenomanian times, connected to tectonic processes, with the presence of sculptured ammonites like *Mantelliceras, Acantheoceras, Turrilites*. Typical for that period are scanty complexes of foraminifera or a complete lack of foraminifera. Largly numerous foraminifera complex with the evident predominance of shallow water taxons of *Hedbergella* genus in the late Cenomanian basin only proves its shallow-water facies. At that particular period of time both planktonic and benthic foraminifera assemblages are impoverished, indicating unfavourable dysoxic conditions around OAE 2. Numerous left-coiled taxa show that water temperature in the Cenomanian basin was not high what can be explained as a result of penetration of cold currents from the Boreal water masses. Seaways on the meridian of the Baksani and Tskhenis-tshali rivers allow immigration of some boreal forms of the bivalve *Aucellina krasnopolskii Paul*. into the South Caucasus. As of the beginning of the early Turonian we observe progressive deepening of the basin and widening of the sea. The evidence is based on the increasing role of carbonaceous marine sediments as well as on the increase in the taxonomical variety of foraminifera. The basin depth was at approximately 200 m, with local dysoxic to anoxic conditions. This most probably reflects a global episode of anoxia when the majority of oceans and shelf seas of North America, Europe and Africa found themselves in the state of stagnation at OAE 2. At the same time when the basin was deepening, there existed archipelagos with admixture of terrigenous material increased and the number of taxa of shallow water organisms increased in the composition of the planktonic foraminifera assemblages. The percentage of left-coiled forms diminishes, indicating a rise of temperature. Till the end of the early Turonian we observe the rise in accumulation of chert, what reflexes the change of a stagnant ocean basin into more active vertical upwelling-type of circulation, and the growth in productivity of the siliceous plankton. The water temperature did not surpass 20-22°C degrees.

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Micro-Thermometric, Raman spectrometry and bulk Crush-Leach investigation of fluid inclusions in fluorite of Jebel Oust (Zaghouan district, north-eastern Tunisia)

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The Jebel Oust F-Cu deposit in northeastern Tunisia is hosted in Jurassic carbonate. F-Cu mineralization occurs as: (i) within calcite veinlets; (ii) tectonic brechia at lower Liassic and Upper Jurassic contact and (iii) fractures filling. Fluorite with different habitus occurs as: (i) large colorless crystals within veinlets crosscutting lower Liassic limestone; (ii) massive colorless within calcite veinlets crosscutting lower Liassic limestone and upper Jurassic marlstone and (ii) white crystals at lower Liassic and upper Jurassic.
Micro-thermometric and Raman bulk Crush-Leach investigation were performed on massive colorless fluorite. Three petrographic types of fluid inclusions have been recognized: liquid-vapor-solid type (FIAA); liquid-vapor type (FIAB) and vapor type (FIAC). FIAA primary inclusions have homogenization temperatures ranging from 146 to 299°C with a mode 251°C, final melting NaCl temperature range from 246 to 279°C, corresponding to salinities of 34 to 36 wt % NaCl equiv. FIAB primary and pseudo-secondary inclusions have homogenization temperatures ranging from 102 to 196°C and salinities between 3 to 15 wt % NaCl equiv. FIAC inclusions have salinities around 3 wt % NaCl equiv.
The semi-quantitative Raman analyses confirmed the presence of water (band stretching at 4120-4180 cm^{-}) and different amounts of CO_2 (band stretching at 1250-1400 cm^{-1}). Bulk crush leach analyses show that the solute compositions (Molar ratio Cl/Br= 655) of the fluids trapped in the inclusions hosted in fluorite ratio are consistent with an evaporated seawater origin.
Microthermometric, Raman and Crush-Leach fluorite from Jebel Oust have demonstrated represent the involvement of a mixture of halite dissolution water and evaporated seawater component, these results are compatible with Mississippi-Valley- type mineralization and in accordance with results of (Bouhlel et al., 1988) (Souissi et al., 1996) (30, 5 à 34 Wt% NaCl equiv) and Bouabdellah et al., 2013) at Jebel Tirremi (44, 2 Wt%NaCl+ KCl equiv) at temperatures up to 218°C.

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Success and failure in Paleogene-Neogene global correlations using golden spikes

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We review here examples of placement of Paleogene and Neogene golden spikes with respect to biostratigraphic, magnetostratigraphic, and geochemical events. Though biostratigraphy is the *sine qua non* for placing modern chronologic tools (high-resolution radiometric dates, magnetochronology, and astrochronology) into proper stratigraphic context, its use as the primary correlation tool for placing Global Boundary Stratotype Sections and Points (GSSP) is undesirable. Here, we advocate for defining of GSSPs at lithologic levels that are globally correlatable using magnetic reversals and abrupt geochemical changes, and the avoidance of biostratigraphic datum levels (that are necessarily biogeographically restricted) as primary criterion for correlation. We provide three examples where placement of golden spikes in association with reversals and global geochemical events has been successful. 1) The Cretaceous/Paleogene [K/Pg] boundary is placed at a level with an Iridium spike that provides a global correlation tool, albeit sometimes complicated by mobility of Ir due bioturbation and re-concentration at redox boundaries; and 2) The Paleocene/Eocene boundary was placed at the initiation of the Carbon Isotopic Excursion, and the $\delta^{13}C$ decrease is particularly useful in marine-terrestrial correlations; and 3) The Oligocene/Miocene boundary stratotype was placed at a level recording the base of Chronozone C6Cn2n; this boundary correlates elsewhere with the Mi1 $\delta^{18}O$ increase. In contrast, the golden spike at the base of Oligocene was placed at a level containing the highest occurrence of the planktonic foraminifera *Hantkenina*, resulting not only in problems in correlation to terrestrial and marginal marine strata, but the unfortunate placement of the largest Cenozoic $\delta^{18}O$ increase as the "earliest Oligocene glaciation." The boundary stratotype should be (re)placed at a level recording the base of Chronozone C13n in association with the $\delta^{18}O$ increase, and not at a tropical-subtropical marine fossil event. Magnetostratigraphy and an associated large δ13C increase at the C13n boundary would facilitate in marine to terrestrial correlations. We highlight that magnetostratigraphy and chemostratigraphy provide the best means of establishing globally correlatable GSSP tied to major events in Earth history and provide an overview of the current status of Cenozoic GSSP.

Influence of Icehouse global sea-level and mantle dynamic topography variations on passive-aggressive continental margins

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Tectonism and global sea level changes leave distinct imprints on the stratigraphic record of passive continental margins. During icehouse intervals such at the last 34 Myr, the waxing and waning of ice sheets dominated sea-level changes on distinct Milankovitch periods, not only short periods (e.g., particularly the 41 kyr tilt cycle, but also 19/21 precession, and quasi-100, and 405 kyr eccentricity cycles) but also on the long 1.2 Myr tilt cycle. Tectonics is superimposed not only on long time scales (10-100 Myr) due to thermal cooling, loading, and flexure, but also shorter time scales to due changes in mantle dynamic topography (>1-2 Myr scale) and Glacial Isostatic Adjustment (5-30 kyr scale). Drilling on the "passive" continental mid-Atlantic U.S. margin (New Jersey to Virginia) by ocean (DSDP/ODP/IODP Legs 150, 174A, and Exp. 313) and continental scientific drilling (Legs 150X, 174AX, and the Chesapeake Bay Impact Drilling Project) has provided unprecedented recovery of Upper Cretaceous to Holocene sequences. Ocean drilling has provided a global array of ocean coreholes allowing application of the $\delta^{18}O$ proxy and Mg/Ca for ice volume. Together, these cores allow two approaches to estimating sea-level changes: 1) backstripping of coreholes from the onshore coastal plain and continental shelf; and 2) scaling deep-sea $\delta^{18}O$ records using Mg/Ca to remove temperature effects. Comparison of the two methods addresses the long-standing debate about the roles of global average sea-level change (eustasy) and tectonism on the stratigraphic record. Our scaled-isotopic and onshore backstripped eustatic changes are remarkably similar on the Myr scale for the interval 34-10 Myr and testify to the importance of glacioeustasy. The dominant beat in the icehouse world of the past 34 Myr is the 1.2 Myr tilt cycle, though in regions of high sediment supply both 405 and quasi 100 kyr variability is preserved. However, there are differences between the onshore and offshore and between New Jersey, Delaware, and Virginia on the 1-5 Myr scale that we attribute to the changes in mantle dynamic topography due to the influence of the subducting Farallon slab. The amplitude of the offsets are consistent with models of mantle dynamic topography that predict these differences. Such changes in continental elevation explain the patchwork preservation of sequences and regional differences on this "passive-aggressive" margin; they also complicate estimates of the absolute position of globally averaged sea level, though glacioeustatic amplitudes of 20-120 m are well-constrained (better than ±10 m).

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Biostratigraphy of the Sakesar Limestone of the Ratuchhah area, Eastern Salt Range, Northern Pakistan

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A section of the Lower Eocene Sakesar Limestone was measured from Ratuchhah area, Eastern Salt Range, Northern Pakistan. The formation is mainly composed of limestone which is light brown in color and mostly nodular. A total number of 19 samples were collected from bottom to top with irregular pattern keeping in mind the minor lithological variations in the formation. The formation has yielded some excellently preserved age diagnostic larger foraminifera belonging to the genera *Nummulites* Lamarck 1881, *Lockhartia Davies* 1932, *Operculina* d Orbigny 1826, *Discocyclina* Gumbel 1868, *Ranikothalia* Caudri 1944, *Assilina* d' Orbigny, 1826 and *Alveolina* d'Orbigny, 1826. During the detailed biostratigraphical studies of the Sakesar Limestone seventeen (17) age diagnostic species of larger benthic foraminifera were recorded including the short ranged taxa *Alveolina pasticillata* SCHWAGER 1883, *Alveolina canaverii* Hottinger 1960, *Alveolina conradi* Sameeni 1997. The stratigraphic range of these three species is from SBZ-5 TO SBZ-8, according to modern Shallow Benthic Biozones. Hence, the Sakesar Limestone has been designated an age ranging from SBZ-5 - 8. This time interval has been named as Ilerdian (Early Eocene) in the geological time scale. On the basis of facies variations and recorded fauna it can be safely concluded that the Sakesar Limestone was deposited in an open marine, shallow shelf environment under low energy conditions.

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Mt. Jenner (Berchtesgaden, Germany) - a Late Triassic fore reef evolution of the Dachstein platform

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The Late Triassic fore reef evolution of Mt. Jenner in the Berchtesgaden Alps, Germany offer a rare geological archive, in which shallow-burial dolomite formation can be studied in context with sequence stratigraphic cycles in the Norian Dachstein carbonate platform growth.
From the uppermost Carnian to Early Norian the internal fore reef architecture is formed by sequences comprised of dissolution breccia at the base, followed in the lower part by pack-/grainstones to float-/rudstones with shallow and hemipelagic bioclasts, and is overlain by higher energetic resediments.
Sequences in Middle Norian change to recurrent alterations of a shallower, higher energetic framework and deeper water bioclasts.
In the uppermost Tuvalian 3 to Lacian 2I transgressive/regressive cycles throughout the earliest Dachstein platform progradation require eustatic lowering of the hydrologic baselevel combined with massive shallow-burial dolomite formation in the fore reef. Mixing advection of seawater with meteoric water through the sediment at surface-near temperatures favours low Ca/Mg ratios, and salinities with an increasing palaeo-seawater ionisation in Br, Li, Na, Cl per cycle. Well-oxygenated depositional conditions suggests that an anaerobic methanogenic archaea biodegrade directly the organic matter from primary producers in producing biogenic methane. Stratabound hydrate water releases in the dolomite are coupled with singular negative shifts of O isotopes. The altered litho- and microfacies is consistent with the SO_4, J and F-poor ionisation. The palaeo-seawater ionisation of Ca, which is analysed by the Crush Leach method, is only weakly affected by the dolomitization in the platform margin, and follows in general the depositional trend of Ca-rich ionisation by a pelagic- and Ca-poor ionisation by a shallow-water influence. An initial stage of ?strike-slip tectonic or ?an extensional pulse in the Lacian 2, as known from the hemipelagic Hallstatt margin, resulted in remobilized erosional products of a volcanic/?ophiolitic hinterland.
The Lacian 2II until Lacian 3 sedimentation is dominated by several eustatic sea-level changes with exposure and stratabound dolomitization in the shallowing-upward cycles. Sulfate reducing bacteria favour in restricted conditions the formation of a distinctive clotted-peloidal micrite microfabric. Characteristic Hopanes in this low energetic environment indicate an input of palaeosoil with biodegraded land plants. Only, in the uppermost cycles of Lacian 3 *Griphoporella* and *Aciculella* dasycladacaen algae occur.
In the Alaunian 1, strong tectonic pulses triggered by strike-slip motions destabilize the geometry also on the proximal Hallstatt margin. Ongoing transgression resp. increasing subsidence, and biogenic crisis led to aggradation in the early Alaunian. Stratabound dolomite horizons with karst fissures top each eustatic sea-level cycle. Corals, microalgae, and calcified microbes recover in the Alaunian 3 and bloom in the latest Alaunian 3II. The platform margin evolution on Mt. Jenner is terminated by the tectonic pulse at the Alaunian/Sevatian boundary.
This Late Triassic fore reef architecture can be directly correlated with other high resolution Dachstein platform successions, dated by means of conodonts, e.g., in the Eastern Alps, Western Carpathians and Julian Alps.

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Lanthanides and microbes influence the deposition of Late Triassic Hallstatt pelagics, Northern Calcareous Alps

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New biostratigraphic, sedimentological, and geochemical data and a thorough review of existing literature modify existing knowledge on the sedimentology, palaeogeography and ocean acidification of the Late Triassic Hallstatt margin from the Northern Calcareous Alps. Criteria are drawn from examples on the variegated Hallstatt facies of the Kälberstein quarry, Germany and the Bad Dürrnberg church section, Austria. Siliceous, deep-water limestones of the Pötschenhöhe quarry, Austria represent the oceanward sedimentation on the Triassic passive continental margin.

In Early Norian hemipelagic settings, distant to large carbonate platforms, shedding of carbonate mud during sea-level highstand has still major control on sediment accumulation rates. In the Lacian 2, the Massiger Hellkalk is formed in high sedimentation rates by low energetic, biturbated biomicrites of deep-water biota. Seismic shocks induced by an initial stage of ?strike-slip tectonic or ?an extensional pulse, favour in monomict breccia horizons mixing advection of seawater through the sediment, coupled with a Na-Cl-anomaly and singular negative shifts of O-isotopes. Shallow-burial fluid flow and acidic formation fluids of surface-near temperatures drive rapidly the accumulation in the homogenized sediment and thus favour sulphate reduction and an anaerobic methanotroph archaea, which is suggested by a biodegraded microfabric, altered apatite structures on conodonts, and the SO_4, F, and J-ionisation. At the base of the Lacian 3, biogenic hydrate water releases in the Hallstatt limestones are coupled with another Cl-anomaly. At the top of Lacian 3 first hardgrounds were established as a consequence of reduced sedimentation rates.

In the Alaunian 1, strong tectonic pulses triggered by strike-slip motions destabilize the geometry on the Hallstatt margin. Variations in the morphology, climatic cooling with reduced stable O- and C-isotopes, and eustatic pulses are coupled with a change in ocean circulation. Erosion of an uplifted deeper continental crust-fragment in the hinterland resulted in remobilized transition and LREE metals. In the rapidly accumulating hemipelagic biomicrites of the Hangend Rotkalk and the Pötschen Limestones, the organic matter becomes extracted by an anaerobic metanotrophic archaea under the presence of metal chelates. This higher biological availability of LREE and some similarities of lanthanides (III) with calcium (II) process these bacteria to replace Ca into Ce in the biomolecules of (some) deeper water biota. The shallow-burial diagenesis in the deep water becomes identified by the altered litho- and microfacies, strongly altered apatite crystallinity on conodonts, intense fluctuations in the Ca-ionisation of the palaeo-seawater, and matrix-selective dolomitization of the bioturbated wackstones and marls.

The Alaunian/Sevatian boundary in the Hallstatt margin is characterized by an abrupt change in deposition. Formation of pull-apart basins perpendicular to the margin is evidenced by polymictic breccia formation. An increased availability of transition metals and lanthanides catalysed the metal chelate and microbial activity in the hemipelagic sediment. Hence, any hydrothermal fluid flow can be excluded on the Late Triassic Hallstatt margin.

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Testing acritarch-based subdivision and correlation of the Ediacaran System

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Taxonomically diverse Ediacaran acritarchs are known globally, and the first records of correlatable species are found within a short time interval from various regions. Subsequent species and/or assemblage appearances are not easy to correlate globally because stratigraphic ranges of discrete taxa are not yet fully established and time constraints are generally poor. Portions of Australian acritarch assemblage zones defined by Grey (2005) are recognized in China, India, Siberia, and the East European Platform. No sections are precisely comparable and it remains difficult to match zone boundaries. These other sections contain additional species, so revisions to Australian zones or even alternative zones are anticipated once stratigraphic ranges are better documented. Many aspects of present subdivisions and correlations remain uncertain. Some successions are sedimentologically discontinuous, unevenly fossiliferous because microfossils are restricted to preservation windows, or have been studied only in selected intervals. Australia provides the most comprehensive Ediacaran succession (maximum thickness of c. 7660 m), and near-continuous successions of five microfossil zones extending over interval c. 800 m thick. Zones range from just above Nuccaleena Formation cap carbonate (Elatina glaciation, c. 635 Ma) to the first records of Ediacara fauna (c. 565 Ma).

In China, the maximum Ediacaran System thickness is c. 400 m from the top of the c. 635 Ma Nantuo glacial Formation to the Cambrian boundary. The Doushantuo Formation in the Yangtze Gorges area is c. 200 m thick, and c. 100 m interval contains acritarchs. The fossiliferous interval begins c.10 m above the top of the Nantuo Formation (Liu et al., 2014). The succession is condensed, comprises several breaks and is diagenetically altered. Acritarchs are exceptionally preserved due to permineralization. New records of ornamented (new and known cosmopolitan) species from Yangtze Gorges lower stratigraphic levels will contribute to defining Chinese zonation and substantiate global correlation. The main significance of acritarch species in China is their stratigraphic position close to the Ediacaran System base at c. 635 Ma.

In Siberia (Patom Uplift area), the Ediacaran System is represented by a c. 3000 m succession, mostly continuous and overlying diamictite attributed to the 635 Ma Elatina/Nantuo interval. Acritarchs in the Ura Formation, c.800 m above the Ediacaran base, occur in a fossiliferous interval only 12 m thick. The Khamaka and Talakh formations (neighbouring Siberian Platform) correlatable laterally with the Chencha Fm. (upper Ediacaran, Patom Uplift) yield cosmopolitan species. If this lithostratigraphic correlation is correct, acritarch species range through a stratigraphic interval of c. 1450 m, representing roughly 40% of the entire Ediacaran succession and covering a substantial time span.

In the East European Platform, the Ediacaran strata are c.800 m thick and the Vychegda Formation interval containing acritarchs is c. 600 m thick. This assemblage is comparable to the two lower Australian zones.

Given the thicknesses of stratigraphic successions in some areas, the presence of condensed, discontinuous or incomplete sections in others, and the enormous time span of the Ediacaran Period (93 my) there is much scope for a better evaluation and subdivision of the Ediacaran System using acritarch zonation. Our talk will address aspects of acritarch zonation and biostratigraphic correlation relevant to the search for candidate stratotype successions.

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Integrated stratigraphy of Lower Cretaceous sediments (Ryazanian - Hauterivian) from North-East Greenland: Refining the calcareous nannofossil zonation for the Boreal

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The reconstruction of past climates and paleoceanography requires a solid stratigraphic framework ideally applicable on a global scale. The earliest Cretaceous was a time of strong floral and faunal provincialism, making supra-regional correlation via biostratigraphy difficult.
Here we present new $^{87}Sr/^{86}Sr$- and stable isotope-data ($\delta^{13}C$, $\delta^{18}O$) from belemnite rostra of the Rødryggen section in North-East Greenland. The integrated stratigraphy based on Sr-isotope ratios, $\delta^{13}C$ data, ammonite and calcareous nannofossil biostratigraphy offers the opportunity for a direct comparison of the different stratigraphic zonation schemes.
In agreement with results from biostratigraphy, the Sr-isotope ratios obtained suggest a Ryazanian – Barremian age of the strata exposed at the Rødryggen section. A mismatch between Sr-isotopy and the nannofossil based biostratigraphy with respect to the position of the Ryazanian / Valanginian boundary caused a reconsideration of the nannofossil biostratigraphy of the Boreal Lower Cretaceous. The integrated stratigraphic data from Greenland suggest, that the calcareous nannofossil index taxon *Sollasites arcuatus* is not restricted to the upper Ryazanian as previously thought, but it has its last occurrence in the lower Valanginian. This re-interpretation shifts the stratigraphic position of the Boreal nannofossil zone BC3, that originally was defined as uppermost Ryazanian - lowermost Valanginian, into the lower Valanginian.
Based on these findings the abundance decline of *Nannoconus* spp. previously described from the Rødryggen section is now dated as late early Valanginian. In accordance with observations from the Weissert Event in the Tethys, the nannoconid decline precedes the shift to more positive $\delta^{13}C_{Bel}$ values. The upper Valanginian positive CIE associated with the Weissert event is a stratigraphically well defined isochronous event. The correlation of the $\delta^{13}C$ data and the nannofossil events of the Rødryggen section suggests that *Micrantholithus speetonensis,* the last occurrence of which is taken as an approximation of the lower/upper Valanginian boundary in the Boreal, is still present in the upper Valanginian.

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The evolution of Oppel‘s “Macrocephalus Zone“ (Callovian, Middle Jurassic)

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In his basic work Albert Oppel subdivided „Die Juraformationen“ into 8 „Etagen“ and 32 „Zonen“. (Oppel 1856-58). There is a long history of confusion as to the meaning of Oppel’s Zones. Using his “Zone des Amm. Macrocephalus” it is explained how his concept has been developed until today. The significance of ammonites for the time-resolution is shown in some examples. The primary inspiration behind Oppel‘s work was the search for a general framework, that allowed all rocks to be assigned uniquely each to a stratigraphical unit according to its age. Oppel’s tables on p. 822/823 and at the end of his book show a continuous succession of units without gaps and overlaps. They are defined by their boundaries and thus correspond to what we call today chronostratigraphic units. That Oppel’s zonal classification did not reach the attainable limits of stratigraphical resolution, have already been clear to him at that time. So he divided his Zone of Amm. macrocephalus into two subzones (Calloviensis and Bullatus), and specified three more (Könighi, Gowerianus and Modiolaris). The Macrocephalus Zone corresponds to today's Lower Callovian. With growing knowledge, the unit could be further subdivided (Callomon et al. 1992). In Central Europe and England it now consists of three standard zones (Herveyi, Koenigi, Calloviense) and 8 subzones. In the 1940s years Arkell pointed out that the finer the steps of the scale, the more restricted they are (Arkell 1946). So we have in addition to the above-mentioned Zones five or six more standard zonations in other faunal provinces. In terms of the ammonites the amounts and quality of material available improved and also the methods used to assess morphological similarities. In some areas it is now possible to distinguish about 20 faunal horizons or biohorizons in the Lower Callovian (Callomon et al. 1988). Some horizons, such as the *toricellii* horizon, are limited to a small area such as Central Europe, while others can be correlated over long distances. So we find the *keppleri* horizon, which defines the base of the Callovian Stage, in Canada, Greenland, the Russian Platform, Georgia, Southern Germany, Switzerland, western France and England. Nevertheless, it is not yet possible to offer for the base of the Callovian a profile that satisfies the stringent requirements of the ICS Guidelines for a GSSP. The reason is the following paradox: the more complete the ammonite record becomes, the more incomplete the stratigraphical record becomes. Thus it is almost impossible to meet the conditions under 4.1: Continuous sedimentation, no gaps (Mönnig, 2014).

On the other side the extension of time resolution down to that of a horizon has important significance for basin analysis, sequence stratigraphy and biogeography. For an example, we return to Oppel’s index fossil *Amm. macrocephalus*. We now know that *Macrocephalites macrocephalus* (Schlotheim) occurs not in the whole Lower Callovian, but is limited to one or two horizons in the higher Koenigi Zone (Callomon et al., 1992, Mönnig, 2010). It belongs to an endemic group that has been preserved in Central Europe, while in other areas *Macrocephalites* became extinct or at least very rare as a result of a sea level rise.

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«Lithostratigraphy extended» – examples from the basement of the Swiss Alps

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Lithostratigraphy has long been applied to describe and analyze the geological record at local to regional scale. In most cases, sedimentary successions have been subdivided into formal hierarchical units named after a type-locality (or at least it is a definite aim to do so). This nomenclature is particularly useful for cartographic purposes. Such a formal procedure has rarely been used for poorly or non-stratified rock bodies. Indeed, these rocks have rather been designated by names based on their petrographic characteristics and geological history (e.g., pre-variscan basement, Ordovician orthogneiss), although reference is sometimes made to specific localities.

Basically, by adding the principle of cross-cutting relationships to the classical principle of superposition, a chronologic sequence can be reconstructed from the geometrical relations observed in the field. In that sense, a somewhat flexible, extended conception of lithostratigraphy should permit to handle all kinds of rock bodies, including quaternary deposits and crystalline basement units. Therefore, the Swiss Committee of Stratigraphy favors the use of the formation as unique elemental lithostratigraphic unit for all rock types. Two examples from the basement of the Swiss Alps are presented here to illustrate the challenges, benefits and limitations of this approach.

In a precursor work, Sartori et al. (2006) recognized a single synthetic series of lithostratigraphic units in the Siviez-Mischabel and Mont Fort nappes (Briançonnais realm), despite strong deformation and a partly polycyclic metamorphic history. As stressed by these authors: "*In this complicated context, the main criterion permitting the distinction of lithostratigraphic entities is cartographic coherence with respect to their content and their limits. The description of the units is based on their main lithological composition, their spatial extension and the description of key lithologies and unambiguous marker levels.*" The definition of the new formations fully complies with the Swiss guidelines for stratigraphic nomenclature, which explicitly state that "*A lithostratigraphic unit may be sedimentary, magmatic, metamorphic or composite.*" (Remane et al. 2005).

In the course of the harmonization of the master legend for the Geological Atlas of Switzerland, a similar approach was promoted. In the case of the crystalline basement of the Aar Massif, the relative timing of events was already well constrained and individual units had long been defined, mainly based on petrographic criteria (also incorporating radiometric ages for the correlation of geographically isolated bodies). In an effort to produce a unified map of the whole massif, Ivan Mercolli and Alfons Berger (work in progress) therefore developed a new lithostratigraphic nomenclature, in order to clearly separate descriptive elements from more interpretative aspects. Locality-based lithostratigraphic groups and formations will be introduced in replacement for expressions such as «Permo-Carboniferous volcaniclastic sediments» or «Late to post-Variscan sedimentary and volcanic rocks», which are not so practical and whose interpretation may be prone to subsequent changes.

In conclusion, this extended lithostratigraphic approach taking into account field relationships – including metamorphic overprint and multiple deformation phases, considered as super(im)posed or cross-cutting elements for relative dating – combined with radiometric ages can also be used for comparisons at a broader scale. This approach will therefore be tentatively applied to basement units from other tectonic domains as well.

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A harmonized lithostratigraphic framework for the Geological Atlas of Switzerland – lessons learned and prospects

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The Swiss Geological Survey has recently completed the semantic harmonization of the master legend for the Geological Atlas of Switzerland 1:25000, in close collaboration with the Swiss Committee for Stratigraphy. This presentation aims to summarize the most important factors that made this project successful, to highlight some positive effects already achieved and to outline the next steps needed for the realization of a seamless national geological map based on the new master legend.

With the achievement of the digitalization of all geological map sheets already published and the GIS compilation of the best available data for the remaining areas, a complete geological coverage of Switzerland at a scale of 1:25000 is now available (GeoCover data set, freely accessible under http://map.geo.admin.ch). However, each map sheet is still based on a somewhat independent legend. Furthermore, historically, the definition of mapped units had not always been based on lithostratigraphic criteria. In order to bring all data set together, a harmonized lithostratigraphic scheme was elaborated with the help of more than 40 experts under the scientific supervision of the Swiss Committee for Stratigraphy. At the start of the project, it rapidly became clear that a harmonization at national scale would only be possible by focusing on lithostratigraphic units mapped at 1:25000 scale (i.e. basically formations). The standard description of the units was guaranteed by the use of a data model. In order to avoid endless discussions, some interpretative aspects were partly left aside or simplified (e.g. controversial chronostratigraphic attributions).

This harmonization project stressed the importance of lithostratigraphy as a common nomenclatorial and descriptive language. Nonetheless, it remains an intellectual and graphical challenge to simplify the complex geological reality in order to represent it on a map (rapid facies changes both laterally and vertically, frequent diachronism and hiatuses, particular cases of the crystalline basement and quaternary deposits). As a positive effect, the project triggered discussions within the geoscientific community and stimulated a renewed interest for regional studies to improve the understanding of geological processes and timing. Despite the involved terminological modifications, we received rather positive feedbacks from both the academic and applied fields (and even from non-specialists). The online lexicon (www.strati.ch), which lists the valid units for each region and gives information on the diagnostic features and historical equivalency of several hundreds of units, proved most welcome. Further units and descriptions will be progressively incorporated and continually updated.

The implementation of the new master legend now requires that the printed map sheets of the Geological Atlas of Switzerland be – at least partly – revised. As long as a one to one correlation is possible between the existing data sets and the new scheme, the old terminology will simply be replaced (reference to the original map legend is however documented in a dedicated attribute). In all other cases, the cartographic delimitation of units will have to be adapted. The latter process will primarily be made with the help of digital elevation models and orthoimages, but will also entail field work. Finally, many poorly characterized units remain to be better defined and formally named. Comparisons and correlations with neighboring regions in Austria, France, Germany and Italy, although already largely taken into account, will also be an important contribution to a clearer, unified image of the geology of Europe.

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Calcareous Nannofossil Biostratigraphy of the Upper Cretaceous (Cenomanian-Campanian) from Northeast Iran

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The distribution and relative abundances of various Late Cretaceous calcareous nannofossil taxa have been recorded in Aitamir Fm. and Abderaz Fm. along the Amirabad stratigraphic section, in Kopet-dagh sedimentary basin, northeastern Iran. Nannofossil bioevents have been utilized to biostratigraphically classify the exposed sedimentary succession based on schemes of Sissingh (1977, modified by Perch-Nielsen, 1985), Roth (1978, modified by Bralower et al., 1995) and Burnett (1998) of which the Sissingh scheme seems most suitable.
The palaeoecological changes across the succession, as predicted by the nannofossil distributions, are in strong agreement with those demonstrated in other recent publications which utilize isotopic evidence. Moreover, the results are comparable with those of other Tethyan and some Boreal studies.
There is some evidence of recording the late Cenomanian Oceanic Anoxic Event (OAE2). A lithology with abundant radiolarian-sands and silts, a relative decrease of *Biscutum* spp. and *Broinsonia* spp., increased abundances of *Eprolithus floralis* (peak) and absence of *Nannoconous* spp., during the late Cenomanian segment of the succession, point towards an anoxia episode. A relative increase of *Biscutum* spp. after the sequence considered to be equivalent of OAE2 indicates higher nutrient availability in surface-waters, during the late Cenomanian/Turonian. Based on cool water taxa, such as *Ahmuellerella octoradiata*, *Gartnerago segmentatum* and *Kamptnerius magnificus*, the gradual and continuous cooling toward the Campanian, is observable during the late Turonian.

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The stratigraphic and isotopic record of the Toarcian Oceanic Anoxic Event from two contrasting facies in Hungary

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In the Early Toarcian (~183 Ma) major global environmental changes took place in the ocean-atmosphere system, including the much studied and widely discussed Toarcian Oceanic Anoxic Event (T-OAE). The interrelated events are characterized bystrong perturbations of the carbon cycle and other biogeochemical systems. A hallmark of the T-OAE is a major negative carbonisotope excursion (CIE), reflecting the injection of large amount of isotopically light carbon into the ocean-atmosphere system. This negative $\delta^{13}C$ spike and a subsequent broad positive anomaly are key signals for chemostratigraphical correlation. We obtained new, high-resolution carbon isotope data from three localities from two different tectonic units in Hungary, representing two different types of depositional environment.

In the Réka Valley section of the Mecsek Mts., a thick siliciclastic Lower Jurassic succession of hemipelagic sediments is interrupted by 13 m of organic-rich black shales in the Lower Toarcian. By contrast, pelagic carbonates dominate the Lower Jurassic in the Gerecse Mts. However, the T-OAE is also reflected by a major change in sedimentation here in both the Tölgyhát quarry and Kisgerecse quarry sections, where a manganiferous hardground on top of the reddish pelagic limestoneis overlain by 20 cm of gray and brown clay, followed by nodular marlstone in the Tölgyhát quarry.

We obtained high-resolution $\delta^{13}C_{org}$ and carbonate content data from the Réka Valley section (Mecsek Mts.) and $\delta^{13}C_{carb}$ and $\delta^{18}O_{carb}$ data from both the Tölgyhát and Kisgerecse quarry sections (Gerecse Mts.), where redox-sensitive trace element concentrations, Mn and carbonate content were also analysed. The $\delta^{13}C_{org}$ record from the Réka Valley section is characterized by very negative values (averaging -32 ‰), with apparently cyclic changes. This patternmay hint to astronomical control, but the similarly high-resolution carbonate content data appear only weakly cyclic. In the $\delta^{13}C_{carb}$ curve from the Tölgyhát quarry a pronounced positive excursionis preceded by a sharp negative excursion of -6 ‰, the latter is restricted to the gray and brownish clay. On the other hand, in the Kisgerecse section only the positive excursion is detected and the unconformity at the base of the nodular marlstone represent a hiatus precluding the preservation of the negatic CIE. Comparison with detailed cyclostratigraphies and the Early Toarcian carbon curve from other sections (e.g. Peniche, Yorkshire), the duration of this gap can be estimated. In the Gerecse Mts., both the hiatus and the presence of the thin clay interval interbedded into pelagic carbonates suggests a crisis in local carbonate productivity during the CIE which might can be related to ocean acidification coincident with the T-OAE. Our high-resolution $CaCO_3$ data show high and stable values in the section prior to the T-OAE, followed by a stepwise drop to very low values (>5 wt%) during the negative CIE. A similar trend occurs in the manganese content. Relatively high values immediately before the CIE can be interpreted to represent prevailing suboxic conditions during the early diagenesis of carbonates. The new high resolution isotope data allow chemostratigraphic correlation among the studied sections, as well as with other European Toarcian successions (e.g. Peniche, Yorkshire, Dotternhausen and Valdorbia). The switch to organic-rich sedimentation in the siliciclastic northwestern Tethyan shelf (Mecsek) was coeval with a temporary carbonate shutdown in the pelagic southwestern Tethyan region (Gerecse), both forced by the environmental and biotic events related to the T-OAE.

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Multi-integrated methods to compile geological maps of planets

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Starting from the earliest observations on remote images, rocky planets and moons in the Solar System required geologist to understand their surfaces. In fact, most of those show different surface properties as for albedo, texture, spatial distribution, geological features etc. Recently, thanks to high-resolution images acquired with the latest missions, Mars has been showing a more complex surface than other planets and geological processes closer to those of the Earth. A lot of geological features were recognized, e.g. deltas, lakes, ancient rivers, volcanoes and many others. Until recently the classic method of mapping the Martian surface was related to the recognition of photographic properties of surfaces, by analyzing the rock stratification interpreted as *photohorizons*. This basic unit of analysis, as for Earth on field observations, could define layers and packages describing *photofacies*, which is the combination of photographic characteristics (tonality and texture) and stratal geometry, including lateral continuity, shape of the erosional profile and bedding thickness and spacing. After this, we can establish the *Photostratigraphic units*, which consist of groups of photohorizons and characteristic patterns of photofacies associations. They don't necessarily match stratigraphic units based on other categories of data or observations (Sgavetti, 1992). Another recent method for mapping the surface of Mars uses hyper-spectral images (in particular OMEGA and then CRISM data), which provide the distribution of some mineralogical species to infer geological units, without the distinction of other photographic properties of the outcrops. In our work, we try to use both methods using GIS software and create guidelines, so that the multiple approaches do not produce inhomogeneity in compiling geological maps. Using CTX images and CRISM data, we map the McLaughlin Crater (Arabia Terra) area to test our method and compare with other ones, resulting in a more accurate map. We start from the spatial distribution of layers and rocks, to progress to the legend contents, by describing units more precisely adding the kind of rocks and/or minerals composing it, close to Earth mapping. Moreover, the use of both methods improves the geological interpretation of the study area and allows avoiding misunderstanding related to bad rendering of photographic units. However, this could bring also disadvantages: because of its complexity, this method requires more time than the classical method. In contrast to the accuracy of the maps, the distribution of hyper-spectral data is very low and many of them suffer from the presence of artifacts, thus affecting mapping large areas. In these cases, we need to choose new strategies to map: units with well-known mineralogy may have the same photographic aspect in areas both covered and not covered by hyperspectral data and by following lateral continuity and photographic properties it is possible to map them inferring it is the same unit. Otherwise, recognized photostratigraphic units without mineralogical data must be mapped with the classic method. All aspects of this integrated method needs to be further analyzed, but initial map compilations on GIS give good results, thus allowing to address the interpretation of geological maps of other planets in a more Earth-like geological concrete way.

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Invalidating reports of sponge spicules below the Ediacaran–Cambrian boundary

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Mineralized sponge spicules are common in the early Cambrian, but are conspicuously rare or absent in the Cryogenian and Ediacaran periods, even though paleontological inferences, molecular clocks, and biomarker fossils suggest sponge crown groups diverged in the Precambrian. In general, Precambrian sponge spicules are rare, poorly substantiated, and controversial. Spicule-like microstructures hosted in phosphatized fossils from the Ediacaran Doushantuo Formation (~635–551 Ma) at Weng'an of South China have been interpreted as the only cylindrical siliceous monaxons preserved with soft tissues in Precambrian strata. In order to assess their veracity as some of the oldest siliceous sponge spicules, we provide data collected via a suite of *in situ* nanoscale analytical techniques—including scanning electron microscopy, synchrotron X-ray fluorescence mapping, X-ray absorption near edge structure (XANES) spectroscopy, focused ion beam electron microscopy, and transmission electron microscopy - on the Doushantuo spicule-like microstructures' ultrastructures and elemental, chemical, and mineralogical compositions. Our data decisively shows that they are carbonaceous in composition and rectangular in transverse sections, and therefore, are not cylindrical siliceous spicules. Instead, these spicule-like microstructures may be microbial strands, axial filaments of early hexactinellids, or acicular crystals molded by organic matter. Regardless, our new data invalidate the only reports of mineralized spicules preserved with putative soft tissues in Precambrian rocks. These results and a comprehensive literature review affirm that no unequivocal sponge spicules occur below the Ediacaran-Cambrian boundary. Thus, sponge spicules may be index fossils for the Phanerozoic.

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Towards an integrated stratigraphy of the Early Cretaceous (Valanginian - Barremian): Implications for Boreal –Tethys correlation and paleoclimate

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The interpretation of past oceanographic events on a supra-regional scale requires precisely dated and well-correlated biostratigraphic schemes. Only synchronous events can be interpreted in a global context. Events of local or regional character therefore have to be accurately correlated with time-equivalent shifts in other areas in order to be interpreted in a wider context. One of the problems of inter-basin correlation based on biostratigraphy lies in floral and faunal provincialism of the relevant index fossils. In order to overcome such limitations, chemostratigraphy can be used as a stratigraphic tool independent of biostratigraphy.
We present $^{87}Sr/^{86}Sr$-isotope data for the Lower Cretaceous (Valanginian - Barremian) based on previously published findings from Speeton (northeast England) and the Vocontian Basin (southeast France) in addition to new findings from Northeast Greenland. The belemnite-based $^{87}Sr/^{86}Sr$ data allow a correlation of the Lower Cretaceous sequences of the Boreal Realm and the Tethys independent of biostratigraphy. This chemostratigraphic approach may help to overcome the biostratigraphic problems which have been discussed for more than 40 years. Various offsets of the biostratigraphic scheme, which are asking for adjustment, are being discussed.
Our findings allow for a correlation of different paleoclimatic, environmental and paleobiological shifts which occurred in the Valanginian – Barremian. These include the Valanginian Weissert Event and the Nannoconid crises, a brief coldhouse state in the late Valanginian - earliest Hauterivian, and a first-order Early Cretaceous warming peak during the Barremian. This mid-Barremian warming event is mirrored by the highest Sr-isotope value that we link to long-term peak continental weathering and increased run-off.

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New Developments at the Basal Cambrian GSSP, Fortune Head, Newfoundland, Canada

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The Global Stratotype Section for the Cambrian System (GSSP) was proposed in 1987 at the base of the *Phycodes* (now *Treptichnus*) *pedum* Zone in member 2 of the Chapel Island Formation at Fortune Head in Newfoundland. This boundary occurs 0.2 m above the highest diagnostic Ediacara-type megafossils and several hundred meters below the lowest Cambrian-type shelly fossil in the section, in the lower part of an interval characterized by rapid evolution of behavioural complexity in invertebrate animals. This three-part stratigraphic relationship has served as the basis for global correlation of the basal Cambrian GSSP in the two decades since it was ratified by ICS and IUGS in 1992.

Ongoing studies of new exposures at Fortune Head and Grand Bank Head over the past 15 years have shown that the first appearance of key ichnotaxa occurs in a stepwise manner through a 20 m interval that begins about 5 m below the boundary. The base of the *Treptichnus pedum* Assemblage Zone is defined by a position in rock, not by the occurrence of any individual ichnotaxon. *Treptichnus pedum* has a broad environmental range, both globally and at the GSSP, occurring abundantly in marine strata ranging from intertidal to offshore subtidal.

The beginning of the Cambrian was a time of dramatic biological and sedimentary changes, including the replacement of Proterozoic-style microbial matgrounds by Phanerozoic-style bioturbated mixgrounds. Recent studies in the basal Cambrian GSSP at Fortune Head show that Ediacaran-style matground-based ecology and taxa persisted into the earliest Cambrian, but with two notable exceptions. Specimens of the globally distributed Ediacaran body fossil *Palaeopascichnus* are present immediately below the top of the Ediacaran but are strikingly absent from the overlying Cambrian succession despite optimal conditions for their preservation. In contrast, Cambrian microbial surfaces in the same section are marked by the appearance of the first abundant arthropod scratch marks in Earth evolution. These occurrences imply that the Ediacaran-Cambrian boundary defined at the GSSP represents an abrupt evolutionary event that corresponded with the appearance of novel bilaterian clades, rather than a fading away of Ediacaran fossils due to the gradual elimination of conditions appropriate for their preservation.

Neoproterozoic-Cambrian isotope chemostratigraphy was still in its infancy when the GSSP was proposed, and early studies did not show any trends in the Chapel Island Formation. More recent time-series geochemical analyses of shallow marine mudstones deposited at the basal Cambrian GSSP in Newfoundland reveal inversely coupled carbon isotope excursions in carbonate and co-existing organic carbon. These excursions initiate with the first evidence of animals able to stir up and promote the oxidation of sediments, which had previously been chemically reduced and sealed by microbial mats. The end of the isotope excursions notably coincide with the first appearance of biomineralized animals in the section. A profound sulfur isotope change across the boundary interval is consistent with ventilation of the sediments, the rise of seawater sulfate, and enhanced microbial sulfate reduction that in concert with methanogenesis promoted the formation of authigenic carbonate, and perhaps also contributed to the profusion of biomineralizing organisms in the Cambrian Explosion.

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Formulating a Terminal Ediacaran Stage

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The Ediacaran Period was ratified by ICS and IUGS in 2004 as the first system-level addition to the geologic time scale in more than a century and the beginning of dynamic ICS initiatives to formalize "Precambrian" subdivision using the GSSP concept. In June of 2014, the Ediacaran Subcommission established the Terminal Ediacaran Stage Working Group to begin Ediacaran subdivision. The upper boundary of this stage will coincide with the base of the Cambrian. Determining its basal boundary GSSP will require integration of a wide range of biological, physical, and chemical criteria, as follows: Pre-Cambrian shelly fossils were first reported from Namibia in 1972, and over the succeeding 40+ years these fossils have been documented in abundance from uppermost Ediacaran (~550-541 Ma) strata worldwide. Ediacaran shelly fossils are typified by *Cloudina* Germs, 1972 and *Namacalathus* Grotzinger, Watters, and Knoll, 2000, two taxa that differ significantly from any Cambrian shelly fossils and that abruptly went extinct 541 million years ago. It would seem logical to pick a GSSP level that is at or slightly below the base of the first appearance of these globally important and distinctive fossils. Uppermost Ediacaran strata typically exhibit a low diversity, soft-bodied megafossil assemblage dominated by long-ranging forms such as *Charnia*, *Pteridinium*, and *Palaeopaschichnus*; some more endemic taxa such as *Ernietta* and *Swartpuntia* may be restricted to the terminal Ediacaran stage. Non-calcified, mm- to cm-scale tubes are also especially common in uppermost Ediacaran strata worldwide, and their significance is only now becoming fully recognized. Simple, mostly horizontal, bilaterian burrows appear in abundance in both shallow- and deep-water marine strata approximately 555 Ma, and are characteristic of uppermost Ediacaran successions worldwide. Terminal Ediacaran microfossils comprise mainly simple leiospheres.

Terminal Ediacaran successions typically exhibit a moderately positive C-isotope excursion followed by relatively invariant and slightly positive C-isotope values. In many localities worldwide, these positive C-isotope values overlie a major negative C-isotope excursion that separates older acanthomorphic acritarch assemblages (in China and Siberia) or older rangeomorph-dominated Ediacara-type impressions (in NW Canada) from strata containing diagnostic uppermost Ediacaran fossils. The top of the negative excursion underlying *Cloudina*-bearing terminal Ediacaran strata has been dated radiometrically at >547 Ma in Namibia and >551 Ma in China, implying that this major negative C-isotope excursion represents a global event and provides a key marker in Ediacaran subdivision. Many workers correlate this excursion with the Shuram/Wonoka excursion, the most extreme negative C-isotope excursion in Earth history, but the presence of several negative excursions in the Ediacaran of China suggests that additional stratigraphic indicators are needed to correlate this excursion worldwide.

In order to be effective, any proposed GSSP for a terminal Ediacaran stage must be amenable to both paleontological and isotopic correlation worldwide, and a high-precision U-Pb or Re-Os date would significantly enhance its correlation potential. Over the next few years, the Working Group will characterize key sections that exhibit these features, with emphasis on integrating high-resolution biostratigraphy (megafossils, trace fossils, microfossils) and chemostratigraphy (e.g. C, Sr, S, redox) of these sections with a search for additional datable materials. A successful field excursion was run in the Yangtze River area of China in 2014 and one is planned for Namibia in 2016; others will be scheduled as required and proposed. It would be helpful if these investigations and excursions to define a terminal Ediacaran stage involved members of both the Ediacaran and Cambrian subcommissions.

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Correlation of the Paleozoic French formations with the International Stratigraphic Chart

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French Paleozoic (meta)sedimentary to crystalline rocks are diverse, and record dynamics of past orogenies and volcanic activities. France can be divided in nine large geological regions. Palaeozoic rocks are found in the Hercynian deformed crystalline regions (the Armorican and Central Massifs, the Vosges, Morvan, and Ardennes, Boulonnais), which contain magmatic complexes and metasedimentary rocks. Further Palaeozoic rocks have been cannibalized in younger orogenies and crop out today in the axial parts of alpine mountain belts (the Alps, Pyrenees and the associated Montagne Noire and Corbières). The diversity of the Paleozoic strata, which are moderately to highly tectonically deformed in each region, leads to large chronostratigraphic uncertainties. The discontinuity of the regions is often considered as a break in their stratigraphic correlation. Here, we propose the first step of a larger project, which attempts to propose biostratigraphic correlations between the Phanerozoic formations of the different French regions and the International Stratigraphic Scale.

Several key-regions among the French Paleozoic domains have been selected to perform biostratigraphic correlations at the formation scale over the Cambrian-early Carboniferous times. Criteria were the relative successions completeness, the published data availability, the biostratigraphic accuracy (using chitinozoans, conodonts, graptolites and/or trilobites) and the field accessibility. Each formation has been re-calibrated using reference biostratigraphic scales. Uncertainties are relatively high for the Cambrian (problematic biostratigraphy) and Llandovery times (rare fossils in glacially-related deposits), and for the highly metamorphized and tectonically deformed strata (especially in the Pyrenees).

The Armorican Massif, exhibiting strata aged from the Precambrian to the Mississippian, is subdivided into three domains (the North, the Mid and the South Armorican units) separated by the North and the South Armorican Shear Zones, respectively. The North Armorican Unit and the Mid Armorican Unit show similar but diachronous deformed strata with strong hiatus from the Furonian to the late Floian and the Rhuddanian for the North American Domain, and the Cambrian-Floian, the Rhuddanian and then the Mid-upper Devonian only for the eastern Mid Armorican Domain.
The metasedimentary formations of the Montagne Noire express most of the Paleozoic history constrained the Hercynian orogeny. The early Paleozoic succession, represented by carbonate to siliciclastic platform sediments, is discontinuous (Cambrian-Floian, Katian, Rhuddanian, Homerian?-Pridoli), mostly recorded in nappes tectonically emplaced during the upper Carboniferous.
Paleozoic rocks in the South of France are highly deformed and occur mainly in the Axial Zone of the Pyrenees but also in the south Corbières. Cambrian and Tremadocian are represented by metasedimentary detrital shallow water series whereas the late Ordovician-Silurian interval (with the exception of Rhuddanian) is characterized by varied facies suggesting mixed to carbonate platform environments. Hiatus extends from late Floian to middle Sandbian. The relatively continuous Devonian to Mississippian strata are represented by detrital and carbonaceous shallow water series and then by the famous flysh series witnessing the Hercynian orogeny.

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A possible Upper Pleistocene global boundary stratotype section and point (GSSP): The Fronte Section at Taranto (Italy)

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The Fronte Section at Taranto (Southern Italy) show a 6,25 m thick pelitic unit characterized by lithologically homogeneous marine sediments occurring above a calcarenitic bed in which ”Senegalese fauna” and in particular *Persististrombus latus* occur. U-Th dating provide reliable age, consistent with the Marine Isotope Stage (MIS) 5.5. The recently collected data evidence that the pelitic unit is continuous, and stable isotope, micropaleontological and palynological analyses suggest a long and undisturbed sedimentary interval correlating to the MIS 5.5 peak (plateau). High sedimentation rates and a successful paleomagnetic pilot study indicate the probability of locating brief chronostratigraphic events useful for correlation with both continental and marine succession elsewhere. These data show the section to be a very promising candidate in the search for the Upper Pleistocene global boundary stratotype section and point (GSSP).
This presentation deals with the preliminary lithological, micropaleontological and magnetic susceptibiliy data from a multiple core drilled at the Fronte locality.

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Calcareous nannofossil in the pre-evaporitic Messinian: Bioevents and paleoenvironmental implications

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During the Messinian (7.2 to 5.3 Ma) the Mediterranean area experienced fast and deep climatic and eustatic structural changes. The stratigraphic framework for this interval is relatively well constrained and the beginning of the Messinian salinity crisis dated at 5.97 Ma determine a duration of at least 1.2 Ma for the pre-evaporitic Messinian that is object of this study. Several sites (Faneromeni, Pissouri, Polemi Fanantello borehole, Lemme, Pollenzo, Govone, Moncalvo; Wade and Bown, 2006; Kouwenhoven et al 2006, Morigi et al 2007, Lozar et al 2010, Dela Pierre et al 2011) show similar calcareous nannofossil record behavior, with several *Sphenolithus* spp.peaks recognised at different quotes in each of the sections.

Therefore, our aim is to compare the calcareous nannofossil data achieved in the above mentioned sections: interestingly, the occurrence of strongly oligotypic assemblages related to high salinity and unstable environments, appear to correlate precisely among the investigated sites and occur immediately before the onset of the Messinian salinity crisis, then offering the possibility to use them as bioevents for local correlation.

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The ambiguity to define volcanic lithostratigraphic units in silicic volcanic terrains

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Formal as well as informal lithostratigraphic units are the basis to create geological maps, including those of volcanic terrains. The international stratigraphic code does not prescribe a uniform mode to define volcanic lithostratigraphy units and therefore mapping in volcanic terrains can follow identification of practical mapping units that might have little relevance to the volcanic processes hidden behind the identified volcanic rock units. During geological mapping highly variable aspects of lithology are commonly selected to define rock formations and members, in volcanic terrains particularly the petrographic aspect playing a dominant role. The way, how the rock formations are defined, plays an important role to transfer geological knowledge to a reader through the geological map. While already established formal lithostratigraphic units are scale and precision independent, the way we define the new ones can reflect the scale and precision of the work. In volcanic context a geology map of a volcanic terrain should capture the volcanic structure as well as the volcanic history including the rock record that can be linked to various eruption phases, episodes and periods that all together can define eruptive epochs. A thorough lithological analysis including a paleovolcanic and environmental interpretation is therefore essential to define volcanic lithostratigraphic units. Such the approach has been used successfully by Konečný and Lexa (*1983 – 1998*) in geological mapping of Miocene volcanic terrains of Slovakia and in a more advanced mode, including informal units, by Lucchi et al. (2013) in the case of Quaternary volcanoes of Aeolian Islands. Here we argue, using two examples, that this approach should be extended to Tertiary and perhaps older volcanic terrains.
Next to Vinicky in Eastern Slovakia previous geological mapping recognized rhyolite tuffs and a lava coulée that were considered informally as a single lithostratigraphic unit with two members. However, a more detailed analysis has revealed that these rhyolite volcanites represent four different sourced volcanic units: 1) a succession of ash/pumice flow, surge and fall deposits – a distal facies of plinian/phreatoplinian type eruptions at unidentified centers; 2) dacitic phreatic/phreatomagmatic pyroclastic rocks – a proximal facies of a pyroclastic ring resting on unconformity marking a period of erosion; 3) both units are truncated by a rhyolite extrusive dome; 4) a rhyolite coulee represents the uppermost volcanic unit with a center 1 km NE of Viničky. The described units represent products of 4 overlapping monogenetic volcanoes and should be recognized as individual lithostratigraphic units.
Across the Miocene Pannonian Basin we can find numerous examples to demonstrate that silicic pyroclastic units, traditionally grouped into three extensive ignimbrite horizons of the Lower, early Middle and late Middle Miocene age, not only represent diachronous rock units but they are also sourced from different vents through similar magma fragmentation, eruption style, pyroclast transportation and deposition processes that affected localized regions. It has been already demonstrated at the southern slopes of Bükk Mts., that it is possible to distinguish several ignimbrite units alone within the framework of the Lower horizon. We can confirm the same situation in the area of Ipolytarnóc, where rhyolite tuffs of the Lower horizon (Gyulakeszi Fm.) are in reality represented by three non-welded ignimbrite units separated by volcano-sedimentary deposits. The lower unit with directed blast surge deposits and fallen trees at the base is relatively fine grained and includes pieces of charcoal. The second and third units are pumice flow deposits with limited extend. A definition of lithostratigraphic units, especially in silicic volcanic terrains, should consider the scale of observation. In a period of only few millions years in history of silicic volcanism multiple pyroclastic units with near-identical physical appearance can mimic a basin-wide single lithostratography unit. Distinction between locally sourced and multiple event derived deposits from single sourced and single event-related horizons is important.

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Stratigraphic Proposal to thePost-Rift I Tectonic-Sedimentary Sequence of Araripe Basin, Northeastern Brazil

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The stratigraphy of the Araripe Basin comprises five tectonosedimentary sequences (Assine, 1992; Neumann and Cabrera, 1999; Assine, 2007): a) Paleozoic, represented by the Ordovician-Devonian continental deposits of the Cariri Formation; b) pre-rift, represented by the Thytonian continental deposits of the Brejo Santo and Missão Velha formations; c) rift, composed of the Neocomian continental deposits of the Abaiara Formation; d) post-rift I, which includes the Aptian continental deposits of the Barbalha, Crato, and Ipubi formations, and the coastal to marine deposits of the late Aptian to the early Albian Romualdo Formation; and e) post-rift II, which includes the Albian-Cenomanian continental deposits of the Araripina and Exu formations.

The post-rift I sequence contains some of the most important fossil-bearing strata of Brazil and is correlated with the Aptian sequences of Brazilian and African marginal basins. The overall sequence includes the sedimentary record of Barbalha, Crato, Ipubi and Romualdo formations. This contribution reviews the stratigraphy of the succession, here proposed as Santana Group.

The Barbalha Formation is the lowest unit and is mainly made up of sandstones with intercalations of reddish shales and minor thin levels of conglomerates arranged in two fining upward fluvial cycles, whose tops are marked by pelitic and carbonate lacustrine beds (Assine, 2007).

The Crato Formation is composed of laminated limestones and calciferous shales deposited in lake environments, recording the main lacustrine phase of the continental succession in the Araripe Basin (Neumann et al., 2003). The most expressive limestone succession occurs in the northern border of the basin, very well preserved in mining quarries.

The Ipubi Formation is represented by discontinuous layers of gypsum, in a facies association with black shales and thin limestone beds, reaching the maximum thickness of 40 m. The gypsum layers are made up of primary laminated beds with columnar crystals, with secondary gypsum in the form of alabaster, porphiroblastic (selenite rosettes) and nodular varieties. Fibrous varieties constitute the last generation as product of recrystallization during diagenesis processes (Silva, 1988).

The Romualdo Formation consists of green and black shales, marls, limestones and interbedded friable sandstones. The sedimentary facies and the fossil content indicate lacustrine and marginal environments, with marine influence in some intervals (Beurlen, 1966; Coimbra et al., 2002). Coquinoid limestones with echinoid forms in the upper beds stand for an important stratigraphic mark and the most remarkable evidence of the late Aptian transgression in the interior of Northeastern Brazil.

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Ammonite and inoceramid biostratigraphy of the Elbtal Group (Cenomanian – Middle Coniacian, Saxony, Germany)

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The Cretaceous sedimentary rocks that are exposed in Saxony between the Czech border in the SE and Meißen in the NW are lithostratigraphically combined in the Cenomanian–Coniacian Elbtal Group. The Elbtal Group formed in a narrow strait between the Mid-European Island in the southwest and the Lausitz Block in the northeast (Westsudetic or Lusatian Island). During the Late Cretaceous period, the Elbtal Group was thus situated in an important intermediate position between the temperate Boreal in the north and the Tethyan warm water areas in the south, and it shows a strong relationships in terms of litho- and biofacies to contemporaneous deposits and faunas of the Bohemian Cretaceous Basin. Lithologically, the Elbtal Group consists of marine sandstones, calcareous siltstones (Pläner), marls and marly limestones which are in part very rich in fossils. Three principal facies zones can be differentiated: a sandy nearshore zone in the SE, today exposed in the Elbsandsteingebirge and a marly-calcareous offshore (Pläner) zone in the NW (Dresden–Meißen area) with an intermediate transitional zone in between (Pirna area). The Elbtal Group describes a transgressive–regressive megacycle with maximum flooding in the late Middle Turonian. Although sedimentation allegedly persisted into the later part of the Late Cretaceous, the youngest strata preserved today date into the Middle Coniacian. The rich faunas of the Cenomanian to Coniacian stages form the basis for the biostratigraphy of the Elbtal Group. Ammonites prevail in the offshore Pläner facies, are rare in the transitional facies and missing in the proximal sandy facies. In total, more than 35 taxa have been documented from the Elbtal Group (Wilmsen & Nagm, 2014), allowing to recognize the following standard zones from Middle Cenomanian to the Upper Turonian, based on the well documented presence of their index taxa: in the Middle Cenomanian, the *Turrilites costatus* Subzone of the *Acanthoceras rhotomagense* Zone; in the Upper Cenomanian, the *Calycoceras naviculare*, *Metoicoceras geslinianum* and *Neocardioceras juddii* zones; in Lower Turonian, the *Watinoceras coloradoense* and *Mammites nodosoides* zones; in the Middle Turonian, the *Collignoniceras woollgari* Zone; in the Upper Turonian, the *Subprionocyclus neptuni* Zone.

Inoceramid bivalves occur across all facies zones of the Elbtal Group and are thus the primary index fossils (Tröger & Niebuhr, 2014). They are represented by the genera *Inoceramus* Sowerby, *Mytiloides* Brongniart, *Cremnoceramus* Cox and *Platyceramus* d'Mercey. Nine *Inoceramus* species with eight subspecies, ten *Mytiloides* species and four *Cremnoceramus* species with two subspecies are briefly discussed in terms of their taxonomy, biostratigraphy and regional distribution in the Cretaceous of Saxony. 18 inoceramid taxa (species or subspecies) are of biostratigraphic value, defining 16 inoceramid biozones throughout the Lower Cenomanian to basal Middle Coniacian. Only Middle Cenomanian strata could not be dated by inoceramid bivalves. The biostratigraphic sequence includes the following inoceramid zones: *Inoceramus virgatus* (Lower Cenomanian), *I. pictus pictus, I. pictus bohemicus, Mytiloides hattini* (Upper Cenomanian to lowermost Turonian)*, M. kossmati, M. labiatus, M. subhercynicus* / *M. hercynicus, I. cuvieri* / *I. apicalis, I. lamarcki, I. inaequivalvis* / *I. l. stuemkei* / *I. perplexus, M. labiatoidiformis* / *M. striatoconcentricus, M. scupini* (Lower to Upper Turonian)*, Cremnoceramus deformis erectus, C. waltersdorfensis hannovrensis, C. deformis, C. crassus* (Lower Coniacian). The occurrence of *Platyceramus* ex gr. *mantelli* indicates the presence of basal Middle Coniacian strata.

Inoceramid bivalve and ammonite biostratigraphy is the most important tool for chronostratigraphic assignments of the formations of the Elbtal Group and correlations into other Cretaceous basins.

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Upper Oligocene to Lower Miocene foraminifera from the Qom Formation (Central Iran)

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The present study focuses on two Oligocene-Miocene outcrops of the Qom Formation in Central Iran located near Zefreh, about 57 km northeast of Isfahan. The Central Iran has a unique paleogeographic position for testing the biogeographic history of the Eastern Mediterranean close to the assumed gateway to the Indian Ocean in the SW. Geodynamic evolution of that pathway must have had propounded effects on the existing fauna. The Qom Formation itself represents marine flooding of the Central Iranian Gulf and is intercalated between thick continental successions termed the Lower and the Upper Red Formation. It displays the characteristic source- and reservoir-rock in Central Iran. In consequence, precise biostratigraphic and paleoecological investigations are also of great importance for purposes of the petroleum exploration.

The sedimentary succession of the Qom Formation at Vartun is 120-m-thick and splits into 3 lithostratigraphic units. The 65-m-thick lower unit is made by yellow to yellowish, highly fossiliferous limestone interbedded with grayish to yellowish marl with abundant larger benthic foraminifera. A 30-m-thick marl follows with abundant echinoderms, mollusks, and small and larger benthic foraminifers. On top, 20 m unit of sandy to marly limestone grading into marl up-section is present. It bears abundant echinoderm and pteriomorph bivalves, but lacks any microfaunal remains. The thickness of the Qom Formation attains 85 m in the Bagh outcrop. The succession is represented there by a thick alternation of highly fossiliferous marl, and sandy to marly limestone.

Considering its microfossil content, the lower unit of the Vartun section can be attributed to the Upper Oligocene (Chattian) based on the presence of *Lepidocyclina* (*N.*) *howchini*, *Eulepidina dilatata,* and *Miogypsinoides* sp. Its middle unit belongs already to the Lower Miocene (Aquitanian to Burdigalian) as suggested by the composition of planktonic foraminifera including *Globigerinoides trilobus*, *Globigerina praebulloides*, and *Globigerinoides altiaperturus*. The abundant *Lepidocyclina* (*Eulepidina*?) *elephantina*, *Nephrolepidina tourneri,* along with the present *Miogypsina* sp. supports the inference of the Early Miocene age. Its smaller benthic foraminifera is dominated by diverse *Quinqueloculina* and *Triloculina* species pointing to installation of shallow water environmental setting.

Abundant benthic foraminifera assemblages were found at Bagh section. The smaller benthic fauna is dominated by diverse *Lenticulina* representatives, followed by *Amphistegina hauerina*, pointing to shallow water depositional settings. The intervals with common epiphytal, oxic indicators *Cibicides* sp. and infaunal, suboxic conditions tolerating *Fissurina obtusa*, and *Vaginulinopsis* sp. may point to the presence of sea-grass settling muddy bottoms. Not very abundant planktonic foraminifera includes *Globigerina praebulloides*, *G. ouachitensis*, *Globigerinoides trilobus*, *Gls. altiaperturus*, and *Gls. bollii* providing straight forward correlation with the middle unit of the Vartun section (Aquitanian to Burdigalian). This is in agreement with the composition of larger benthic foraminifera.

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The Permian strontium isotope stratigraphy on key Volga river section data

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In the present paper the $^{87}Sr/^{86}Sr$ values have been analyzed for the Permian regional key section – Pechishchi. Samples for isotope studies were collected from layers 5, 8, 9, 13, 16, 18, 19, 20, 21, 22, 25, 26, 27, 28 and 30 of the Pechishchi section. The Permian trend was identified and described using core samples of the subsurface continuation of the Pechishchi section: the Lower Kazanian, the Lower Permian and the Upper Carboniferous strata.

The Pechishchi section was formed in the Kazanian paleosea. This zone includes the most complete Kazanian marine sections. The section clearly features three Noinsky's cycles associated with the cycles of evaporate formation in the Kazanian palaeosea. Each Noinsky's cycle consists of three components. A lower component includes carbonate rocks, a middle component – evaporate rocks and an upper component – terrigenous rocks. These components reflect alternation of environments from normal marine through higher salinity to lake and lagoon conditions.

The Rb-Sr classification of carbonates has been studied using the bulk carbonate component after solving a weighed portion of the crushed sample in 10% acetic acid. Rb and Sr have been conventionally separated by the ionexchange technique using Dowex AG50Wx8 cation exchanger (200 to 400 bags) and 2.5N HCl as an eluent. Rb and Sr contents have been determined by the mass-spectrometric method of isotope dilution using a mixed ^{87}Rb-^{84}Sr indicator. The Sr isotopic composition has been determined by the Finnigan MAT-261 multiple collector mass-spectrometer simultaneously recording ion currents of all isotopes. The $^{87}Sr/^{86}Sr$ average ratio normalized to $^{86}Sr/^{88}Sr = 0.1194$ in the standard SRM 987 sample has been estimated at 0.71025±0.00001. The degree of preservation/alteration of carbonates has been estimated using published criteria. The separation of samples with disturbed and undisturbed isotopic systems has been performed using the following Mn/Sr and Fe/Sr values: <5 and <20 for limestones and <10 and <60 for dolomites, correspondingly.

The analysis of data on $^{87}Sr/^{86}Sr$ shows the highest ratios, characteristic of the Asselian, and average at 0.70832. In the Artinskian, the $^{87}Sr/^{86}Sr$ ratios decrease to 0.70774. In the Kazanian, the strontium ratio is much lower: 0.70769 in the Early Kazanian and 0.70740 in the Late Kazanian.

The position of received local data on global evolution $^{87}Sr/^{86}Sr$ curve, in common, is satisfactory.

The Early Permian sea basins of the eastern portion of the Russian Plate are characterized by high $^{87}Sr/^{86}Sr$ ratios corresponding to the global $^{87}Sr/^{86}Sr$ ratios in the ocean at that time.

A decrease in the $^{87}Sr/^{86}Sr$ ratio, recorded for the Early Kazanian and early Late Kazanian, generally corresponds to the global curve and indicates the connection between Kazanian paleosea and the ocean, but local $^{87}Sr/^{86}Sr$ ratios are relatively high reflecting the role of continental water currents that carried heavy strontium. At later times, the salinity of the basin apparently increased, probably due to the arid climate. Salinization of the Kazanian paleosea over time is indicated by a considerable increase in the content of dolomite (relative to the volume of carbonate rocks), from 40% in the Lower Kazanian substage to 85% in the Upper Kazanian substage, and by a two-fold increase in the content of sulphates in the Upper Kazanian substage relative to the Lower Kazanian substage. The generally low background $^{87}Sr/^{86}Sr$ ratios on the local and global curves indicate the gradual drying of continental flows under arid environments on the vast Pangaea continent, although their local effect could periodically increase $^{87}Sr/^{86}Sr$ ratios as demonstrated by a local maximum in layer 27.

The discrepancies between local and global data observed at some points can be explained by the local features of the Permian deposition in the eastern part of the Russian platform (the evaporite trend and considerable isolation from the ocean); and problems with the chronostratigraphic positioning of the $^{87}Sr/^{86}Sr$ Phanerozoic evolution curve and local $^{87}Sr/^{86}Sr$ curves within the Permian. Multiple determinations of strontium isotope ratios in the Permian carbonates and the isotope dating of key samples would allow the revision of the Permian stratigraphic record.

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Changes in foraminiferal and calcareous nannoplankton assemblages on the Badenian/Sarmatian boundary (Planina Syncline, Slovenia)

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Foraminifera and calcareous nannoplankton from the Badenian/Sarmatian boundary was studied in the Planina syncline situated in the Kozjansko region of Eastern Slovenia. Basal Badenian beds consist of limy conglomerate, composed mostly of biogenic carbonate grains. These strata are followed by massive marly calcarenite, alternating marly calcarenite and calcarenite, and topped by marl. This study shows that the marl previously believed to be Upper Badenian is actually earliest Sarmatian. The results of this study also give evidence of continuous sedimentation across the Badenian/Sarmatian boundary for the easternmost Slovenian region.

Based on the occurrences of index species, five Badenian and one Sarmatian biozones were established; Lower Badenian (Lower and Upper Lagenidae Zones), Middle Badenian (*Pseudotriplasia robusta* and *Uvigerina* cf. *pygmea* Zones), and Upper Badenian *Bolivina dilatata* Zone. The lowermost Sarmatian assemblage represents the Lower Sarmatian *Anomalinoides dividens* Zone. The Upper Badenian *Bolivina dilatata* Zone is defined by the first common occurrence (FCO) of *Bolivina dilatata* and the agglutinated species *Pavonitina styriaca*, as well as other bolivinas, buliminas and globobuliminas. Diversity of planktonic foraminifera is observed to decrease in this zone. Genera *Dentoglobigerina, Globigerinella, Globigerinoides, Globorotalia* and *Orbulina* are not present, only a high number of small-sized globigerina specimens and other related taxa are present (*Globigerina praebulloides, G. tarchanensis, Turborotalita quinqueloba*). The uppermost part of this zone was found to have strongly reduced benthic foraminiferal diversity; impoverished assemblages are dominated by *Bolivina dilatata, Virgulinella pertusa, Cassidulina laevigata* and *Globocassidulina oblonga*. Other species, *Caucasina gutsulica, C. subulata, Sphaeroidina bulloides, Hansenisca soldanii* and *Hanzawaia boueana* are scarce and represented by small specimens. Planktonic foraminifera, when present are of small size and few in number. These uppermost Badenian strata are assigned to the *Rotalia beccarii* Zone.

The Lower Sarmatian *Anomalinoides dividens* Zone was identified by the FOD of the index species *Anomalinoides dividens, Elphidium hauerinum, E. josephinum, E. reginum* and *Orthomorphina dina*. The zone is characterized by low benthic species diversity; aside from the named index species, *Schackoinella imperatoria*, other *Elphidium* and miliolids complete the assemblage. Planktonic foraminifera are absent.

The Badenian/Sarmatian boundary is placed into nannoplankton Zone NN6. Nannoplankton assemblages were studied quantitavely and show strongly changes around the boundary. The Badenian part of NN6 is characterized by high percentages of *Coccolithus pelagicus*, accompanied by common helicoliths (*Helicosphaera carteri*, *H. euphratis*, *H. walbersdorfensis*) and reticulofenestrids (*Reticulofenestra gelida*, *R. minuta*, *R. pseudoumbilicus*) pointing to the stable marine environment characterized by normal salinity and higher nutrient content.

In marked contrast to Badenian sediments, calcareous nannoplankton assemblages from the Sarmatian part of NN6 contain low amount of *C. pelagicus* and helicoliths. A strong increase of *Calcidiscus pataecus* in the uppermost Badenian reaching the highest value in the lowermost Sarmatian sample (ca. 85%) could be documented. This event can be of the importance for defining the Badenian/Sarmatian boundary by calcareous nannofossils. The last occurrence of *H. walbersdorfensis* in the investigated section could be observed in the uppermost Badenian. Sarmatian nannoplankton assemblages are characterized by in strong variation of the dominating *Sphenolithus moriformis*, *Reticulofenestra gelida* and *R. pseudoumbilicus* as well as ascidian spicules, caused by shallow, unstable paleoenvironment conditions.

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Well Logging Data as Tools for Astrochronological Dating

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Drilling of exploration and development industrial-wells includes the acquisition of logging data as a routine operation. Integrated analysis of these data is an effective method for characterizing physical, chemical, or electrical properties of the rocks and fluids penetrated while drilling. Given that logging has become an extended practice, which is indistinctively carried on over diverse basinal settings and lithological records, most of the conventional acquisition tools are standardized allowing integration of multiple source data. Consequently, logging data is in itself a large, continuous and reliable lithological archive that allows evaluation and reliable correlations of stratigraphic sequences.

Herein, we intent to extend the use of the logging data by demonstrating how it can be used for high-resolution dating when integrated with independent chronostratigraphic references. We correlated characteristic alternating patterns in gamma ray, sonic and resistivity records with astronomical solutions, using well-dated biostratigraphic events as age constrains. This methodology was applied to three Tortonian-Pliocene successions from the Atlantic Ocean and the Mediterranean Sea (Guadalquivir, Alicante and Valencia basins). Studied sedimentary sequences included different depositional settings, ranging from shallow waters to deep marine settings. In all cases, large and small-scale cyclical alternations were positively correlated with astronomically forced cycles (400, 100 and 20 kyr). Thus, we were able to establish consistent astronomical datings with errors no higher than 20 kyr. Furthermore, well-log records were used to produce high-resolution chronostratigraphic frameworks, as well as intra- and interbasinal correlations. Our results indicate that logging tools can efficiently record large- and short-scale astronomic-driven lithological changes. Therefore well log data is not only useful to provide petrophysical characterization of the rocks, but also to build high-resolution chronostratigraphic models that can be integrated with reference outcropping sequences.

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Revised Matuyama-Brunhes polarity transition record from a marine succession at the Chiba composite section of central Japan, a potential Lower-Middle Pleistocene GSSP

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We report revised paleomagnetic records of the Matuyama-Brunhes boundary (MBB) from a continuous marine succession at the Chiba composite section of the Kokumoto Formation, Kazusa Group. The Chiba composite section is the one of the candidate sites for the Lower-Middle Pleistocene Boundary GSSP. In the section, a wide spread tephra bed named as Byk-E is intercalated just 80 cm below the MBB. An age model for the section, provided by newly obtained oxygen isotopes of benthic foraminifera from a 100 meters succession across the M-B boundary, indicates that the boundary is situated in the middle to late part of the interglacial period of MIS19. Recently, a U-Pb zircon age of 772.7±7.2 ka was measured at the Byk-E tephra bed, which yielded a MBB age of 770.2±7.3 ka using from the oxygen isotopic stratigraphy. In order to provide globally comparable VGP (virtual geomagnetic pole) and paleointensity (past geomagnetic field intensities) records from the Chiba composite section, we have taken 130 oriented mini-cores from a 13 meters succession across the Byk-E tephra bed from the Tabuchi and the Yanagawa sections which are parts of the Chiba composite section. Thermal magnetic experiments suggest that the samples include iron sulfides, magnetites but no hematite. Measurements of magnetic hysteresis indicate that the magnetic domain state is PSD. Progressive alternating field demagnetization (AFD) indicate a reversed to normal polarity transition boundary is at around 1.5 meter below the Byk-E bed as well as previous studies, however the transition boundary is observed at around 0.8 meter above the Byk-E bed in thermal demagnetization (ThD) results. Therefore, the reversed to normal polarity transition boundary seen below the Byk-E bed is thought to be overprint. This overprint, which might be carried by iron sulfide, is particularly observed in a transitional interval. Since iron sulfides generally decompose and oxidized into magnetites due to heating during ThD, the yielded magnetites have no magnetic signal but provide an over estimate of magnetic grain amount which prevents to estimate paleointensities. To provide a reliable paleointensity record, we applied to use a composite demagnetization technique consisting of a 300°C ThD and a regular progressive AFD sequence. After the 300°C ThD, most of the overprint has been removed but the magnetic susceptibility has not changed even in the air condition, indicating that iron sulfides just lose magnetic signals due to the ThD but not to change the amount of magnetic grains. The VGP latitudes and preliminary derived paleointensities using the composite demagnetization technique from the Chiba composite section quite match well with the U1308 records. To use the both independent techniques of oxygen isotope and paleointensity will provide a further reliable stratigraphic correlation across the Lower-Middle Pleistocene Boundary.

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Strontium-Isotope Stratigraphy for Oligocene-Miocene Carbonate Systems in Puerto Rico and Dominican Republic: Implications for Caribbean Processes Affecting Depositional History

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$^{87}Sr/^{86}Sr$ mean ages from low-Mg calcite *Kuphus incrassatus* and *Ostrea haitensis* bivalves provide an updated and refined chronostratigraphy for Oligocene-Miocene carbonate and siliciclastic units in Puerto Rico (PR) and Dominican Republic (DR). Results indicate middle to Late Oligocene for the San Sebastian Formation (ca. 29.78-26.51 Ma), Lares Limestone (ca. 26.51-24.73 Ma), and Montebello Member (ca. 27.30-24.10 Ma); Middle to early-Late Miocene for the Cibao Formation (ca. 12.17 Ma), Aguada (Los Puertos) Limestone (ca. 14.67-11.14 Ma), and Aymamón Limestone (ca. 10.98 Ma) in northern PR, the Ponce Limestone (ca. 14.97-9.84 Ma) in southern PR, and the Yanigua-Los Haitises formations (ca. 15.75-12.58 Ma) in northeastern DR; and Late Miocene for the Cercado Formation (ca. 6.31-5.88 Ma) in northwestern DR. Our Sr-derived mean ages indicate some overlap in the timing of deposition of defined Oligocene and Miocene PR units, which suggest that parts of the units reflect lateral facies changes, from proximal to distal locations. This suggests a new stratigraphic model for their deposition that differs from previous work. The San Sebastian Formation eroded from uplifted areas marked the last major input of siliciclastics in PR. The time equivalent Lares Limestone composed of a diverse warm and cool, turbid coral assemblage and the Montebello Member, characterized by large benthic foraminifers and molluscs, reflects depositional environments that were differentially influenced by upwelling. The disappearance of warm water corals coincides with the end of global warming and coral extinction events. The Cibao Formation, Aguada (Los Puertos) Limestone, Aymamón Limestone, Ponce Limestone, and Yanigua-Los Haitises formations are similarly composed of red algae, molluscs, benthic foraminifera, echinoids, and bryozoans, and cool-, turbid-water corals in the upper parts. These time-equivalent facies characteristics indicate shallow marine environments affected by prevalent upwelling. The re-appearance of corals indicate an environmental change, perhaps related with the closure of the Central American Seaway, which resulted in restriction, warm temperatures and low nutrients that eventually created suitable conditions for diverse coral reef development as shown by the shallow-water mixed carbonate-siliciclastic Cercado Formation. The ability to constraint the PR and DR ages within resolution limits of ~0.3-1.3 My provide a temporal framework that allows for 1) evaluation and understanding of time-equivalent regional and local factors that may have influenced deposition; 2) comparison with other areas; and 3) refining and constraining known chronostratigraphy.

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The Upper Jurassic Facies in Jebel Zaghouan (Tunisian dorsal)

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Detailed biosedimentologic analysis of the Upper Jurassic limestone in some sectors of Jebel Zaghouan (Tunisian dorsal) shows that:
After a pelagic mode of sedimentation in the Kimmeridgian, a platform was installed where favourable conditions for production of benthic skeletal carbonate grains (algae, echinoderms, foraminifera) and non-skeletal grains (pellets, lithoclasts and oolites) prevailed. The evolution in the sedimentation mode from a pelagic to a platform sedimentation coincides with a eustatic decrease on a global scale (Vail and Al, 1987; Soussi et al., 1994).
In the Tithonian, however, the juxtaposition of two facies belonging to very different bathymetries (only in a part of Jebel Zaghouan pelagic sedimentation continued all around the area of Zaghouan and even in the SW part of this Jebel: Foum El Galta, Jebel stah, ...) is obviously due to a local tectonic activity which raised part of Jebel Zaghouan already since the Bathonian (Castany, 1955; Bonnefous, 1972; Soussi et al. 1994, 1996).
The installation of the platform in the upper Tithonian which was relatively timid at the beginning became effective in the upper Tithonian-Berriasian.
Three main stages characterize the evolution of this platform, in relation to eustatic variations associated to extensional tectonic movements:

- ✓ The onset of the platform accompanied by progradation of the deposits towards the basin (beginning of upper Tithonian); where the platform is flooded at the time of eustatic rise this is reflected by the pelagic development of layered sediments with microfauna (ph. 8 et 9);
- ✓ The development of reefal bodies in the platform/basin transition zone;
- ✓ The last phase was characterized by the installation of a carbonate platform showing reefs built mainly by rudists in the NE, at Sidi Taya sector (ph.1 to 7) (Ourribane et al. 1999, 2000), and turbidite deposits with slumps in the SW part of tne area (442 top and old mines), which are witness of another phase of progradation.

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A new high-resolution ammonite biochronology for the Hettangian Stage (lowest Jurassic) of North West Europe

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New sampling of the remarkable Lower Jurassic coastal sections of the West Somerset coast (SW England) has confirmed the presence of probably the most detailed ammonite sequence known for the basal Jurassic, Hettangian Stage in Europe, possibly the world. Around 100 successive ammonite faunas have now been recorded, representing in excess of 2,500 specimens, through 74 m of Blue Lias Formation mudrock-limestone cycles. These results have been integrated with additional high-resolution sampling of other classic Blue Lias sequences in the region (near Lyme Regis, Devon, SW England) and at Lavernock Point (Glamorgan, S Wales). Preliminary analysis suggests that up to around 45 ammonite biohorizons may ultimately be recognisable within the 8 subchronozones of a standard Hettangian Stage for NW Europe, a significant increase in available stratigraphical resolution from an earlier scheme of around 25 biohorizons (Page, 2005, 2010). The sequence is dominated by the characteristic NW European succession of the ammonite genera *Psiloceras*-*Caloceras*-*Waehneroceras*-*Schlotheimia*, within which it is possible to recognise a clear sequence of dimorphic species assignable to many European nominal species. Crucially it is now possible to place many of these in stratigraphical order and assess a range of intraspecific variation. In addition, there is a range of more 'exotic' forms, such as possible New World '*Sunrisites'* and a succession of more Mediterranean early Arietitidae, including *Laqueroceras*, *Alsatites* and *Shrienbachtites,* which provide possibilities for more global correlations. Although the basal Hettangian ammonite *Ps. spelae* Guex is not known in the UK, the upper part of the lowest Hettangian, Tilmanni Chronozone, can still be recognised through the presence of related *Ps. erugatum* (Phillips) (Page, 2010). The base of the Hettangian, however, is correlated on the basis of a widely recognisable negative carbon isotope excursion (Clémence et al., 2010). The base of the succeeding Planorbis Chronozone can be usefully correlated internationally with the first occurrence of *Neophylites*, as *Ps. planorbis* (J.Sowerby) itself is poorly known outwith the UK. The Liassicus Chronozone is characterised by evolution of the schlotheimiid genus *Waehneroceras* s.l. and its base can be drawn at the first occurrence of a *Waehneroceras*-dominated fauna belonging to *W.* (*Curviceras*) ex gr. *prometheus* (Reynès), although there is an overlap between the last typical Planorbis Chronozone, Johnstoni Subchronozone genus *Caloceras* and the first *Curviceras.* The base of the succeeding Angulata Chronozone corresponds to an apparent replacement of *Waehneroceras* by *Schlotheimia* of the *S. amblygonia* Lange group. The top of the Hettangian is defined by the GSSP for the base of the Sinemurian Stage at East Quantoxhead (Bloos and Page, 2002) where early Arietitinae belonging to *Vermiceras* ex gr. *quantoxense* Bloos and Page replace the last *Schlotheimia* ex gr. *quadrata* Spath (contrary to claims by some authors, there is no stratigraphical gap at this level). Collaborative work also in progress aims to calibrate this ammonite time scale using orbitally-driven (Milankovich) sedimentary cycles, and it is hoped that the new biochronology will ultimate provide an actual time-scale in terms of thousands of years for the Hettangian.

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From Oppel to Callomon – and beyond! Building a high resolution ammonite-based biochronology for the Jurassic System

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From 1842 to 1849, Alcide d'Orbigny proposed a very modern looking *global* subdivision of Brongniart's original *Jurassique* system of 1829, into a sequence of 10 *étage*s for a Jurassic, inspired by many pioneering works from across Europe and further afield. Although d'Orbigny's stages were based on a basic biostratigraphical framework, grouped crudely within 'zones', the faunal changes between the stages were envisaged as being due to global catastrophes and replacement rather than continuous evolution. Other aspects of d'Orbigny's scheme were also flawed, as already pointed out by Quenstedt in 1858 and not all of his claims of correlations could be substantiated. However, Albert Oppel, a student of Quenstedt, took d'Orbigny's framework of *étage*s and placed "*breathe* [*d*] *new life into it*" and "*..place*[*d*] *the whole science of stratigraphical geology on a new footing*." (Arkell, 1933, p.15). In 1854 he set out to travel across Europe, to try and establish a true correlation between each region (1856-1858). Within each of his 8 '*Etagen'* (or 'Zonengruppen'), Oppel established a sequence of 'Zones'. Although he did not originate this latter term, he refined its use, changing it *"... from mere local records of succession to correlation-planes of much wider (theoretically universal) application*." (Arkell, 1933 – a very clear and unambiguous statement of what we today would term *chronostrati-graphy*). If Oppel established the principles of a modern approach to chronostratigraphical practice, it was S.S. Buckman who really began to realise the full potential of fossils to take such chronologies to their ultimate, high-resolution expression. He recognised very fine time divisions which he called '*hemera'* explicitly calling them 'chronological divisions' in 1893, recognising that the time scale was entirely independent of the deposits preserved. Buckman's ideas were poorly understood by most of his contemporaries and it was not until 1933, that W.J. Arkell brilliantly synthesised the development of Jurassic stratigraphy, truly setting the record right concerning all that had developed beforehand, from Humbolt to Buckman. Arkell's contributions to Jurassic stratigraphy and palaeontology are many, and although they include his remarkable attempt to correlate all the Jurassic rocks in the world in 1956, his lasting contribution has certainly been to stabilise the concept of Jurassic time, based on a framework of ammonite chronozones (although he actually used the term 'Standard Zone'). As a disciple of Arkell, John Callomon was a staunch proponent of a formal chronostratigraphy, but he was also largely responsible for the re-instatement of Buckman's concepts of a high resolution ammonite based biochronology, adopting the terms *horizon* or *biohorizon* for the rock (i.e. chronostratigraphic) equivalent of *hemera* (i.e. geochronology) (Callomon, 1995). Like Arkell before, it is this clear concept of time and stratigraphy which Callomon had which should live on and guide us into the future. However, are we really there yet? Have the ordered dreams of Oppel and his successors and disciples really been realised?? The answer has to be 'not quite..'. Of the 11 stages now formally recognised within the Jurassic, 4 still do not have a ratified GSSP, and within the entire system, there still appear to be no formal agreements on what really are the 'Standard [ammonite] Zonations' for each bioprovincial unit. And even within existing zonations, many do not yet have an appropriate sequence of recognised horizons or biohorizons. What is perhaps more worrying, however, is the all too common confusion – even sometimes forced on authors by editors – about the nature of ammonite zones. As John Callomon continuously reminded congresses, they are chronozones *not* biozones, they have been implicitly chronozones since Oppel's day, and as the stratigraphical building blocks of all 'modern' Jurassic stages, they must still be!

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The age of the Badenian/Sarmatian Extinction Event – New insights on the chronology of the Middle Miocene Paratethys Realm

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The Badenian/Sarmatian Extinction Event (BSEE) is considered to be the strongest faunal turnover in the history of Central Paratethys (Piller et al., 2007). It marks the loss of open marine ecosystems and their replacement with the Sarmatian restricted environments in which an endemic, Paratethys specific fauna develops and thrives.

Determining the age of the event is problematic due to frequent stratigraphic gaps at the BSEE level and as a result most of the current age models rely on correlations with global events. It is considered that the BSEE is caused by the restriction of the connections between Central Paratethys and the open ocean (Rögl, 1998). Correlations with various global events that could have reduced the connectivity are therefore used in dating the BSEE. This has led to age models for BSEE that vary between 12.7 and 13.32 Ma. However, the chronostratigraphic evidence for these correlations is scarce and prevents an in-depth understanding of the triggers and nature of the event.

Finding a correspondent of the BSEE in Eastern Paratethys is also problematic. The Kossovian substage (late Badenian) of the Central Paratethys is correlated with the Konkian stage (Popov, 2004) and the Sarmatian Stage is found in both realms. This would imply that BSEE could correspond to the Konkian/Sarmatian boundary but evidence on how the two boundaries correlate is scarce.

We have focused our study on key sections from a deeper basin of Central Paratethys, the Romanian Carpathian Foredeep and circum-Black Sea sections for correlations with Eastern Paratethys. Using an integrated stratigraphic approach that combines paleomagnetism techniques (magnetostratigraphy & rock-magnetism) and biostratigraphy (foraminiferans & nannoplankton studies) we have developed an age model that places the BSEE at 12.65 Ma. The continuous Badenian/Sarmatian sedimentary succession used for dating the event provides more information on the duration and the nature of the BSEE while the age allows a more precise correlation with the global events for an insight on the potential triggers of the Badenian/Sarmatian Extinction Event. The attempt to correlate the BSEE with an Eastern Paratethys event remains problematic and could hint to complex interactions between the two seas at the time when BSEE occurred.

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A new chemostratigraphic marker of the Triassic-Jurassic boundary

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The Triassic-Jurassic boundary (TJB) was only recently defined by a GSSP that was ratified in 2010. The definition uses the first appearance of an ammonoid species (*Psiloceras spelae*), even though global ammonoid diversity and abundance was at a minimum after the end-Triassic mass extinction. The primary marker therefore has only limited global correlation value. Another issue is that the system boundary thus defined is not aligned with the most significant changes in the Earth system in the TJB interval, expressed as a major mass extinction and related environmental crises. These events are not only widely regarded as the true division between the two periods in Earth history, but they also offer more practical stratigraphic signals as concurrent range terminations of many fossil groups are coincident with a major negative carbon isotope excursion (CIE). Here we explore the use of trace element geochemistry in marine sedimentary sections in search of other geochemical anomalies which are also of stratigraphic value and which may offer clues to the causality of the end-Triassic events.
To test if a rare earth element (REE) anomaly near the TJB, previously recognized in the Kendlbachgraben section (eastern Eiberg basin, Northern Calcareous Alps, Austria), were present in other sections, we measured trace element abundances across the TJB in the GSSP locality of Kuhjoch (western Eieberg basin) and in another well-studied boundary section at Csővár, Hungary. Although *Psiloceras spelae* only occurs at Kuhjoch, all three sections display the most characteristic CIE in the TJB interval, known as the initial CIE.
Of the three analyzed sections, the most pronounced heavy REE enrichment is the one documented earlier from the topmost limestone layers of the uppermost Rhaetian Kössen Formation at Kendlbachgraben, coincident with the initial negative CIE. A more subdued HREE anomaly occurs in exactly the same stratigraphic position in the Kuhjoch section. At Csővár, where carbonate deposition is uninterrupted across the system boundary and the sedimentation rate is higher, the HREE anomaly is also detectable but more muted due to the dilution effect. Significantly, it also occurs in the narrow stratigraphic interval characterized by the initial negative CIE.
The most likely source of extra REE added to the otherwise low background of marine sediments is distal air-fall volcanic ash originating from the largest eruptive pulses of the Central Atlantic Magmatic Province. Prior to breakup of Pangea, the studied sections were located c. 2000–2500 km from CAMP. Our data support the synchrony of CAMP volcanism, carbon cycle perturbation and marine extinction, and strengthen the case that major pulses of CAMP volcanism triggered a cascade of environmental and biotic changes. The detected REE anomaly permits chemostratigraphic correlation within the Eiberg basin and between sections in different basins immediately below the TJB, even in the absence of the rare earliest psiloceratid ammonoids. Further studies can test the applicability of this novel chemostratigraphic marker in other TJB sections worldwide. The geochemical fingerprint of the REE anomaly might also help matching it with certain flow units in the eruptive sequence of CAMP basalts.

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Shallow Benthic and Calcareous Nannofossil Zones of the Eocene Monte Postale section, northern Italy

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The Monte Postale, near Bolca (Lessini Mts., northern Italy), is one of the most famous localities of the Italian Eocene, especially because of the fish-bearing laminated limestones.

Recently, a series of intensive fieldwork and studies focused on the non-laminated limestones and marls allowed to collect new data about the biostratigraphy of the Monte Postale section. The larger foraminifera, mainly *Alveolina*, are very common in the non-laminated limestones along the entire section, more than 90 m thick. Several marly layers were investigated for calcareous plankton analysis, but only in a few of them the calcareous nannofossil content was suitable for dating.

The *Alveolina* assemblages are indeed quite homogeneous along the section, but the range of the index species is different from the one reported in the standard SB Zonation of Serra-Kiel et al. (1998). It seems that a mix of elements from the SBZ 11 and 12 is present throughout the section, whereas some species characteristic of SBZ 10 are scattered only in the lowermost part of the section itself. The latter species could reasonably be reworked, but as to the rest of the assemblages the abundance and the preservation state of the specimens rather suggest the coexistence of species since now regarded as belonging to separate SBZ.

Amongst calcareous nannofossils, the presence of *Nannotetrina cristata* s.l. and the absence of *Nannotetrina alata* in the lowermost part of the Postale section suggest the CNE 8 Zone (=NP 14b; Agnini et al., 2014) or lowermost Lutetian, according to the recent GSSP formalization of the base of the Lutetian (Molina et al., 2011). The correlation with the SBZ needs therefore to be revised, because both SBZ 11 and 12 are currently regarded as belonging to the Cuisian (=upper part of the Ypresian).

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Cementation in Mixed Carbonate-Siliciclastic Shoreface Sediments of the Oligo-Miocene: Study of Asmari Formation, from Gale Bar Pass (Semirom), East Zagros Basin, Iran

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The Zagros Mountains are located in the middle part of the Alpine-Himalayan orogenic belt, its basin extending NW-SE from the Taurus Mountains in NE Turkey to the Strait of Hormuz in Iran. The Zagros is the result of a multi-phased collision between the Arabian plate, the former southern margin of the Neo-Tethys Ocean, and the Central Iran Microplates (van Buchem et al., 2010). The Gale Bar Pass is 7 km west of Semirom city at the Isfahan province in central Iran at 51°29'40"- 51°30'50" longitude and 31°26'20"-31°27'20" latitude. Based on the tectonic map of the Zagros, the Semirom area belongs to coastal Fars but is known as the Semirom subzone, based on its specific characteristic and tectonic setting (Sedaghat et al., 1987). The Asmari Formation, a thick Oligo-Miocene carbonate sequence, is the main petroleum reservoir in southwest Iran. It was deposited on a carbonate platform developed across the Zagros Basin. In the study area the Asmari Formation, with 52-meter thickness, is of Aquitanian age and mainly composed of carbonate and mixed carbonate-siliciclastic deposits. Two sedimentary facies have been recognized in the Asmari Formation: carbonate (bioclastic benthic foraminifera, corallinacean wackestone - grainstone and bioclastic corallinacean packstone to grainstone-rudstone) and carbonate-siliciclastics (sandy gravelly allochemic limestone). Oligocene to Early Miocene production is from the widely distributed Asmari Formation, a shallow- to marginal-marine limestone of the Zagros Basin (Ziegler, 2001). The facies suggest that sedimentation occurred in a mixed carbonate-siliciclastic environment near the Oligo-Miocene coastal area. Diagenetic processes in the study area, decreased porosity, and thus the Asmari formation has no reservoir properties.

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Lower Cambrian boundary problem is back again

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The beginning of the Cambrian remains one of the most important frontiers in the evolution of Earth's biota called the "Cambrian explosion". Regardless of the actual triggers of this mass diversification of skeletal organisms, which are still debatable, this unique event is nicely recorded in the geological strata. The general pattern of skeletal fossil distribution seems adequate and supported by the similar fossil records from different regions of the world. The major 'steps' in this sequence became well-known during the last decades and roughly can be figured in the following way. 1) Appearance of calcareous *Cloudina*-like tubular fossils in the Vendian – Ediacaran of Siberia, Gondwana (China, Argentina, Namibia, Oman) and Laurentia (Canada, SW USA and Mexico). *Namacalathus* is another problematic calcareous fossil, associated with *Cloudina* in several localities (Namibia, Siberia, Canada, Oman). 2) Appearance of a number of simple tubular small shelly fossils (SSF), e.g., *Cambrotubulus, Anabarites*, *Hyolithellus*, the protoconodont *Protohertzina*, and few others in the late Precambrian of Siberia, China, Mongolia, Kazakhstan, Iran, Laurentia (at the beginning of Nemakit-Daldynian stage of Siberian stage terminology). 3) Appearance of a rather diverse SSF assemblage including halkieriids, chancelloriids, etc. and the first univalved mollusks at the terminal Precambrian in Siberia, China and Mongolia (at the end of Nemakit-Daldynian stage of Siberian stage terminology). 4) Appearance of taxonomically very diverse skeletal fossil assemblages (almost worldwide), including tommotiids, brachiopods and first archaeocyaths (latter only in Siberia) at the very beginning of the Cambrian. 5) Appearance of first arthropods, including trilobites, and echinoderms at the first half of the Early Cambrian in Siberia, China, USA, Morocco, Australia (at the beginning of Atdabanian stage of Siberian stage terminology). This sequence of biotic events near the Precambrian-Cambrian boundary spans the interval of ca. 550-520 Ma.

The question where the base of the Cambrian system (i.e. the base of whole Phanerozoic) is 'better' to be placed has a long history. The most significant breakthrough in this field was made in 1960s due to the discovery of diverse SSF fauna in the lower Cambrian beds of the Siberian Platform, later called the Tommotian stage. Tommotian deposits are characterized by mass appearances of archaeocyaths, hyoliths, molluscs, inarticulate brachiopods, sponges, and SSF. Since then the base of the Tommotian was generally accepted as the base of the Cambrian system not only in Russia, but also in many other regions of the world. However, several other units were suggested to be lowest Cambrian stages below the Tommotian on Siberian Platform (e.g. Nemakit-Daldynian, Manykayan, Khayalakhian stages). This can be explained by uncertainties in correlation of local formations and general belief that the Cambrian should start with the first appearance of skeletal fossils. Later studies of SSF revealed rather diverse fossil assemblages of two biostratigraphic zones (*Anabarites trisulcatus, Purella antiqua*) below the Tommotian. Both zones are recognized within the Nemakit-Daldynian stage that now is generally accepted as terminal Precambrian. Though the international standard for the Cambrian base was still wanted, for almost 25 years the Tommotian stage was informally used as the basal stage of the Cambrian. The dubious idea that skeletal fossils should not be used as primary markers for the Cambrian base, since their appearance in the sections reflects taphonomy but not real biotic evolution, led to shift for ichnofossils, and *Treptichnis pedum* was chosen as the index for the Cambrian base (Brasier et al., 1994). Over 20 years of stratigraphic practice showed the fallibility of this decision (Rozanov et al., 1997; Babcock et al., 2014). Now we are back at the problem of the Lower Cambrian boundary again. In spite of the tremendous progress in paleontology and stratigraphy of that interval during last years, the general pattern of skeletal fossil distribution remain almost the same, and the sequence of five above mentioned 'benchmarks' of skeletal biota evolution is still valid. Considering the huge experience of our predecessor and previous studies, we can conclude that the most practicable marker for the Cambrian base is the level of mass appearance of SSF, archaeocyaths and brachiopods that corresponds to the Tommotian stage base.

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Resolving eustatic and tectonic influences in a sedimentary basin: upper Oligocene/lower Miocene of southern Patagonia, South America

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Extensive high-latitude marine sedimentary rocks of late Oligocene-early Miocene age form the San Julián and overlying Monte León formations in the Austral Basin, southern Patagonia, South America.These deposits are important geological archives of tectonic, oceanographic, and climatic changesin response to development of the Drake Passage to the south, and sedimentary and diagenetic response of the Austral Basin to the Cenozoic compressional history of the Andean orogen to the west. The basin is an important paleogeographic location in which to develope regional climate and oceanographic frameworks spanning the Paleogene/Neogene boundary in the Southern Hemisphere. Integrated sedimentological and taphonomical studies of twelve sections in this part of Patagonia identify depositional conditions incorporating mixed (carbonate, siliciclastic) sediments of shallow marine platform to low-salinity marginal-marine environments. Paleoenvironmental analysis, facies-stacking patterns, and Sr-isotope ages obtained from biogenic carbonate, establish an integrated stratigraphic framework to unravel relative sea-level changes in the local sedimentary basin to differentiate eustatic and tectonic signatures.

Correlation with the global sea-level curve of Kominz et al. (2008) shows matches and mismatches. The lowest beds of the San Julián Formation register a deepening upward trend from marginal-marine to inner shelf that does not fit well with the global sea level curve. However, upper beds of inner shelf to subtidal environments correlate with global sea-level highstand ranging from 23.5 to 22.6 Ma. A glacioeustatic lowering in sea level in the earliest Miocene may correspond to a sequence boundary between the San Julián and Monte León formations that is well exposed in outcrops in the Puerto San Julián region. The significance of this correlation is threefold: (1) the lowermost Monte León Formation is of early Aquitanian age; (2) the Oligocene–Miocene boundary is positioned either within the uppermost San Julián Formation or lies between the two stratigraphic units; and (3) there is a mismatch between renewed transgression defined by the lowermost Monte León Formation and decrease in global sea level during the early Aquitanian. In the upper portion of this latter formation, well exposed at the mouth of the Santa Cruz River, and in Monte León National Park, inner-shelf to subtidal siltstone and fine tuffaceous sandstone with intercalated shell beds correlate with a global sea-level stillstand of ~19 to 18 Ma. Sea-level fall in the mid Burdigalian (~18 Ma) may be responsible, in part, for a marked shift in coastline position towards the basin interior, resulting in accumulation of intertidal and marginal-marine facies in the uppermost part of this formation and lowermost strata of the overlying Santa Cruz Formation.

Comparison of local sedimentation patterns with global sea-level change identifies the roles of local tectonic versus eustatic influences on deposition of sediments comprising the San Julián and Monte León formations. Tectonic controls in this foreland basin are related to development of the Patagonian Andes to the west. Although more integrated (e.g., bio, magneto- and chemostratigraphic) studies are necessary, the well-defined chronostratigraphic, facies, and sequence stratigraphic frameworks for this succession offer an unusually good opportunity for regional and supraregional correlations. This results in improved understanding of tectonic, paleoceanographic and paleoclimatic changes during the Paleogene/Neogene transition.

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The Messinian Evaporites in the SE part of the Adriatic Foredeep (Albania)

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The Messinian evaporites in the Pre-Adriatic Basin (Albania) are the only outcrops along the eastern side of the Adriatic Sea, and consist of blue-greyish marls with massive gypsum beds and halite, and comprise in the up to 750 m thick Kavaje section the following units:
a. Under-Gypsum Marls represent the topmost part of the mainly Tortonian Mengaj Fm. (320 thick marine blue-greyish marls) and consist of 90 – 97 m thick marls, characterized by oligotypical faunal assemblages suggesting a strong environmental change (onset of Messinian Salinity Crisis).
b. Gips-Sharre Gypsum consists of a 286 m thick cyclic succession of gray to light bluish clays and marls with crystalline selenite gypsum, halite, and sandstone. In total up to 9 - 12 gypsum beds occur of which 3-5 thicker beds occur in the lower part of the unit. The first massive selenite (60 m thick) in the lower half consists of twins of gray-brown large crystals up to 10 - 12 cm, and passes laterally into 2 - 3 beds separated by marls. In the uppermost part white microcrystalline platy gypsum occurs with needle crystals. The fine-grained dolomites, 0.25 - 0.30 m thick, and grey-blue marl, up to 12 m thick, occur within massive selenite gypsum. Upwards a white massive selenite bed occurs, 4.0 m thick, and another, 3.0 m thick, which laterally changes in gypsarenite with debris of oysters. An approximately 10 m thick rhythmic alternation of thin gypsum and clay (laminated gypsum) and halite, 16 - 30 m thick, are present in the uppermost part of the evaporite unit. The 2 - 3 m of the lowermost part of the massive halite bed consist of intercalations of marl layers and gypsum clasts from 2 - 5 cm up to 30 cm thick. Rarely, a halite bed follows above thin gypsum.
c. Inter-Gypsum Marls start with a 1.0 – 1.5 m thick conglomeratic layer consisting of small, mainly carbonate and less ophiolithic pebbles and marl clasts (sub-aerial Messinian erosional surface). It is followed by a thick rhythmic alternation of grey clays and marls with rare fine-grained sandstone layers, from 5 – 12 cm up to 0.30 m thick, with two massive, concretionary coarse-grained sandstones, 12.8 m and 14.0 m thick, respectively. The thickness of the unit is 281 m.
d. Mushnike Gypsum is represented by a chain of lenses of massive selenitic bodies and gypsum arenite, rich in fine grained clastic materials (clays, mudstone), with frequent lateral changes, both in its composition, gypsum/mudstone and thickness from 1 - 2 to 4 m.
e. Over-Gypsum Marls (Lago Mare) consist of a 82 m thick sequence of a regular alternation of grey marls and clays with thin sandstone layers, often very frequently grading into a cyclic succession of 5-10 m thick marls and 3-5-7 cm thick sandstone layers, and small nodules of white carbonate sands.
Pliocene sediments (Acme of *Sphaeroidinellopsis* ssp.) transgressively overlie the Messinian evaporites.
Biostratigraphy. The Messinian oligotypical faunal assemblages represent, in general, brackish to hyperhaline, stress tolerant, dwarfed planktonic specimens, and low diversity, mainly brackish benthic foraminifera, scarce mollusks, rare ostracods (*Cyprideis*), fish (*Mictophum* sp.) which are gradually evolving, followed by a brackish to freshwater foraminifera assemblage in Over-Gypsum Marls.

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The Lutetian/Bartonian transition at the Oyambre section (northern Spain): implications for standard Eocene chronostratigraphy

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With the aim of finding a Global Stratotype Section and Point (GSSP) for the base of the Bartonian Stage, the potential of the Eocene successions exposed throughout the Basque-Cantabrian and Aquitanian basins (western Pyrenees) was presented in the Strati 2013 meeting held in Lisbon (Payros et al., 2014). It was determined that the Acebosa Formation (Fm) exposed on the eastern side of the Cape of Oyambre in San Vicente de la Barquera (province of Cantabria, North Spain) yielded positive preliminary results (Dinarès-Turell et al., 2014). Consequently, more in-depth studies were carried out and the results are presented herein.

While the Oyambre section does comply with the majority of the requirements of the International Commission on Stratigraphy, several shortcomings were also found, which apparently make it unsuitable for the GSSP for the base of the Bartonian Stage. The main problem is that the potential marker for the Lutetian/Bartonian boundary (i.e., Chron C19n) could not be indisputably identified in the Acebosa Fm.

An unexpected finding was that the chronostratigraphic calibration of the Oyambre planktonic foraminiferal events revealed major discrepancies with the standard geologic timescale. The accuracy of these anomalous results was further substantiated with data from other areas, strongly suggesting that the standard Middle Eocene chronostratigraphic framework was in need of amendment. The Oyambre findings, if proven significant at a global scale, would have two important chronostratigraphic outcomes. Firstly, the standard Eocene planktonic foraminiferal biostratigraphic scale would need revision, as there would be practically no space to accommodate zones E9 and E11 as currently defined. Secondly, an array of sound biostratigraphic markers would now be defined around the Chron C19n time interval, thus facilitating correlation of a potential GSSP.

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Principles and protocols of biostratigraphy as applied to marine calcareous microfossils

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Calcareous nannofossils and planktonic foraminifera are widely used for biostratigraphic correlation of Cretaceous and Cenozoic marine sediments, especially pelagic and hemipelagic deposits. Biostratigraphic zonation schemes for these groups have evolved over many decades of refinement. Workers have approached their task from different philosophical standpoints (regarding ‘time’ and ‘rock’ units for example) and have used various protocols for naming and recognizing biostratigraphic levels and subdivisions. Since the first publication of the *International Stratigraphic Guide* in 1976 there has been a reasonably consistent set of guidelines (not rules) to apply; and the *North American Stratigraphic Code* has also been very influential. These guides are broadly consistent with each other, although contradictory in places, and neither is comprehensive. As part of the *Earthtim-EU* initiative we have reviewed the principles and protocols of biostratigraphy and biostratigraphic nomenclature in an attempt to achieve a common approach for nannofossil and planktonic foraminifer schemes. We present these proposals for discussion across the community with a view to eventually publishing a set of recommendations. Despite the evident practical usefulness of the highly evolved biostratigraphic schemes for these groups, we also highlight the relatively poor state of historical biohorizon calibration and inter-calibration, and we propose procedures for formalizing calibrations with respect to magneto- and cyclostratigraphy.

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New advances for the Callovian-Oxfordian GSSP from the Lazer section (Subalpine Basin, France)

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An integrated stratigraphic study, including ammonite, nannofossil and dinoflagellate biostratigraphy, sedimentology, chemostratigraphy, physical stratigraphy and cyclostratigraphy, was recently conducted in the Subalpine Basin (SE France) on two complementary sections, Thuoux and Saint-Pierre-d'Argençon (Pellenard et al., 2014). During a previous workshop organised by the French Jurassic group, a new section, Lazer, was proposed as a very promising Callovian-Oxfordian GSSP candidate (Pellenard, 2013). Lazer is located in the Subalpine Basin, near Laragne-Montéglin, 15 km from Thuoux and 4 km from Savournon, a section previously proposed by the Oxfordian Working Group. Savournon section now crops out poorly, and is thus less well-adapted for precise lithology and high-resolution stratigraphic methods. We thus consider that Thuoux and Lazer are the best candidates for a GSSP section in the Subalpine Basin. These two sections have more continuous sedimentation, with clear marker beds and the complete ammonite zonation recognised for the Western European basins, based on Oppeliidae, Aspidoceratidae, Perisphinctidae, and also Cardioceratidae, more abundant in the Boreal domain, allowing correlations between biogeographic provinces. New investigations, recently conducted at Lazer, support the great homogeneity of the biological, geochemical and physical proxies used to validate stratigraphy in the Subalpine Basin. Recently collected ammonite fauna provide a precise biostratigraphic framework for Lazer, where the Callovian-Oxfordian boundary is accurately bordered by the *paucicostatum* and *thuouxensis* biohorizons, consistent with the biostratigraphy of the Thuoux and Saint-Pierre d'Argençon sections. Ongoing studies of nannofauna and dinoflagellate cysts reinforce this biostratigraphic framework. Physical stratigraphy (gamma-ray spectrometry and magnetic susceptibility) measured at high resolution (10 cm) reveals the occurrence of sedimentary cycles necessary for robust cyclostratigraphy. Finally, a high-resolution chemostratigraphic study, based on $\delta^{13}C_{carb}$, $\delta^{13}C_{org}$, COT and $\delta^{15}N$, shows long- and short-term fluctuations, which could serve as additional markers for the Callovian-Oxfordian boundary. All the requirements for a GSSP, with the exception of magnetostratigraphy, are in place at Lazer, which could therefore be the main section (associated with Thuoux) to define the base of the Oxfordian Stage.

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New data of palaeoscolecids from the Cambrian of Guizhou, China

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Cambrian is widely distributed in eastern Guizhou, China and is composed by different type lithological characters, including limestones, dolomites, silicates, sandstones, shales and mudstones. Of which the Balang, Tsinghsutung and Kaili formations dominated by shales and mudstones contain 3 importent fossil assemblages, which are named respectively as the Balang Fauna, Jianhe Biota and Kaili Biota.

They not only represent higher invertebrate taxa but also contain representatives of non-biomineralized and light nonbiomineralized soft-body fossils, therefore, are praised as Burgess Shale-type biotas. Soft-body fossils are mainly dominated by arthropods or part of arthropods, worms, and medusiform animals. Most worm fossils in the 3 biotas display a cylindrical body with clear annulations densely separated by intersegments on each annulation, which possess a cuticle consisting of numerous, tiny, individual button-shaped plates. They should be representatives of priapulid worms. Based on SEM (scanning electron microscope) micrographs of button-shaped plates on the surface cuticle of annulations, the characters of the plates are similar to those of *Wronascolex*. The earliest representative of *Wronascolex* is known from the Sinsk Formation of the early Cambrian of the Siberian Platform.

Wronascolex from Guizhou show higher species-level diverse. *Wronascolex* from the Balang Biota has been recognized as *W. geyiensis* Peng, Zhao and Sun, 2015.

Comparing *W. geyiensis* with fossilsfrom the Jianhe and Kaili biotas show obviously disparities, such as the arranged mode of annulation on the cylindrical body and the characters of the plates on the surface cuticle of annulations. Based on SEM observations of button-shaped plates on specimens from Jianhe and Kaili Biota, with reference to numbers of plate rows on every annulation, the specimens of *Wronascolex* should be described respectively as two new species, *W. jianheensis* sp. nov. and *W. miaobanpoensis* sp. nov. The Balang, Tsinghsutung and Kaili formations represent a time sequence from early to later, and the morphologic characters of the 3 species of *Wronascolex* provide some evidences for their evolution. The discovery of *Wronascolex* from the Cambrian of Guizhou extends the geographic and stratigraphic distribution of *Wronascolex* and provides additional evidence for understanding its morphology based upon correlation of body configuration and cuticular ornaments.

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Proposed GSSP candidate for Cambrian Stage 10 (Furongian Series) at Wa'ergang, Hunan, China

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The uppermost stage of the Cambrian System, provisional Stage 10, is undefined. In December, 2004, the International Subcommission on Cambrian Stratigraphy (ISCS) voted to use the first appearance of the agnostoid *Lotagnostus trisectus* (a junior synonym of *L. americanus*), or an equivalent horizon, as the marker for the base of the stage. That position was selected in part because it is recognizable on all paleocontinents using multiple stratigraphic criteria, and in part because it would provide stage/age intervals in the upper two series of the Cambrian that are of roughly equal time duration. Subsequent discussions on Cambrian Stage 10 have centered on the potential definition of the stage, including alternate possibilities for a marker horizon higher in section, and on potential stratotypes. Proposed alternate horizons would result in considerable chronostratigraphic/time reduction of Stage/age 10 from its original, intended concept, making it among the shortest Paleozoic stages/ages. The underlying rationale for seeking alternate possibilities, namely the minority view that concepts of agnostoid species such as *L. americanus* are too broad, and that they should not be used for intercontinental correlation, is something we regard as incompatible with the evidence. Documentation has been provided to show that *L. americanus* has moderate morphologic variability within geographically restricted populations, including on individual bedding planes at specific localities. It has similar variability among geographically widespread populations globally. The extent of morphologic variability expressed in agnostoid material referred to *L. americanus* falls within the range of variation commonly accepted for other agnostoid species.

In view of current information, the *L. americanus* horizon remains a strong choice for marking the base of Cambrian Stage 10. A number of potential GSSP stratotypes, on various paleocontinents, are options. One well exposed, well documented, and richly fossiliferous section is in the village of Wa'ergang, Hunan Province, South China. The Wa'ergang section, located in the Wuling Mountains, is in the same paleogeographic region as the other Furongian stratotypes, and is in a relatively deep water, slope succession, which is also similar to the other Furongian stratotypes. The first appearance of *L. americanus* at Wa'ergang is 29.26 m above the base of the Shenjiawan Formation. This position is approximately two-thirds of the way through the Furongian succession in the Wuling Mountains. *Lotagnostus americanus* is moderately common in the Shenjiawan Formation at Wa'ergang, and it shows moderate morphologic variation, similar to that observed at other localities in North America, Scandinavia, and Siberia. The Wa'ergang section is stratigraphically complete, structurally uncomplicated, and easily accessible. As such, it is an excellent stratotype candidate for the GSSP marking the base of Cambrian Stage 10.

Revision of *Arthricocephalus chauveaui* Bergeron, 1899, type species of *Arthricocephalus* (Trilobita, Cambrian)

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The concept of the monospecific genus *Arthricocephalus* is a matter of great confusion. Originally, Bergeron (1899) illustrated a single exoskeleton but apparently based the limits of the type species and the genus on four exoskeletons, one cranidium, and one pygidium, all preserved on the same slab. Restudy of the material shows that three species, all referred to separate genera, are among the original six specimens. Lane et al. (1988) selected one of the non-illustrated specimens as the "lectotype" for *Arthricocephalus chauveaui* Bergeron, 1899 (Lane et al., 1988), and that specimen is referable to *Oryctocarella duyunensis* (Chien, 1961). Bergeron's illustrated specimen should be regarded as the holotype of *A. chauveaui*. Such recognition allows for clarification of the concepts of *Arthricocephalus* and *A. chauveaui*.

As revised, specimens belonging to Bergeron's original material are referred to either *Arthricocephalus chauveaui*, *Oryctocarella* [formerly *Arthricocephalus*] *duyunensis* (Chien, 1961), or *Duyunaspis duyunensis*. *Arthricocephalites* Chien in Lu et al., 1974 and *Haliplanktes* Blaker & Peel, 1997 are regarded as junior synonyms of *Arthricocephalus*. *Oryctocarella* Tomashpolskaya & Karpinski, 1961, which previously was considered to be a junior synonym of *Arthricocephalus*, is revived as a valid genus. It differs from *Arthricocephalus* in having a cylinder-shaped glabella with nearly parallel sides and pitted glabellar furrows isolated from axial furrows, a thorax with more segments, and a proportionally smaller pygidium with no posterior or lateral borders. *Oryctocarella duyunensis* embraces a number of species previously assigned to *Arthricocephalus*, including *Arthricocephalus granulus* Chien & Lin in Zhou et al., 1977; *Arthricocephalus jiangkouensis* Yin in Yin and Lee, 1978; *Arthricocephalus horridus* Chien & Lin in Zhang et al., 1980; *Arthricocephalus fuyangensis* Ju, 1983; *Arthricocephalus tenuis* Zhang & Zhou, 1985; *Arthricocephalus* sp. *sensu* Zhang & Zhou, 1985; *Arthricocephalus* cf. *chauveaui* Bergeron, 1899 *sensu* Geyer & Peel, 2011. Many specimens previously assigned to *Arthricocephalus chauveaui* should be also transferred to *Oryctocarella duyunensis*.

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Preliminary macrostratigraphic analysis of Precambrian sedimentation in Laurentia

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The Precambrian-Cambrian transition in most regions of Laurentia is characterized by the Great Unconformity. This unique geomorphic surface records the physical and chemical weathering of crystalline igneous and metamorphic rocks followed by transgressive marine shoreface erosion and sedimentation during the Cambrian. Although the most prominent feature of the Great Unconformity is the nonconformity that juxtaposes crystalline basement rocks and overlying Cambrian marine sediments, there remain regions with comfortable or nearly conformable sedimentary successions that span the eon boundary. A significant quantity of Precambrian sedimentary and metasedimentary rock also remains on the continent. Here, I present new macrostratigraphic results from the Macrostrat database covering the past 3000 Myr in Laurentia. These results reinforce the marked and relatively abrupt increase in epicontinental sedimentation that occurred during the Cambrian in Laurentia. The Great Unconformity is remarkable in this quantitative view and it clearly separates the physical record of sedimentation into three distinct phases with transitions between them that, together, broadly parallel published estimates of atmospheric oxygen concentration: Archean, Proterozoic, and Phanerozoic. These results also demonstrate that the Proterozoic sedimentary record is sufficiently rich to preserve Phanerozoic-like sedimentary cycles with durations of approximately 500 Myr. These cycles are comparable in duration to the supercontinent coalescence and breakup cycle, which exerts a first-order control on the Phanerozoic record of sedimentation. Like the Phanerozoic, this is no strong overall temporal trend in preserved sedimentary quantity. Overall these new quantitative results from the Macrostrat database highlight the pressing need for better stratigraphic resolution in the Precambrian and for quantitative, macrostratigraphic synthesis and analysis of the global geological record.

The Coniacian-Santonian interval in southern coastal Tanzania (East Africa): planktonic foraminiferal evolution, biostratigraphy, and depositional trends

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The Coniacian-Santonian (~89 - 83 Ma) is considered a time of key evolutionary changes among planktonic foraminifera and is one of the warmest periods of the Mesozoic. However, this interval is represented by relatively uncommon and discontinuous stratigraphic sections in surface exposures and deep sea drilling sites, a situation that prevents complete documentation and integration of its paleontological and climatic trends regionally and globally. Drilling in southern coastal Tanzania by the Tanzania Drilling Project (TDP) during recent years has provided a wealth of lithological, bio-, and chemostratigraphic data from sediments spanning most of the Late Cretaceous, including a 101-m-thick, stratigraphycally complete subsurface section from the Coniacian-Santonian (TDP Site 39). Samples from this site provide an unprecedented opportunity to examine the planktonic foraminiferal evolution and biostratigraphy, paleoceanography, and depositional patterns across a continuous record of the Coniacian-Santonian from the subtropical-tropical Indian Ocean, and yield results with implications for elsewhere.

Planktonic foraminifera are abundant in TDP Site 39 samples and, although infilled by calcite and/or pyrite, the specimens exhibit remarkably well-preserved tests. The recovered sequence suggests a high rate of diversification, with the appearance of six new genera and several species that in stratigraphic order include *Pseudotextularia nuttalli*, *Dicarinella asymetrica*, *Globotruncanita stuartiformis*, *Globotruncanita elevata*, *"Heterohelix" papula*, *Sigalia carpatica*, *Costellagerina pilula*, *Globotruncana linneiana*, *Ventilabrella eggeri*, and *Globotruncana arca*. The *Dicarinella concavata* Zone is recognized in TDP Site 39 based on the absence of *D. asymetrica* and the presence of abundant marginotruncanids and dicarinellids. The overlying *Dicarinella asymetrica* Zone is identified based on the consistent presence of *D. asymetrica* with common and large-sized marginotruncanids. A comparison of TDP Site 39 with the GSSP for the base of the Santonian in northern Spain (Olazagutia section) reveals a remarkable reproducibility of planktonic foraminiferal events. The implication is that, in the absence of the inoceramid *Platyceramus undulatoplicatus* whose first appearance marks the base of the Santonian in the GSSP, the Tanzanian record may constitute a reference section for the Coniacian-Santonian in the Indian Ocean.

In addition to providing a continuous biostratigraphic section, the importance of the Tanzanian record is that it probably was influenced by open marine conditions and its paleontological and paleoceanographic signatures could be connected to those of the global ocean. Deposition occurred in an outer shelf to upper slope setting under relatively low energy conditions. A case study for these open marine conditions is represented by the lithological, geochemical and paleontological changes observed near the boundary of the *D. concavata* and *D. asymetrica* Zones. Common, undisturbed laminated intervals in the *D. concavata* Zone suggest relatively low oxygenation in bottom waters, whereas abundant bioturbation in the *D. asymetrica* Zone points to increased oxygenation and/or nutrient levels. At similar stratigraphic intervals, the %$CaCO_3$ and %C_{org} show, respectively, a 20% increase and 0.2% decrease, above which their records never return to pre-excursion values. Similarly, this biozone boundary constitutes the culmination of a 35-m-thick negative trend in bulk rock $\delta^{13}C$. Finally, the planktonic foraminiferal assemblages reveal major speciation and extinction at the base of the *D. asymetrica* Zone. A leading explanation is that these changes were related to changes in the water column. Beyond the proximate causes, a final goal is to evaluate whether the ocean circulation changes proposed for the Southern Ocean during the Late Cretaceous were the ultimate forces for the changes observed in our unusually complete Coniacian-Santonian record.

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The role of planktonic foraminifera in Cretaceous chronostratigraphy

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Planktonic foraminifera play an essential role in biostratigraphy being characterized by an excellent geological record and by high morphological diversification and speciation rates. To date the 79.0 mys-long Cretaceous Period, from Berriasian to Maastrichtian, is subdivided in 38 planktonic foraminifera biozones defined on highest or lowest species occurrences, 7 of which are taxon range zones.

Planktonic foraminifera are the primary tool in stratigraphic correlations, and sometimes the unique tool allowing practical correlation among sections to determine the magnitude and extent of regional and global events found in the geological record. They play a fundamental role in the identification of the stage boundaries when the defining criteria are not reliable or not detectable. For these reasons, planktonic foraminifera strongly contributed to the multi-disciplinary efforts to improve Cretaceous chronostratigraphy in pelagic settings.

Recent improvements have been accomplished for the Campanian and Maastrichtian intervals with the identification of a reliable sequence of bioevents allowing the implementation of calibrated age-depth curves from deep-sea sites and the correlation of high-resolution orbital tuning and chemo-magneto-stratigraphic records from pelagic chalk sections.

On the contrary, particularly critical is the Aptian to Santonian interval for which a high-resolution integrated geochemical, physical and biostratigraphic framework exportable worldwide is still needed. Reasons rely on many factors including the inapplicability of the magnetostratigraphy and the lack in accuracy, resolution and reproducibility of the data.

In particular, over the years two major problems were identified by the scientists regarding the ability to precisely and accurately establish planktonic foraminiferal correlations.

The first problem pertains to taxonomic inconsistencies, species misidentifications, and difficulties in the identification of lowest occurrences using gradually evolving species as well as to ambiguous/different species concepts that accumulate over time in the literature. The second problem deals with diachronous species distributions and with the reproducibility of bioevents in stratigraphic sections even when they are located in the same paleogeographic area.

Addressing the taxonomy and phylogeny of Cretaceous planktonic foraminiferal species is a priority that underpins many of the correlation issues. For this reason a long-term project of the Mesozoic Planktonic Foraminifera Working Group (http://portal.chronos.org) is focused on studying and re-illustrating primary type specimens and on documenting stratophenetic changes in wall microstructure and shell morphology. The Working Group has recognized the importance of wall microstructure in the classification of Cretaceous planktonic foraminifera and determined that the phylogenetic classification should be primarily based on the diameter of shell perforations and secondarily based on shell ornamentation.

A critical overview of the new developments in planktonic foraminifera taxonomy, biostratigraphy and a discussion on the reliability of some marker taxa currently used to place biozonal boundaries is presented. New findings and observations are used to identify alternative markers that could be used to substitute unreliable markers and to derive a more accurate sequence of bioevents. Results are aimed to refine the planktonic foraminiferal biozonation and to build a more consistent correlation of biostratigraphic events and calibration against other stratigraphic tools.

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The climate and landscape conditions of the Middle Volga at the Miocene - Pliocene boundary

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Climate changes had been spread over the whole territory of the Russian plain at the Miocene - Pliocene boundary. The transformation of landscape environment on Middle Volga region took place under the influence of increasing climate chilling and large scale tectonic rearrangements as on Volga region, so on adjacent regions. It was reflected in the qualitative alteration of its entire characteristics.
Ural's elevation and consecutive elevation of the east of Russian platform during middle-late Miocene and Pliocene triggered general elevation of Middle Volga region. At the same time with elevation of eastern part Russian platform had been occurring sinking of South-Caspian depression and Caspian syneclise. Regression of Caspian sea reached its maximum in Messina time with simultaneous lowering sea level till minus 500-600m.
Falling of base level, increasing of height difference and increasing damping leaded to intensive deep-water erosion and spreading of deep cut river beds of Middle Volga and its feeders. After this moment had started partitioning of raised denudation plateau which was widespread from early Miocene. If we consider that the surface watershed was at a level of 300 – 380 m then height difference could reach 600 m.
During general chilling and humidifying of climate started in the middle Miocene the taiga was becoming prevailing zonal type of vegetation over broad-leaved forests and mixed forest of Turgai's kind in the Middle Volga region. Mixed forests with a dominationnce of broad-leaved breeds (*Ostrya, Carpinus, Ulmus, Acer, Tilia, Corylus, Quercus, Betula*) with additive of thermophilic elements (*Tsuga, Nyssa, Pterocarya, Sciadopitys*) at the end of the Miocene were replaced by broad-leaved – firry – piny formation where broad-leaved breeds had minor place.
Climate was becoming more arid in the early Pliocene. In the forests the spruces were being replaced by pines which are more resistant to water shortage. In spite of general chilling, the climate conditions in this time were milder than in the modern time. It proven by fact of simultaneous growth of plants which are typical for modern flora of region (*Picea, Pinus, Abies, Betula, Tilia, Quercus, Ulmus, Corylus,* etc) and plants which grow at present in the mild-temperate and subtropical climatic areas of northern hemisphere (*Tsuga, Sciadopitys, Juglans, Pterocarya, Nyssa, Ostrya*, etc). Assumed an average January temperature was about 0^o C or even possible positive meanwhile an average July temperature was not less than $+20^o$ C. The estimated amount of precipitation in this time was not less than 800 mm per year.

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Reef evolution in the Panthalassa domain: new data from Upper Triassic reef limestone of the Sambosan Accretionary Complex, Japan

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Nowadays, Triassic stratigraphy is mainly based on Tethyan and East Pantalassa sections. Conversely, western Panthalassa shallow water settings are poorly constrained. Therefore, carbonates from the western Panthalassa domain are pivotal to understand the overall Triassic stratigraphy. In this contribution, we investigate shallow water atoll-type carbonates from the Sambosan Accretionary Complex (Japan), aiming at improving our knowledge of the Late Triassic stratigraphy of the Panthalassa domain.

The Upper Triassic carbonates from the Sambosan Accretionary Complex record the evolution of diversified shallow water environments from the initiation of the carbonate platform during the Ladinian?-Carnian to its demise in the Rhaetian. Accordingly, the Sambosan limestone yield valuable insights regarding the reef recovery and development that took place during Middle and Late Triassic. These profound environmental changes and biotic turn over are well-known in the Tethys but poorly documented in the Panthalassa.

Quantitative microfacies analysis, in combination with an integrated biostratigraphy (i.e., reef fauna associations together with conodonts and foraminifer biostratigraphic markers) allow us to characterize both Ladinian?-Carnian and Norian-Rheatian reef bioconstructions. Our results provide additional constrains for understanding the evolution and the biogeographic distribution of Upper Triassic reef biota. Comparison with Tethys and East Panthalassa counterpart strengthen the Tethyan affinity of the reef fauna from the Sambosan Accretionary Complex.

This original study refines the biostratigraphic framework of the shallow water carbonates of the Sambosan Accretionary Complex, considered here as representative of West Panthalassa atoll-type environments. These findings highlight the long geological history of carbonate build ups in the Panthalassa during the Late Triassic and emphasize connections with the Tethyan domain.

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Paradigm changes in Paleogene larger foraminiferal biozonation

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A. Oppel's seminal work in the 19th century contributed to the rise and development of biostratigraphy by means of what have now become known as the Oppel zones. This powerful and flexible tool, first used for Jurassic-Cretaceous ammonoids, was later employed for establishing biozonal schemes by using different fossil groups.

The historical development of Paleogene larger foraminiferal biozonations is a striking example of change of zonation paradigms in time. A historical overview of these changes and their rationale, starting from the 1850's, shows the changing role of early biozonations, Oppel zones, phylozones, chronozones, and datums.

A rigorous definition of Paleocene-Eocene Oppel zones based on alveolinids and nummulitids for the western Neo-Tethyan domain was mainly due to the influential work of L. Hottinger and H. Schaub in the 1960's. In their taxonomic approach, species and subspecies were typologically defined. Their Oppel zones are based on stratigraphically ordered key localities and their assemblages; the resulting zonation is discontinuous, being separated by intervals of unknown extent and not by sharp boundaries, as in continuous zonations. The choice of these key localities from the Mediterranean Neo-Tethyan domain was influenced firstly by the presence of larger foraminiferal assemblages and their historical significance, inasmuch many are type localities for species group taxa. Secondly, their vertical ordination reflected basic criteria of geological superposition and correlation with calcareous planktonic and nannofossil zonations. Thirdly, the sedimentary settings of these key localities were mainly neritic (in part, also deeper flysch deposits with their allochthonous assemblages were included) and thus their fossil record was intrinsically discontinuous, i.e. linked to unconformity-bounded units.

A different biometrical tradition in larger foraminiferal studies, which originated in the 1930's especially in radial (orbitoidiform) larger foraminifera and Oligo-Miocene nummulitids, led to the construction of zonal schemes based on phylozones based by chrono(sub)species represented by arbitrary segments of evolutionary lineages. In contrast to Oppel zones, phylozones based on this approach produce continuous zonations. This research program achieved its most complete formulation with C.W. Drooger and coworkers, and later studies in orthophragmines by G. Less.

A change in paradigm took place in the late 1990's, when Serra-Kiel and coworkers attempted to reconcile in a modern research program Paleogene larger foraminiferal Oppel zones and phylozones and supersede the previous approach with chronozones, mainly based on the calibration of larger foraminiferal zones with magnetostratigraphy from the Iberian peninsula. The refinement of this research program is still ongoing, also drawing upon new correlations with the plankton stratigraphy, magnetostratigraphy, and isotopic data.

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Stratigraphic, Taphonomic and Paleoenvironmental Anylysis of the Devonian Pimenteira Formation, Parnaíba Basin, Brazil

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The distribution and mode of occurrence of the taphocoenoses of the Pimenteira Formation, including its Passagem Member (formerly assigned to the overlying Cabeças Formation), on the eastern border of the Parnaíba Basin, are used to reassess their paleoenvironmental settings. Previously regarded in the literature as tempestites, these deposits are currently interpreted as the distal part of mouth-bar deposits, delta-front lobes, and the prodelta of a flood-dominated fluvio-deltaic system entering a shallow, epicontinental sea. According to this most recent depositional model, hyperpycnal flows originating from episodic flood events gave rise to transfer zones far more extensive than those of ordinary deltaic systems. These flows would have penetrated beyond the limits of the ancient littoral zone, reworking littoral to shallow-shelf bioclasts. The identification of these inundites in the Parnaíba Basin helps elucidate some puzzling issues, such as the occurrence of indisputable marine shelly faunas within strata bearing typical fluvial and fluvio-deltaic sedimentary structures. Taphofacies analyses have also been providing independent evidence in support of the sedimentation processes and depositional environments inferred from the lithofacies studies of the Devonian rock units in the Parnaíba Basin. The application of this predictive model has resulted in the discovery of new fossil localities and of additional fossiliferous levels in previously known sites. Formerly considered as restricted to the base of "tempestites", Middle Devonian macrofossil assemblages of the Parnaíba Basin are now demonstrably more abundant and diversified in sandstones with sigmoidal clinoform structures (bearing asymptotic cross-stratification), in climbing-ripple cross-laminated and plane-parallel stratified sandstones and siltstones, and even in conglomerates. The taphonomic attributes of fossil invertebrates from the Pimenteira Formation and those from the Passagem Member (regionally restricted to the eastern border of the Parnaíba Basin) present very similar patterns, corroborating the interpretation of the latter as a proximal facies of the upper Pimenteira Formation (both dated palynologically as late early Givetian). Those units are unconformably overlain by sandstones and diamictites of the Cabeças Formation *sensu stricto*, of late to latest Famennian age. This regional unconformity accounts for the absence of late Givetian through early or middle Famennian strata in the eastern Parnaíba Basin. The geographically restricted distribution of the Passagem Member along the eastern border of the basin is consonant with the NW-oriented flood-dominated deltas in this region, where the distal-most marine deposits remained essentially shelfal.

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Upper Lochkovian to lower Famennian evolution of the Carnic Alps: perspectives from the 'transitional facies'

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The Carnic Alps correspond to the non- to low-metamorphic portion of the Variscan substratum of the Southern Alps, and display an Upper Ordovician to Upper Carboniferous succession that represents the best preserved example of Variscan succession within the Alps. The Pragian to Frasnian stratigraphic interval is characterized by the differentiation of the basin in shallow water, including carbonate buildups, and pelagic parts, and the so-called 'transitional facies' represent a sort of 'connection' between these two parts. We analyzed the depositional evolution of the basin through these facies because they 1. reflect well the depositional dynamics; 2. are datable using conodonts, unlike the shallow water units; 3. are less subject to tectonic elisions/repetitions than the basinal units.

We performed geological mapping, measured stratigraphic sections of all the units and dated by conodonts all the lithostratigraphic transitions, in order to infer the lateral correlations throughout the basin, also supported by some marker beds/levels. The depositional environments of the different units have been recognized.

The main aspects of the basin evolution can be summarized as follows. A transgression between the uppermost Lochkovian and the basal Pragian drowned the first patch reefs recorded in the Carnic Alps. The margin was ramp-type until the Emsian with patch reefs and shoreface deposits distally passing to tempestite and pelagic sediments. During the Emsian, a by pass slope margin separating the shallow water and the basin started to develop as shown by the increasing amount of gravitative-driven deposits that persisted until the lower Famennian. In the lower Givetian the gravitative-driven deposits show their maximum progradation on top of the basinal deposits. From the Frasnian, a transgression, possibly enhanced by extensional or transtensional tectonic activity, led to progressively drowning of the carbonate buildups.

The depositional evolution appears to follow the supra-regional eustatic trends until the Frasnian. From the Frasnian, the evolution differentiates from the eustatic supra-regional trends, suggesting the importance of a local tectonic control.

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Equatorial Layered Deposits in Arabia Terra, Mars: Facies and process variability

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Light-toned layered deposits are widespread on Mars in different geographical and geological settings and many different processes have been suggested to explain their formation, including lacustrine, sub-ice volcanism, weathering of basalts, pyroclastic, impact base surge and dust airfall. Interplay between airfall and aeolian processes with groundwater fluctuations leading to episodes of evaporite precipitation, interaction between lacustrine deposition and hydrothermal vents or large mud volcanoes, groundwater upwelling leading to spring deposits precipitation and/or mud volcanoes deposition have been also proposed.

In order to contribute to this discussion, we present the recently published results on the Equatorial Layered Deposits (ELDs) of Arabia Terra in Firsoff crater and on the adjacent plateau.

We produced a detailed geological map that included a survey of the relative stratigraphic relations and crater count dating. We reconstructed the geometry of the layered deposits and inferred some compositional constraints. We analyzed the sedimentary structures and textures observable at the available scale both inside and outside the craters.

ELDs drape and onlap the plateau materials of Late Noachian age while they are unconformably covered by Early and Middle Amazonian units. ELDs show the presence of polyhydrated sulfates. Layer morphologies, albedo, structure, composition and stratigraphic setting enable us to include the ELDs in Firsoff crater and the surrounding plateau in the wider frame of the sulfate-bearing layered deposits seen elsewhere on Mars at the Noachian-Hesperian transition.

ELDs found in craters and in the plateau can be distinguished from each other on the basis of basin-scale morphologies (kilometers-thick crater bulges *vs* 100s meter-thick sheet drape deposits) and local-scale morphologies (rounded shape, sub-circular depressions, raised rims, bowl-shaped appearance and serrated layer *vs* flat-topped bodies or dune fields with cross stratification). These morphologic differences suggest that genetic processes might at least partly be different, too.

In the crater ELDs consist of mounds made of breccia sometimes displaying an apical pit laterally grading into a light-toned layered unit disrupted in a meter-scale polygonal pattern. These units are frequently associated with fissure ridges suggestive of subsurface sources. We interpret the ELDs inside the craters as spring deposits, originated by fluid upwelling through the pathways likely provided by the fractures related to the crater formations, and debouching at the surface through the fissure ridges and the mounds leading to evaporite precipitation.

On the plateau, ELDs consist of rare mounds, flat-lying deposits and cross-bedded dune-fields. We interpret these mounds as possible smaller spring deposits, the flat-lying deposits as playa deposits, and the cross-bedded dune-fields as aeolian deposits.

Groundwater fluctuations appear to be the major factor controlling ELDs deposition, leading to different depositional environments depending on the physiography of the basin.

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Constraining typological error in the calibration of Cenozoic planktonic foraminifera bioevents: a case study from the Pliocene

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Many Cenozoic planktonic foraminifera lineages exhibit rapid morphological evolution, resulting in the development of numerous short-ranging species which are of critical importance as biostratigraphic marker species. High-resolution sampling often reveals gradual morphological change (anagenesis) across whole evolutionary lineages (i.e. 'morphoclines'). Such anagenetic morphological change leads to 'pseudospeciation' rather than 'true' speciation (cladogenesis). However, prevailing taxonomic practice is such that species are defined typologically, and transitional morphotypes within morphoclines must be arbitrarily split into taxonomic units, or 'morphospecies', for biostratigraphic utility. However, this is an inherently subjective method. Contrasting taxonomic decisions may result in the same transitional morphotypes being assigned to different morphospecies, and hence producing disparate assessments of stratigraphic first and last occurrences (i.e. 'typological error'). A corollary is that potentially large typological error is incorporated into the calibration of biostratigraphic events and thus into biochronologic age models. This intrinsic error may be minimised by implementing rigorous temporal morphometric analyses of populations across speciation and extinction bioevents.

Here we assess the stratigraphic record of the tropical Pliocene-Pleistocene foraminifer, *Globigerinoides fistulosus*; a short-lived descendant of (extant) *Globigerinoides sacculifer*. The morphological evolution from *G. sacculifer* to *G. fistulosus* is characterised by the development of large, finger-like protuberances on the final chambers. Its distinctive morphology and short stratigraphic range make it an ideal biostratigraphic marker species, but its speciation and extinction bioevents are both poorly constrained. Transitional morphotypes between *G. sacculifer* and *G. fistulosus* are abundant through both bioevents; they form a *G. sacculifer-fistulosus* morphological plexus. These transitional morphotypes hinder morphospecies delimitation and thus prevent reliable stratigraphic assessment of first and last occurrences of *G. fistulosus*.

Using high-resolution sampling from Ocean Drilling Program (ODP) Sites 926 (western equatorial Atlantic) and 1115 (western equatorial Pacific), we use morphometric analyses to constrain the speciation and extinction of *G. fistulosus*, and compare bioevent synchrony between the ocean basins. Mid-Pliocene populations contain no *G. fistulosus*, and are composed only of *G. sacculifer* sensu stricto. Subsequently, specimens with incipient protuberances appear and show a proportionate increase in succeeding populations, until *G. fistulosus* sensu stricto, with large protuberances, is present among the populations. This pseudospeciation bioevent is apparent at both sites. Whilst the extinction appears to be through gradual morphological change at Site 926, the extinction at Site 1115 is abrupt and *G. fistulosus* sensu stricto persists until immediately before the extinction. Bioevent timings are constrained using population-based taxonomic definitions.

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The Middle Anisian (Bithynian) foraminifera from North Dobrogean Orogen, Romania

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The North Dobrogean Orogen is built up of several Cimmerian tectonic units: Măcin Unit, the innermost, Consul Unit, Niculiţel Unit, and Tulcea Unit, the outermost one. These tectonic units, excepting the Niculiţel Unit that is an ophiolitic suture zone, are regarded as high-angle basement thrusts (Săndulescu, 1984) that involve relics of a Variscan Orogen.
Triassic sedimentary deposits of Tethyan-type occur in all the major tectonic units of the North Dobrogean Orogen, cropping out on large areas especially in the last two units, but the most complete stratigraphic succession of the Triassic System is found in the Tulcea Unit.
Triassic sedimentation of the Tulcea Unit starts with Scythian terrigenous deposits lying transgressively on the Variscan basement, and continues with wide spreading and varied carbonate facies deposited during the Early Spathian to Norian time interval. The carbonate deposits are differentiated in several major facies zones, showing a gradual transition from the shallow-water carbonate platform facies in the eastern part of the Tulcea Unit towards the deeper water carbonate platform facies in the central part and the basinal facies occuring in the western part of the same unit (Grădinaru et al., 2000).
The present study is focused on carbonate deposits belonging to the Caerace Formation (Middle Anisian), in the eastern part of Tulcea Unit. Studied section is cropping out in a quarry located in the Caeracul Mare East Hill, south of the Mahmudia village. The Caerace Formation is subdivided into a number of lithological units: massive dolostone, pelagic dolomitized limestone, stromatactis limestone, bioclastic limestone, nodular limestone, reefal (*Tubiphytes*) limestone and pelagic limestone, some of them reccuring in the succession. Microfacies analysis reveal a microbial buildup located on the upper slope of the carbonate platform (Popa et al., 2014).
The studied foraminifera assemblage comes from the reefal (*Tubiphyte*s) limestones, part of a 200 m thick section exposed in the northeastern corner of the quarry. Macroscopically, these limestones are strongly compacted with poorly developed sedimentary structures. Thin section analysis revealed a rich foraminifera assemblage belonging to the following families: Ammodiscidae, Endotriadidae, Endotebidae, Endothyridae, Nodosinellidae, Trochamminidae, Lituolidae, ?Fischerinidae, Variostomatidae, Nodosariidae, Placopsilinidae.
The most frequent taxa belong to the Ammodiscidae familiy, among them *Pilammina densa* Pantić, *Glomospira roesingi* Blau, Wenzel, Senff & Lukas, *Glomospira gordialis* Jones & Parker, *Glomospira* sp., and to the Endotebidae family.
Microfacies types that contain foraminifera are grainstone, mudstone and wackstone-packstone.
The early Middle Anisian (Bithynian) age of the reefal limestones from the Mahmudia area is documented by the ammonoid fauna and the whole fossil content (foraminifera, nautiloids, crinoids, bivalves, bryozoans and brachiopods).

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New integrated stratigraphic data from Hungary and a global carbon isotope stack across the Jurassic-Cretaceous boundary

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We present new carbon and oxygen isotope curves from sections in the Bakony Mts. (Hungary), constrained by biostratigraphy and magnetostratigraphy in order to evaluate whether carbon isotopes can provide a tool to help establish and correlate the last system boundary remaining undefined in the Phanerozoic as well provide data to better understand the carbon cycle history and environmental drivers across the Jurassic-Cretaceous interval. We observe a gentle decrease in carbon isotope values through the Late Jurassic, and a δ^{13}Ccarb minimum occurs in the Berriasian, in the upper part of magnetosubzone M19n2n, towards the middle of calpionellid Zone B (i.e. the alpina Subzone). A pronounced shift to more positive carbon isotope values does not occur until the Valanginian, corresponding to the Weissert event. For comparison and correlation, we compiled 24 published and stratigraphically constrained carbon isotope records from the Tethyan, Atlantic, and Boreal realms, to produce a new global δ^{13}C stack for the Late Oxfordian through Early Hauterivian interval. The new data from Hungary is consistent with the global δ^{13}C stack. The stack reveals a steady but slow decrease in carbon isotope values until the Early Valanginian. Aside from the well-defined Valanginian positive excursion, chemostratigraphic correlation across the Jurassic–Cretaceous boundary interval is difficult, due to relatively stable δ^{13}C values, compounded by a slope which is too slight. There is no clear isotopic marker event for the system boundary. The long-term gradual change towards more negative carbon isotope values across the Jurassic-Cretaceous transition has previously been explained by increasingly oligotrophic condition and lessened primary production. However, this contradicts the reported increase in ^{87}Sr/^{86}Sr ratios suggesting intensification of weathering, in agreement to our δ^{18}O data that also point to a warming trend. The concomitant rise of modern phytoplankton groups (dinoflagellates and coccolithophores) would have also led to increased primary productivity, making the negative carbon isotope trend even more notable. We suggest that gradual oceanographic changes, more effective connections and mixing between the Tethys, Atlantic and Pacific Ocean, would have promoted a shift towards enhanced burial of isotopically heavy carbonate carbon and effective recycling of isotopically light organic matter. These processes account for the observed long-term trend, interrupted only by the Weissert event in the Valanginian.

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The new IAVCEI Commission on Volcano Geology

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Volcanology has made great advances in the last three decades, becoming a modern interdisciplinary science for quantifying volcanic processes, their associated hazards and impacts on society and the environment. In this scientific and technological revolution undertaken by modern volcanology, new mathematical and computational modelling tools have become a key part of comprehensive volcanic process studies. The explosion of new techniques has reduced the prominence and perceived value of geology, despite its remaining the main source data for volcanic system, process and hazard modelling. In order to highlight and strengthen the role of geology as a critical foundation for modern volcanology, a new IAVCEI commission on Volcano Geology has been instituted. This will promote postgraduate research in geological aspects of volcano studies, provide a forum for discussion among researchers on new developments in geological studies in volcanology, and encourage multidisciplinary research across the wide range of geological fields involved in volcanology. A special attention is given to the geological fieldwork and mapping in volcanic areas as the basis for detailed volcanological, magmatic studies, computational modelling and for understanding the behaviour of volcanoes and their future activity in terms of volcanic hazards (for active or recent volcanoes).

A key first initiative of this new IAVCEI commission will be to develop robust and widely applicable guidelines for field geological mapping, rock-unit description, practical volcano-stratigraphy and volcanic facies associations. This will encourage more active collaboration and address the wide and often discordant methods currently applied around different parts of the world, allowing also large scale correlations and understanding of the underlying volcanic processes.

Ongoing activity of this Commission will be to organize and promote regular field-based workshops, special sessions at major conferences and special volumes to encourage development of new geological approaches and tools toward improving our understanding of volcanic systems. Further, it will form a focal point for exchange of information between geological researchers and students and a portal by which a broad range of geologists may access and contribute to volcanology.

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Magnetic susceptibility as a possible correlation tool in Quaternary alluvial stratigraphy

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Stratigraphic correlation in alluvial sequences characterized by irregular facies changes is usually ambiguous. To test the relevance of climatic cycles in regional and global correlations, we reinvestigated a set of previously drilled, fully cored drill holes of the alluvial water reservoirs of the Pannonian basin. The 200 - 600 m thick succession represents 2.5 million years of the Quaternary.
Based on former results (Nádor et al., 2003), the magnetic susceptibility (MS) of cores from five boreholes was measured and involved into log correlation. Magnetic cycles of 100 and 400 ky were identified on the correlated MS records with low MS values at their bases and sets of MS peaks upwards. These magnetic cycles contribute significantly to the regional correlation and coincide well with orbital cycles (Berger and Loutre, 1991). Global correlation was investigated by comparison with MS record of the Chinese Loess Plateau (Ding et al., 2005). The cosine similarity function confirms the similarity of the Hungarian fluvial and the Chinese aeolian MS records ($c_{xy}(\tau)=0.76$ at $\tau=0$).
The interbedded alluvial palaeosols have definitely low MS values, while the MS peaks are associated with sands. According to SEM-EDX data, magnetite of multiple origin is the dominant magnetic mineral in sands. Three populations of magnetite have been observed: (1) large (50 – 200 □m) rounded crystals, (2) small (5-20 □m) idiomorphic octahedrons, (3) crystal fragments smaller than 2 µm. SEM images prove that the fine (<20 µm) fractions are mostly released from the transported volcanic material and from disintegrating large grains.
Silty overbank deposits were investigated in depth intervals representing 400 ky and characterized by minimal variations in lithology. Full width at half maximum of smectites and illit/mica on XRD spectra, the kaolinite content measured by infrared spectroscopy and the molecular water content measured by thermal analysis proved to be important features of overbank materials. Their coinciding peaks indicate weathering intensity maxima and are associated with low MS values.
In our interpretation, under cold-and-dry climate, magnetic minerals were released in the adjacent hinterlands and were transported into the alluvial plains at the very beginning of the humid-and-warm periods, due to the increasing discharge of rivers. Thus, early warming events are expressed by the occurrence of MS maxima providing stratigraphic markers for regional and global stratigraphic correlations in fluvial sequences. With further warming, however, the weathering-sensitive magnetite soon disappeared from the fluvial load. As a result, the palaeotemperature maxima and the subsequent cooling periods remain concealed in alluvial MS records within the tracts of low MS values.

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Ordovician biostratigraphy and biochronology, and the convenience of the Bohemo-Iberian regional chronostratigraphic scale for correlating the south polar Gondwanan areas

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Before the establishment of the Ordovician System by Lapworth in 1879, the French palaeontologist Joachim Barrande (1799-1883) already recognized the separate character of the Bohemian Ordovician faunas by the definition of a regional stage ("étage D") within the extent assigned by him to the "Silurian system" of Murchison in the Prague Basin, and bearing a considerable part of his "Second" fauna. Since the definition in 1852, this regional stage was subdivided into five "bands", comprising the current Lower and Middle Ordovician series ("bande d1") and the Upper Ordovician one ("bandes d2–5"). More than a century later, Czech geologists V. Havlícek and L. Marek proposed, in 1973, the adoption of a different and better defined Bohemian regional scheme to improve the correlation of most of the Ordovician system within the Mediterranean palaeoprovince. Their main reason of their proposal was the changing views and the lack of applicability enhanced by the historical British chronostratigraphic scheme, regarding the Ordovician sequences of some European and north African areas lying at high southern perigondwanan palaeolatitudes in that period. The Bohemian regional scheme was latter completed with an additional stage defined in Spain and now comprises a total of five regional stages plus the global Tremadocian and Hirnantian. None of these regional stages allow a direct correlation with the global scale of the Ordovician system, because many of their formal GSSPs involve deeper-water facies and faunas not recorded in the high-paleolatitudinal settings of southern peri-Gondwana. The regional scale is thus based on the distribution of endemic shelly fossils combined with some graptolites and a good palynological record. However, sporadic occurrences of graptolites and shelly faunas of Baltic or Avalonian affinities allow for indirect correlation with the global stages through their own regional scales.
Our presentation will examine the main regional biostratigraphic and biochronological criteria used in the definition of the Bohemo-Iberian regional scale, that allowed a more precise correlation between the Ordovician southwestern and central Europe (Ibero-Armorica, Sardinia, Bohemia, Bulgaria) and the vast area from northern Africa to Saudi Arabia and part of the Middle East.

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The Rhine Graben System

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An overview of all Tertiary deposits and Formations is given in the Stratigraphic Table of Germany 2002 (STG 2002), published by the German Commission on Stratigraphy (DSK).
The Rhine Graben system is one of the most important systems in Tertiary time. It reflects the sedimentation in the Hessian Depression, in the Mainz – or Hanau Basin and in the Rhine Graben itself. The importance of the Rhine Graben in Tertiary times extends from Eocene to Pliocene.
That time it acted as a temporary gateway between the paleo North Sea and the Tethys in the South. The deposits are characterized by alternating ingressions from the N or S or intermittent interruptions of sedimentation. The initial sedimentation, after a long terrestrical time periods, starts with compensational clastic deposits.
The graben system over time is accompanied by volcanites regarding volcanic activities of the Kasiserstuhl, and in the regions Kraichgau, Odenwald, Vogelsberg, Westerwald and in northern Hessian. On the eastern shoulder of the graben system, the volcanic maar with the lake Messel was formed with fossil deposits of the world heritage.
Influences of salt deposits are documented in the southern Rhine Graben.
Famous deposits in the Mainz Basin are well known for their fossils since more than 200 years. Marl and Calcareous Tertiary sediments are deposited in the Mainz Basin and Hanau Basin on the eastern shoulder of the Northern Upper Rhine Graben. The first fully marine ingression in the Northern Upper Rhine Graben is represented by the Middle Pechelbronn Beds (Lowest Oligocene), the 2^{nd} transgression with maximum high stand by the Bodenheim Formation (Rupelton, Lower Oligocene). All subsequent deposits show marine-brackish conditions, whereas toward the final stage the Rhine Graben system, the sediments have only brackish or limnic character. More and more isolated sedimentation events with clastic character (*avernensis* Schotter) of the Ur-Rhine (Dinotheriensand) and other river systems increasingly develop.
The Calcareous Tertiary is represented by regional features such as algal reef limestones. In the Upper Miocene, the appearances of cool deposits are occurring with seam layers (Ginnheimer Flöz, Bockenheimer Flöz, Kahler Braunkohle, Niederräder Klärbecken).

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Glacial sequence stratigraphy applied to isolated onshore Quaternary sections enables revision of the glacial history of the Scandinavian Ice Sheet

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Sequence stratigraphic approach has been applied little for the interpretation of the Quaternary history of glaciated areas. Glacial sequence stratigraphy has been applied in a few cases to offshore sections of these areas, where seismic or acoustic sounding profiles have assisted the interpretations. However in the central onshore areas of Quaternary glaciations sequence stratigraphy has been less applied. These areas have, however, repeatedly faced profound base level changes due to glacioisostasy and glacioeustasy, connected with the laterally extensive changes in the focus of time transgressive glacial erosion and sedimentation. These profound environmental changes, relatively small sedimentation rates and strong topographic bedrock control in the Achaean and Proterozoic shield areas have created a network of spatially localised sedimentary records with high temporal variation. In the interpretation of these records the horizontal dimension plays a much bigger role, than in traditional sequence stratigraphy. The sequence stratigraphic framework must be built from the regionally isolated outcrop sections. These sections have normally even very small lateral and vertical extent.

In this study, glacial sequence stratigraphy is applied to isolated Saalian, Weichselian and Holocene onshore outcrop sections in the central area of Quaternary glaciations in Finland. The analysed sedimentary records and sections have traditionally been investigated, interpreted and published separately by different authors without an attempt to a methodologically more systematic survey. By putting new field data and old previously published observations into a regional sequence stratigraphic framework (Powell and Cooper, 2002), it is shown how previously unnoticed regularities could be found in the lithofacies successions and fossil records. The studied depositional successions consist mainly of Saalian-Eemian glacial sequences with basal Saalian glacial retreat system tract (GRST) sediments followed in most cases by Eemian glacial minimum system tract (GMiST) sediments. These sequences are erosionally covered by a Weichselian-Holocene glacial sequence with Weichselian glacial maximum system tract (GMaST), Weichselian GRST and Holocene GMiST sediments. This framework gives the basis for a more comprehensive sequence stratigraphic interpretation of the glacial history.

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Calcareous nannofossils as dating tool in shallow marine environment: examples from the upper Paleogene and lower Neogene sedimentary successions in the Central Apennines

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Calcareous nannofossils are widely recognized to be a powerful tool for regional and worldwide biostratigraphic correlations. The use of nannofossils is essential for biostratigraphic studies of marine sedimentary sections. In well preserved planktonic assemblages, nannofossils are usually abundant, tend to be ubiquitous, and are generally more resistant to diagenetic changes (dissolution and overgrowth) than foraminifers. Therefore, these microfossils are ideal for obtaining high-resolution biostratigraphy and robust biochronology, as those available for the Cenozoic. Such data support stratigraphic correlations and often result in accurate and precise dating that is a key to the interpretation of other stratigraphic records. Calcareous nannofossils are the major component of deep-sea calcareous oozes, so that can be found as abundant in pelagic and hemipelagic marls.

Here we describe two cases of unusual presence of rich nannofossil assemblages in sediments deposited in neritic (shallow water) environment that provide reliable biostratigraphic information useful to improve the limited biostratigraphy known from previous studies and to enhance the stratigraphic correlation potential to the open ocean. Both these findings come from stratigraphic successions that outcrop in the Northern area of the Majella Mountain (Abruzzi- Central Apennines), the upper Paleogene "S. Spirito Formation" and the "Bolognano Formation", late Oligocene to Miocene in age.

Rich calcareous nannofossil assemblages have been observed within mottles of chalk found inside chert nodules that are included in the "S. Spirito Formation". This lithostratigraphic unit represents middle to outer carbonate ramp sediments, mainly micritic and marly limestones, with chert lenses and nodules distributed within. The analysis of nannofossil chalk enclosed by the chert nodules and lenses throughout the section provided a series of bio-horizons with robust chronology that permit to constrain the section between ~38 Ma (Priabonian) and ~31 Ma (early Rupelian). This precise stratigraphic assignment refines the correlation to the Eocene/Oligocene transition already known from the literature.

The other example of the utility of nannofossils in studying carbonate ramp sediments comes from the biostratigraphic results obtained in the "Bolognano Formation". In a "work-in-progress" comprehensive study (Cornacchia et al., this Session), nannofossil assemblages were found in lithologies of the "Bolognano Formation" including middle to outer ramp calcarenites and outer ramp to hemipelagic marly limestone. Although moderately preserved and diluted by fine terrigenous input, nannofossil assemblages provided remarkable biostratigraphic data that resulted in a precise chronologic assignment by means of reliable upper Oligocene to middle Miocene bio-horizons.

These examples are a good case in point that clearly shows how the use of nannofossils in shallow water sections, accompanied by detailed stratigraphic investigation and accurate sampling of suitable lithologies, permits to obtain significant biochronologic data even in such not ideal sedimentary successions. The nannofossil biochronology can improve the usually poor stratigraphic resolution of these records and their correlation potential to open ocean successions, and provides a basis for age models that can be used for interpreting stratigraphic and geochemical proxy records.

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Biostratigraphy and chemostratigraphy of Upper Albian- Lower Cenomanian deposits in southwest Qayen area of eastern Iran

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The studied area is located at the eastern margin of the Lut Block (Fauvelet and Eftekharnezhad, 1990). New ammonite material was described from eastern Iran. We also provided a temporal record of oxygen isotopic composition in bulk carbonate of the central Tethys region, which may improve the time constraint on episodes of temperature variation.
The Kerch section in soutwest Qayen area (NE Iran) has been examined. The section is 413 meters thick and composed of marl with marly limestone intercalation in lower and middle part (Unit 1), conglomerates, sandstone (Unit 2) and sandy limestone in upper part (Unit 3). In marl beds (with thickness of 245 meters) the ammonites were identified as follows: *Hyphoplites costosus, Mantelliceras mantelli, Sharpeiceras* cf. *schlueteri, Sharpeiceras laticlavium, Mantelliceras saxbii, Mantelliceras* sp. and *Puzosia mayoriana*. Based on the identification, *antelliceras mantelli* Zone, *Mantelliceras saxbii* Subzone, and with regards to fauna assemblage, it is possible to introduce *Stoliczkaia dispar* Zone and *Hypoturrilites carcitanensis* Subzone (Kennedy, 1971; Reboulet et al., 2014). The ammonite assemblages and suggested biozones indicate a late Albian-Early Cenomanian age for the Kerch section.
The $\delta^{18}O$ values of bulk carbonates in marl unit (Unit 1) are varied between –5.8‰ and –0.5‰ in VPDB. The lowest values appear to coincide with *Puzosia mayoriana* event. After this event, the $\delta^{18}O$ values are gradually increased with a sudden decrease at the middle part of the unit, and then keep in a narrow range between –3.2‰ to –3.7‰ in VPDB. At the beginning of *M. Mantelli* Zone, a gentle decrease of the $\delta^{18}O$ values is observed and finally the $\delta^{18}O$ values increase at the most upper part of Unit 1. Furthermore, limited data obtained in Unit 3 (limestone and sandy limestone) show a variation in $\delta^{18}O$ values between –6.7‰ to –5.0‰ in VPDB. The seawater temperatures were estimated between 15ºC to 41ºC with a mean of 32 ºC during the precipitation of carbonates for Unit 1, which infers that the Kerck section was located at 10º - 20º northern paleolatitudes. The variation of estimated paleotemperatures seems to correlate with morphological characteristics of ammonites, which indicated their living water depths and temperatures. The result is consistent with previous studies examining stratigraphic sections at the same period and paleolatitude (Voigt et al., 2003; Reboulet et al., 2013).
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Building a better eustatic model: comments on Palaeozoic sea level change

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The establishment of a eustatic model of sea level (SL) change requires a global dataset rooted in a detailed knowledge of regional stratigraphy and built around key reference sections containing detailed age and relative SL information. An understanding of events affecting the biosphere, atmosphere and hydrosphere is also critical in the calibration of SL change between multiple palaeo-continents. The utilisation of such a global dataset is presented here and provides a clearer understanding of eustatic SL change and associated events during the Palaeozoic.

By an evaluation of over 220 key sections from 40 countries, augmented by primary fieldwork, we have identified 19 second and 64 third order sequence stratigraphic cycles in the Palaeozoic Era. In establishing our record of SL change only sections that are biostratigraphically well constrained, show an unambiguous sedimentological expression of relative SL change and are associated with tectonically stable regions have been used. Furthermore, attention has been given to sections exhibiting isotope excursions, biotic events, glaciogenic sediments and palaeo-water-depth indicators.

The long-term SL trend shows a broad rise through the Cambrian to Late Ordovician, with second order SL lows during Series 3, Furongian and Middle Ordovician times. Following the Late Ordovician SL high, pronounced SL fluctuations are observed until the middle Silurian and appear coincident with the Early Palaeozoic Icehouse. After which SL broadly falls until the Early Devonian. The remainder of the Devonian is represented by three drawn-out episodes of transgression (second order) separated by pronounced regressions. Carboniferous to middle Permian times are associated with the Late Palaeozoic Icehouse and exhibit some of the most notable SL changes of the Palaeozoic. With the exception of a Visean SL low, second order SL lows occur near each of the Epoch boundaries during Carboniferous and Permian times.

From Cambrian to Devonian times SL change varies in magnitude from a few tens of meters to a little over one hundred meters, with the largest changes broadly coeval with glacial-interglacial intervals. More substantial SL changes are reported from the Carboniferous and early Permian. In addition episodes of regionally developed sea floor anoxia, biotic change and carbon isotopic excursions also appear closely linked to second and third order SL change and are most widely evident during Middle Ordovician to Early Mississippian times.

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New data on the stratigraphy of the *Rzehakia* (*Oncophora*) Formation in the German part of the North Alpine Foreland Basin (Western Paratethys, late Burdigalian)

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The *Rzehakia* (*Oncophora*) Formation (Rz Fm) is traditionally thought to represent the regressive facies of the late Ottnangian in the Central Paratethys. However, some of the ten currently described faciostratotypes of the Rz Fm are located above crystalline basement rocks while others overly Eggenburgian sediments (Čtyroký et al., 1973). It is therefore possible that the facies characterized by *Rzehakia* and co-occuring molluscs developed locally and indicates a brackish facies during the early/middle/late Ottnangian rather than a precise late Ottnangian age (Reichenbacher et al., 2013). The "Kirchberger Schichten" (KS) at the type locality near Ulm, SW Germany, represent the only faciesstratotype of the Rz Fm that is located in the Western Paratethys. In our previous work (Reichenbacher et al., 2013), we have provided a new magnetostratigraphic framework for the KS and their under- and overlying strata and we have correlated the KS to the early Karpatian (C5Cr and C5Cn.3n). Since that study, we conducted additional sedimentological, micropalaeontological and magnetostratigraphic work based on a total of eleven drill cores located in the German Molasse Basin. Our new data confirm the Karpatian age of the KS, but indicate an even slightly younger age for the KS (C5Cn.2r and C5Cn.2n). Furthermore, our sedimentological data suggest that the lowermost unit of the KS is the shelly layer with abundant *Cerastoderma* and *Mytilopsis* (rather than the sands with *Rzehakia* that underlie the shelly layer) and that this shelly layer accumulated during a new transgression. Considering the definition of the Karpatian stage (Cicha et al., 1967; Cicha & Rögl, 2003), (i) the Karpatian is a time span of the Miocene between the terminal beds of the Ottnangian and the global first appearance of *Praeorbulina glomerosa*, (ii) the Karpatian overlies at its stratotype the brackish Rz Fm, (iii) the Karpatian mollusc, foraminiferal, ostracod and otolith fauna is different from those of the Eggenburgian and Ottnangian and includes mostly species that are also typical for younger Miocene strata. The KS fulfill criteria (i) and (ii). We therefore conclude that the KS represent the transgression of the Karpatian in the German Molasse Basin, rather than the regressive facies of the late Ottnangian. However, a still enigmatic feature of the KS is that their beds hold numerous species of bivalves, gastropods, fishes and also some foraminifers that are currently considered as typical for the late Ottnangian and that new faunal elements are scarce. Our new data additionally indicate an age of approximately 16.47 Ma for the KS/Upper Freshwater Molasse boundary, which means that deposition of the Upper Freshwater Molasse at the northern rim of the German Molasse Basin started later than previously expected (Reichenbacher et al., 2013; Abdul Aziz et al., 2010). This new age matches nicely with the previously determined age for the base of the OSM in the Swiss Molasse Basin (~16.5 Ma; Reichenbacher et al., 2013).

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Geochemical Expression of speleotheme growth from XRF and LA-ICP-MS: Paleoclimatic implications

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Carbonate cave deposits have a widespread use in deciphering climatic signals from the past using several proxies (e.g. stable isotope compositions). In the western central part of Portugal, the Mesozoic sediments of the Lusitanian basin are particularly susceptible to dissolve by interaction with meteoric waters and to develop karstic caves, especially in the Lower and Middle Jurassic limestone and dolomitic limestone formations. A set of the existing caves from Sicó and Estremadura Carbonate Massifs (e.g. Soprador do Carvalho, Buraca Grande and Ourão Caves, as well as Vale do Pena and Algar do Pena Caves) were detailed study and several speleothem samples (stalagmites and flowstones) were collected aiming to contribute to the deciphering of the climatic evolution of this region.
The selected cave stalagmite was collected in the main epiphreatic conduct of the Soprador do Carvalho Cave (an underground system located on the eastern border of the Sicó Massif) and was studied by handheld X-ray fluorescence to determine the major elements trends and by LA-ICP-MS for the analysis of the minor and trace-elements. The cave floor is covered by siliciclastic fine (clayey/sandy) and clast-supported conglomerate sediments carried into the cave from the adjacent areas by floodwater.
As expected, the chemical composition of the speleothem is dominated by the presence of calcium with all samples presenting counts of the same magnitude for this element, although the older portion of the stalagmite has slightly lower counts than the rest of it. Iron is another remarkable element that present a subtle tendency to be more concentrated in the outer (younger) layers. With LA-ICP-MS several transects were made on the thin sections covering layers of distinct optical characteristics. The older layers, which exhibit a more hyaline aspect, have higher counts of elements such as sodium, uranium and lead and lower counts on rare-earth elements and yttrium. More, the analysed elements oscillate between high counts and low counts from layer to layer along the entire sample. The oscillatory character of the trace-element distribution in the stalagmite can be interpreted as the result of the seasonal variations of meteoric water input, and time of residence on the hanging-wall formations, with periods of more efficient dissolution of the percolating water alternating with periods of less efficiency. The more general evolution observed in the composition of older and younger sectors of the speleothem can be interpreted as being the evidence for a probable change in the paleoclimate conditions of the area and perhaps can be used to detect underground flood events during the Quaternary.

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Fluvial limestone tuffs from S Portugal (Loule-Tavira) and N Morocco (Tetuan): comparison and environmental implications

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Limestone tuff deposits precipitated in fluvial environments are widespread in the northern Morocco and the S Portugal. These deposits represent environmental conditions prone for the carbonate precipitation mainly in areas of Mesozoic limestone substratum with active water seepage from the aquifers.

The mesoscopic and microscopic characteristics of tuff deposits from Tetouan (Morocco) and Loule and Tavira (Portugal) are very alike; namely on deposit types (e.g. phytoherm barriers; banded limestones with abundant vegetation macro-remains; carbonates precipitation as cement of some early alluvial conglomerates or interbedded alluvial deposits). The common textural features and macro-facies (e.g. banded calcite in regular layers ; moldic porosity; textures resulting from carbonate precipitation mediated by bacteriological activity) point to a similar origin of these limestone tuffs on both sides of Gibraltar Strait despite their slightly different climatic conditions that are influenced by the active inflow of surface Atlantic water towards the Mediterranean (for the Tetouan region) and by the Azores anticyclone (for the Loulé-Tavira region). The field observations show that the limestone tuffs precipitation is nowadays residual and radiocarbon dating of Portuguese deposits points to a chronological framework for their formation starting in the beginning of the post-Younger Dryas climatic recovery and ending around 2.5 ky BP. The oxygen stable isotopes data show a gradual change in the tuffs isotopic signature through the time interval during which the system remained active, without any particular record of climate events such as the 8.2 ka.

The available data and those from monitored modern pluvial characteristics allow the speculation on the parameters controlling the limestone tuffs deposition on both northern and southern sides of the Gibraltar Strait during the Holocene. The carbonate deposition on fluvial systems, such as the studied ones, probably depends on the precipitation / evaporation balance leading to the availability and turbulence of the flowing water along the streams.

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Long-term oceanic stability and orbital control on carbon cycle prior to the Late Triassic mass-extinction

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We established a new high-resolution carbonate isotope record from the lower Carnian to the late Rhaetian in the Northern Calcareous Alps of Austria. The new curve has an excellent biostratigraphic control based on ammonoids and conodonts. Among the six sampled sections was the proposed GSSP section (Steinbergkogel) for the Norian-Rhaetian Boundary. The Carnian has been sampled from intraplatform carbonate, whereas the middle Norian to lower Rhaetian curve is established from a sequence of different Hallstatt-type limestones. These consist of fine-grained bioclastic wackestone deposited from periplatform ooze. Hallstatt limestone deposition was ended by the Rhaetian terrigenous event of the Zlambach Formation. Its toe-of-slope to basin environment of alternating marls and subordinate micritic limestone is episodically overlain by allodapic carbonate sedimentation.

The initial Upper Triassic curve displays a gentle increase with three negative excursions of 2 to 3 per mille amplitude during the early Carnian. The two first excursions rebound to previous values, whereas the third negative excursion, at the Julian-Tuvalian boundary, is followed by a positive excursion up to plus 5 per mille. The remaining Upper Carnian shows stabile values around 2 per mille. The Carnian-Norian boundary interval is marked by a minor increase of less than 1 per mille. The carbon isotope curve display a gentle decrease from the late early Norian (3.5 per mille) to the base of the Rhaetian (1.8 per mille) with two accelerated steps, one in the middle Norian and the other one just after the Norian-Rhaetian Boundary. This last 1 per mille decrease corresponds however to a change in lithology from Hallstatt limestone to an alternation of marls and limestone. The values show then a small increase during the early Rhaetian, with a maximum in the middle Rhaetian (at 2.4 per mille). The general stability of the curve even through the Norian-Rhaetian boundary crisis event describes a stable oceanic structure prior to the end-Triassic mass extinction. From an isotopic point of view, only the two Lower Carnian excursions, the Lower Upper Carnian Boundary and the Triassic-Jurassic Boundary can be interpreted as events, whereas other biotic crises of the Late Triassic seem to have occurred during periods of gradual changes in the carbon isotopic composition of seawater.

Superimposed to this long-term trend, the delta^{13}C isotopic curve in the Zlambach Formation records distinctive cycles. First results of the spectral analyses reveal a prominent 400 kyr. cyclicity in the curve, which correlates with Milankovitch long eccentricity changes. Cycles occurring in our record resemble those observed in several Cenozoic and Cretaceous records, suggesting that a link between orbital forcing and carbonate cycling existed also in Late Triassic time. These 400kyr cycles in the Late Triassic could have been linked to sea-level changes influencing the carbonate export from the platform or, as during the Cretaceous, may have been related to a fluctuating monsoonal regime.

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Global species richness record and biostratigraphic potential of early to middle Neoproterozoic eukaryote microfossils

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Over the past several decades, a number of studies have addressed the record of eukaryotic species richness in the Precambrian Eon. However, the relative scarcity of radiometric age constraints on rocks of this interval necessitated the use of coarse time bins (~100 Ma) and the omission of fossiliferous but poorly dated units, resulting in low resolution. Here we describe a new dataset of Tonian and Cryogenian paleontological, geochemical and radiometric data to which the CONOP9 seriation algorithm has been applied—permitting inclusion of poorly dated units.

The CONOP9 (*co*nstrained *op*timization) algorithm operates by evolutionary ordination—considering data from all stratigraphic sections simultaneously and starting from a random ordinal sequence that improves by mutations retained or removed according to best-fit rules. This program has been applied widely to biochronologic and biostratigraphic problems throughout the geologic record, perhaps most notably in resolving Paleozoic time-lines and extinction dynamics.

Here we apply this objective approach to a new compilation of geochemical data and taxonomically well-constrained organic-walled microfossil occurrences from more than eighty formations in 30 paleogeographically distant successions. From this information CONOP9 produced an ordinal sequence of biotic, isotopic and dated events, with uncertainty bounds that we calibrated to geologic time to produce a high-resolution eukaryotic species richness record for the early to middle Neoproterozoic Era. We find an increase in species richness at ~805 Ma, sustained high richness levels until a decrease ~770 Ma that resulted from a large number of acritarch extinctions, and then a sharp and short-lived increase at ~760 Ma reflecting first appearances of vase-shaped microfossil taxa, and finally a sharp decrease in richness and extended nadir through the Sturtian and Marinoan glacial periods.

Use of CONOP with this dataset also permitted assessment of fossil taxa that had been previously suggested as Neoproterozoic biostratigraphic index taxa. Our results provide support for biostratigraphic use of the acritarch *Cerebrosphaera buickii* and for vase-shaped microfossils as a group and individually.

The section correlation derived from these data reveals a reduction in the number of units described during the second half of the 1 Ga to 635 Ma interval of study and can be used to make testable predictions for potential sections recording specific fossil taxa and carbon isotopic excursions such as the Bitter Springs stage and Islay isotopic anomalies.

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GSWA's Explanatory Notes System: a seamless digital legend for Western Australia's geology

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Western Australia covers 2.6 million square kilometres, a third of the Australian continent. Its geological history spans 4.4 billion years with Archean cratons rimmed by Archean to Proterozoic orogenic belts and separated by Neoproterozoic and Phanerozoic basins. Geologists at the Geological Survey of Western Australia (GSWA) have spent 130 years unravelling the State's stratigraphic framework. On-going geological mapping, geophysical data acquisition, geochemistry and geochronology/isotopic studies constantly challenge previous geological interpretations.

To synthesize the vast amount of geoscience information available for Western Australia, GSWA has developed an Explanatory Notes System (ENS) as a single comprehensive digital repository that integrates stratigraphic relationships with links to all tectonic units and events recognized in the State. The system allows incremental updates for new data and refined interpretations, providing a seamless, up-to-date summary of the geology of Western Australia.

ENS comprises several components:

- a data entry application where geologists can add new units, modify existing ones, and write full explanatory notes, with well-constrained business rules and permission levels. A database geologist administers the system to ensure a consistent approach, and all notes are fully edited before release;
- production tools that allow geologists, cartographers, GIS officers and editors to extract and assess information for map legends and digital lookup tables;
- an online application and a standalone equivalent that enable customers' spatial and text searches, and report delivery.

ENS enables the sorting of rock units in a chrono-stratigraphic sequence. Stratigraphic units are linked by parent–child relationships that allow stratigraphic sorting from geologically youngest to oldest units within a set of relational database tables. This creates discrete stratigraphic 'trees', each representing a separate stratigraphic succession with the highest ranking unit at the 'top of the list' (TOL in ENS). In a separate ENS module, TOL lithostratigraphic units and their associated discrete stratigraphic trees are sorted relative to each other under a single tectonic unit. Tectonic units are similarly linked to each other in parent–child relationships, but there is only a single tree for the whole of Western Australia — all tectonic units in the State are geologically sorted within a single tectonic 'sequence'. Dedicated reports in ENS combine the tectonic sequence for the State with the sorting of TOL trees under their designated tectonic unit, thus generating a state-wide 'geological column'.

ENS has been designed to align with the Australian Stratigraphic Units Database (ASUD), the national repository for lithostratigraphic units maintained by Geoscience Australia (a Federal agency) on behalf of the Australian Stratigraphy Commission. A table with all Western Australian current lithostratigraphic units is periodically extracted from ASUD and updated in ENS, and any discrepancy addressed by GSWA's geologists in cooperation with ASUD staff. A detailed description of each lithostratigraphic unit in ENS is compiled through a series of narrative fields that mirrors the structure of ASUD's definition cards, allowing easy compilation of the latter — thus contributing to consistency and completeness of Australian stratigraphic unit information at the state and national level.

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The Pignola-Abriola section (southern Apennines, Italy): a new GSSP candidate for the base of the Rhaetian Stage

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The base of the Rhaetian stage (Norian/Rhaetian boundary, NRB) is still awaiting formal designation by the International Commission on Stratigraphy. At present, only the 4.30 m-thick Steinbergkogel section (Austria) has been proposed as GSSP (Global Stratotype Section and Point) candidate for the base of the Rhaetian. Here we present the Pignola-Abriola section (Southern Apennines, Italy) as an alternative valid candidate for the Rhaetian GSSP (Rigo et al., 2015).
The Pignola-Abriola is a 63 m-thick basinal section composed of hemipelagic-pelagic carbonate deposits belonging to the Calcari con Selce Formation. It was deposited in the Lagonegro Basin, which is considered as the western part of the southwestern branch of the Tethys Ocean and is bordered to the north by the Apenninic and Apulian carbonate platforms.
The Pignola-Abriola section matches all the requirements for a GSSP:
- it is well exposed with minimal structural deformation;
- it crops out on the western side of Mt. Crocetta along road SP5 "della Sellata", and thus is easily accessible;
- it is is located in the protected area of the Parco Appennino Lucano Val d'Agri Lagonegrese;
- it is rich in age diagnostic fossils (e.g., conodonts and radiolarians);
- it yields a geochemical record suitable for correlation (e.g., $\delta^{13}C_{org/carb}$);
- it has a robust magnetostratigraphy and it is correlated with the Newark APTS for age approximation of the NRB and additional Rhaetian bioevents.

In the Pignola-Abriola section, we place the NRB at the 44.4 meter level, coincident with a prominent negative shift of ca. 6‰ of the $\delta^{13}C_{org}$. This level is located 50 cm below the FAD of the conodont *Misikella posthernsteini* s.s. within the radiolarian *Proparvicingula moniliformis* Zone. Both the negative $\delta^{13}C_{org}$ shift and the FAD of *Misikella posthernsteini* occur within Pignola-Abriola magnetozone MPA-5r, at ~205.7 Ma, according to magnetostratigraphic correlation to the Newark APTS.

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The Pizzo Lupo section (Sicily, Italy): preliminary $\delta^{13}C_{org}$ around the Carnian/Norian boundary

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The Carnian/Norian (Upper Triassic) succession of Pizzo Lupo is located near Castronovo di Sicilia (central Sicily), a village in the Monti Sicani nature park. This succession belongs to a tectonic unit of the Maghrebian fold and thrust belt. It consists of Carnian to Miocene deep-water sediments that were deposited in the Sicanian Basin, a paleogeographic unit of the southwestern Tethys. The Pizzo Lupo section is exposed along an inactive quarry wall and it consists of about 49.40 m of well-bedded cherty calcilutites, with thin clayey intercalations, known as Scillato Formation (Auct.). Along the stratigraphic section, well preserved biomarkers such as conodonts, ammonoids and bivalves belonging to the genus *Halobia* are abundant, making Pizzo Lupo an ancillary and coeval section of the Pizzo Mondello GSSP, which is a candidate for the Norian Stage (Nicora et al., 2007). The Carnian/Norian boundary in Pizzo Lupo section has been placed at 41 m (bed CPL93) with the FO of *Epigondollella quadrata*, based on a preliminary conodont biostratigraphic investigation.
The Pizzo Lupo section has been studied and numbered bed by bed. The $\delta^{13}C_{org}$ data presented here concern the interval from bed CPL30 (12.40 m) to the bed CPL107 (49.20 m), covering an about 37 m thick interval.
The $\delta^{13}C_{org}$ analyses was performed on 30 samples at the University of Padova using a Delta V Advantage mass spectrometer connected to a Flash HT Elementar Analyzer. The obtained profile depicts two significant negative shifts: the first one, occurring between 14.40 and 21.90 meters, has an amplitude of ca. 3.50‰; the second one shows an amplitude of ca. 4‰ and occurs between 29.10 and 39.20 meters, ca. 1.50 m below the Carnian/Norian boundary placed with the occurrence of *Epigondella quadrata*.

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Lower Miocene (upper Burdigalian, Karpatian) volcanic ash-fall at the south-eastern margin of the Bohemian Massif in Austria – New evidence from $^{40}Ar/^{39}Ar$-dating, palaeomagnetic, geochemical and mineralogical investigations*

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At the south-eastern margin of the Bohemian Massif in Lower Austria and the Czech Republic several tuffs and tuffite layers are intercalated in the Lower Miocene shallow marine sediments. During geological mapping in north-eastern Austria an outcrop with 90 cm thick tuffs and tuffites was found close to Straning, a village about 4 km SE of Eggenburg. The whitish-grey, indistinct bedded volcaniclastics were preserved from erosion in a small-scale graben inside granites of the Thaya-Batholith. Corestone-weathering and limonitic crusts (tafoni-weathering) on the granite surface give evidence that the primary tectonic graben existed before sedimentary filling. Before the ash-fall the major part of the graben was filled by marine, greenish-grey, thin and plane bedded, non-calcareous, smectitic silty clays of the Zellerndorf Formation (middle Burdigalian, Ottnangian). The uppermost part of these clays already shows thin tuffitic intercalations. The almost monospecific microfauna (predominantly ?*Silicoplacentina* sp. ("*Saccammina*") and very rare *Triloculina* sp.) in this upper section is typical for shallow, probably brackish-water deposits. The shallow depositional environment may also explain the preservation of the exceptionally thick acidic volcaniclastics above. The overlying multiphase Straning ash consists of silts with a fine silty mean between 7.1 and 8.6 Phi (i.e. 7.3 - 2.6 µm) typical for distal fallout tephra. The tephra consists of high amounts of volcanic glass as well as biotite, alkali feldspar, plagioclase, quartz, ilmenite, apatite, and zircon. Smectite (84 %), small amounts of illite (14 %) and traces of kaolinite are the characteristic clay minerals of the Zellerndorf Formation, whereas the overlying tuffs and tuffites only consist of smectite in the clay fraction < 2 µm. The chemical composition of the volcanic glass indicates a rhyodacite/dacite character of the volcanic source, originating from a calc-alkaline arc volcanism. The typology of the volcanic zircons give evidence of very high eruption temperatures of about 850° C and also reveals a hybrid character of the parental magma, close to an anatectic origin. Volcanic zircons and the composition of Rare Earth elements are significantly different from other Burdigalian (Eggenburgian, Ottnangian) and Langhian (early Badenian) tephra from the surrounding region in Austria and Czech Republic. K-feldspar crystals of the tuffs were dated by the $^{40}Ar/^{39}Ar$ technique. The inverse isochron age of 17.23 ± 0.18 Ma corresponds with the middle - late Burdigalian (Ottnangian - Karpatian) transition. The reversed palaeomagnetic polarity of the tuff restricts the age interval to the lowermost part of the chron C5Cr and therefore per definition to the basal part of the late Burdigalian (early Karpatian). Consequently the volcaniclastics can be correlated with the lowstand systems tract (LST) in the basal part of the global 3rd order sea level cycle Bur 4. The volcanic source of the Straning tuffs might be traced back to the western Inner Carpathian volcanic arc. The tuffs are most likely genetically related to the Middle Rhyolite Tuff (late Burdigalian, Karpatian) of northern Hungary to southern Slovakia.

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Anabarites trisulcatus Assemblage Zone of Siberia – candidate for the final stage of the Ediacaran System

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First appearance of biologically controlled mineralization by metazoans is suggested as one of the criteria for defining the base of the final stage of the Ediacaran System. In the Siberian Platform, this criterion is used to define the lower boundary of the *Anabarites trisulcatus* Assemblage Zone and the base of the Nemakit-Daldynian Regional Stage (Khomentovsky, 1975).

On the NW slope of the Olenek Uplift, arctic Siberia, the *Anabarites trisulcatus* Ass.-Zone is represented by the Turkut Formation (Khorbusuonka Group) and most of the Syhargalakh Formation (Kessyusa Group). The Turkut Fm. consists of microbial dolostones, intraclastic, oolitic and pisolitic dolostones, and stromatolitic dolostones. The microbial dolostones contain fossils of the skeletal invertebrate *Cambrotubulus decurvatus*, which defines the base of the *Anabarites trisulcatus* Ass.-Zone. The first appearance of *Cambrotubulus decurvatus* is 1.4 m above the lower boundary of the Turkut Fm. and is found throughout the Turkut Fm. The top of the Turkut Fm. is marked by a karstic, subaerial exposure surface overlain by fluviomarine sandstones (7 m) of the Syhargalakh Fm. The middle part of the Syhargalakh Fm. is intruded by diatremes consisting of tuff breccias that yielded a U–Pb zircon age of 543.9 ± 0.3 Ma (Bowring et al., 1993). Laterally discontinuous stratiform bodies of the tuff breccia localised around the diatremes interfinger with the middle part of the Syhargalakh Fm. Carbonate clasts in the tuff breccia yielded the small skeletal fossils *Cambrotubulus decurvatus* and *Anabarites trisulcatus*. The upper part of the Syhargalakh Fm. contains trace fossils (*Treptichnus pedum*) and small skeletal fossils (*Purella antiqua* Ass.-Zone) of early Cambrian (Fortunian) age. The U–Pb zircon date of 543.9 ± 0.24 Ma provides the best constraint on the age of the boundary between the *Anabarites trisulcatus* and *Purella antiqua* ass.-zones.

The oldest fossil metazoans with biologically controlled mineralization postdate the first appearance of peculiar meniscate structures, which have been variously interpreted as body fossils (Shen et al., 2007; Dong et al., 2008; Meyer et al., 2012; Tarhan et al., 2014) or as a result of activity of mycetozoan pseudoplasmodia (Zhuravlev et al., 2009), but are better explained as the oldest ichnofabric of burrowing metazoans (Rogov et al., 2012, 2013a, b). On the NW slope of the Olenek Uplift, the ichnofabric occurs in the Khatyspyt Fm. which immediately underlies the *Anabarites trisulcatus* strata of the Turkut Fm. In the Uchur–Maya Region of Siberia the age of the Khatyspyt-type ichnofabric is poorly constrained by a Pb–Pb isochron date of 553 ± 23 (2σ) Ma (Semikhatov et al., 2003; Zhuravlev et al., 2009). In China, the Khatyspyt-type ichnofabric is younger (U–Pb zircon date of 551.1 ± 0.7 Ma on volcanic tuffs) (Condon et al., 2005; Shen et al., 2007; Dong et al., 2008). Identical ichnofabric is found in the Yaryshev Fm. of Podolia, East European Platform, with a U–Pb zircon date of 553 Ma from the Bernashevka Mb. (Rogov et al., 2013a), which could be coeval with a Rb–Sr isochrone date of 552 ± 53 Ma from tholeitic basalts and a U–Pb zircon date of 551 ± 4 from volcanic tuffs of the Volhyn Gr. (Compston et al., 1995; Nosova et al., 2008). Finally, the meniscate structures have been found in the Lesser Himalayas in strata below the lowermost stratigraphic occurrence of small skeletal fossils of the *Anabarites trisulcatus* Ass.-Zone (Tarkhan et al., 2014). To summarise, the Khatyspyt-type ichnofabric first appears in the strata 553–551 Ma old and becomes globally distributed. The age of the lower boundary of the *Anabarites trisulcatus* Ass.-Zone is younger than 551 Ma.

One of the main conclusions of the study is that small skeletal fossils of the *Anabarites trisulcatus* Ass.-Zone appear significantly earlier in the fossil record (~550 My ago) than it is currently assumed (~541 My ago; Kouchinsky et al., 2012). The next abrupt increase in taxonomic diversity of metazoans with biologically controlled mineralization occurred ~544 My ago with the *Purella antiqua* Ass.-Zone. The duration of the *Anabarites trisulcatus* Ass.-Zone does not exceed six million years. If the first appearance of biologically controlled mineralization by metazoans is selected as the criterion for defining the final stage of the Ediacaran System, the base of the *Anabarites trisulcatus* Ass.-Zone of the Nemakit-Daldynian should be considered as a candidate.

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The Aramachay Formation in the Western Andean Cordillera of Central Peru: Sedimentary Facies, Paleoecology, Geochronology, and relation to Metallic Ore Formation

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The Lower Jurassic Aramachay Fm., belonging to the Pucará Group, is formed by massive and nodular cherty dolomites in the Western Andean Cordillera (WAC) of central Peru, in contrast to widespread black shale-rich facies of the Eastern Andean Cordillera (EAC).
Detailed sedimentological, paleontological, and microfacies analyses were conducted at six sites of Aramachay Fm. in the WAC. They reveal that cherty dolomites contain sedimentary structures pointing to on-shelf deposition and contrast with deeper deposition systems represented by the black shale-rich facies in the EAC (Rosas et al., 2007). Thus, the previously proposed massive transgression near the Triassic/Jurassic boundary is apparently not recorded at the studied locations of the WAC.
Analysis of cherty dolomites of Aramachay Fm. in the WAC evidence a siliceous sponge dominated ecosystem, including sponge body fossils, compressed *in situ* sponge materials, and transported spiculites. Siliceous sponges account for chert lithology and dominated the local ecology during early Jurassic time. The Central Peruvian record would be worldwide the second locality where this important event of siliceous sedimentation on epicontinental platforms is recognized in high stratigraphic resolution for the early Jurassic (Ritterbush et al., 2015). Occurrences of similar age have been recorded in only few other geographically distant locations. Analyses of stratigraphically expanded successions of lowest Jurassic strata at New York Canyon, Nevada, were investigated with high-resolution palaeoenvironmental observations, fossil surveys, and microfacies analysis (Ritterbush et al. 2014), showing that following the collapse of the uppermost Triassic carbonate ramp, the lowest Jurassic units record a midshelf habitat dominated by siliceous sponges.
Our results indicate that the role of biocalcifiers in sediment production and ecological structure was profoundly reduced at the Triassic-Jurassic transition, representing an ecological shift from pre-extinction carbonate to post-extinction siliceous dominated eco-systems before the carbonate system recovered. Simple mass balance calculations suggest that siliceous sponge takeover was permitted by an increased silica flux as a consequence of weathering Central Atlantic Magmatic Province basalts. Thus, the post-extinction dominance of siliceous sponges is the result from a general collapse of reef habitats, coinciding with specific seawater composition, most likely following massive eruption and subsequent weathering of CAMP basalts and lasting for around 2 million years.
Owing to the presence of a predominantly shallow water environment, the siliceous sponge rich facies is the dominant ecosystem following the end Triassic mass extinction in the western part of the Aramachay Fm. Ammonite associations containing *Arnioceras*, as well as new high-precision U-Pb zircon ages of 199.22 - 198.93 Ma of volcanic tuffs indicate that the cherty dolomites at the base of Aramachay Fm. prevailed only during Sinemurian. This finding is in contrast to the stratigraphic record in Nevada, which contains Hettangian. Ongoing geochronological work will focus on the underlying carbonate Chambará Fm. in the WAC to confirm whether the role of biocalcifiers in sediment production was consistently reduced right after the T/J boundary or not.
Carbonates of Pucará Group at WAC host a number of Miocene replacement ore deposits. The Aramachay Fm. is often erroneously described as "silicified limestone", but is not replaced by hydrothermal fluids and would better be termed "siliceous sponge rich cherty dolomites". Thus the siliceous lithology hindered replacement acting as a seal for rising hydrothermal fluids across the underlying carbonate rocks (Chambará Fm.), in which ore bodies developed.

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Environmental changes in the Paleogene World: Insights from organic matter-rich Oligocene rocks in the Paratethys

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Organic matter accumulation and preservation are largely controlled by environmental factors like climate, salinity, redox conditions, sediment dilution, etc. Thus, organic matter-rich rocks are archives for environmental changes in the depositional realm.

Organic matter-rich Oligo-/Miocene rocks in the Paratethys are proven hydrocarbon source rocks in the Alpine foreland basin, the Carpathians, the Hungarian Paleogene basin, the Black Sea, the Caucasus and the Caspian Sea. Borehole and outcrop sections of these sediments have been studied using organic geochemical parameters (incl. biomarkers) and applying a high resolution approach in order to study vertical variations in the source rock potential. The aim of the present contribution is to compare the source rock intervals in different basins and to evaluate the controls of basin-wide environmental changes on organic matter richness.

Source rocks in the Alpine foreland basin (Schöneck Fm., Dynow Fm., Eggerding Fm.) are characterized by high lateral continuity, but major vertical changes in source richness, which can be related to the establishment of photic zone anoxia, changes in salinity as functions of the isolation and connection of the Paratethys, and dilution by cyclic blooms of calcareous nannoplankton. Similar processes together with diatom blooms controlled source rock quality in the western Carpathians (Menilite Fm.).

Stratigraphic ages of the Oligocene rocks are still discussed controversially. However, some marker horizons help to correlate sections in the Central and Eastern Paratethys. Amongst these is the Dynow Formation, which forms a prominent carbonate-rich horizon in the Alpine foreland basin, the Carpathians and the western Black Sea area and which can be correlated with the Ostracoda Bed of the Maikop Fm. in the Caucasus area. In all mentioned areas, rocks with high hydrogen index values indicating enhanced organic matter preservation are related to this (“Solenovian”) horizon.

On a large scale two trends are visible: (1) Organic matter contents and organic matter preservation decrease eastwards from the Central Paratethys towards the Easter Paratethys and (2) organic matter contents and organic matter preservation decrease from Lower Oligocene towards Upper Oligocene successions. In some areas organic matter-rich rocks occur in the Lower Miocene section. On a smaller scale, the large scale trends are influenced by local factors controlled by the tectono-sedimentary evolution of each basin.

It is planned to study additional profiles in the future, but the greatest challenge ahead is to date the sediments precisely.

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Sedimentology of Facies and Ordovician Paleogeography - Quartzite El Hamra (Algerian Desert)

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The main objective of this study is to identify the environment and the depositional conditions of terrigenous formations in the study area. The vertical distribution of microfacies permitted to identify two sedimentary units:

The lower unit is characterized by a fine to medium particle size, shapes are rounded to sub-rounded and occasionally sub-angular grains with a few grains showing stripes, sorting is good to medium. This level is marked by the presence of different types of stratifications: oblique, intersecting horizontal, indicating a change in type of unidirectional and bidirectional currents. We also note the presence of erosion surfaces and hardened surfaces with soil development (paleo sols and traces of roots) indicating an emersion. Sometimes we find pebbles of clay; *Skolihos* trace fossils occur in a few levels.

The upper unit is characterized by sandstone with sub-angular grain shape and good sorting with silty and clay seals of ripple structures (HCS); stratification is essentially horizontal. This level is marked by an abundance of *Skolithos* characteristic for a shallow marine environment.

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Stratigraphic study on the lower part of Gebel Tabaghbagh section, Qattara Depression, North Western Desert, EGYPT; New fossil approach

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Gebel Tabaghbagh is a Tertiary stratigraphic section of considerable thickness (130 m). It is located 90 km to the east of Siwa oasis in the south of the western side of the Qattara Depression. Stratigraphically, it can be subdivided into two major units, a lower and an upper. The present work is focused on the lower part which consists mainly of alternating beds of glauconitic sandy shales, siltstones and mudstones (55 m). Fossils occur rarely. An exception represents beds 3 and 4 where limited assemblages of different types of fossils were recorded, such as shark teeth, pieces of vertebral column bones, broken pelecypods and nautiloids. 35 nautiloid specimens were collected. Five genera have been identified for the first time from this area. These are *Nautilus balcombensis*, *Deltoidonautilus* sp., *Eutrephoceras laverdei*, *Aturoidea parkinson*, and *Aturia aturi*. They are mostly crushed, partially fragmented shells, mostly showing well preserved suture lines and subcentral siphuncles in the well preserved specimens. The abundant nautiloids occur in random orientation through the clastic-dominated succession. They are mostly represented by middle-aged and mature specimens. Recently, that lower part of Gebel Tabaghbagh was assigned to the Late Eocene. The identified nautiloid assemblage, however, strongly supports a Neogene age.

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Large Benthic Foraminiferal Biostratigraphy of the Shallow Water Aptian Deposits in Central Tunisia

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Tethyan shallow waters are documented to benthic microfossils during Aptian times, notably a number of Large Benthic Foraminifera (LBF). Apart from their palaeoecological interest, these latter could also be considered as good biostratigraphical tools, especially in the absence of pelagic fauna in such shallow water environments. In that way, a biostratigraphical study is herein carried out on the basis of LBF in order to characterize the lithostratigraphic succession and the lateral extent of the Aptian shallow water series cropping out in the Jediri (HL) section of central Tunisia.

LBF stratigraphic distribution led to the establishment of three benthic foraminiferal Zones: the *Palorbitolina lenticularis* Zone of Bedoulian age followed by the early Gargasian *Orbitolinopsis* sp. Zone and the late Gargasian *Archaeoalveolina reicheli* Zone. Indeed, this LBF biozonation proposal could be improved in a hemipelagic environment hosting both pelagic and benthic assemblages in deeper localities basinwards.

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Foraminiferal Biostratigraphy and Palaeoecology Through the Campanian-Maastrichtian in Northern Tunisia

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Numerous attempts were intended worldwidely to specify the Campanian/Maastrichtian (C/M) boundary on the basis of several taxonomic groups (e.g., ammonites, foraminfera). In that way, the integrated biostratigraphical study applied at the C/M boundary GSSP (Tercis les bains, France) has resulted in the use of the First Appearance Datums (FADs) of *Rugoglobigerina scotti* and *Contusotruncana contusa* to pinpoint the early Maastrichtian. However, several prominent works suggest other foraminiferal bioevents to indicate the aforementioned boundary (e.g., the FAD of *Pseudoguembelina palpebra*). Besides, a number of key species Last Appearance Datums (LADs) might be furthermore useful to recognise the boundary (e.g., *Globotruncanita subspinosa*).

Given that ammonite occurrences could be rare in the field and might be very difficult to observe in drillings, the present work aims to characterise the composition of the foraminiferal assemblages in the Campanian/Maastrichtian (C/M) interval in order to establish an adequate biostratigraphic scheme. The subzonation herein applied is based on the evolutionary tendency of multiserial heterohelicids and rugoglobigerinids through the studied interval in northern Tunisia (KD section in El Kef and A well in the Gulf of Hammamet). Observed foraminiferal bioevents surrounding the C/M boundary in the studied localities place it stratigraphically in the lowermost part of the El Haria Formation, nearly 20 m above the Abiod Formation top.

Besides, foraminifera are also herein involved in palaeoecological indexes calculation in order to follow their behaviour during this transitional period in terms of occurrences, abundances and palaeoecological strategies.

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Carbon and strontium-isotope stratigraphy of a Middle Ordovician Bahamian-type carbonate platform (central Appalachian Basin) reveals a global carbon cycle perturbation

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Carbon isotope stratigraphy is used both to correlate strata and to recognize changes in the global carbon cycle. However, in addition to diagenesis, questions have been raised as to whether carbon isotope trends derived from shallow-water carbonate platforms are representative of dissolved inorganic carbon from a well-mixed global ocean reservoir. In response to sea level, both diagenesis and changes in water mass residence may potentially produce trends in C-isotopes on ancient carbonate platforms that are opposite to or superimposed on changes in global carbon cycle fluxes.

Because of the problems in correlating shallow and deeper-water carbonate sequences, it can be difficult to isolate global versus local signals in carbon isotope curves in shallow water sections. Studies of C-isotopes in modern carbonate platform settings such as the Great Bahama Bank (GBB) provide important analogues. For example, carbonate sediments of the GBB may have elevated C-isotopes relative to open ocean waters reflecting differential photosynthetic fractionation and precipitation of calcium carbonate (which lowers pH and converts bicarbonate into 12-C enriched carbon dioxide, leaving residual bicarbonate heavier).

Many Mesozoic studies have utilized strontium isotope stratigraphy as a means of correlating between carbonate platform settings and deeper water environments to sort out local versus global signals. These studies reveal that major global perturbations, such as those associated with oceanic anoxic events (e.g., in the early Toarcian, early Aptian, Cenomanian-Turonian), are preserved in shallow water successions.

Few Paleozoic studies have attempted to explicitly compare C-isotope trends in both restricted platform settings and open marine settings. Here, a restricted Bahamian-type carbonate platform of Middle-Late Ordovician (Darriwilian-early Sandbian) age in the central Appalachian Basin, notable for sedimentologic evidence of severe restriction and a general lack of open marine macrofauna, is compared with more open marine deposits of the Baltic region. Sr isotope stratigraphy utilizing conodont apatite as a medium allows for detailed correlations of C-isotope trends. Coeval C-isotope trends from open marine settings in the western United States and Estonia are comparable to the restricted platform in the Appalachian Basin. Local factors appear to have modified the magnitude of the global trends, but not the timing and direction. A more difficult question is whether magnitude differences are in part a function of sedimentation rate and completeness.

Integrating and correlating non-marine Early Cretaceous palaeoenvironmental and climate cyclicities – a novel multidisciplinary stratigraphic approach

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While recent refinements of the geological time scale have made major advances for the marine Cretaceous to yield a resolution at Milankovich scales (405, 100 kyr eccentricity cycles), dating of Lower Cretaceous non-marine ('continental' aquatic, limnic and terrestrial palaeoenvironments) successions is notoriously insufficient, often less accurate than stage level. As a consequence, the tremendous non-marine Cretaceous archives, such as the Lower Cretaceous of the North American Western Interior foreland basin, are practically excluded from being considered relevant for the stratigraphic record and the high-resolution Cretaceous timescale. This is primarily a result of the lack of high-resolution stratigraphy – let alone correlation to the marine standard successions. However, it is also matter of perception of the relevance of the non-marine Cretaceous record and stratigraphy: Even the existing options and potential of higher-resolution integrated non-marine (bio-)stratigraphy have not yet been – and still are not – appropriately recognized by the majority of (marine) stratigraphers in general.

A new interdisciplinary project and pioneering multi-proxy study funded by the Austrian Science Fund (FWF) uses the Lower Cretaceous European record (English Wealden) as a test site for the integration of ostracod biostratigraphy and assemblage changes, and cyclostratigraphy (orbitally/climate driven cycles). Ostracods (microcrustaceans with a calcified bivalved shell) are the most useful biostratigraphical and palaeoenvironmental tool in Lower Cretaceous non-marine sequences. During the past two decades, research progress in late Mesozoic non-marine ostracods led to their extended applicability, whereas their wide dispersal ability has become a key consideration in their supraregional (inter-basinal to global) biostratigraphical utility.

The central approach is non-marine ecostratigraphy, i.e. to 'turn the tables' in that the strong facies control – thus far widely considered a substantial drawback as to biostratigraphical utility of non-marine ostracods – shall be (re-)analysed and tested for cyclostratigraphic use. The integrative methodology applied in this project targets the correlation of the ostracod faunal composition change with the variation of geochemical and sedimentological parameters through time, and inferences on controlling (palaeoenvironmental) factors and their regulating mechanisms ('climate changes', orbital cycles?). The approach is multiple: 1) Biostratigraphy in the supraregional to global context, 2) cyclostratigraphy using ostracods, lithologic parameters and sediment geochemistry, 3) stable isotope geochemistry, and 4) magnetostratigraphy for chronological control. The combination of methods used, evaluated and optimized within the scope of this project, can then be efficiently applied on larger scopes and to larger datasets. Thus, based on the idea of a non-marine cyclostratigraphy, main objectives on a longer term are the better linking of marine and non-marine Cretaceous successions, enhancement of resolution in the considerable (particularly Lower) Cretaceous non-marine record, and integration of these data into the Cretaceous timescale.

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Cyclic climate-environmental deteriorations in the Cretaceous: Approaches and concepts towards improved marine to non-marine correlations

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Recent refinements of the geological time scale have made major advances for the Cretaceous to yield a resolution comparable to that of younger Earth history – in the marine realm. It is now for the first time possible to correlate and date significant short-term (10s kyr to a few myr, i.e., 3rd to 4th order cycles) Cretaceous sea-level records with a resolution appropriate for their detailed analysis. Investigation of the timing, the in part controversially discussed causes, and the consequences of these is the ultimate goal of the UNESCO IGCP (International Geoscience Programme) project number 609 "Climate-environmental deteriorations during greenhouse phases: Causes and consequences of short-term Cretaceous sea-level changes" (2013-2017; http://www.univie.ac.at/igcp609/). Recognized Cretaceous sea-level changes can be tied to the new, high-resolution time scales, using sea-water isotope curves and cyclostratigraphic records reflecting the major astronomical (405, 100 kyr eccentricity) cycles. This will determine whether the recognized sea-level changes are of regional or global significance and will also indicate their possible relation to climate and/or tectonic events.
In contrast, studies on non-marine Cretaceous stratigraphy, climate cycles, and changing environments (including control factors and feedback mechanisms) are few, primarily a result of the lack of high-resolution stratigraphy and correlations to the marine record. Dating of Lower Cretaceous non-marine ('continental' aquatic, limnic and terrestrial palaeoenvironments) successions is notoriously insufficient, often less accurate than stage level. Strong lateral facies change, the geologically short time intervals continuously recorded (or long timer intervals recorded with numerous, often unrecognized, hiatuses, respectively), as well as the frequent lack of (what is being considered as) adequate index fossils are characteristic of many Cretaceous non-marine successions, and are widely considered as major drawbacks regarding their age assignment and correlation.
However, above mentioned progress in Cretaceous climate change and marine cyclostratigraphy as well as progress in non-marine (bio-)stratigraphy has led to changing concepts, approaches and new hypotheses on proxies and methods for improved marine to non-marine correlations. In principle, these are based on the single synchronous, continuous signal recorded in various proxies in both marine and non-marine successions: astronomically forced, cyclic, short-term (< 1 myr) and medium-term (a few myrs) global climate change. Amongst others, such methods include the analysis of "limno-eustatic" lake-level fluctuations that are considered to have an out-of-phase interrelationship with short-term sea-level fluctuations during "hothouse" climate. Another approach is non-marine "ecostratigraphy" in interdisciplinary approaches aiming at a non-marine cyclostratigraphy, with geochronologic and magnetostratigraphic control. Non-marine microfossils – such as ostracods (microcrustaceans with a bivalved shell) for example – are considered of limited use in biostratigraphy because of their strong facies control. The consideration that palaeoenvironmental changes that control assemblage changes of microfossils along with changes of lithological and geochemical parameters of corresponding sedimentary successions are, ultimately, climatically controlled leads to the coherent approach that these cyclic(?) changes can be analysed and tested for cyclostratigraphic use. For the further develompment of the integrated, high resolution Cretaceous timescale, the integration of the idle potential of the considerable non-marine record should be tackled with more efforts.

Upper Depth Limit of selected Upper Paleogene to Neogene Benthic Foraminifera and their Potential for Improving Paleobathymetric Assessments of the Eastern Venezuela Basin.

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Between mid 1950s to late 1970s in the national oil company of Venezuela (PDVSA), numerous studies have been conducted using benthic foraminiferal. These studies had a significant impact in many oilfields located in the main oil and gas basins of Venezuela (East and West). In the Eastern Venezuela Basin (EVB), most oil and gas deposits in some cases are called as a benthic foraminiferal genus or species; for instance, in the La Pica Formation (Late Miocene) the main sandstones reservoirs are called *Sigmoilina*, *Textularia* and *Frondicularia.* These names were taken by Mene Grande Oil Company who was used these names since 1957 in order to maintain in secret their stratigraphic position and spatial distribution.

A total of thirty six (36) key wells, drilling by PDVSA in the EVB during 2000 to 2015 were selected to carry out this project. The purpose of this project is: (1) improve and update the benthic foraminiferal occurrences and dating for the Cenozoic groups, formations and members; (2) provide and update benthic foraminiferal database (3) provide an upper depth limit of key benthic foraminiferal (4) update the timestratigraphic framework, using the geologic time scale (Gradstein et al. 2012) and (5) provides an important information resource for all the projects (ESP, PGO, PGP, PEP, PDD) belongings to the department of *Proyectos Exploratorios y Delineación* (ESP, PGO, PEP, PGP and PDD).

Due to regional variations in the stratigraphic and tectonic sequences found at different wells within the EVB, it is not feasible to treat the study area as a single unit in summarizing the benthic foraminiferal biostratigraphy of it. Therefore, the EVB has been divided into five (5) regions; from northeast to southwest they are: Region 1 (Tropical / Orocual Oilfields), Region 2 (Chaguaramal / Amarilis Oilfields), Region 3 (Travi / Santa Bárbara Oilfields), Region 4 (Jusepin / El Paso Oilfields) and Region 5 (Pato / Roblote Oilfields).

For the past fifteen years, have been compiled all benthic foraminiferal reported and described in the main oilfields of Venezuela (easternmost part). The stratigraphic ranges and the bathymetric distribution of three hundred and twenty seven (327) marker species have been revised and update in order to provide the correct taxonomic information according to the new published literature for the Tropical and Caribbean Region. Microsoft Excel was used to construct a spreadsheet containing all validly calcareous and agglutinated benthic foraminifera.

The First Consistent Occurrence (FCO) and Last Consistent Occurrence (LOC) of all marker species of benthic foraminifera identified in each well have been revised as part of this study and are documented separately for each well, oilfield and region and were called Upper Depth Limit (UDL); these UDL are most useful in paleoenvironmental and paleobathymetric interpretations.

The bathymetric distributions inferred by Sanchez et al. (2014), Robertson (1998), Whittaker (1988) and van Morkhoven et al. (1986) were used for calcareous benthic foraminiferal and Kaminski and Gradstein (2005) for agglutinated benthic foraminiferal. All benthic foraminiferal provided in this study were calibrated in a timestratigraphic frameworks of Wade et al. (2011) and Gradstein et al. (2012).

As preliminary conclusions this study shows once again the relevance of how document representative paleobathymetric assessments of benthic foraminiferal faunas play a significant role in the analysis of the paleogeographic, sedimentary sequences, and tectonic histories of the Eastern Venezuela Basin. Using this database the department of *Proyectos Exploratorios y Delineación* can reduce time and cost in order to finish each project before the estimated date.

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A different stratigraphic approach to date and reconstruct the Karpatian and Badenian seas in Central Europe

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The Paratethys sea region in Central Europe experienced many paleogeographic changes during the Early-Middle Miocene. The interplay between tectonics, basin infill and eustatic sea level variations caused the existence of different marine transgressions. In many localities marine sediments of the Early Miocene ‘Karpatian’ stage are discordantly covered by marine deposits of the Middle Miocene ‘Badenian’ stage.

Distinguishing and precise dating of the different marine deposits has always been a challenge. Two difficulties are the scarcity of reliable age constraints and the fact that the regional time scale is partly based on endemic fauna and regional sea level variations that cannot be compared directly to the global record. Therefore, foraminifers and nannoplankton species are being widely used for correlation to the global time scale (e.g. Hohenegger et al., 2009; Coric et al., 2009). Most Central Paratethys research is using the biostratigraphic scheme of the Atlantic Ocean to date the successions (e.g. NN-zones). The ages of these bio-events can differ over 0.5 Myrs from those in the recently revised Mediterranean biostratigraphic schemes (e.g. MNN-zones) by Iaccarino et al. (2011) and Di Stefano et al. (2011). Here, we use the Mediterranean schemes to re-date the classic Paratethys successions of the Central Paratethys basins. This alternative approach reveals a remarkable change in Central European sea configuration.

The Karpatian sea stretched from the North Alpine Foreland Basin (S. Germany and Switzerland) to the Styrian and Vienna basins and was most likely connected to the Mediterranean via the Rhone Valley (Berger et al., 2005). Around 16.2 Ma the sea retreated westward. During a period of ~ 1 Myr (16.2 to 15.2 Ma) almost no marine sediments are present in the Central Paratethys, which is related to the ‘Styrian’ tectonic reconfiguration. Subsequently the Badenian transgression occurred through a connection via the Transtethyan corridor in Slovenia and covered Central Europe from the south (Croatian basins) to the north-west (Austrian Molasse and Vienna basins) and east (Transylvanian basin). Meanwhile, the Western Paratethys region remained continental.

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Bivalves and the stratigraphic history of the Neogene deposits of l'Oranie (Northwest Algeria)

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Bivalves are one group of molluscs that marked a significant and frequent presence in the various Neogene deposits of l'Oranie (Bas Chelif basin, Tafna basin, M'sirda Basin). This was investigated by the pioneer stratigraphers of Northwestern Algeria (e.g., Pomel, 1858; Brives, 1897; Dalloni, 1915; Perrodon, 1957). They used them quite often in association with gastropods and echinoderms to determine the first subdivisions of the Tertiary lands of l'Oranie. Indeed, the old divisions of the Miocene of Bas Chelif basin (e.g., Cartennian, Helvetian, Vindobonian) were mainly based on the frequent presence of the following bivalves: Mytilidae, Pectinidae, Ostreidae, Gryphaeidae, Veneridae, and Cardiidae. Recently, some of the pectinids are even used to establish a biostratigraphic zonation within the Mediterranean as proposed by Demarcq (1990a-b) in Ben Moussa (1994), from the upper Oligocene to the Quaternary. In the same context, the pectinids *Chlamys pesfelis, Pecten jacobaeus* and *Pecten reghiensis* and additional species (*Flabellipecten flabelliformis* and *Flabellipecten alessiii*) constitute the PN8 association which characterizes the Pliocene deposits.

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Biostratigraphy and correlation of Devonian successions in the Taurides (Turkey)

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Detailed studies on Devonian coastal to shallow marine successions in the Eastern and Central Taurides conducted within the framework of two bilateral Turkish-German cooperation projects (DEVEC-TR and DECENT) resulted in a large set of new data on the biostratigraphy for the region; furthermore, aspects of sedimentology, bio- and lithofacies, palaeogeography and global events have been also addressed. Three sections, Halevikdere and Tırtat-Kocadere in the Eastern Taurides and Eceli-Akkuyu in the Central Taurides, have been measured and sampled at high resolution. Each of the sections is more than 1000 m thick – altogether more than 4000 m of Devonian rocks have been studied. Recent biostratigraphic assignments are based on different fossil groups. Precise placement of certain boundaries, such as the Silurian/Devonian transition and the Frasnian/Famennian boundary, are of special interest and will therefore be addressed in greater detail. At other levels within the Devonian, location of stratigraphic boundaries is better achieved. This biostratigraphic control enables good correlation of the three measured sections and comparison with the established regional lithostratigraphy. Accordingly, a revision of the ages of the lithostratigraphic units is now possible. Overall changes of facies regimes through time, i.e., dominant siliciclastics in the Lower Devonian (at least in the Eastern Taurides), prevailing carbonates in the Middle and lower Upper Devonian, and mixed siliciclastics and carbonates in the upper part of the Upper Devonian can be correlated between the studied sections and compared to facies developments in regions elsewhere. Some of the Devonian global events are recognised.

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The geological history of the Carnic Alps in a global context

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The Carnic Alps of southern Austria and northern Italy represent an outstanding combination of internationally significant geological and geomorphological features. The area comprises largely unspoiled nature of unrivalled beauty. Its geology spanning the interval from the Middle Ordovician to the Triassic Periods reflects approx. 250 million years of the Earth's history, including a number of internationally important time-markers, reference sections and fossil localities. The property also contains a large range of outstanding landscape features. It is renowned for its contribution to Earth science-related activities for almost 200 years including geology, structural geology, paleontology, sedimentology, geochemistry, and Quaternary research. The rich paleontological heritage of both faunas and floras of the Paleozoic strata of the Carnic Alps is documented in several hundred scientific publications; based on more than 1500 scientific publications the Carnic Alps are considered by Earth scientists as one of the most intensively studied areas in the world.

In the Lower Palaeozoic the record of life comprises different marine environments ranging from shallow water lagoonal deposits to coral-stromatoporoid buildups, fore-reef, slope to off-shore pelagic settings. The faunal spectrum covers planctonic, nectonic and benthonic animal groups.

With regard to the Paleozoic Era, the 90 most famous world fossil sites have almost nothing in common with the Carnic Alps since they mainly comprise freshwater and shallow marine faunas (tetrapods, arthropods, fishes).

Conclusions from a comparative analysis of the properties inscribed in the UNESCO World Heritage List (WHL) reveal that, with few exceptions, major stages in Earth‘s history are not sufficiently represented in the WHL.

In fact, there is no other property than the Carnic Alps comprising six successive stages wich range from the Middle Ordovician to the Middle Triassic providing evidences of drifting plates, shifting palaeoclimates and mountain building processes.

Rocks and fossils suggest a continuous northward drift of one of the Peri-Gondwanide terranes from high southern and cool-tempered latitudes in the Ordovician to the moderate and tropical belt in the Silurian, Devonian and Carboniferous followed by an equatorial position with desert conditions in the Permian; ongoing drifting during the remaining 250 m.y. moved the continental plates to the present position. Recently, palaeomagnetic data have confirmed these settings.

The Carnic Alps fill an other important gap in Earth‘s history by documenting the Variscan Orogeny in the Middle Carboniferous. It is represented by texbook-like examples of an angular unconformity between the pre-Variscan basement rocks and the post-Variscan cover sequences.

Following the Variscan Orogeny, the late Upper Carboniferous and Lower Permian shallow-water deposits range from coastal swamps to those of an intertidal shelf embayment of the expanding Tethys Sea. They are characterized by exceptionally rich faunal and floral remains. During the late Lower Permian shelf-edge reefal deposits accumulated which were terminated due to an uplift event resulting in a short gap in sedimentation and subsequent karstification. In the Middle and Upper Permian this episode was succeeded by the red clastics of the Gröden Formation and the locally evaporitic Bellerophon Formation.

Ongoing research by different national and international working groups will certainly expand the already impressive base of knowledge in this mountain region.

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Paleomagnetic results from the volcanic massif Königsberg-Klöch in Styria indicate volcanic activity during a magnetic polarity reversal in the Pliocene

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Changes of the polarity of the earth's magnetic field are world-wide phenomena, enabling correlation and dating of geological material. For Mesozoic to Quaternary times, the geomagnetic polarity record is central to the construction of geologic time scales, linking biostratigraphies, isotope stratigraphies and absolute ages. We present the paleomagnetic results of an extensive geophysical and geological study of the Pliocene volcanic massif Königsberg-Klöch in Southeast Styria (Austria).

The southern part of the area around the hill Seindl is dominated by a batholith. Basaltic dykes, slabs and veins are related to this volcanic dome and penetrate the overlying tuff and sediment layers. The thickness of the structures varies between some centimeters and tens of meters. Geomagnetic mapping showed that the Königsberg in the North can be considered as a second volcanic centre. A connection between Königsberg and Seindl is possible. Shallow extensive layers were detected in the area between, which can be explained as lava flows. The castle of Klöch is built on another basalt body, which is restricted to the South of the hill Hochwarth.

Paleomagnetic analysis of basalts, tuff and sediments from 15 sites in the quarry Klöch and surrounding areas was performed applying thermal and alternating field demagnetization techniques. IRM (Isothermal Remanent Magnetization) and Curie temperature measurements aimed at the identification of the magnetic carrier minerals. Titanomagnetite with high contents of titanium could be observed in almost every investigated sample. Some samples contained magnetite and goethite as well. Samples from all sites yielded well clustered characteristic remanence directions with a locality mean declination of 211.0° and an inclination of -35.1°. A trend towards shallower remanence directions is observable for the tuff samples and some sediment sites. Some variation of the mean primary remanence directions of basalt samples from different positions in the locality was observable, but a discrimination of different basalt generations based on paleomagnetic vectors was not possible.

All of the investigated samples from all sites showed only inverse polarity. However, the observed inclinations are far too shallow for an undisturbed Pliocene paleomagnetic direction and the declinations point to a significant tectonic rotation (clockwise) after the remanence acquisition. Our results match with previous paleomagnetic results from the same locality and other Pliocene volcanics presented by POHL & SOFFEL (1982), who mentioned tectonic displacements in the Styrian basin as a possible working hypothesis for the unusual pole positions. Manifestations of block rotations in the Styrian basins have been reported by different authors (Gross et al., 2007; Sachsenhofer, 1997). However, the amount of tectonic displacement, that is necessary to explain the observed paleomagnetic directions, is fairly large to take place within the time span from Pliocene to present.

Volcanic activity during a pole reversal might be another possible reason for the deviant paleomagnetic directions of the Pliocene rocks in the Styrian Basin. K/Ar-datings yielded an age of 2,56 Ma for the basalt of Klöch (Balogh et al., 1994), that matches with the Gauss-Matuyama boundary. However, the uncertainty of the age determination is fairly large (± 1,2 Ma) and several other polarity changes of the Earth´s magnetic field have to be considered as potential candidates for a correlation in this time interval. Further investigations including magnetic paleointensity determinations are needed to determine the reason for the abnormal paleomagnetic directions and the exact chronostratigraphic positioning of the basalts.

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Early Eocene Danish tephra-bearing lagerstatten offers excellent stratigraphic correlation archive and evidence of pioneer intercontinental biota migration

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The Fur Formation is a Danish fossil-rich and tephra-bearing marine diatomite (~55,6 - 54,5 Ma), deposited under neritic conditions. The deposit holds large calcareous concretions and glendonite interbedded with over 200 distinct tephra layers originating from early stages of the North Atlantic Igneous Province (NAIP) and is known for supplying accurate $^{40}Ar/^{39}Ar$ radiometric datings (e.g., Storey et al., 2007). The Paleocene-Eocene boundary occurs at the base of the Stolleklint Clay, immediately underlying the Fur Fm. The Stolleklint Clay was deposited during the 200 ky Paleocene-Eocene Thermal Maximum event (PETM; ~55.8 Ma). The Early Eocene is characterised by long-term global warming during which a partially new biota was established. During the PETM, a massive release of methane and/or carbon dioxide resulted in a global temperature increase of 5–8° C that lasted for ~200 ky. This Eocene hyperthermal resulted in subtropical climates at high latitudes. Organic geochemical studies (Schoon et al., 2015) indicated the temperature development across the PETM in Denmark and generation of photic zone anoxia. Pollen and spores of the recovery phase of the PETM were described by Willumsen (2004). The Fur Fm. can be precisely correlated to other European Early Eocene deposits that contain NAIP ash layers, such as the Danish Ølst Fm. and Austrian sections (Egger and Rögl, 2012), but also to the many PETM sections around the world. The Fur Fm. does not only include marine taxa (diatoms, fish, >10 turtles), but also elements of nearby terrestrial environments, indicated by 150 spore and pollen species, fruits, leaves and driftwood, 200 insect and >30 bird species. Special attention has been given to the birds, insects, fish and a large marine turtle. For example, Lindgren et al. (2014) has shown that the turtles, fish and birds pioneered the field of preserved melanomas. Furthermore, Bonde (2008) has verified a marine stage for osteoglossomorphs, which were before only known as freshwater fish. Insects such as giant ants, have migrated across Greenland (Archibald et al., 2012). For a geologically brief period, the existence of land bridges over Arctic regions and Greenland, allowed for the migration of insects and plants between North America and Europe. To conclude, the diatomite at Fur holds an important and rare record of both the earliest Eocene floral, faunal and environmental changes.

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Lithostratigraphy in crystalline rocks – experiences from the Eastern Alps

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The Alps are one of the orogenic belts that have been studied in detail. It formed since the Early Cretaceous from narrow paleogeographic realms and exhibits a complex tectonic history. Large areas of the Alps have been mapped before modern lithostratigraphy has been established, but until now most of the diagenetic and weakly metamorphosed Mesozoic and Paleozoic successions have been subdivided into lithostratigraphic units properly. In contrast minor amounts of the metamorphic rocks are grouped and formalised in lithodemic units. Experiences from the past 15 years show that the lithodemic nomenclature of the NACSN (2005) is a proper tool for the subdivision of crystalline areas within a young orogenic belt, but there are some aspects which should be mentioned when an earlier traditionally established nomenclature exists:

In general, orogenic belts are characterized by a decrease in metamorphic grade from the internal to the external zones. In former maps of the Eastern Alps tectonic boundaries within the metamorphosed internal zone are shown only in places where slivers of Mesozoic metasediments could be identified between a huge scale of mica schists and paragneisses. The latter were denoted as “Altkristallin” (old crystalline) and thought to represent Variscan consolidated basement. However, modern petrological and geochronological investigations revealed internal metamorphic and lithological discontinuities within the “Altkristallin” implying nappe boundaries between different units. Often these units are indicated by the occurrence of special rock types (e.g., eclogites, different types of orthogneisses) appearing within macroscopically similar metapelites and metapsammites. However, to produce consistent maps these rocks have to be subdivided and grouped in lithodemic units.

Names have to be created for these newly identified units and it has to be decided whether a traditional term (e.g., “Radegund crystalline unit”) is altered or a new one is created. In general, altered traditional terms are accepted rather than new ones, but in addition it has to be proofed if the traditional term has been used in a tectonic or lithostratigraphic sense. There is no rule prohibiting to use the same local term for a tectonic (e.g. Radegund Nappe) or lithostratigraphic unit (e.g. Radegund Lithodeme). However, this should not be the target solution because it may cause confusion.

To state the rank of a lithodemic unit is not always unambiguous. Units mostly include metasedimentary and metaigneous rocks and therefore have to be defined as complexes (“an assemblage or mixture of rocks of two or more genetic classes”, NACSN, 2005). Rarely is it possible to subdivide these complexes completely into lithodemes. For example, most complexes of the Austroalpine Superunit contain marbles. These marbles are present as distinct layers with characteristic features, but also appear as irregular distributed bodies, boudins and tiny patches with variable mineralogical composition and colour. The distinct layers can by formalised as lithodemes but for smaller bodies it is not clear whether they represent one co-genetic lithodemic unit or another.

Furthermore, in many cases distinct formations from the terminal and unmetamorphosed fold and thrust belts are traceable into metamorphosed areas. In these cases the metamorphosed rocks may be part of the same formation or separated from latter as metamorphosed equivalent but individual named units. This problem has been also addressed for Precambrian areas (Easton, 2009). In younger orogenes, like the Alps, intense deformation creates an even more complicated situation, because the distribution of now dispersed formerly continuous layers over several thrust sheets with different metamorphic grade is challenging. Previous experience suggests to separate the metamorphosed rocks from their unmetamorphosed precursor rocks when they are remarkably different or penetratively deformed with (highly) complicated structural relations. For example a formation consisting of shales and limestones at the type locality should not include garnet-mica schists and marbles.

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Palaeogeographic significance of the unconformity between Hauterivian/Barremian and pre-Cretaceous in eastern Asia

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There commonly exists a plane of unconformity and a large depositional gap between Hauterivian/Barremian and pre-Cretaceous in both continental and marine facies of eastern Asia. In SW Japan, the Hauterivian Albian Tetori Group of Inner Zone and Monobegwa Group of Outer Zone are respectively rests unconformably on the pre-Jurassic Hida Metagranites and Permian Accretionary Complexes. In Gyeongsang Basin of SE Korea, the Aptian Albian Sindong Group unconformably overlies the Valanginian Myogog Formation which is unconformable with the pre-Cambrian Wonnam Formation. In Transbaikalia area of SE Russia, the Hauterivian Albian Tranbaikalia Group is unconformably resting on the Middle Jurassic Tugnui Formation. In Choyr Basin of SE Mongolia, the Barremian Aptian Khalzan Formation unconformably overlies the pre-Cambrian Formation. In NE China, the Hauterivian Barremian Longzhaogou Group and Jixi Group unconformably overlie the Permian or older basement in eastern Heilongjiang, the Hauterivian Aptian Jehol Group unconformably rests on the Valanginian Tuchengzi Formation which is unconformable or disconformable with the pre-Tithonian Tiaojishan/Lanqi Formation in western Liaoning, the Hauterivian Huoshiling Formation of Songliao Basin, Hauterivian Barremian Tuntianying Formation of Yanji Basin, Wuyiling Group of Jiayin Xunke basin, Xing'anling Group of Hailaer and Erlian basins are all unconformably overlying the pre-Cretaceous as early as Palaeozoic rocks. In Zhejiang of eastern China, the Hauterivian early Albian Jiande Group is apparently unconformable with the Middle Jurassic Yushanjian Formation. In Peninsular Thailand, the Aptian Lam Thap Formation unconformably overlies the Jurassic Khlong Min Formation. Furthermore, all the Cretaceous basins were oriented subparallel to the NE- to NNE-trending fault zones, and almost all the Hauterivian Albian rocks overlying the unconformity more or less contain violently eruptive volcanic rocks including lavas and tuffs.

Such widely distributed unconformity and distinct hiatus, and the Hauterivian Albian volcanics overlying the unconformity probably have demonstrated that 1) during Hauterivian/Barremian Tithonian even earlier eastern Asia was major in an upland condition that was affected by uplift associated with orogeny, caused by the downgoing and squeezing of Palaeo-Pacific plate to eastern Asian continent. As a result, eastern Asian landmass was suffered a long-lasting erosion and the ecosystem of Yanliao Biota was destroyed. 2) The non-marine Cretaceous basins containing eruptive volcanics mostly did not develop until the Hauterivian/Barremian, within the peak time (130~120 Ma) of destruction of the North China Craton. They were controlled by faults and particularly tectonic movements associated with violent volcanic eruptions and local transgressions, caused by the retreat of Palaeo-Pacific plate, creating an environment especially suitable for the origin and thriving of Jehol Biota.

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The middle-late Eocene nannofossil bioevents in the Bakhchisaray section, Crimea

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The continuous succession of the middle to late Eocene sediments is exposed in the quarry of cement plant and southern slope of Kazantash Mountain in the northeastern outskirts of the town of Bakhchisaray, southwestern Crimea. It is composed by greenish marly limestone of “Keresta” Fm. (ca. 30 m of exposed thickness), dark thinly laminated limestone of Kuma Fm. (ca. 40 m, up to 7% TOC) and white limestone of Belaya Glina Fm. (ca. 50 m). All sediments contain abundant, diverse and well preserved nannofossils.

Nannofossil assemblage of “Keresta” Fm. is characterized by high species diversity (>60 species) and includes abundant *Discoaster*, *Chiasmolithus* and *Sphenolithus*, which characterize temperate basin with normal oxygenation. In the Kuma Fm., nannofossils persist to be very abundant, but the assemblage becomes to be less diverse (<50 species). It is widely dominated by reticulofenestrids and contains diverse holococcoliths, while both discoasters and chiasmoliths dramatically reduce their abundance. This nannofossil turnover is evidently related to increased eutrophication and relative cooling of the basin. In the Belaya Glina Fm., the relatively poorer assemblage (<40 species) is dominated by *Reticulofenestra* and *Dictyococcites*, while *Discoaster* and *Chiasmolithus* slightly recover their abundance.

The nannofossil assemblage at the base of exposed succession contains *Nannotetrina* spp., *Chiasmolithus gigas*, *Sphenolithus furcatolitoides* and corresponds to CP13b subzone (=NP15 part, CNE10). The most important nannofossil bioevents up the section are as follows:

“Keresta” Fm.

- increase in abundance of *Sphenolithus cuniculus* (base of CNE11 zone);
- last occurrence (LO) of *Chiasmolithus gigas* (base of CP13c = CNE12).
- first occurrence (FO) of *Dictyococcites scrippsae*;

Kuma Fm.

- LO of *Nannotetrina* spp.;
- FO of *Reticulofenestra umbilicus* (base of CP14a and CNE13);
- FO of *Cribrocentrum reticulatum* (base of CNE14);
- FOs of *Sphenolithus predistentus* and *Reticulofenestra oamaruensis*;
- LO of *Blackites gladius* (base of NP16)
- FO of rare *Cribrocentrum erbae*;
- LO of *Sphenolithus furcatolitoides*;
- FO of *Dictyococcites bisectus* (base of CNE15);
- LO of *Discoaster bifax*;
- FO of *Corannulus germanicus*;
- LO of *Sphenolithus spiniger* and *Chiasmolithus solitus* (base of CP14b and NP17);
- FO of rare *Chiasmolithus oamarusensis*;

Belaya Glina Fm.

- constant *Chiasmolithus oamarusensis* (base of NP18);
- FO of rare *Isthmolithus recurvus*;
- LO of *Chiasmolithus grandis* (base of CP15a);
- constant *Isthmolithus recurvus* (base of CP15b and NP19);
- FO of *Cribrocentrum isabellae* (base of CNE19);
- LO of *Cribrocentrum reticulatum* (base of CNE20).

The scarcity of *Sphenolithus obtusus* and *Cribrocentrum erbae* in the section does not allow to define the LO of the first and common occurrence of the later that make the recognition of the zones CNE16, CNE17 and CNE18 in the section impossible.

Middle-late Eocene nannofossils and palynomorphs from the Landzhar outcrop section, southern Armenia

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During the Paleogene, the south Armenian marine basin, located southward the Lesser Caucasus Archipelago, was a transitional area between the Tethys and Peri-Tethys and characterized by siliciclasctic and calcareous-siliciclastic sedimentation with significant portion of tuffaceous material. The middle-upper Eocene sediments of the Landzhar outcrop section (Arax fold zone, south Armenia) revealed relatively diverse nannofossil and palynomorph assemblages that enabled the recognition of a number of important nannoplankton and dinocyst bio-events.

Nannofossils are rather abundant in the most part of the studied succession, but they progressively reduce their abundance toward the top. Nannofossil assemblages are dominated by *Cyclicargolithus floridanus*, *Dictyococcites* spp. and *Reticulofenestra* spp., while discoasters are rare and chiasmoliths are scarce. Palynological assemblages within the studied part of the Landzhar section demonstrate significant changes in ratio between dinocysts, other algae and continental palynomorphs. Thus, the lower part of the section is characterized by the alternation of dinocysts (up to 60%) and prasinophytes dominance. The middle part of the studied section revealed an important increase in bissacate pollen and is characterized by the alternation of dinocyst and conifers dominance. The upper part of the section differs by significant reduction of dinocysts (from 20% to 0%) and an evident dominance of continental palynomorphs. Dinocyst assemblages, in their turn, are relatively diverse in the lower part of the studied section interval. They are dominant by *Achilleodinium biformoides*-acme in the lowermost part, replaced in the following by the *Enneadocysta* and *Spiniferites* eco-groups dominance. Significant drop of presumably autotroph *Enneadocysta*- and *Spiniferites*-groups and an increase of deflandroids (up to 50%) characterize the middle part of the section. The upper part of the section, revealed almost monospecific dinocyst assemblage dominated by *Deflandrea phosphoritica*.

The lower part of studied interval of the Landzhar section corresponds to the late middle Eocene CP14b subzone (=NP17) and contains nannofossils *Reticulofenestra umbilicus*, *Dictyococcites bisectus*, *Cribrocentrum reticulatum*, *C erbae*, a.o. The lowermost part of this interval can be identified as CNE15 zone by the occurrence of *Sphenolithus obtusus* (Agnini et al., 2014). It is featured by presence of dinocysts *Enneadocysta pectiniformis, Enneadocysta robusta, Rhombodinium aidae, Thalassiphora fenestrata,* and a series of first occurrences (FOs) of *Enneadocysta multicornuta, Rhombodinium rhomboideum, Cooksonidium capricornum*-group and *Wetzeliella spinula*. The base of CNE16, defined by last occurrence (LO) of *S. obtusus*, corresponds to the FOs of nannofossil *Corannulus germanicus* nannofossil and dinocyst *Rhombodinium draco-prosum*. Successive FOs of dinocysts *Hemiplacophora semilunifera, Enneadocysta deconinckii, Enneadocysta harrisii* and *Reticulatosphaera actinocoronata* characterize this interval. Slight increase in *Cribrocentrum erbae* abundance up to the section allows to suggest the CNE17 zone. The change from *Enneadocysta*-group dominated dinocyst assemblages to deflandroids dominated assemblafe corresponds to the base of this interval. The LO of *Chiasmolithus grandis* (top of CP14 zone), which lies at to the Bartonian/Priabonian transition, is revealed within this interval. Above this level, impoverished nannofossil assemblage includes common coccoliths and very rare *Dictyococcites bisectus, Discoaster barbadiensis* and *D. saipanensis*. The Eocene/Oligocene boundary is marked by the LOs of rosette-shaped discoasters and the FO of dinocyst *Wetzeliella gochtii*.

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Microfacies of P-Tr and O-S boundary layers in Upper Yangtze Region, China: implications for delayed mass extinctions after main volcanic events

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In Upper Yangtze Region, continuous and complete sequences of the Permina-Triassic and Ordovician-Silurian boundary (PTB and OSB) are marked by abrupt lithological changes and multiple clay layers. Three main sections, i.e. Shangsi P-Tr Section in Guangyuan, Dongsheng P-Tr Section in Nanchuan and Qiliao O-S Section in Shizhu are selected and the microfacies of these boundary sections representing two mass extinctions in the Phanerozoic are obtained. Both mass extinctions occurred shortly after and asynchronously with the main and thickest tuff layers, even though the corresponding volcanic events might cause lithologic changes and the termination of carbonate deposition.

In Shangsi Section, along with the tuff called as white clay reflecting the PTB volcanic activity, the depositional environment changed from the latest Permian relatively deep-water Basin to early Triassic shallow-water continental shelf (Jin & Huang, 1985). The boundary clay layers are mainly in Bed 25 (0.15 m) and the Bed 27 (0.15 m). Bed 27 can be divided into three sub-beds, i.e. Bed 27a (0.04 m, shale), Bed 27b (0.06 m, tuff) and Bed 27c (0.05 m, shale). Bed 26 with 0.25 m thick is radiolarian silicalite and Bed 28 is mainly silty mudstone (Jin & Huang, 1985), at the lower part of which the PTB deposited (Jiang et al., 2007). The radiolarian silicalite deposited above the thicker tuff (Bed 25), which indicates that the main volcanic event did not cause the so called chert gap.

The PTB layers in Dongsheng Section are mainly composed of limestone and deposited on a carbonate platform. The dark gray bioclastic limestone of Permian Changxing Formation is overlain by the boundary clay which then changes into the laminated Feixianguan Formation of shale and microcrystalline limestone. In this boundary succession (2.8 m thick), six tuff layers of cm-scale could be recognized among which the thickest one is up to 8 cm. Fossils of corals, bryozoans, crinoids, ammonoids, bivalves, brachiopods, etc. can be seen above this thickest PTB clay, which is similar to that in the GSSP Meishan Section.

At Qiliao, the grayish-green argillaceous limestone of the upper Ordovician Linxiang Formation was deposited on a carbonate platform and tuff layers developed on the top. The thickest tuff bed is found at the boundary of Linxiang Formation and Wufeng Formation, indicating the termination of carbonate production. The thickness of the uppermost Ordovician Wufeng Formation is 10.45 m and it contains mainly black carbonaceous shale of basin facies. In the lower and middle part of Wufeng Formation, at least 12 tuff layers in cm-scale are seen and a 0.35 m thick siltstone layer develops on the top overlain by black shale of the Silurian Longmaxi Formation. The OSB event appeared on the top of the Wufeng Formation, indicating that this mass extinction happened some time after the late Ordovician volcanic activities.

It has been widely assumed that volcanic events were the cause of mass extinctions. However, it is revealed in this study that radiolarian silicalite and bryozoan-crinoid fossils were still deposited after the main PTB volcanic event. In latest Ordovician, the shale of more than 10 m thickness was deposited between the main volcanic event and the mass extinction. Even the uppermost tuff is about 1.1 m lower than the OSB extinction. The cause needs further study.

Towards a natural time scale for the Proterozoic Eon: Examples from the Cryogenian and Tonian

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This year a rock-based definition for the base of the Cryogenian System has been added to the international geological time scale. The new Cryogenian Period begins at c. 720 Ma, pending formal ratification of a GSSP, and so brackets in time the major glaciations of the Neoproterozoic (commonly referred to as the Sturtian and the Marinoan). Although glacigenic strata of this age are very common around the world, pre-glacial shallow marine facies, in which to place any future GSSP, tend to be eroded. Recent Sr- and C-isotopic data from pre-glacial carbonate successions appear to confirm this and exhibit variously truncated trends. Over the past few years, we have begun to reconstruct the isotopic evolution of seawater from pre-Cryogenian strata on the Sino-Korean craton (North China Block) that cover the interval from c. 900 - c. 780 Ma, based on isotope-based correlations with other continents. A negative carbon isotope excursion, evident in the Majiatun Formation near Dalian (~ Shijia Formation near Xuzhou), can be correlated using Sr isotope data with the global 'Bitter Springs Negative Anomaly', which is constrained to c. 800 Ma. Underlying strata exhibit more muted $\delta^{13}C$ variability and much lower $^{87}Sr/^{86}Sr$ values typical of the pre-800 Ma Neoproterozoic. In the continued absence of adequate biostratigraphic control, carbon isotope stratigraphy, cross-referenced against the emerging Neoproterozoic seawater $^{87}Sr/^{86}Sr$ curve, is the favoured method of calibrating Tonian strata around the world. The stage is set for discussions to establish a more natural rock-based subdivision of the rest of the Proterozoic.

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The sedimentary record and petrophysical logs from the Spanish Central Pyrenees: Implications for paleoclimate change in the Early Devonian

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High-resolution petrophysical correlation methods were applied for the first time to the mid-Paleozoic rocks of the Pyrenees. The methods include magnetic susceptibility measurements (MS), gamma-ray spectrometry (GRS) and alignment of MS logs using the dynamic time warping (DTW) algorithm. The primary intention of the study was to attain the highest precision of stratigraphic correlation especially at the Lochkovian–Pragian boundary interval. Conodont biostratigraphy provided the basic framework for the GRS and MS logs. In spite of differences in sediment patterns and accumulation/erosion rates, the logs from two selected sections in the Spanish Central Pyrenees show a striking symmetry that also correlates well with the previously published logs from the Prague Synform in the Czech Republic. The high similarity between the petrophysical records from paleogeographically related but distant areas has a potential to contribute to present discussions about the prominent eustatic and climatic changes at the transition from the Lochkovian to the Pragian.

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Introducing Ammonites of the Delichay Formation in Polour Section (Central Alborz, Iran)

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In this research lithostratigahphy and biostratigraphy have been studied in south Polour of the central Alborz zone. According to the field observations about 80 meter of the thickness of Delichay formation in this zone is systematically sampled. In the whole mass of rocks, lithological characters have been noticed while sampling. Ammonite samples have been gathered among the layers and debris, sent to the laboratory in order to study and identify the genus and species. The importance is that the lithologic characteristics, including texture and structure, do not differ a lot from the type section of Delichay. In this section, the Delichay formation is composed of alternating marls and limestones with a rich ammonite fauna. Below the Delichay formation the Shemshak formation occurs and it is overlain by the Lar limestone formation with a gradual contact. Remarkable concerning the lithology of the Delichay formation are thin layers at the basis with many cracks which become continuously thicker upsection and contain iron layers. Sometimes thin clastic layers are observed in the limestone. As a whole, the formation is gray. According to the fossil content over the whole formation thickness 8 types of ammonits have been identified. The identified species are:
Sowerbyceras PARONA & BONARELLI, 1895, *Hecticoceras* BONARELLI, 1893, *Macrocephalites* ZITTEL, 1884, *Rehmannia*, SCHIRARDIN, 1956, *Reineckeia* BAYLE, 1878, *Procerites* SIEMIRADZKI, 1898, *Loboplanulites* BUCKMAN, 1925, *Choffatia* SIEMIRADZKI, 1898, *Homoeoplanulites* BUCKMAN, 1922.
The oldest ammonite which is identified in the studied section is *Procerites* sp. (early Bathonian) and the youngest is *Reineckeia* sp. (late Callovian) giving an age of the Delichay formation ranging from early Bathonian to late Callovian.

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Dinoflagellate cysts across the Cretaceous/Paleogene boundary, Dababyia corehole, Southern Egypt

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The current study present qualitative palynological analyses of 52 samples from ca. 70 m continuous core drilled in the Dababyia Protectorate, near Luxor, Southern Egypt, covering the late Cretaceous-early Paleocene. The core penetrated the Dakhala Shale Formation (in parts) and the section is dated by foraminifera and calcareous nannoplankton. A rich dinoflagellate cysts assemblage is recovered and about 200 species and subspecies are identified. No sharp qualitative changes in the dinoflagellate cyst assemblage occur which could confirm the continuous sedimentation across the late Maastrichtian-early Danian.as previously stated. The determination of the late Cretaceous and early Paleocene is based on global dinoflagellate cyst bioevents. Whereas, latest Maastrichtian is recognized by the last occurrence (LO) of *Dinogymnium* spp. and *Alisogymnium euclaense* and the first occurrence (FO) of *Carpatella cornuta, Senoniasphaera inornata, Palynodinium grallator, Disphaerogena carposphaeropsis, Glaphyrocysta perforata, Senoniasphaera inornata, Membranilarnacia tenella and Manumiella seelandica.* The earliest Danian bioevent is indicated by the first occurrence of *Damassadinium californicum, Kallosphaeridium yorubaense, Cassidium fragilis and Alisocysta circumtabulata.*

In comparison with regional and global published data, the recorded assemblage confirms a Maastrichtian to Danian age for the studied part of the core. Finally, the dinoflagellate cysts findings coincide with the published data and the Maastrichtian/Danian boundary is suggested to be at 80.25 m depth.

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Dinoflagellate biostratigraphy in the Miocene of the Western Central Paratethys

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A detailed dinoflagellate cyst investigation of more than twenty surface outcrops and exploratory drill holes from Upper Oligocene - Miocene successions in the North Alpine Foreland Basin as well as the Vienna and Styrian basins (Austria), Western Central Paratethys, is conducted and a biozonation for the studied interval is suggested. The proposed dinoflagellate zonation of the Western Central Paratethys "WCPD" (WCPD1-WCPD8; upper Chattian – Tortonian; Egerian-Pannonian) is based on the first occurrences (FO) and last occurrences (LO) of many selected marker taxa. The zonation consists of eight interval biozones, they are from the oldest to the youngest:
WCPD1- *Deflandrea phosphoritica* (upper Chattian-mid Aquitanian (Egerian); NP25-lower NN2).
WCPD2- *Sumatradinium soucouyantiae* (upper Aquitanian-mid Burdigalian (Eggenburgian); NN2).
WCPD3- *Exochosphaeridium insigne* (mid Burdigalian (uppermost Eggenburgian-Uppermost Ottnangian); uppermost NN2-Lower NN4).
WCPD4- *Distatodinium paradoxum* (upper Burdigalian (uppermost Ottnangian-Karpatian); NN4).
WCPD5- *Operculodinium*? *borgerholtense* (lower Langhian (lower Badenian); Upper NN4.
WCPD6- *Unipontidinium aquaeductum* (upper Langhian-lower Serravallian (mid-upper Badenian); upper NN4-lower NN6.
WCPD7- *Pentadinium laticinctum* (upper Serravallian (Sarmatian); upper NN6-lower NN7.
WCPD8- *Spiniferites Oblongus* (lower Tortonian (lower Pannonian); upper NN7-NN8.

Many of the lower and middle Miocene stratigraphically most important taxa recorded from, e.g., the Mediterranean and the North Atlantic have been found. Due to the very restricted environmental conditions which prevailed during the late Miocene in the Central Paratethys most of the described dinoflagellates are endemic. The zonation is partly well age-constrained and can be correlated to the previously published Miocene dinocyst zonations of the North Sea Basin, the North Atlantic and of Northwestern Europe. This study demonstrates the applicability of dinoflagellate cyst markers from Late Oligocene and the Miocene for a detailed biostratigraphic correlation in the Western Central Paratethys.

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Integrated Sr isotope variations and global environmental changes through the Late Permian to early Late Triassic

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New $^{87}Sr/^{86}Sr$ data based on 127 well-preserved and well-dated conodont samples from South China were measured using a new technique (LA-MC-ICPMS) based on single conodont albid crown analysis. These reveal a spectacular climb in seawater $^{87}Sr/^{86}Sr$ ratios during the Early Triassic that was the most rapid of the Phanerozoic. The rapid increase began in Bed 25 of the Meishan section (GSSP of the Permian-Triassic boundary, PTB), and coincided closely with the latest Permian extinction. Modelling results indicate that the accelerated rise of $^{87}Sr/^{86}Sr$ ratios can be ascribed to a rapid increase (> 2.8×) of riverine flux of Sr caused by intensified weathering. This phenomenon could in turn be related to an intensification of warming-driven run-off and vegetation die-off. Continued rise of $^{87}Sr/^{86}Sr$ ratios in the Early Triassic indicates that continental weathering rates were enhanced > 1.9 times compared to that of the Late Permian. Continental weathering rates began to decline in the middle-late Spathian, which may have played a role in the decrease of oceanic anoxia and recovery of marine benthos. The $^{87}Sr/^{86}Sr$ values decline gradually into the Middle Triassic to an equilibrium values around 1.2 times those of the Late Permian level, suggesting that vegetation coverage did not attain pre-extinction levels thereby allowing higher run-off.

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Termination of the Early Triassic hyper-greenhouse by enhanced organic carbon burial at the Smithian-Spathian boundary

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The Smithian-Spathian boundary (SSB) at ~250 Ma records what was likely the most profound climatic-biotic event of the Early Triassic in the aftermath of the end-Permian mass extinction. The SSB was associated with the termination of the Early Triassic hyper-greenhouse climate, a large (+6‰) positive carbon isotope excursion, a second-order mass extinction event, and large dislocations among marine and terrestrial biotas. However, the underlying cause of these biotic and environmental changes and their interrelationships remain poorly understood. Here, we undertake petrographic and geochemical analyses of the iron-sulfur-carbon (Fe-S-C) system in two SSB sections in South China. Iron speciation and pyrite framboid size data demonstrate that euxinic conditions prevailed at least locally during a possible interval of ~60 - 300 kyr at the SSB. Concurrent positive excursions in $\delta^{13}C_{carb}$ and $\delta^{34}S_{CAS}$ are evidence of enhanced burial of organic carbon and pyrite on a regional or global scale. Both patterns are attributed to a transient increase in marine productivity and the sinking flux of organic carbon, causing an expansion of oceanic oxygen-minimum zones that enhanced organic burial. Modeling shows that the combination of large $\delta^{13}C_{carb}$ and $\delta^{34}S_{CAS}$ excursions and limited areas of seafloor anoxia (as required for oceanic oxygen-minimum zones) is most readily achieved through low seawater sulfate concentrations (~1 mM) and a prolonged SSB event interval (~300 kyr). Global climatic cooling of >4°C is likely to have triggered the SSB event, and a positive feedback driven by falling atmospheric CO_2 levels as a result of organic burial would have intensified cooling for the event interval. Changes in oceanic and atmospheric conditions at the SSB had a profound influence on marine and terrestrial biotas and, thus, the tempo and pattern of the Early Triassic recovery from the end-Permian mass extinction.

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An investigation on the sediment and metals export during storm events in a humid area

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The transport and subsequent deposition of sediments and metals in natural environments are dominated by hydrological processes and these, in turn, by climatic factors and the specific characteristics of the drainage area.
In this work an analysis of temporal variability in the transport of sediment and metals (Cu, Zn, Al, Fe, Mn) on small time scales (storm-event) was carried out in a small rural headwater catchment located in NW Spain. The geology is uniform across the site, comprised by basic metamorphic schists of the Órdenes Complex formed by easily alterable minerals, such as biotite (sometimes chlorite), plagioclase and amphiboles. Most common soils in the catchment are Umbrisols and Cambisols, characterised by acid pH, silty and silty-loam texture and variable organic matter content in the topsoil. The catchment land cover consists of a mixture of forest (65%), agricultural fields (30%) and impervious areas (5%). The area's climate is humid temperate. Mean annual temperature is 13 °C. Mean annual rainfall is 1020 mm and it is usually concentrated in autumn and winter. Consequently, most storm events occurred in autumn and winter.
About 100 storm events (rainfall ranging from 7 to 110 mm) were analysed. Sediment and metal loads were obtained from water samples collected with an autosampler at the catchment outlet. Sediment concentrations were determined gravimetrically by passing the water samples through filters (0.45 µm). Total and dissolved metals were measured with ICP-MS. Particulate concentrations were calculated from the difference between total and dissolved concentrations. Chemical analyses were combined with discharge measurements to calculate loads. Sediment and metal loads were determined by the sum of the product of mean concentration and the discharge increase between two consecutive samples.
The results showed the following order of metal exportation: Fe > Al > Mn > Zn > Cu. Storm events were characterised by a high variability in sediment and metal loads (e.g. total Al ranged about from 0.1 to 653 kg and total Cu between 0.0007 and 0.8 kg), a few events representing a high percentage of the sediments and metals exported. Thus, about 65%-70% of load of each metal exported occurred in only 15 out of the events studied. The largest sediment and metal loads were observed during events of great rainfall and runoff magnitudes, but in addition to rainfall and runoff, other processes such as soil erosion favour the sediment and metal loads in the stream. The metal fraction mainly exported corresponded to the particulate indicating that the transport of these elements during storm events essentially occurred linked to particles.

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Proposal for a revised Famennian (Upper Devonian) standard conodont zonation

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The proposal for a revision of the Famennian part of the Late Devonian Standard Conodont Zonation of Ziegler and Sandberg (1990) is based mainly on two different conceptual considerations: 1) philosophical, refusing the equivalence between biozones and time, and the presumed phyletic concept on which this zonation was based; 2) practical, trying to solve difficulties that arose in the recognition of some biozones defined by Last Appearance Datum (LAD), and to simplify the zonation eliminating the zonal groups named after only one taxon.
The proposed revision is largely based on the zonation of Ziegler (1962) and the Late Devonian Standard Conodont Zonation of Ziegler and Sandberg (1990) using mostly the same zonal markers, and therefore is for the most part correlatable with them. Modifications have been only made when strictly necessary, as the aim of the proposal is to keep stability over more than 50 years of studies.
The 22 zones constituting the revised zonation are defined by the First Appearance Datum (FAD) of species and subspecies whose stratigraphic ranges are well known, and have wide geographic distribution. Each zone is named after the species or subspecies whose FAD defines the lower boundary. The proposed biozones in stratigraphic order are: *Palmatolepis subperlobata*, *Palmatolepis triangularis*, *Palmatolepis delicatula platys*, *Palmatolepis minuta minuta*, *Palmatolepis crepida*, *Palmatolepis termini*, *Palmatolepis glabra prima*, *Palmatolepis glabra pectinata*, *Palmatolepis rhomboidea*, *Palmatolepis gracilis gracilis*, *Palmatolepis marginifera marginifera*, *Palmatolepis marginifera uthaensis*, *Alternognathus beulensis*, *Palmatolepis rugosa trachytera*, *Pseudopolygnathus granulosus*, *Polygnathus styriacus*, *Palmatolepis gracilis manca*, *Palmatolepis gracilis expansa*, *Bispathodus aculeatus aculeatus*, *Bispathodus costatus*, *Bispathodus ultimus*, and *Protognathodus kockeli*. The stratigraphic distribution of most Famennian conodont taxa has been updated on data available in literature, and unpublished information of the authors.
The lower boundary of the Famennian is identified as proposed by Klapper (2007), a revision of the current definition of the base of the Famennian is therefore suggested. The definition of the upper boundary (base of the Carboniferous System) is currently under discussion and study.

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Ocean Acidification, the Permian Mass Extinction and the Naked Coral Effect

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Paleozoic corals and reefs died out at the Permo-Triassic boundary, along with a wide variety of other shallow-water calcifying marine organisms. This greatest extinction so indelibly etched in Earth's fossil record, created the well-known Triassic gap for both corals and reefs. The post-extinction interval of the Early Triassic was a time of anoxia, perturbation of the marine carbon cycle, and other changes. Modern corals (order Scleractinia) building reefs today, have a rare single occurrence in the Permian but then in Middle Triassic time, some 10-12 million years after the Permian, there is a sudden appearance of high diversity calcified corals. The diversity and advanced corallum morphologies were unexpected for a newly evolved group, implying a lengthy history without a fossil record. The "Naked Coral" hypothesis was proposed to explain this sudden appearance. It posits that the coral's skeleton is ephemeral with respect to calcification, allowing both calcified and "naked" or skeletonless forms to exist. The Naked Coral effect could explain extinction gaps in the stratigraphic record and major calcification events. However the triggers for such changes remained unclear.

The final phase of the Permian extinction, under continuing Siberian Trap volcanism, resulted in an abrupt injection of large amounts of carbon into the oceans created severe ocean acidification (OA). This OA negatively affected many calcifying organisms and reduced deposition of carbonate sediment in the succeeding Triassic. Physiologically reef corals are hypercalcifying unbuffered organisms so biomineralization is negatively affected by the Ω Arag and increasing pCO_2. This is becoming uncomfortably clear with OA and reef corals today which each year are moving reefs closer to collapse. In the Early Triassic post-extinction aftermath, OA in concert with other factors, may explain the inability of corals and reef organisms to rebound or their sudden debut after amelioration of the world's oceans.

The appearance of scleractinian corals in the Middle Triassic, some 10-12 my after the extinction, is explained by the "Naked Coral" hypothesis, confirmed by molecular studies and by OA experiments in which living corals induced by alkalinity change, lost their skeletons and lived perfectly well without them after which when conditions were returned to normal, developed skeletons. The "Naked Coral" effect suggests that certain lineages of anemone-like forms survived protracted intervals of the extinction aftermath to acquire skeletons much later, during the Triassic recovery, perhaps stimulated by development of conditions favoring calcification. The Naked Coral effect also may help explain other reef gaps in the fossil record.

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Transitional Ediacaran – early Cambrian small skeletal fossil assemblages: significance for the chronostratigraphy and evolution

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The Ediacaran-Cambrian transition represents a time interval of major reorganization and innovation in the geo-, hydro-, and biosphere on Earth. The Cambrian bioradiation of Metazoa is a key biotic revolution in Earth history during which most metazoan bauplans appeared within a short duration of about 20 my in the fossil record. It is mostly manifested in the worldwide appearance of Small Skeletal Fossils (SSFs) and the dramatic increase in number and complexity of trace fossils. The trace fossil *Treptichnus pedum*, which was officially choosen as index fossil for the definition of the Cambrian System has a globally diachronous first appearance datum (FAD) and is thus not desirable for defining a chronostratigraphic unit. Its stratigraphic range is extremely long- from the basal Cambrian to the Eocene. In regions with preferentially clastic sediments it may occur in roughly time-equivalent strata and may be used for stratigraphical purposes, such as for Avalonia, Baltica and part of Laurentia (White Inyo Mt.). In South China and the Karatau-Naryn Terrain the FAD of *Treptichnus pedum* lays in the late Fortunian. A similar delayed FAD occurs in Australia, India and part of Laurentia. In some regions, such as Greenland the FAD of *Treptichnus pedum* is in younger trilobitic strata. Therefore, we propose not to base chronostratigraphic decisions on the distribution of this and other trace fossils. Instead we suggest to utilize widely distributed protoconodonts, such as *Protohertzina anabarica* and *Protohertzina unguliformis* to define the Fortunian Stage and Cambrian System. Our new distribution data of *Protohertzina* indicate that the FAD of *P. anabarica* and *P. unguliformis* is near to the first major negative excursion of carbon isotopes at the Pc-C boundary. These potentially new index fossils of the Fortunian Stage are known from South China, Karatau-Naryn Terrain, Dzhabkan-Mongolia, Siberia, Laurentia, India, Iran and the Tarim Block.

The Pc-C boundary is globally also marked by significant lithological changes. In a wide region the basal Cambrian is indicated by the appearance of a chert facies, such as the Daibu Mb. (South China), Aksai Mb. (Kazakhstan), basal Lower Tal Formation (India) and the basal Yurtus Fm. (Tarim, W China). These chert formations are often biostratigraphically poorly dated. In South China and Maly Karatau of Kazakhstan previously the earliest SSFs were reported from the overlying phosphorite deposits of Zhujiaqing Mb. respectively Karatau Mb. Here we first report a low-diversity fauna with *Ganluodina symmetrica, Olivooides multisulcata, Protohertzina anabarica* from the basal Kuanchuanpu Fm. and Daibu Mb. indicating a typical Cambrian faunal association for this interval. However, the fauna also contains specific tubular remains, such as *Rugatotheca typica*, which reveal a transitional Ediacaran component for this stratigraphical horizon. A similar SSF association is recovered from the siliceous Aksai Mb. of Maly Karatau with typical Cambrian fauna, such as *Protohertzina anabarica* and *Anabarites trisulcatus*, but also Ediacaran-type tubular remains, such as *"Pseudorthotheca" costata*. Here we note that the basal Cambrian strata contain a mixed fauna of typical Cambrian skeletal remains of the earliest Cambrian *Anabarites trisulcatus- Protohertzina anabarica* Ass. Zone and tubular remains with similarities to Ediacaran cloudinids, such as *"Pseudorthotheca" costata*. The Ediacaran cloudinids seem not to be eradicated during the terminal Ediacaran and no extinction event preceded the Cambrian bioradiation event.

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"Eustatische Bewegungen": The theory and definition of Eustasy by Eduard Suess, 1888

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Eduard Carl Adolph Suess (1831 – 1914) was one of the most outstanding geologists of the 19th and beginning of the 20th century. Just to remember, he introduced an entirely new theory for the origin of the Alps (1875) and similar mountain chains and the origin of ocean basins, he named the supercontinent "Gondwana-Land", defined "Laurentia" and "Angara-Land" discovered the lost ocean "Tethys" and introduced the "Sarmatian"-Stage in the stratigraphic sequence of the Paratethys. From 1883 to 1900 he published three volumes of "*Das Antlitz der Erde*" ("The Face of the Earth"), the first comprehensive work on the geology of the world. With these volumes he became the founder of modern geology.

In the second volume of "The Face of the Earth", published 1888, he developed and defined his theory on Eustasy his "*Eustatische Bewegungen*" and the principles what we call today Sequence Stratigraphy. The idea on Sealevel Fluctuations was born during his fieldwork in the large Neogene Basins in Austro-Hungary, especially in the northern Molasse-Basin, in the vicinity of the town of Eggenburg. Suess thought that mainly changes of the volume of sedimentary basins are causing sealevel fluctuations – named by him "*Eustatische Bewegungen*". He recommended to use the neutral terminology of R. CHAMBERS (1848), speaking of *„shifts of relative sealevel"* and writes *„Sobald man sich für diese neutralen Worte entschieden hat, müssen folgerichtig die Verschiebungen der Strandlinie gegen aufwärts als die p o s i t i v e n und jene nach abwärts als die n e g a t i v e n bezeichnet werden, und zwar darum, weil dies die Bezeichnungsweise aller Pegel und Mareographen der Welt ist"*. Deepening of the basins would be followed by a negative movement of the shoreline ("*eine negative eustatische Bewegung der Strandlinie*"), what we would call a regression and the filling up of the basin with sediments he would call a positive movement of the shoreline ("*eine positive eustatische Bewegung der Strandlinie*"), what we call nowadays a transgression. In that sense Suess was already seeing the causes of sealevel changes as we interpret them today by changes in the volume of oceanic basins. He also recognised, that climatic changes might be responsible for the changing sealevel, when he writs about "*beträchtliche Anhäufungen des Eises in den höheren Breiten*" and following by these thoughts the publication of PENCK, 1882 on the "Schwankungen des Meeresspiegels".

In his alpine studies, writing about the Triassic and Jurassic transgression in the north of the continent, he interprets these facts as results of worldwide sealevel changes and distinguished here between different "Cycles". He found out that there are several smaller cycles which create than a larger cycle. *„Dies sind mit anderen Worten, die kleineren Cyclen innerhalb der großen Cyclen. Noch bestimmter endlich treten die grössten Phasen oder grössten Cyclen hervor. In diesen grössten Phasen fällt es aber auf, dass jene, welche am genauesten bekannt sind, dem positiven Theile* (Transgression) *eine weit grössere Zeitdauer zuzumessen scheinen als dem nachfolgenden negativen Theile* (Regression)". In this sense he postulated already 1888 the basic concepts of Sequence Stratigraphy.

In conclusion E. Suess writs 1911: *"When I wrote of eustatic movements in 1883, I confessed that I did not understand the transgressions. I thought that variations in rotation might somehow have influence. I also believed and still think that the accumulation of sediment was a vera causa, but hardly sufficient. Now, after twenty-seven years, I can not offer you more than a heap of doubts regarding the explanation. I have learnt more and know less about it."*

Shallow-water benthic foraminifera across the Cretaceous-Paleogene boundary (Kambühel Limestone, Lower Austria): preliminary results

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A variety of papers deal with the turn-over of planktic foraminifera across the Cretaceous-Palaeogene (C-Pg) boundary in pelagic depositional settings, but only little is known about the impact on benthic, shallow-water fauna. A succession of late Maastrichtian mixed siliciclastic-carbonates with orbitoidids and *Siderolites*, followed by Danian-Selandian carbonates is reported from Mount Kambühel in Lower Austria. In the Kambühel Limestone (KL), besides the disappearance of orbitoid foraminifera (and *Siderolites*), the most important biotic change across the preliminary fixed C-Pg boundary is expressed by a blooming of bryozoans and withdrawal of corallinaceans. The early Danian notably records an impoverished microfauna with an assemblage including *Cibicidoides succedens*-*Stomatorbina*? *binkhorsti*-*Planorbulina*? *uva* and associated nodosariids and polymorphinids. Agglutinating taxa only constitute minor faunal elements. In some parts of the succession, encrusting *Solenomeris* abounds. Along with the successful recovery of corallinaceans, debris of corals, dasycladaleans and representatives of *Peneroplis*? sp., and Rotaliida (*Rotorbinella hensoni-detrecta*, *Pararotalia* gr. *tuberculifera*) occur. Higher in the section, large thick-walled *Gyroidinoides*, *Cocoarota orali* and fragments of encrusting *Haddonia praeheissigi* are common. The latter two species become more significant in the following micritic mostly bioclastic coral limestones together with large-sized dasycladaleans (*Neomeris deloffrei*, *Dactylopora bystricki*). In the same levels, tiny euendolithic foraminifera are also frequently observed. Our tentative biostratigraphy is largely based on planktic foraminifera, which occur in some parts of the section, since larger benthic foraminifera providing the base for the Shallow Benthic Zones (SBZ) are almost absent. The Selandian age of the coral limestones, making up the top of the KL can be assigned to the P3 Zone (*Morozovella angulata*, *Globanomalina chapmani* group). Thanetian shallow-water carbonates are only known from olistolites, as reported from various localities in the Northern Calcareous Alps.

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The Middle Triassic (Anisian) Bulog Formation in the Dinarides: Definition, use and reality. New insights from new and revised sections in the Dinarides (Dinaridic Ophiolite Belt, Serbia)

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More than 120 years ago Hauer (1888) and Kittl (1904) named the in parts cephalopod-rich red nodular limestones on top of the shallow-water Steinalm Limestones in the Dinarides Han Bulog or Bulog Limestones. Since that time uncountable contributions were made on these limestones which were deposited widespread on the Balkan Peninsula. In a lot of cases the Bulog Limestone was compared with the in parts cephalopod-rich Schreyeralm Limestone (Mojsiscovics, 1882) of the Northern Calcareous Alps, the lowermost unit of the Middle Triassic to Early Jurassic Hallstatt pelagic successions. Schreyeralm and Bulog Limestones are similar in lithofacies and microfacies, but their overlying sedimentary successions can be quite different. The term Schreyeralm Limestone is only used for limestones at the base of Hallstatt Limestone sequences deposited in the outer shelf realm. In contrast, the Bulog Limestone was deposited more widespread: At the base of the Hallstatt pelagic successions and below the later evolving shallow-water platforms (Wetterstein and Dachstein platforms). In the type area near Sarajevo the Bulog Limestone is the lowermost unit of the Hallstatt pelagic successions, in fact equivalent/synonym with the Schreyeralm Limestone. Up to recent in a lot of palaeogeographic reconstructions the view of the depositional realm of the Schreyeralm/Bulog Limestone of the type region was adopted also for the Bulog Limestone in general. This resulted in the reconstruction of a lot of intraplatform basins in the Dinaridic realm and the main argument for their existence is the more or less identical litho- und microfacies of the Bulog Limestone elsewhere: below the Hallstatt pelagic successions and below the later evolving carbonate platforms. These reconstructions of long lasting intraplatform basins ignore the fact, that in the time span late Ladinian to Rhaetian no transitional facies was ever found between platforms and basins in the Dinarides – like in the Northern Calcareous Alps, where the interpretation of existing intraplatform basins was changed in recent times. Furthermore, the existence of the Hallstatt pelagic successions, meaning the various coloured Middle to Late Triassic open marine limestone successions, was long time ignored in the Dinaridic Ophiolite Belt, where the existence of true Hallstatt pelagic successions is crucial for palaeogeographic reconstructions and the question “how many Triassic oceans” were in the Tethyan realm. Sudar et al. (2013) introduced the Bulog Formation after revision of sections in the Dinaridic Ophiolite Belt and discussed the correlation of Schreyeralm Limestone and Bulog Formation. But several open questions remain, therefore additional sections and data as contribution to the Bulog Limestone problem are presented. The depositional characteristics of the Bulog Formation and equivalents is quite heterogeneous: A) as “normal” underlying of the Hallstatt pelagic successions, B) as “normal” underlying of the later Wetterstein platform, C) as matrix of mass-flow deposits indicating the formation of new relief in the frame of the break-up of the Neotethys Ocean. In all cases the Bulog Formation overlies the Middle Anisian Steinalm shallow-water ramp with a drowning unconformity. The depositional age of the Schreyeralm Limestone and Bulog Formation is restricted from the Late Pelsonian to the Illyrian. As difference the Bulog Formation is in a lot of cases directly overlain by Illyrian to Fassanian/early Longobardian radiolarites, whereas the Schreyeralm Limestone is normally overlain by various coloured open marine limestones, except in the Meliata Facies Zone. As consequence, isolated Bulog Formation occurrences cannot be used for interpretations about the palaeogeographic provenance. The Bulog Formation as part of complete Hallstatt Limestone successions is of crucial importance for the reconstruction of the provenance of the Dinaridic Ophiolite Belt: relic of an independent oceanic realm (Dinaridic Ocean) between Pelagonia and Adria or westward overthrusted.

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Correlation of Foraminiferal Zones of Biarmia and Notal Regions

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I. Many foraminifera species are in common between Biarmiya and Australia. Permian is almost everywhere in Australia, but especially in Queensland with the richest set of small foraminifera. In Queensland Palmier identified foraminiferal zones that were subsequently compared to the lithostratigraphic formations, located in different structural-facial areas of Australia. In the Priuralsky department the zones of *Hyperammina vulgaris, Nodosaria longissima, Nodosaria pseudoincelebrata, Ichtyolaria prima, Nodosaria monile, Nodosaria netschajewi* and in Biarmiysky department *Turritellella regulata, Geinitzina kazanica, Hemigordius planispiralis, Hemigordius schlumbergeri, Nodosaria suchonensis, Ichtyolaria longissima, Haplophragmoides opinabilis* were identified.
The Australian zones *Howchinella woodwardi* and *H. rigida* are confined to Biarmia *Hyperammina vulgaris* z.. The zones are represented by the genera *Hyperammina, Hyperamminoides, Ammodiscus, Ammobaculites, Earlandia, Nodosaria, Protonodosaria,* species are *Hyperammina elegans, H. fusta, Saccammina ampulla*. *Hyperammina fusta* is known in Pechora, Nordvik. *Saccammina ampulla* is typical of the Upper Artinskian of the Kozhim River. The Australian *Pseudohyperammina radiostoma* z.and the lower *Pseudonodosaria serocoldensis* z. are confined to *Nodosaria longissima* z. The genera *Psammosphaera, Saccammina, Reophax, Hyperammina, Ammodiscus, Nodosaria, Ichtyolaria* are abundant, species are *Trepeilopsis australiensis, Ichtyolaria rigida*. *Nodosaria pseudoincelebrata* z. is confined to the lower Australian *Pseudonodosaria serocoldensis* z.. Genera are *Earlandia, Hyperammina, Saccammina, Reophax, Ammobaculites, Ammodiscus, Tolypammina, Thuramminoides, Nodosaria, Protonodosaria, Ichtyolaria* with *Ichtyolaria aulax, Reophax minutissima*. *Ichyolaria prima* z. corresponds to the middle part of *Pseudonodosaria serocoldensis*. Common species is *Nodosaria raggatti*. It is found in Queensland, New South Wales, Western Australia and is common in Pechora Province. *Nodosaria monile* z. corresponding to the Lower Ufimian is confined to the upper part of *Pseudonodosaria serocoldensis* and to the lower *Ammodiscus corrugates* z., with common species *Ichyolaria limpida, Ichyolaria aulax*. These species are found in the Ufimian deposits of Pechora Province and in Queensland and Western Australia. The middle part of *Ammodiscus corrugates* z. is confined to *Nodosaria netschajewi* z. Common genera are *Hyperammina, Saccammina, Reophax, Ammodiscus, Thuramminoides, Nodosaria, Pseudonodosaria, Protonodosaria, Ichtyolaria, Lingulonodosaria, Tolypammina, Calcitornella*, species are *Ichtyolaria impolita, I. hillae, I. parri*. The upper Australian *Ammodiscus corrugates* z. is confined to *Turritellella regulata, Geinitzina kazanica, Hemigordius planispiralis* z. and lower *Hemigordius schlumbergeri* zone corresponding to the Lower Kazanian. Species are *Ammodiscus bradyinus, Ichtyolaria woodwardi, Rectoglandulina borealis*. The lower *Ammodiscus corrugates* z. and *Pseudonodosaria borealis* z. correspond to *Hemigordius schlumbergeri* z. to the lower Upper Kazanian. *Pseudonodosaria borealis* is found. The Australian zone *Lunucammina maior* is confined to *Nodosaria suchonensis, Ichtyolaria longissima* z. *Nodosaria raggatti, Pseudonodosaria borealis, Ichtyolaria woodwardi* z. disappear. The lower *Lunucammina maior* z. and *Howchinella mantuanensis* z. are confined to *Haplophragmoides opinabilis* z. *Haplophragmoides, Eocristellaria, Maichelina, Plummerinella* occur.
II. The similarity of the fauna of the Permian sections of Pechora and of Australia suggests a connection between Biarmiyskim gulf and Australian gulf. In Australia, which was the center of diversification of small foraminifera, Permian microfauna was most diverse. Migration of the microfauna begun with agglutinated forms. This indicates the bipolarity between the two areas: Small foraminifera of Australian are much older than pechora's. The close match at species level can be attributed to the similarity of paleoclimatic conditions. In Australia, Permian climate was cold as evidenced by the absence of fusulinids. Two polar belts were separated by theequatorial belt and warm temperatures were extremely unfavorable for agglutinated forms. Therefore there are practically no agglutinated foraminifera in these areas, but abundant calcareous ones. In a very short time period small Australian foraminifera reached the outskirts of the Notalian zone and Biarmiya where theyfurther evolved. Due to wide migration routes these small foraminifera can be used for correlation.

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High Amplitude Redox Changes during the Smithian/Spathian (Early Triassic) extinction in South China

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The Early Triassic was a time of remarkably high temperatures, large carbon cycle perturbations and episodes of widespread ocean anoxia. The sediments in the Nanpanjiang Basin of South China provide superb opportunities to examine the sedimentary response to these extreme conditions especially during the crisis interval at the Smithian-Spathian (S-S) boundary. We have investigated a shallow water section at Mingtang and a deeper water section at Jiarong to constraint these changes. A range of facies are seen, including black shales, micritic limestone units and rudaceous carbonate event beds that include flat pebble conglomerates and breccia debrites that bear similarities to the hybrid event beds seen in clastic turbidite successions.

Redox proxies (pyrite framboids and trace metals) reveal that widespread anoxia in the late Smithian persisted into the *Novispathodus pingdingshanensis* conodont zone of the early Spathian before a sharp transition to highly oxygenated “Griotte facies” (red marine strata) in the *Icriospathodus collinsoni* conodont zone. The Griotte facies records an “oxic rebound” from the anoxic-euxinic waters of the S-S interval. This may have been triggered by climatic cooling and oxygen increase driven by organic carbon and pyrite burial.

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Sequence Stratigraphy by Wavelet Analysis

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Geophysical well logging (GWL) data is nonstationary in character. It detects cyclicity, trends, sudden changes in sedimentation and stratigraphy. Wavelet analysis is more effective for analyzing nonstationary signals in which a signal can be represented as the sum of different frequency components with different resolutions. The driving impetus behind wavelet analysis is their property of being localised in time (space) as well as scale (frequency). This provides a time-scale map of a signal, enabling the extraction of features that vary in time. This makes wavelets an ideal tool for analysing signals of a transient or non-stationary nature. Geophysical well-log (bore-hole) data represent the rock physical properties as a function of depth measured in a well. They aid in demarcating the subsurface horizons, identifying abrupt changes in physical properties of rocks and locating cyclicity in stratal succession. Since wavelet transformations can better identify the abrupt changes in cyclicity common in nature, they become important tools for sequence stratigraphy. Currently spectral decomposition methods (Continuous Wavelet Transform, Matching Pursuit Algorithm decomposition, Discrete Wavelet Transform) are used to detect hydrocarbon zones. The wavelet transform is a multi-scale operator and is well known to point out singularities in the analysed signal . The way in which the wavelet transform analyses the signal can be compared to the geoscientist's interpretative behaviour in the hydrocarbon upstream industry: both look at the signal at different scales (frequency range), detect breaks "major events" and heterogeneity and characterise trends. In order to measure multi-fractility of any signal the Holder Exponents and Singularity Spectrum attributes are computed. Mathematical transformations are applied to signals to obtain a further information from that signal that is not readily available in the raw signal. Wavelet analysis generates useful information from well-log responses. It is a useful tool for automated cyclostratigraphy. Wavelet analysis is a multiresolution framework and, thus, it is well suited for upscaling rock and flow properties in a multiscale heterogeneous reservoir. The compact support property of the wavelet transform assures efficient computation. Choice of regularity provides a flexible way to control the smoothness of the resulting upscaling properties. Because the upscaled property images obtained from wavelet transform capture the characters of the original property fields, the predicted performance from upscaling property fields matches well with that from the original fine-scale property fields. Morlet wavelet is best suited to gamma ray logging signal to identify cyclic geological information like sequence stratigraphy. Detrended fluctuation analysis of well logging data provides precise sequence stratigraphy. SeisLab(analysis/display of seismic and well-log data),MATLAB Wavelet Toolbox are employed for GWL data analysis.

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Jurassic radiolarite deposition in the Northern Calcareous Alps: possibilities for a refined Middle/Late Jurassic radiolarian biostratigraphy

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Radiolarites in the Northern Calcareous Alps are significant sedimentary rocks and occur widespread in the Jurassic. In the Middle-Late Jurassic the trench-like basin fills (carbonate-clastic radiolaritic flysch) could reach a thickness of about 2000 metres, but radiolarites cover in Callovian-Oxfordian time practically the whole area of the Austroalpine in varying thickness. These radiolarites vary sedimentologically from black, greenish to red ribbon-like radiolarites and greyisch fine-laminated turbiditic variations. They often overly condensed red nodular limestones of the Klaus Formation. Here especially the radiolarite sections with underlying red nodular limestones, dated with ammonoids, play an important role to calibrate the existing radiolarian zonations. It is very important to note, that the onset of radiolarite deposition is not contemporaneous. In the southernmost Northern Calcareous Alps, where the first trench-like basins were formed due to the propagating nappe front, radiolarite deposition started in the Bajocian/Bathonian. The next generation of basins was formed in the Callovian and carry the most important part of the Hallstatt Mélange. More to the north the trench-like basins were formed around the Callovian/Oxfordian boundary (Tauglboden Mélange). On top of the nappe stack a Kimmeridgian to Berriasian carbonate platform pattern evolved (Plassen Carbonate Platform). Therefore radiolarite deposition in the remaining trench-like basins changed to calcareous radiolarites or cherty limestones partly rich in *Saccocoma*, especially in the Hallstatt Mélange areas. More to the north, radiolarite deposition prevailed until in earliest Tithonian. In that area of the Tauglboden Mélange the transition from radiolarite to more calcareous deposition is late Early Tithonian. North of the Tauglboden Basin again a carbonate platform evolved in the Kimmeridgian and influenced the northernmost Northern Calcareous Alps.

Still crucial is in Bathonian to Oxfordian time the calibration of the existing radiolarians zones due to the lack of ammonite bearing sections all over the world. Therefore the radiolarian biozones have a relatively wide age range and the stratigraphic ranges of different radiolarian species very often lack exact calibration. We present key sections in the Northern Calcareous Alps, which allow to calibrate the existing radiolarian zonations: The Brielgraben section (middle Callovian), the Klauskogelbach section (lower Callovian) and the Fludergraben section (Oxfordian) of the Salzkammergut area, all dated with ammonoids at the top of underlying red nodular limestones.

Micropaleontological investigations of the Norian/Rhaetian boundary interval in the Csővár borehole, Transdanubian Range, Hungary

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The Csővár borehole, which was drilled at the easternmost part of the Transdanubian Range in Hungary, exposed a nearly 600 m thick succession of cherty limestones and dolomites representing toe-of-slope and basinal facies. The conodont fauna indicated a Carnian – Rhaetian age and enabled the precise identification both the Carnian/Norian and Norian/Rhaetian boundaries. The aim of the present study is to give a detailed micropaleontological description of the Norian/Rhaetian boundary interval, because the exact definition of this boundary is debated in the international stratigraphy.

Samples from the lower part of the investigated interval (125 - 110.3 m) yielded conodonts characteristic of the uppermost Norian. Beside *Oncodella paucidentata*, *Norigondolella steinbergensis* and *Misikella hernsteini* transitional forms between *M. hernsteini* and *M. posthernsteini* appear as well. The first appearance of true *M. posthernsteini* could be observed in sample 109.3 - 110.3 m from where upwards the fauna is dominated by the Rhaetian forms of the genus *Misikella*.

In this interval the holothurian fauna consists of four species: *Canisia symmetrica, Fissobractites subsymmetricus, Theelia immisorbicula* and *T. variabilis.* According to the literature *C. symmetrica* and *T. immisorbicula* indicate Norian age while *F. subsymmetricus* and *T. variabilis* are generally found both in the Norian and the Rhaethian. In the core, the last occurance of *C. symmetrica* is at 125 m, little bit below the first appearance of the conodont *M. posthernsteini* whereas the last occurrence of the *T. immisorbicula* is somewhat above it (104 m) which makes the latter holothurian species a short-term survivor of the Norian/Rhaetian boundary. This pattern of disappearance points out that the change in the fauna was not a momentary episode but occurred in more steps.

The Foraminifera association is varied by depth. In the lower part (114.8 – 126.7 m) a diverse and abundant fauna was found. The main components are the different *Duostomina* and *Variostoma* species, and the relatively abundant *Galeanella panticae*, *G.* sp. *Ophthalmidium triadicum*, *O.* sp.. The rest of the fauna is composed of *Rheopax*, *Gaudryina*, *Planiinvoluta,* Involutinidae? and some smaller agglutinated species. Besides the foraminifers there are Bivalvia and Brachiopoda fragments, and pellets in greater numbers and, mostly in the lowest levels (below 117.8 m), strongly fragmented Gastropods and Ostracods, moreover the similarly fragmented other biodetritus.

Above these rich samples (113.0 - 113.8 m) instead of the foraminifers, which are totally absent in this interval, the microfacies consists of the mass of sponge spicules and radiolarians, and a few Brachiopoda embryos.

Above the previous level (113.0 – 105.0 m) the foraminifers reappear but their diversity and abundance are significantly less than in the lower part. Only few Nodosariidae, *Earlandia*?, *Ophthalmidium* and *Lenticulina* were found. In the uppermost part (between 105.0 and 100.0 m) the diversity is gradually growing, but the abundance remains low.

The results of the multi-taxonomic analysis of conodonts, holothuroids and foraminifers from the Norian/Rhaetian boundary interval in the Csővár borehole can be a useful tool for more accurate biostratigraphic investigations in other successions from this age.

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Trachyhystrichosphaera aimika as a potential Tonian index fossil

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Biostratigraphy is an important tool for stratigraphic subdivision and correlation. However, Precambrian biostratigraphy is hampered by the limited number of widely distributed and age diagnostic fossils that can be used as index fossils. Compared with the Ediacaran and Cryogenian systems, a biostratigraphic definition and subdivision of the Tonian System (~720 to 1000 Ma) is even more challenging because of the lack of globally recognized index fossils.

However, in the past few decades, significant progress has been made in Tonian paleontology. Dozens of moderately to richly diverse organic-walled microfossil assemblages, as well as carbonaceous macrofossil assemblages characterized by *Chuaria* and *Tawuia*, have been described from Tonian strata. Although the full spatial and temporal ranges of many Tonian species have not been completely documented, a few of them have wide geographic distribution and seem to be largely if not exclusively restricted to the Tonian Period. One of such taxa is the acanthomorphic acritarch *Trachyhystrichosphaera aimika*, which is characterized by medium to large spheroidal to sub-spheroidal vesicle with irregularly distributed heteromorphic, hollow, cylindrical or conical processes and an outer membrane. The oldest known occurrence of this species is in the Lakhanda Group of Siberia (1025 ± 40 Ma, whole rock Pb–Pb isochron age; >1005 ± 4 Ma, baddeleyite U–Pb age), which is considered to be the latest Mesoproterozoic according to the currently used GSSA. All other confirmed occurrences of *T. aimika* from South Australia, North China, Siberia, Arctic Canada, central India, and East European Platform appear to be restricted to the Tonian Period according to the current GSSA. Therefore, although *T. aimika* has the disadvantage of being a long-ranging taxon, it can be considered as a useful Tonian index fossil and its first appearance could be used to define the base of the Tonian.

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New proposals for the Russian and International stratigraphic scale of the Quaternary

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Recent changes of the International Chronostratigraphic Chart (ICC) of the Neogene and Quaternary in 2009 required a coordinated modification in the lower part of the General Stratigraphic Scale of Russia (GSS). The final decision was ultimately approved by Interdepartmental Stratigraphic Committee (ISC) of Russia [1]. The structure of the Quaternary in the GSS of Russia traditionally differs from that of the International stratigraphic scale. As compared to the tripartite division of Pleistocene in the ICC into lower, middle, and upper subseries, in the GSS of Russia the Pleistocene is divided into two parts (divisions), Eopleistocene (1.8-0.78 Ma) and Neopleistocene (0.78-0 Ma). A particular way of integration of the Gelasian into the hierarchy of the Russian GSS caused a debate. Two main options include 1) the inclusion of the Gelasian into Eopleistocene [2], and 2) the allocation of the Gelasian to the newly defined basal division of the Quaternary, Paleopleistocene [3, 4]. We favour the second option that along with the updated structure of traditional domestic units will also contain stages of the ICC. Pleistocene is divided into three divisions: Paleopleistocene (equating the scope of Gelasian), Eopleistocene (Calabrian), and Neopleistocene (combining scopes of provisional "Ionian" and "Tarantian" stages). Two parallel votes among bureau members of the Quaternary stratigraphic commission of the Russian ISC, and the whole body of the commission, showed a slight preference to the first option in the first vote, and the overwhelming support for the second option in the second vote. Based on these results, the Russian Stratigraphic Committee (April of 2015) has refrained from formalizing any of the variants of the structure pending the finalizing of the inner structure of the Quaternary by the International Stratigraphic Commission. As a possible update of the upper part of the Quaternary in the International Chronstratigraphic Chart, we propose to consider the Middle and Late Pleistocene of the current ICC in the frame of a single "Italian" stage as an alternative to the two stages of the current chart. In this case, this stage will comprise sediments of natural phase of the Earth climatic evolution, the so called Glacial Pleistocene. Furthermore, the Quaternary including three stages, comparable in duration, will get closer to other systems of the Cenozoic. The Upper Pleistocene of the current version of ICC neither in duration nor in the character of the biota cannot be regarded as independent stage. This problem was recently discussed by Polish colleagues who proposed to lower the base of the Upper Pleistocene to the base of MIS 11 [5].

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T/J boundary in peritidal carbonates from South-Western Tethys

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The stratigraphical and sedimentological study of uppermost Triassic-lowermost Jurassic peritidal carbonates in western Sicily, define the stratigraphic record of T/J boundary in a South Western shallow water tethyan section.
At Monte Sparagio (San Vito Lo Capo Peninsula), the microfacies analysis has allowed to place the T/J boundary across a thick undifferentiated succession made of Upper Triassic-Lower Jurassic peritidal cycles, on the base of the last occurrence of megalodont shells and of *Triasina hantkeni* and the appearance of oligotypic facies with *Thaumatoporella parvovesiculifera* and *Aeolisaccus*. The transition appears fully conformable without any record of possible variations of the sedimentary regime (e.g. sea level fall, tectonic deformations) besides the faunal turnover.
In this section evidence of a sea-level lowering are recognized well below the T/J boundary, roughly in the middle part of the Triasina zone, thus of the Rhaetian. This event is suggested by the presence of a particularly thick red paleosol that covers a karstified surface, laterally correlated with a structure that is interpreted as a paleosinkhole. Moreover an huge system of paleokarstic caves develops downward from this surface. The caves are filled up by collapsed breccias to form, in some parts "breccia pipes". The breccia elements clearly derive from the peritidal host rock and are surrounded by polychrome silty matrices that rendered this breccia of great interest for ornamental purposes. The uplift of the platform can be estimated at about 130 m, a value that is difficult to explain only in terms of eustatic variations. So a tectonic forcing has to be considered possibly induced by the adjacent rifting of the Alpine Tethys.

The Ordovician deep and shallow water conodont biozonal scales of Kazakhstan

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The Ordovician in Kazakhstan occurs in tectonically imbricated island arc and microcontinent successions separated by ophiolite zones. It is represented by a wide range of facies - from shallow-water carbonates of sub-littoral zones to clastic continental slope deposits and deep-water cherts of abyssal zones. Deep water strata deposited below the carbonate compensation depth (CCD) besides rare lingulids and poorly studied pelagic arthropods contain stratigraphically significant graptolites and conodonts. In contrast, shallow-water carbonates of Kazakhstan yield mostly endemic trilobites and brachiopods that cannot be used in age determination. Until recently, conodonts were known from few carbonate localities in Kazakhstan only, however even their first studies have shown that taxonomic composition of shallow-water conodont assemblages differs significantly from those of siliceous deep-water successions. Prior to this study, the only conodont zonal scale in Kazakhstan was the scale of the Upper Cambrian-Lower Ordovician Batyrbai section of the Maly Karatau Mountains proposed by S. Dubinina in 2000.

Thus, the stratigraphic correlation of shallow- and deep-water strata important for reliable tectonic and paleographic reconstructions in the region was a complicated task. Active studies of conodonts in Kazakhstan performed in last ten years were aimed to solve this problem on the base of conodont biostratigraphy.

Biozonal scale for the deep-water successions is based on conodonts from the Burubaital Formation whose siliceous condensed deposits are widespread to the south-west of Lake Balkhash of Southern Kazakhstan. The pelagic cosmopolitan species of *Pygodus, Prioniodus,* and *Periodon* genera that are commonly used as zonal indices in the regional conodont scales of the North Atlantic biogeographic province, including Baltoscandia, have been selected as zonal indices for the Kazakhstanian deep-water biozonal scale as well.

Conodont assemblages from shallow-water carbonates in Kazakhstan usually contain species typical for deep-water siliceous strata, but their content is directly related to the depth of sedimentary environment. In the most shallow-water sandy and algal limestones the open-water species are sparse (e.g., limestones in the Urumbay area of Northern Kazakhstan). Therefore, the zonal scale built on the distribution of conodonts in siliceous sections, in spite of its good correlation potential, is often inapplicable in carbonate successions.

Over the past decade, a large amount of new data on conodonts from carbonate rocks in Kazakhstan resulted in compilation of biozonal scale for shallow-water deposits in the region. The scale is based on shallow-water species, typical for most of the studied localities. In case of absence of specific shallow-water conodont taxa determination of biostratigraphic units was based on the open-water species.

The shallow-water conodont scale has a relatively low stratigraphic resolution, however, it allows to determine the age of the shallow-water strata and correlate it with the deep-water siliceous successions in the region.

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Middle Eocene seagrass assemblage from Apennine carbonate platforms (Italy)

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The aim of this work is to characterise a Middle Eocene (Lutetian - Bartonian) seagrass deposits that crop out in the Apennine carbonate platforms (Italy). Two stratigraphic sections located respectively in the Latium-Abruzzi (Monte Porchio, Cassino Plain, south-eastern Latium) and in the Apulian carbonate platform (S. Cesarea, Salento), were measured and sampled to document the sedimentological characteristic and the faunistic assemblages.
The micropaleontological and sedimentological investigations were carried out on thin sections of the consolidated bioclastic grainstones.
The main components were point counted (up to 500 points for each thin section) using the software JMicroVision 1.2.7. The collected data were statistically processed by the software SPSS 22.0; a factor analysis and a hierarchical cluster analysis (Ward method with squared Euclidean distance) of the main components were obtained and discussed.
The investigated assemblages are dominated by porcellaneous foraminifera such as *Idalina*, *Alveolina*, *Orbitolites* and small miliolids (*Spiroloculina*, *Quinqueloculina*, *Triloculina*) and abundant permanently-attached acervulinids taxa, represented especially by saddle-shaped *Gypsina*, associated with articulated coralline red algae and green algae *Halimeda*. *Fabiania,* rotaliids and textulariids as well as nummulitids are subordinated. The samples were assigned to Lutetian (SBZ13-16) according to the occurrence of *Assilina* cf. *maior, Nummulites* cf. *lehneri, Alveolina elliptica, Idalina berthelini, Orbitolites complanatus*, *Slovenites decastroi* and *Medocia blayensis*. At Santa Cesarea reticulate nummulites occur in association with *Alveolina* spp. and *Halkyardia minima* marking the lower Bartonian (SBZ17).
This biotic assemblages suggest that the depositional environment is consistent with a vegetated shallow inner ramp in tropical to subtropical water withinand oligotrophic conditions.

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Terrestrial Permian-Triassic Boundary Sequences in China

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Marine Permian-Triassic (P-Tr) boundary strata are widespread in South China and well developed in various paleogeographic facies from shallow platform to deep basin and in various lithofacies from terrigenous clastics to carbonate sediments. Consequently, South China provides unique settings for studying the P-Tr boundary stratigraphy and understanding the critical Paleozoic-Mesozoic transition. Besides the defined global P-Tr boundary, numerous studies related to the great P-Tr transitional events have been extensively performed in South China. However, the terrestrial facies of P-Tr boundary are even more widely spread in China, including all sedimentary basins in the vast northern China as well as the marginal areas around the oldlands in South China. The coarse sandstone or conglomerate facies occurred only in some analogous foreland and intermountain basins, whereas the fine-grained P-Tr boundary stratigraphic sequences dominated by the fluvial-lacustrine facies were much more common and widespread. The latter are clearly in favor of the definition of P-Tr boundary and the study of the great Paleozoic-Mesozoic transitional events and process. Three types of terrestrial P-Tr boundary sequences are characteristic in China.

1. Paralic limnetic-lacustrine facies, which typically occurred in the northeastern side of the Kandian Oldland, where a series of P-Tr boundary sequences can well be traced and correlated from marine to terrestrial facies via the sea-land transitional zone. Various studies have been done across the marine-continental transitional zone in the western Guizhou and northeastern Yunnan though the terrestrial facies has received relatively less study. Meanwhile, most areas that were occupied by the terrestrial facies at the P-Tr boundary evolved into marine facies in the late Early Triassic.
2. Inland lacustrine facies, which was well developed in Northwest China and the Dalongkou section in Jimsar, Xinjiang is the best studied sequence. The section was ever proposed as the candidate of the Auxiliary Stratotype Section and Point for the terrestrial P-Tr boundary. However, the definition of the P-Tr boundary and its correlation with the marine sequence are still facing great difficulty.
3. Fluvio-lacustrine facies, which was well present on the North China block. The P-Tr boundary sequences are composed of the alternation of fluvial and lacustrine facies while some marl beds with marine linguloid and bivalve fossils are intercalated in the boundary strata in the marginal areas of the North China block. However, the study on the P-Tr boundary is very little in this facies.

As a whole, China should be a profitable region to study the P-Tr boundary sequences and related biotic and environmental events and processes and to construct the correlation of marine and terrestrial P-Tr boundaries. However, it might be impossible to make a direct correlation between the marine and terrestrial sequences only based upon fossils, and even it is very difficult for fossils to correlate the P-Tr boundaries in the different terrestrial facies. The abiotic environmental events related the great P-Tr transition would provide critical clues to resolve this problem.

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Integrated biostratigraphy and the larger benthic foraminiferal extinction across the Eocene/Oligocene at Noroña, Western Cuba

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The extinctions of some major and widespread larger benthic foraminifera groups are associated with the Eocene-Oligocene transition in the Caribbean shallow water carbonates, including the orthophragminids, agglutinated conical forms and some species of Nummulitids and Lepidocyclinids. However, it is difficult to precise the exact timing of the larger foraminifera extinctions as only very few sections are complete across the boundary and the planktic biostratigraphy is not well defined. A continuous marine section across the Eocene/Oligocene boundary at Noroña, Western Cuba provides a good opportunity to constrain the larger benthic foraminiferal biostratigraphic ranges as they co-occur with abundant planktic foraminifera and calcareous nannofossils. Three levels containing late Eocene larger benthic foraminifera represented by the *Discocyclina- Asterocyclina, Pseudophragmina-Nummulites-Heterostegina- Fallotella- Lepidocyclina* assemblages are found in the lower and middle part of the planktic foraminiferal O1(P18) and in the middle part of the calcareous nannofossils Zone NP 21 (CP 16) (Rupelian). Although the larger foraminifera have been displaced from their original habitats, evidence of reworking, such as mixture of species from different ages or prior fossilization, have not been observed. Furthermore, the traditional Late Eocene marker *Fallotella cookie* is an abundant taxa in the Oligocene at Noroña section, consistent with the strontium isotope stratigraphy data from lower Oligocene sediments from Jamaica.
Our data from Noroña, as well as other previously studied sections across the Eocene/Oligocene boundary suggest that a number of long-ranging and widespread Eocene larger benthic foraminiferal taxa are present in the lower Oligocene. Based on our hypothesis, their extinction could be diachronic, disappearing near the Eocene/Oligocene boundary in low latitudes (e.g. Tanzania) and becoming extinct in the Rupelian (lower Oligocene) in the Caribbean-American bioprovince (e.g. Cuba and Jamaica) and at low-middle latitudes of the Tethys (e.g. Italy and Spain).

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Larger benthic foraminiferal biostratigraphy and microfacies analysis of Priabonian shallow water limestones (Lower Austria and Burgenland)

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Papp (1958) reports on reworked boulders of Eocene limestone in Miocene deposits of eastern Austria. For our study, occurrences of such boulders at Kirchberg am Wechsel (Lower Austria) and Wimpassing an der Leitha (Burgenland) were re-sampled and thin sections were made to analyze microfacies and to up-date larger benthic foraminifera stratigraphy. At both localities, limestones display diverse fossil assemblages consisting essentially of fragmented coralline algae, larger benthic foraminifera, bryozoans, corals and smaller benthic foraminifera. At both localities, genera usually common in Tethyan assemblages as *Asterocyclina*, *Pellatispirella*, *Spiroclypeus* were not found and *Assilina* and *Orbitoclypeus* show very rare occurrences. Two microfacies types were identified which are characterized by foraminiferal assemblages: the *Asterigerina* facies and the orthophragminids facies.

(1) At Wimpassing, orthophragminids occur in the *Astigerina* facies. The assemblage is dominated by the species *Asterigerina rotula* in co-occurrences with *Nummulites stellatus* and the large miliolid *Borelis vonderschmitti.*The latter two species indicate the Priabonian Shallow Benthic Zones SBZ19 to SBZ20 in the zonation of Serra-Kiel et al. (1998).

(2) At Kirchberg, the orthophragminid facies contains bryozoans. This indicates an outer platform environment with deeper water conditions than at Wimpassing. The larger benthic foraminiferal assemblage is dominated by the genus *Discocyclina* that appears to be monospecific.

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The middle late to late Eocene Heterostegines evolution and biostratigraphy in Western and Central Cuba

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The heterostegines are an example of Tertiary lamellar perforate larger benthic foraminifera, where their evolution was accomplished by strong morphological changes. Morphometric investigation of their diagnostic internal features as presented in equatorial thin sections have been used to explain changes in the evolutionary-ecological process affecting this group.

Four *Heterostegina* populations ranging from late middle to late Eocene of Western and Central Cuba were investigated in order to assess their relationships and to determine the nature and timing of their morphological changes. The species *Heterostegina ocalana, H. cubana* and an unidentified (? new) species were classified based on morphometric methods using growth independent and growth-invariant characters that allow modelling of the test shape for each growth stage.

The species *Heterostegina cubana* and *Heterostegina* sp. originate from the same locality, where the larger foraminiferal assemblages suggest late middle Eocene age. These species are clearly distinguished by the much stronger increase of the marginal spiral inducing a strong backbend of chambers and thus a much higher number of chamberlets of *H. cubana* compared to *H.* sp. Additionally, in *H. cubana*, the first chamberlet of a chamber close to the inner spiral chord is extremely long compared to its peripheral chamberlets and is characterized by incomplete septula.

The *Heterostegina ocalana* populations show strong variability of their diagnostic features at different localities that could be assumed as ecophenotypic variants. It differs from *H. cubana* by significantly smaller proloculi, the smaller chamber height, the weaker backbend of chambers correlated with a lower chamberlet number within chambers and the much shorter length of the first chamberlet with no separation by incomplete septula. This species is considered an exclusive marker for the late Eocene in the Caribbean realm; however, in Western Cuba this species co-occur with abundant planktonic foraminifera and calcareous nannofossils that suggest Lower Oligocene age.

The Cuban *Heterostegina* populations thus shows a rapid evolutionary trend around the late middle Eocene and the late Eocene based on the reduction of the number of operculinid chambers and the reduction in proloculus size. Similar evolution patterns have also been observed in Eocene heterosteginids from the Western Tethys.

Late Cretaceous (Campanian-Maastrichtian) Stratigraphy of Kuwait

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The Campanian-Maastrichtian subcrop section of Kuwait consists of carbonates known as Hartha, Qurna and Tayarat formations. The Hartha Formation unconformably overlies the marine limestones of the Sadi Formation. The average thickness of 170 meters of the Hartha includes a lower section composed of skeletal packstones and wakestones interbedded with calcareous shales. The middle section is characterized by rudist rudstones and skeletal grainstones with few ooid beds, and the upper section is characterized by peloidal packstones/wackestones interbedded with bioclastic packstones and dolowackestones. Abundant foraminifers, ostracods and nannoplankton indicate that the Hartha was deposited in the Inner Ramp to proximal Middle Ramp settings during the Early-Middle Campanian.
The overlying Qurna Formation, with a thickness range of 20 to 150 meters, represents marine outer ramp mudstones that are rich in planktonic-benthic foraminifera, and nannoplankton. The occurrence of *Radotruncana calcarata* in the Qurna lower section, and the nannofossil assemblage (UC17 Zone) at the top indicates a Late Campanian to Early Maastrichtian age. The increasing planktonic to benthonic foraminifer ratio and common keeled species in the lower section represents a major deepening and associated to the Late Campanian transgression in the Arabian Plate.
The Tayarat Formation with an average thickness of 300 meters, is characterized by a lower unit with dolomites and dolomudstones, locally limestones and shales. The upper unit is composed mainly of skeletal-large foraminiferal grainstones/packstones interbedded with calcareous and carbonaceous shales and some rudist floatstones beds. Nodules of anhydrite occurs at the top of the section. The Tayarat Formation is dated Early to Late Maastrichtian, based on the foraminifera species of *Loftusia* and *Omphalocyclus* and widely distributed in the Arabian region during Maastrichtian. The litho-biofacies show that depositional environments within the Inner and Middle Ramp dominated the sedimentation of the Tayarat Formation.

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Astronomical tuning of the La Vedova section (Ancona, Italy) between 15 and 16.2 Ma. Implications for the origin of megabeds and the Langhian GSSP

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An astronomical time scale for the younger part of the Middle Miocene Climatic Optimum in the Mediterranean is here presented. It is based on the litho-bio-magnetostratigraphic and geochemical records of the Lower La Vedova Beach section (Ancona, Italy), which is characterized by the occurrence of 7 conspicuous limestone beds, termed megabeds, intercalated with marly intervals. The tuning to ~100-kyr eccentricity seems robust, but that to precession and insolation is less certain partly as a consequence of uncertainty in the phase relation. Nevertheless, the tuning provides astronomical ages for the sedimentary cycles, calcareous plankton bio-events and magnetic reversals for the interval between 15 and 16.2 Ma. The megabeds are related to the ~100-kyr eccentricity cycle and correspond to eccentricity minima. The deposition of the megabed interval is partly controlled by the 405-kyr cycle, as it marks two successive minima and the maximum in between. However, no relation with very long period eccentricity cycles is evident, and a link to a major orogenic phase at the base of the Langhian and the likely associated Langhian transgression seems more plausible. The higher sedimentation rate in the megabeds may be explained by the additional preservation of biogenic silica, which may also explain the poor planktonic foraminiferal faunas. With the integrated magnetobiostratigraphy, and the tuning to eccentricity and to precession/insolation, the Lower La Vedova Beach section meets key requirements for the Langhian GSSP.

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The Lochkovian (Lower Devonian) subdivision based on conodonts: From biozones to chronozones; past and future

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Biostratigraphy deals with organizing bodies of rocks by the fossil content while chronostratigraphy deals with age of rocks and their time relations. Differences between bio -and chronostratigraphy are clear, but many times these two different concepts are intermingled. Besides, subdivision of stages in workable units that can be applied globally has been based on biozones that subsequently were unsoundly applied and correlated beyond the area they were coined and without previous reliable correlation, i.e., without demonstration of the equivalence either in age or in fossil content.

Many workers use zonal names without taking into account their meaning; for instance, they “recognize” a biozone without records of any of the defining or characterizing fossils. But because there is a “ready to go” list of arranged “zones” they apply these names to a set of rocks, without testing the position of their boundaries, which, in turn, make difficult subsequent reliable correlations and introduce noise in the global picture of Geological History.

Besides these problems, the way the (bio)zones are currently been defined and termed has introduced some miscommunication among specialists and gives credit to biostratigraphy detractors. The purposes of this work are to analyze some of these difficulties, provide a potential solution for minimizing them and show a practical case in the Lochkovian subdivision (Lower Devonian) by means of conodonts. Since the first comprehensive Lochkovian biostratigraphical subdivision in Western North America, the Lochkovian has been subdivided into four (bio)zones that through time were indistinctly treated as chronozones. Noteworthy this initial fourfold subdivision was only intended for local purposes, but it was soon used elsewhere without testing their correct applicability. The four initial zones were in ascendant order *hesperius*, *eurekaensis*, *delta* and *pesavis*. *Icriodus hesperius* and “*Ozarkodina eurekaensis”* were mostly endemic taxa of Western North America; only recently *I. hesperius* has been reported from Europe. The basis of the *delta* Zone was based in the Northamerican endemic species *Amydrotaxis praejohnsoni*, although many stratigraphers didn’t realize this, and used the *delta* Zone with different meanings. The *pesavis* Zone was also based in a different taxon and applied to any *Pedavis* with long tail that appears in the upper part of the Lochkovian. All these facts create confusion and resulted in misleading global correlations.

After many years of common efforts the Lochkovian taxonomy was better understood, but most of the new formal zonal concepts also failed in providing accurate correlation because they were used in different ways by biostratigraphers. The problem with current zonal definitions is the degree of ambiguity that they entailed. In solving this, a dual terminology is preferred. It has the disadvantage of longer names (the two taxa implied). However, the benefit of effective communication and flexibility in adapting to the past and future global records outruns the burden of a long name. Moreover if the designated index taxa represent worldwide, almost simultaneous Bioevents, they can be strong tools for recognizing the corresponding chronozones.

As an example in the upper half of the Lochkovian (upper half of former *delta* Zone and *pesavis* Zone) the following bio and chronozones can be established: *transitans-trigonicus, trigonicus-kutscheri, kutscheri-pandora* beta, p*andora beta-gilberti* and *gilberti-irregularis.* These zones are clearly defined and further records in any region can be integrated in this scheme without modifying the initial meaning of any given zone.

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Emsian (Lower Devonian) Event in the Aragonian Pyrenees (Spain)

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Three global intra Emsian Events linked to minor deepening pulses are documented in many places around the Earth, the Basal Zlíchov Event, the Upper Zlíchov Event and the Daleje-Cancellata Event. The Upper Zlíchov Event is widely documented by a sharp lithologic coupled with a biotic change that took place above the first occurence of the conodont *Polygnathus gronbergi*.

In the Pyrenees over 20 sections comprising Emsian strata have been investigated. Only one of these sections (Baliera 6, Aragonian Pyrenees) shows a 5 cm thin bed of black limestone and shales that can be related to an Emsian Event.

Section Baliera 6 consists of about 28 m, subdivided into 64 levels, of bluish grey platy and well-bedded limestone with millimeter thick shales interbedded. All the limestone belong to the Llaviero Member of the Basibé Formation and contain a rich conodont record allowing a detailed bio and chronostratigraphy from the Pragian through the lower Emsian (*pireneae*-*nothoperbonus* conodont zones).

Level 50 represents a sharp and sudden sedimentological change marked by the entry of a 5 cm thick layer of black limestone and shale representing a deepening pulse. This layer is located about 15.5 m above the base of the section and represents an important conodont turnover at the base of the lower *nothoperbonus* Zone. Three *Polygnathus* (*P. e. excavatus, P. excavatus* 114 and *P. nothoperbonus*), *Icriodus riosi, Pandorinellina*? sp. and *Criteriognathus steinhornensis* ssp. became extinct in Bed 50. Another three species of *Polygnathus* (*P. carlsi, P. pannonicus* and *P. gronbergi*) and eight of *Icriodus* (five new species, *I. curvicauda, I.* aff. *bilatericrescens* and *I. gracilis*) disappeared in Bed 49. Above Bed 50 the conodont record is scarce and restricted to *P. ramoni*, *P. aragonensis*, *P. luciae* and *I. bilatericrescens*.

Both characteristics, sharp lithologic and conodont record change, suggest an Event; its stratigraphic position above the base of the *nothoperbonus* Zone would indicate that this pulse would be an expression of the Upper Zlichov Event in the Pyrenees.

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New astronomically tuned age model for the Messinian Spanish Atlantic margin

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We present a new high resolution cyclostratigraphic age model for the Spanish Atlantic margin based on Messinian sediments of two cores (i.e. the Montemayor-1 and Huelva core) drilled in the Guadalquivir Basin in southern Spain, which formed part of the marine corridor linking the Mediterranean with the Atlantic in the Late Miocene. Tuning of high resolution geochemical records combined with planktonic foraminiferal astrobiochronology reveals a strong precessional cyclicity in both carbonate and grain size proxies, with maximum clastic supply from river run off coinciding with maximum summer insolation. We recognize a gradual change in the typical cyclic fluctuations in elemental compositions of the sediments through these cores, which is associated with a gradual change in depositional environment as the basin infilled. After applying this new age model the upper Messinian glacial stages and deglaciation are clearly identified in the Montemayor benthic oxygen isotope record. This high resolution age model can serve as a reference framework for studies in the Messinian Spanish Atlantic margin and allows correlation of changes within this region to Messinian Salinity Crisis events.

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Russian Standard stratigraphic scale of Cambrian system, its update project and its comparison with the International stratigraphic scale

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The Cambrian part of the General stratigraphic scale (GSS) of Russia requires development. At the same time, the GSS is significantly different from the currently developed International stratigraphic scale (ISS) of the Cambrian.

In the GSS Cambrian system is subdivided into 3 series. In the GSS the lower boundary of the Cambrian is drawn on the base of the Tommotian Stage of the Lower Cambrian, on the bottom of *Nochoroicyathus sunnaginicus* Zone. The upper boundary of the Cambrian system in the GSS is drawn on the top of the Nyayan regional Stage at the level that is approximately correlated with the part of the *Cordylodus lindstromi* conodont zone, containing Cambrian and Ordovician boundary GSSP in Green Point section, Newfoundland, Canada, marked by the FAD of conodont *Iapetognathus fluctivagus* Nicoll et al..

The Lower Cambrian in GSS is subdivided into 4 stages: Tommotian, Atdabanian, Botomian, Toyonian. Segmentation of the Lower series is the most conventional one. In the updated GSS of the Lower Cambrian project it is proposed to bring in two subseries: Aldanian and Lenian, each one includes two stages.

The Middle Cambrian in GSS is subdivided into 3 stages: Amgan, Mayan and Ayusokkanian. Boundary with the Lower Cambrian is drawn on the bottom of the *Ovatoryctocara* Zone. In the updated GSS project it is proposed to point out two subseries in the Middle Cambrian system: Amgan and Mayan, and 4 Stages: Molodoan, Chayan, Tiksian and Bulunian, two in each subseries.

The Upper Cambrian in GSS is subdivided into 3 stages: Sakian, Aksayan and Batyrbayan. The boundary with the Middle Cambrian is drawn on the base of the *Glyptagnostus reticulatus* Zone. In the updated GSS project it is proposed to point out two subseries: Kugorian and Tukhanian, and four stages: Omninan, Mokuteyan, Novotukalandian and Khantayan, two in each subseries. The upper boundary of the Cambrian system in the updated GSS project is drawn by the FAD of conodont *Cordylodus proavus* Müller, which closely coincides with the FAD of trilobite *Eoapatokephalus antiquus* Rosova.

Comparison of Russian GSS and ISS shows a smaller volume of the Cambrian system in Russia. The lower boundary of the Cambrian in the ISS is drawn stratigraphically lower than this one in GSS. Moreover, in recent years the lower boundary of Cambrian System (GSSP) is being reconsidered.

There are great differences in theoretical basis of GSS and ISS development. First of all, this applies to stratotypes of stratigraphic units: the ISS relies only on boundary stratotypes. In contrast, the GSS is based on units stratotypes, boundary stratotypes are supplemental.

Existing concept of ISS development includes stratigraphic boundaries rigid in specific physical points in sections, selected in accordance with certain requirements (GSSP concept). As such, GSSP concept initially contains self-destructive elements. In stratotype section in case of detection of representatives of the primary marker beneath boundary position institutionalized by formal ratification, arises a need for a new boundary selection in the same or a different section, and perhaps for choosing a different primary marker of the boundary. Eventually, this results in a complete repetition of the procedure of establishment of boundaries, which is an extremely time-consuming and long-term process. The probability of such scenario is quite high. The situation with the lower boundary of the Cambrian System may serve as an example.

In case of establishment of boundaries of ISS we suggest to exclude the determination of the position of a physical point of the boundary from the mandatory part of the decision, limiting to the conclusion that the boundary is defined in the stratotype section by FAD of primary marker. With this approach, the findings of the representatives of the primary marker beneath the initial level will only cause the automatic transfer of the boundary, avoiding the formal procedure of boundary revision.

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Correlation of Quaternary deposits of the East European plain and Caspian Sea

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Chronostratigraphical studies of continental deposits in southern European Russia conducted during the recent few years revealed the development history of the loess-soil formation (LSF) within the Pleistocene. In particular, it was established that LSF development in the southern parts of the European Russia has begun at approximately the time of the Brunhes-Matuyama magnetic inversion (about 780 thousand years ago). The data on the fauna, paleosoils, and palynological data make it possible to start an analysis of the steppe zone evolution from its origination in the Late Miocene (app. 7.5 mln years ago), to follow its development throughout the entire Late Cenozoic, and therefore outline the trend of its further development. Along with the LSF, the territory in question contains sub-coastal formations – lagoon and marine deposits of various ages, which were formed throughout the Quaternary. It creates the necessary prerequisites for correlation of the continental and marine deposits, both of the inland Caspian Sea, and of the Sea of Azov, which is connected to the World Ocean through the Black Sea. Studies of temporal and spatial relationships of marine and continental layers in the region will permit us to correlate landscape and climatic changes on land with the 'regional' level oscillations of the Caspian Sea, as well as with the oceanic level changes of the Azov and Black seas.
Preliminary studies loess-soil formation on various terraced levels of the Eastern Azov reviles prospects for the reconstruction of landscape and climate change with high resolution throughout the late Cenozoic. The first results of the research are published in several articles. Application paleopedological, paleontological, palynological, paleomagnetic methods allowed more fundamental approach to the chronological assessment of individual horizons. The study of a number of key sections of Azov region and the Volga region allowed specifying the chronological position and underlying subaqueous deposits, which is the basis of the estimated correlations of continental and marine sediments. Based on comprehensive research the diagnose of various types of different aged soils of humid, subarid and arid ecosystems, was developed, reflecting the evolution of the Quaternary interglacial phases of soil formation and the emergence of steppe formations in the Miocene-Pliocene. To date, based on the extensive research, new factual results was obtained for the Pleistocene and Holocene of the Caspian and Black Sea and the Manych depression. Compiled stratigraphic schemes made on the basis of a unified biostratigraphic correlation - on features of spatial-temporal distribution of the genus Didacna Eichwald, which is promising for the correlation of the quaternary deposits of Caspian Sea and Pontus. Through comparison of loess-soil series of Azov Sea region with marine and estuary-lagoon sediments of Pontus it is possible to correlate the deposits of the East European Plain Caspian sea region. An additional source of important data will be study and correlation of Caspian deposits from continental formations involving the horizons of fossil soils.

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The Jurassic-Cretaceous boundary: radiolarian potential

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Episodes of significant decrease in taxonomic diversity of radiolarians and ammonites in the Late Jurassic within Boreal Realm in both groups were synchronous (Mitta, Vishnevskaya, 2006). Late Volgian crisis coincided with significant changes in the morphotypes of ammonite and radiolarian skeletons. A typical Lilliput effect of the latest Mid Volgian in Late Jurassic Boreal ammonite faunas is described by Rogov (2014, 2015). The specimens of the latest Mid Volgian/Late Volgian cyrtoidal Nassellaria (*Parvicingula, Spinicingula)* also have lilliput size, small reticular pores, weak distinct ridges or almost no external circumferential ridges. Bjorklund and Swanberg (1987) explained reticulated pores by the neritic or glacial relict in contrast to the oceanic round pores. Some extinction of radiolarians at the end of the Jurassic began in the Volgian, and most likely resulted from a marine regression and climatic cooling. It was confirmed by predominance of cold-water representatives of Genus *Parvicingula* in radiolarian associations and boreal Family *Craspeditidae* among ammonites at that time in the Middle Russian, Timan-Petchora and West Siberian Seas (Mitta, Vishnevskaya 2006; Vishnevskaya, Kozlova, 2012).The rapid evolution of *Radiolaria* and a bloom of morphological diversity of *Parvicingula* with development of numerous abnormal skeletons may have been caused by stress conditions, as it was proposed for Lilliput effect in ammonites Rogov (2014, 2015). Probably, only the more accommodated often-primitive vulgar forms of *Parvicingula* and *Stichocapsa* survived to order give rise to new trends (*Spinicingula* end others) and provide evolutionary progress.

It is observed the change of Jurassic *Parvicingula* rich assemblage into *Echinocampe, Nordvikella* and *Spinicingula* rich at the Jurassic-Cretaceous boundary. Just at the Jurassic-Cretaceous boundary (in earliest Berriasian) the occurrence of *Thanarla, Mita, Dictyomitra, Neorelumbra, Quasicrolanium* groups was recorded among Radiolaria.

The degree of endemism in high conical Parvicingulidae Pessagno and Echinocampidae Bragin took place owing to great abundance of morphotypes with external cephalic spines and apophyses (Vishnevskaya, Kozlova, 2012) at the Jurassic-Cretaceous boundary in the Boreal Realm. Also, the decrease of chamber number was fixed in Late Volgian representatives of genera *Parvicingula, Spinicingula* and *Stichocapsa*.

The high-conical representatives of the Family Parvicingulidae Pessagno have principal stratigraphic significance (only Genus *Parvicingula* includes 64 species) and can be used for dismembering and correlation of sequences on the Jurassic and Cretaceous boundary. This group rapid evolved, spreaded in high paleolatitudes of the entire Pacific and even penetrated into the Arctic and Antarctic regions.

The phylogenic lines of Family Parvicingulidae allowed to compile stratigraphical zonal schemes for Jurassic to Lower Cretaceous sequences of California (Pessagno, 1977; Hull, 1997), Argentina and Antarctida (Kiessling, 1999), as well as North of Russia (Vishnevskaya, Murchey, 2002) and Russian Far East (Popova et al., 1999).

Due to radiolarian provincialism the correlation of radiolarian biozones between Boreal (North of Eurasia and America) and Tethyan Realm (South Europe, Baumgartner et al., 1995; Hardenbol et al., 1998) is hampered during the Late Jurassic-Early Cretaceous interval. Nevertheless, it is possible to use Pacific zonation as missing link to correlate Tethyan and Boreal scales.

The abundant presence of Parvicingula within the oil shale sequences of the Arctic Margin (Dyer and Copestake, 1989; Vishnevskaya, Kozlova, 2012) provides a basis for establishing a preliminary boreal zonation at the Tithonian/ Berriassian boundary: P. haeckeli (Upper Tithonian), Arctocapsula devorata arctica (Lower Berriasian), and Parvicingula khabakovi (Upper Berriassian) Zones (Vishnevskaya, 2001).

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Palaeoclimatic records from the Late Cretaceous calcareous and siliceous planktonic assemblages of Eastern Europe

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The assemblages of planktonic foraminifers and radiolarians are investigated from the same samples that have been collected from Cenomanian-Maastrichtian sequences of East-European platform, Caucasus, as well as the Cenomanian-Campanian of Crimea.
The Cenomanian interval was a time of polytaxic development due to warm greenhouse and correlated with sea level rise. The appearance of abundant multichamber cyrtoidal pseudomacrocephalic, as well as cryptocephalic and cryptothoracic forms in the Cenomanian is apparently reflected a changing of hydrological conditions and it was probably caused by the active adaptation. The extinction of single-keeled rotaliporides in foraminiferal community, reduction of a morphological variety, violation of the correct system of porosity in radiolarians coincides with the Cenomanian–Turonian boundary event.
The Turonian-Coniacian diversification of all foraminiferal and radiolarian groups probably is related to a sea-level highstand and hot greenhouse climatic environment. The Tethyan species reached Moscow Region of the Russian Plate. Acme of double-keeled and single-keeled marginotruncanids, concavatotruncanids and their diversification in Turonian-Santonian reflects more stable conditions in a more oligotrophic regime. The replacement of very specialized marginotruncanids/ concavatotruncanids into marginotruncanids by *globotruncanids* at the Santonian-Campanian boundary probably are related to penetrating of cold water to south up to North Caucasus and Crimea and reflected a cooling episode. The occurrence of temperate and high paleolatitude family Prunobrachidae Pessagno in the North Caucasus locations is also indicative of cool greenhouse environments.
The invasion of cold water from Arctic Region through the Russian Plate (Baraboshkin et al., 2003; Naidin et al., 2007; Blakey, 2012; Pugh et al., 2014) to South is confirmed by finding of Genus Prunobrachium in North Caucasus and Crimea Location. Latest Cretaceous family Prunobrachidae Pessagno occurs mostly in temperate and high paleolatitudes. Mass abundance of Prunobrachidae is indicative of cold water environments, which were characterized for Polar Urals, Russian Plate, Siberia, Russian Far East, South PaleoPacific (Tasman Sea) and New Zealand. Analysis of Prunobrachidae paleogeography during Late Santonian-Campanian shows bipolar distribution in temperate and high paleolatitudes. The distribution areas are almost symmetrical relative to the equator: 35º-62º N in the Northern Hemisphere and 50º-52º S in the South. It is very important to use representatives of family Prunobrachidae in the study of paleogeography and ecostratigraphy, as well as stratigraphic correlation of Tethyan and Boreal sequences of the Upper Cretaceous.
The finding of calcareous dinocyst Pithonella globosa Futterer widespread in an interval Middle Maastrichtian–early Danian together with Orbiculiforma australis Pessagno, O. renillaeformis ampbell et Clark, Tholodiscus densus (Kozlova), allows to indicate rather warm episode during accumulation of the Late Maastrichtian siliceous clays.

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Integrated stratigraphy and eustatic sea-level fluctuations around the Santonian-Campanian boundary interval

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The Gosau Group successions in the Northern Calcareous Alps of Austria and Germany provide sections that allow the integration of various stratigraphic signals from macro- and microfossils to chemostratigraphy and magnetostratography. Sections in the area of the Gosau valley, e.g. the Postalm section (Upper Austria - Salzburg) expose a Santonian to Maastrichtian succession of neritic to bathyal sediments. At the Postalm, the Santonian-Campanian boundary interval comprises a deepening succession from a sandy conglomerate with a hardground on top, overlain by grey to yellowish shelf marls grading into red marly limestones. The base of the Campanian can be defined by magnetostratigraphy, i.e. the reversal from Chron C34n (the Long Cretaceous Normal Polarity-Chron) to C33r. An interval of ca. 80 cm of undetermined magnetostratigraphy between clearly normal and clearly reversed polarities is present. A 1 m thick interval of unusual high magnetic susceptibility values is present at the end of chron C34n (latest Santonian).
Two of the main suggested plankton biomarkers to pinpoint the Santonian-Campanian boundary, i.e. the first occurrence of the nannofossil *Broinsonia parca parca* and the last occurrence of the planktonic foraminifer *Dicarinella asymetrica* occur in close proximity to the reversal. Strontium isotope stratigraphy indicates a value of 0.707532 for the base of the Campanian in the Postalm section. Carbon isotopes show a positive excursion near the boundary, i.e. the Santonian-Campanian carbon isotope event.
Oxygen isotopes show a negative excursion slightly below the Santonian-Campanian boundary, followed by a trend to more positive values. Together with the magnetic susceptibility data, sequence stratigraphy interpretations and global correlations a sea-level lowstand can be inferred to occur just at the boundary, preceded by a rather short-duration sequence of late Santonian age, and a longer sequence of early Campanian age. The inferred lowstand at the Santonian-Campanian boundary, at the base of chron C33r, is also characterized by a significant rudist extinction event.

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News from the old Anthropocene

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The Anthropocene, since its conceptual formulation in 2000, has been the subject of intensive discussion, including attempts to define a base. Besides major issues and challenges in defining the Anthropocene as a formal chronostratigraphic unit, the questions of how and when to define the base of the Anthropocene are one of the major tasks of the Anthropocene Working Group of the Subcommission of Quaternary Stratigraphy (AWG) of the International Commission of Stratigraphy. The problem of a formally defined base in terms of a chronostratigraphic unit is closely linked to the wider and extremely diverse discussion of the Anthropocene. This discussion centers on if and when the influence of humans on the Earth system, and especially on geological processes, started to be significant and fundamental to substantiate the definition of a new geological time unit that terminates or replaces the Holocene. The AWG published recently on the usability and stratigraphic optimal placement in the midst of the 20^{th} century, and suggested using the world's first nuclear bomb explosion, on July 16th 1945 at Alamogordo, New Mexico, USA (Zalasiewiecz et al., 2014).

Three possible time frames are in discussion for a base of a chronostratigraphic Anthropocene: (1) an early Anthropocene, beginning more than 2 millenia BP; (2) the Industrial Revolution, including dates from 1500 to 1850; (3) a mid-twentieth century beginning related to the Great Acceleration after WW II. In addition, a diachronous beginning was put forward by some authors.

An alternative definition for the Anthropocene in respect to early human influence may be around 3000-2800 BP, with the onset of mining-induced trace metal pollution, as defined by (relative) lead enrichment and lead isotopes. Although this event signal so far is limited to the Northern hemisphere, potential correlations and secondary markers may be present in the Southern hemisphere, using, e.g., climate events (the 2800 BP climate-insolation event), and magnetostratigraphy (low in dipole latitude and peak in dipole moment at 2700-2550 BP, the European ‘f-event’).

Such an early Anthropocene definition has some advantages over a definition of the Anthropocene at around the midst 20th century such as proposed recently by Zalasiewicz et al. (2015):

- It encompasses significantly more time, allowing a considerably larger quantity and better quality of Anthropocene stratigraphic records in a larger variety of archives to have been established. The early Anthropocene base as suggested involves a large quantity of anthropogenic deposits, man-made ground and legacy sediments.
- This definition conforms to some extent with the (diachronous) base of the Archaeosphere in putting the base of the Anthropocene into the prehistoric archeological record, but it contradicts the Archaeosphere concept in not using the physical (and thus diachronous) lower boundary.
- It allows a definition of the base of the Anthropocene by applying the GSSP concept, as used for most of the Phanerozoic boundary definitions yet, and thus conforming stratigraphy rules and principles. It furthermore allows a definition by setting the GSSP in an Arctic ice core as already used for the GSSP base of the Holocene.
- It is still in line with definitions of the Holocene and proposed subdivisions in the Holocene, i.e. with a late Holocene base at 4200 BP.
- Some global (solar radiation), regional (e.g. volcanic, magnetostratigraphic) and southern hemisphere (e.g. climate) events may be related and correlated to the suggested primary marker, giving secondary marker events in auxiliary reference sections around the globe.

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International Geoscience Program Project IGCP 609: News on Greenhouse climate sea-level changes and the Cretaceous World

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The recent rise in sea-level in response to increasing levels of atmospheric greenhouse gases and the associated global warming is a primary concern for society. To predict future sea levels a better understanding of the record of past sea-level changes and controlling factors especially during Greenhouse climate phases is strongly needed. UNESCO IGCP 609 addresses correlation, causes, and consequences of significant short-term sea-level changes during the last major greenhouse episode of Earth history, the Cretaceous. 3rd to 4th order (kyr to a few Myr), sea level changes are recorded in Cretaceous sedimentary sequences. The mechanisms for these are controversial and include brief glacial episodes, storage and release of groundwater, regional tectonism, and mantle-induced processes.

Based on the progress in the GTS, it is now for the first time possible to correlate and date short-term Cretaceous sea-level records with a resolution appropriate for their detailed analysis. Orbital cycles of various length are more and more identified in the Cretaceous stratal record, and used to assess the duration of events and intervals, and to date stage boundaries and bio-zones in high precision. More and more proxies for sea-level changes in deeper-water shelf to pelagic archives are integrated within a high-resolution and high-precision time scale, such as high-resolution carbon isotopes (climate-driven carbon isotope cyclicity), mineralogy (i.e. distribution of phyllosilicates), grain size analysis (silt/clay ratio in pelites), sediment geochemistry (e.g. uranium peaks during sea-level rise; Sr/Ca ratios where Sr rich shelf carbonates weather at times of sea level lows and introduce more Sr into the ocean), and strontium isotopes (continental erosion vs. magmatic values).

Thus, IGCP 609 investigates sea-level cycles in detail in order to differentiate and quantify both short- and long-term records. Main goals are (i) to correlate high-resolution sea-level records from globally distributed sedimentary archives to the new high-resolution absolute time scale, using sea-water isotope curves and orbital (405, 100 kyr eccentricity) cycles; (ii) the calculation of rates of sea-level change during the Cretaceous greenhouse episode and evaluation of the role of feedback mechanisms; (iii) to investigate the relation of sea-level highs and lows to ocean anoxia, oxidation events and lake-level changes, and to evaluate the evidence for ephemeral glacial episodes or alternative climatic drivers.

Prominent sea-level fluctuations during major greenhouse episodes of the Earth are often explained by the presence of ephemeral ice sheets even during extreme 'hothouse' phases as in the mid-Cretaceous. However, the possible effect of groundwater storage and release on sea-level change has been widely underestimated in its order of magnitude. It is considered to constitute a water volume that is about equivalent to today's ice volume, thus corresponding to a potential sea-level change of up to ca. 50 m applying isostatic adjustment. Groundwater aquifer storage, including both freshwater and saline pore waters above sea level, exceeds lake and river storage capacities by several orders of magnitude.

The term "limno-eustasy" was introduced to describe the effect of water volumes resulting from groundwater and lake storage or discharge on sea-level fluctuations during hothouse climate. Evidence for limno-eustatic cycles during supposed ice-free periods of the mid-Cretaceous come from wet-dry weathering cycles and high-resolution stratigraphic correlations between marine and continental lake archives. Lake-level and sea-level fluctuations should be in an out-of-phase relation, i.e., a major marine sea-level lowstand should correspond to a lake-level highstand, and vice versa. Tests using the Turonian to Campanian Late Cretaceous record of the long-lived lacustrine Songliao basin in China indicate such an out-of-phase relation, and thus support the limno-eustatic hypothesis and its stratigraphic utility.

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Planktonic gastropods: survivors in a changing ocean

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The geological record of the pteropods (Thecosomata) and heteropods (Pterotracheoidea) probably begins in the earliest Eocene (55 million years ago), although there are records – in the earliest Jurassic and mid–Cretaceous – of taxa that may be planktonic gastropods. In the early Paleogene there was the transition from a calcitic ocean to an aragonitic ocean and it appears more logical that these aragonitic gastropods appeared at that time. While graphs of diversity or species richness are subject to taxonomic 'distortion', especially when comparing biological data with palaeobiological data, the heteropods appear to have been the product of our modern, thermohaline–driven ocean. The pteropods, with a potentially longer record, appeared during the hyperthermal events of the earliest to mid–Eocene surviving the transition to the modern, thermohaline–driven ocean and the onset of the present 'icehouse world'. The fossil record of the planktonic gastropods can be used in biostratigraphy but, as their thin, fragile shells are composed of aragonite, their geological history is certainly incomplete. In some locations they are preserved as phosphate, pyrite or limonite moulds, though such preservation often fails to retain some of their diagnostic characters, making speciation difficult. In the Mediterranean region during the Miocene–Pliocene it is clear that they do have some stratigraphical resolution, though the lack of research is, everywhere, a limitation. While both the pteropods and heteropods are important constituents of the plankton at the present time, they are suffering from ocean acidification, although work on the Pleistocene glacial/interglacial cycles has shown that they can survive changes in pH during the interglacials (especially MIS 5e).

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Late Eocene marine fossil evidence for disappearance of Tethys-Himalayan Sea

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Paleogene marine sediments are well exposed in the Tethyan Himalaya. The Cenozoic pre-collision related Tethys Himalayan Sequence varies between locations. The initial timing of the Indian-Eurasian collision and the elimination of the Tethyan Ocean are directly constrained by the cessation of the marine sedimentation on Indian margin. The Tethyan Ocean that once covered parts of southern Tibet was eliminated when the Indian and Eurasian continents collided along the Yarlung Tsangpo suture zone. The timing of the last marine sedimentary rocks thus places a constraint on this first-order tectonic event. Although several sedimentary successions have been reported from southern Tibet their documentation is commonly incomplete or important questions remain regarding stratigraphic continuity and/or the reliability of fossil identifications.

The existing data are critically assessed in order to correlate and compare between sections in three zones: one to the north of the suture on the Asian margin and two to the south on the northern margin of India. We examine the planktonic foraminiferal and nannofossil biostratatigraphy of the youngest sections, which occur in the Tibetan Himalayan succession and lie around 100 km south of the suture. This also includes a previously unreported section 70 km east of Gamba. We also consider the ages of radiolarians from cherts in mélange zones immediately south of the suture zone in Ladakh, NW India and Tibet. We discuss the implications of our results for understanding the timing of continent-continent collision. In doing this we take into account the effects of crustal loading, eustatic sea level variation, orogenesis associated with the on-going convergence between India and Asia together with the likely migration rate of any fore-deep in front of a colliding continental mass. This research demonstrates that a marine seaway remained in existence south of the Yarlung Tsangpo suture zone until at late Priabonian time. However, the Paleogene basins in southern Tibet are not oceanic, but foreland basins, with the characteristics of epicontinental basins. Early collision causes basin formation through tectonic loading. It is implied that during the Paleocene and Eocene, marine shelf deposition was widespread in the Himalayan region, indicating the existance of a Tethys seaway along strike the Indus-Yalung Tsangbo Suture Zone, extending from Kohat, Zanskar and Simla to southern Tibetan and as far as the eastern syntaxis area. According to the foraminiferal assemblages within these final marine sediments, we suggest the faunas were similar and probably shared the same habitat in the foreland basins. The shallow marine deposition might have been connected with the Bengal basin and extended as far as to the Indus-Burman suture zone. Shallow marine conditions did not change until the end of Lutetian in most parts of Himalaya region. As subduction continued, the Indian and Eurasian plates finally collided completely and the foreland basins disappeared resulting from the syn-collisional uplift. According to our results from investigation of the last marine deposit in the Gamba-Tingri region, the Tethys seaway still existed in the Priabonian indicating that continental collision did not happen until at least that time.

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New progress on the study of the Visean-Serpukhovian (Carboniferous) boundary in South China

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A synthetic study on biostratigraphy, sedimentology and geochemistry of the upper Visean to Serpukhovian succession in South China is being undertaken in order to comprehensively understand the evolutionary change of the biota and global correlation around the Visean/Serpukhovian boundary. The studied sections include the following: the Naqing, Narao, Luokun, Dianzishang and Yashui sections, among of which the former three are relatively deep water (slope) facies and the last is shallow water (platform) facies.

Abundant P1 elements of conodont *Lochriea* species, which have a wide morphological variability throughout the Upper Visean–Lower Serpukhovian boundary interval in the Naqing section, are recently restudied. Two lineages are herewith proposed: 1) noded *Lochriea* species, such as *L. mononodosa* – *L. nodosa* – *L. ziegleri, L. senckenbergica* and *L. multinodosa*, and 2) ridged *Lochriea* species such as *L. monocostata* – *L. costata* – *L. cruciformis*. The numerous and very variable species of *Lochriea* across the V/S boundary in the Naqing section, South China are sorted out for the first time, and the possibilities for their derivation are discussed.

In addition, detailed conodont biostratigraphy across the V/S boundary intervals in the Luokun section and the Narao section have also been studied based on a bed-by-bed sampling during 2013-2014. Abundant foraminifers have been found in the Dianzishang and Yashui sections around the V/S boundary interval. Several volcanic ash beds have been collected from the Naqing section and wait for dating. A preliminary chemostratigraphic study shows that a negative carbon isotope excursion exists shortly above the FAD of conodont *Lochriea ziegleri* in all the Naqing, Narao and Luokun sections, which might be used for global correlation.

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Shaanxilithes from Qaidam Basin, North China: a potential index fossil for the late Ediacaran

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Shaanxilithes is a problematic ribbon-shaped fossil consisting of a serial of intensive stripes. This fossil was first described from the upper Ediacaran Dengying Formation, southern Shaanxi Province, South China in 1980s. Since then, it has been reported from the upper Ediacaran of different tectonic units both in China (e.g. South China Plate, North China Plate, and Qaidam Block here) and elsewhere (e.g. India and Siberia). Fossil material in this study was collected from the upper part of the Zhoujieshan Formation, a silty shales dominated rock unit that is unconformably contacted with the overlying Cambrian rocks. Fossils are extremely abundant in a 30 cm thick shaly bed about 7 m below the Ediacaran−Cambrian boundary in the region. Specimens are highly flattened and preserved as straight or distorted ribbons with closely spaced annulations. Each form has consistent width, varying from 1 mm to 9 mm in different individuals. The maximum preserved length is over 15 cm. Disarticulated fragments are fairly common, occurring as dense assemblages (Fig. 3A) on bedding surfaces. *Shaanxilithes is* similar to *Sabellidites* in overall body architecture. However, the multi-layered body wall with fibrous texture has not been observed in *Shaanxilithes*. By comparison with specimens from the type locality, we conform that *Shaanxilithes* is an organic-walled tubular fossil rather than a trace fossil. Although its biological affinities remain problematic, the wide paleogeographical distribution makes it a potential index fossil for upper Ediacaran successions in both regional and interregional scales.

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Early Cretaceous nonmarine ostracod biostratigraphy of western Liaoning area, NE China

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The Early Cretaceous ostracod fauna in western Liaoning is divided into eight successive ostracod assemblages:

1. *Cypridea liaoningensis – Damonella circulate* assemblage (mainly in the lower part of the Yixian Formation)
2. *Cypridea liaoningensis – Ziziphocypris linchengensis – Cypridea gujialingensis* assemblage (mainly in the upper part of the Yixian Formation of Kazuo – Chaoyang Basin)
4. *Cypridea deflecta – Lycopterocypris infantilis* assemblage (mainly in the upper part of the Yixian Formation)
5. *Cypridea deflecta – Lycopterocypris liaoxiensis* assemblage (mainly in the lower member of the Jiufotang Formation)
6. *Limnocypridea grammi – Scabriculocypris pingquanensis – Cypridea delnovi* assemblage (mainly find in the upper member of the Jiufotang Formation)
7. *Mongolocypris kleinbergi – Mongolianella palmosa – Cypridea tumidiusula* assemblage (corresponding to the lower member of the Fuxin Formation)
8. *Mongolocypris globra – Candona*? *dongliangensis* assemblage (corresponding to the upper member of the Fuxin Formation)
9. *Cypridea echinata – Cypridea* (*Bisulcocypridea*) *edentula – Triangulicypris* assemblage (in the Sunjiawan Formation)

These assemblages have provided information about age constraint of relevant nonmarine Early Cretaceous strata: Yixian Formation – Hauterivian to Barremian, probably up to Aptian; Jiufotang Formation – Barremian to Aptian; Fuxin Formation – Aptian; Sunjiawan Formation – Albian. According to the revised age for the upper part of the Yixian Formation in the Kazuo – Chaoyang Basin, which is Hauterivian – Barremian, *Ziziphocypris linchengensis* is the earliest record of the genus *Ziziphocypris*. This work demonstrates that the supra-regionally distributed ostracod species, including species of *Cypridea*, are useful for biostratigraphic correlation and age determination of lacustrine deposits. In contrast, the endemic *Cypridea* species are helpful for regional biostratigraphic correlation of scattered basins within western Liaoning.

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Low-latitude terrestrial climate cooling event in the Late Triassic (Norian-Rhaetian): palaeobotanical evidence from the Sichuan Basin, southern China

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The Sichuan Basin is one of the largest inland basins in the low latitude region of southern China. The Upper Triassic deposits are terrestrial origin and well developed and in the basin. However, the climate conditions of the Late Triassic were poorly understood for a long time. It was supposed to be a warm and humid condition during the entire period of the Late Triassic. However, our recent investigations have provided palaeobotanical evidence showing that a cooling climate event occurred in this region during the Late Triassic episode. The finding of a new *Xenoxylon* fossil wood taxon in the Xujiahe Formation in Guangyuan, northern Sichuan Basin contributes to a better understanding of the yet poorly documented *Xenoxylon* early radiation during the Late Triassic. As a palaeobiogeographically significant genus, the occurrence of *Xenoxylon* in the Sichuan Basin of southern China indicate a short-term cooling event, sandwiched within a period during which warm and wet climate condition largely prevailed over lower latitude regions of the Northern Hemisphere. Such a cooling event is suggested to be indirectly influenced by the temporary onset of a megamonsoon phenomenon during Late Triassic. In addition, our palynological data and the Sporomorph Ecogroup Model (SEG), analysis from the Xujiahe Formation support that there some climate perturbations in this time, thus showing congruence for the climate cooling event.

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Conodont stratigraphy and palaeobiogeography near the Frasnian/Famennian boundary at Wulankeshun, Junggar Basin, NW China

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Upper Devonian strata are wide-spread and well-exposed in northwestern Junggar, NW China. During geological mapping a monoclinal outcrop of the Hongguleleng Formation in the Wulankeshun region was discovered ca. 100 km west of the Bulongguor Reservoir stratotype. Our study confirms that the Hongguleleng Formation has a conformable contact with the strata of the under and overlying Zhulumute and Heishantou formations.

The conodont succession of the Wulankeshun section is characterized by shallow-water assemblages.

In the lower member, separate local icriodid and polygnathid conodont zones are established that can roughly be correlated with the pelagic “standard zonation”. The basal beds of the Hongguleleng Formation are assigned to a low diverse *I. praealternatus ferus* n. ssp. Zone, which possibly includes topmost Frasnian strata but which continues into the basal Famennian. At present, the Frasnian/Famennian boundary cannot be fixed unequivocally with the help of conodonts and there are no obvious Upper Kellwasser equivalents. In the early Famennian partly endemic icriodid lineages provide successive *I. cornutus, I. stenoancylus junggarensis* n. ssp., and *I. plurinodosus* n. sp. zones. The base of the Famennian is possibly marked by the oldest but endemic species of *Neopolygnathus, Neo. huijunae* n. sp. It is followed by local *Neo. communis communis, “Polygnathus” pomeranicus, Po. argutus,* and *“Po.” pseudocommunis* n. sp. zones. The base of the first Zone is correlated with the base of the Lower *crepida* Zone, the second approximately with the base of the Upper *crepida* Zone (due to the entry of *Ancyrognathus bifurcatus*), the third with the base of the Lower *rhomboidea* Zone, and the fourth, based on rare occurrences of *Palmatolepis rhomboidea* and, higher up, of *Palmatolepis glabra prima* M3, with ca. the base of the Upper *rhomboidea* Zone, continuing into the Lower *marginifera* Zone.

There are restricted similarities with shallow-water conodont faunas from eastern Europe, Kazakhstan, and Iran. But we report first occurrences of taxa that were originally described from far distant regions, such as NW Canada and eastern Australia. Accordingly, the local high number of endemic taxa (17 (sub) species, 46 %) points to a significant plate tectonic isolation of the Junggar Basin in the early Famennian.

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Is the Anthropocene distinct from the Holocene?

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The inaugural meeting of the Anthropocene Working Group of the SQS in Berlin (Oct. 2014) produced a consensus statement that “humans have altered geologic processes across the Earth system sufficiently to cause a planetary transition to a new interval of geological time”, with the timing of the onset of continued debate, but with a majority in favour of a mid-20th century beginning. The name has driven the assumption that the Anthropocene should be an epoch, but are its signatures truly driven out of the range evident for most of the Holocene, or are changes comparable or subsidiary to Holocene stages? The evidence rests upon a broad range of signatures reflecting humanity’s significant and increasing modification of Earth systems. These are visible in anthropogenic deposits in the form of the greatest expansion of novel minerals in the last 2.4 billion years and development of ubiquitous materials, such as plastics, present in the environment only in the last 60 years. Globally distributed spherical carbonaceous particles of fly ash represent another near-synchronous and permanent proxy. The artefacts we produce, the technofossils of the future, provide a decadal to annual stratigraphical resolution. These materials and deposits have in recent decades extended into the oceans and increasingly into the subsurface both onshore and offshore. These anthropogenic deposits are transported at rates exceeding those of the sediment carried by rivers by an order of magnitude, fluvial systems themselves showing widespread sediment retention in response to dam construction across most major river systems. The Anthropocene is evident in sediment and glacial ice strata as chemical markers. CO_2 in the atmosphere has risen by ~45 % above pre-Industrial levels, mainly through combustion of hydrocarbons. Although average global temperature increases and sea-level rises are still comparatively small, the shift to more negative $\delta^{13}C$ values in tree-rings, limestones, speleothems, calcareous fossils and $\delta^{13}CO_2$ in ice forms a permanent record. N and P contents in surface soils have approx. doubled through increased use of fertilizers as the human population has also doubled in the last 50 years. Industrial metals such as Cd, Cr, Cu, Hg, Ni, Pb, Zn and persistent organic compounds have been widely and rapidly dispersed. A clear novel signature is radioactive fallout from atomic weapons testing, initiated in 1945 but becoming global in 1952 and in the case of Pu^{239} representing a long-lasting marker event. The Earth still has most of its complement of biological species, however, current trends of habitat loss and predation, if maintained, will push the Earth into the sixth mass extinction event. Dramatic elapsed changes include trans-global species invasions and population modification through agricultural development on land and contamination of coastal zones. Although these changes are not synchronous, within near coastal environments microfauna/flora commonly show pronounced assemblage changes in the mid-20th century.

Considering the entire range of environmental changes reflected in stratigraphic signatures, the global, large and rapid scale of change related to the mid-20th century is clearly distinct from previous Holocene signatures, consistent with interpretation of the Anthropocene as a potential epoch.

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Carbon isotope geochemistry – proxy for paleoceanography and tool for stratigraphy

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The discovery of isotope geochemistry as a powerful tool in oceanography and paleoclimatology is dating back into middle of the 20th century. Oxygen isotope records stored in carbonate of planktic and benthic foraminifera were recognized as archives of the "orbital pulse", or, in other words, of Milankovich cyclicity and this opened the possibility to use systematic oxygen isotope fluctuations as a tool for stratigraphy. Carbon isotope geochemistry was identified as a potentially powerful tool for paleoceanography only in the late 1960ties, when Helen Tappan published her fundamental study on "primary production, isotopes, extinction and the atmosphere" (1968). It took another ten years until carbonate carbon isotope data were used as a proxy of changes in the marine carbon pool and, in a next step, of variations of the global carbon cycle. Changes in the open marine carbon pool are regarded as synchronous on a global scale due to short mixing time of the oceans in the order of thousand years. Based on this, fluctuations in the C-isotope record of marine carbonates can be used as accurate stratigraphic markers. Pelagic carbonates continue to serve as reference archives for C-isotope stratigraphy. Orbital variations (long eccentricity), greenhouse climate conditions triggered by volcanic degassing or by sudden methane release are identified as possible cause of changes in marine C-isotope records. Today carbon isotope stratigraphy based on bulk carbonate analyses is established as a stratigraphic tool in Phanerozoic and Proterozoic archives. However, poor understanding of source and origin of pelagic micrites in pre-Jurassic oceans complicates interpretations of C-isotope records. Projection of pelagic C-isotope curves into hemipelagic or neritic environments asks for a thorough understanding of environmental conditions during formation of these sediments and of diagenesis affecting the isotopic composition of marine sediments. Wiggle matching of C-isotope curves at increasingly high resolution and using low amplitude fluctuations <0.5permil provokes the question on forcing factors causing proposed global changes in the marine carbon isotope signature on time scales less than 100 kyr. Future C-isotope investigations will focus on processes affecting C-isotope signature of marine carbonate. Organic carbon isotope records will remain relevant as additional source of information on possible diagenetic overprint of carbonate carbon isotope signatures.

Closing the Middle Eocene Cyclostratigraphic Gap

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To explore the causes and consequences of past climate change highly accurate age models are required. The reliability of astronomical calibrations of the geological time scale beyond 40 million years critically depends on the fidelity of orbital models and radio-isotopic dating techniques. Discrepancies in the dating of sedimentary successions and the lack of suitable records spanning the middle Eocene have hitherto prevented the development of a continuous astronomically calibrated geological timescale for the entire Cenozoic Era. We have addressed this problem by constructing an independent astrochronological stratigraphy based on Earth's stable 405-kyr eccentricity cycle between 41 and 48 million years ago (Ma) with new data from deep-sea sedimentary sequences from Ocean Drilling Program (ODP) Sites 702 (Leg 114) and 1263 (Leg 208) in the South Atlantic Ocean. This was achieved by the development of a good magnetostratigraphy across magnetic polarity chrons C20r and C21n at Site 1263 that subsequently have been linked to new high-resolution bulk carbon isotope records from Sites 702 and 1263. Together with previously available shipboard stratigraphic data we constructed a robust 405-kyr cyclostratigraphic framework across a ~7-Myr interval of the middle Eocene. These new records bridge the existing gap in the Paleogene astronomical time scale and provide a chronology fully independent of uncertainties inherent in radio-isotopic dating methods and unstable components in orbital solutions commonly used for astronomical tuning of geological data. Our new records resolve the long-standing questions and inconsistencies regarding the accurate absolute ages of both the Paleocene-Eocene Thermal Maximum (PETM, 55.930 Ma) and the Cretaceous/Paleogene boundary (66.022 Ma) and confirm the inter-calibration of radio-isotopic and astronomical dating methods. In addition, the new data reveal inaccuracies in the planetary ephemeris used to calculate the orbits of the planets in the solar system.

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The palaeobiological factors as a clue for recognition of the environmental-climatic conditions at the Oxfordian/Kimmeridgian transition (Upper Jurassic, Wieluń Upland, Central Poland)

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The studies at identifying the uniform boundary of the Oxfordian and Kimmeridgian stages within the Boreal, the Subboreal, and the Submediterranean successions in Europe have concentrated so far mostly on the precise correlation of the relevant ammonite zonal schemes. Recent study of two sections (Katarowa Góra and Bobrowniki) in the Wieluń Upland (central Poland) beside showing that the boundary in question lies close to the Submediterranean Hypselum/Bimammatum zonal boundary, has yielded new data on the variations in composition of the succeeding faunal assemblages. These variations seem to be environmentally/climatically controlled and are correlated with variations observed in elemental geochemistry being the subject of an independent presentation.
The deposits studied are the bedded limestone-marly limestone deposits of the sponge megafacies of the deep neritic northern Tethyan shelf. The ammonite faunas occurring here are mostly of the Submediterranean character, but the Boreal ammonites (Cardioceratidae: *Amoeboceras*) and bivalves (*Buchia*) as well as the Subboreal ammonites (Aulacostephanidae) become quite common at some levels. The longer term, as well as the shorter term faunal variations in the assemblages studied may be recognized –the former are especially well visible – and are commented herein. A prominent maximum of occurrence of the colder-water Boreal-Subboreal faunas is observed in the middle of a lower part of the succession (about 6-7 meters thick) of the Hypselum Zone of the uppermost Oxfordian – around the "*Amoeboceras* layer" (over 70% of Boreal cardioceratids). Another similar in thickness interval displaying increase (but a weaker one) in number of the Boreal-Subboreal faunal elements is recognized in the upper part of the Hypselum Zone. The deposits studied show also the occurrence of the radiolarian faunas – mostly of the Tethyan origin – but the representatives of the Boreal *Paravicingula* assemblage do occur in the "*Amoeboceras* layer". The occurrence of the Boreal-Subboreal ammonite assemblages in the Hypselum Zone of the uppermost Oxfordian could be related with activity of the sea-currents which additionally brought the nutrient-rich waters which enabled the development of the radiolarian assemblages. Action of sea currents along the existing sea-ways between the northern and southern areas of Europe, were stimulated by contrasted climate changes during the latest Oxfordian. The recognized fine siliciclastic supply – which is generally higher below, and declining upwards - within the uppermost Oxfordian studied - is in general agreement with such interpretation.
A marked change in faunal assemblages is observed in the upper part of the succession in question – in the lowermost Kimmeridgian (Bimammatum Zone). It corresponds to decline of a colder-water Boreal-Subboreal faunas, and the dominance of a warmer-water Submediterranean ammonites (Oppeliidae). Their dominance follows mostly a well developed tectonically enhanced omission surface – which is recognized also at the Oxfordian/Kimmeridgian boundary over vast areas of northern Europe – delimiting there two contrasted environmentally faunal assemblages. The dominant oppeliids are mostly small-sized necto-pelagic forms which occurrence along the Tethyan radiolarians indicate the presence of nutrient-rich waters, but also diminished mixing of seawater and partly anoxic conditions at the sea-bottom. It is in general accordance with a markedly decreasing siliciclastic material supply, general increase in the biogenic phosphorus content, as well as a decrease in the Th:U ratio, when compared with underlying uppermost Oxfordian deposits.

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Seawater temperatures and variations in $\delta^{13}C$ values of marine carbonates in central European basins during and after the Middle–Late Jurassic transition (Late Callovian–earliest Kimmeridgian)

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Stable isotope values as well as Mg/Ca and Sr/Ca ratios of well-preserved and well-dated belemnite rostra, brachiopod shells and bulk-carbonates from the Upper Callovian–Lower Kimmerdgian of the Polish Jura Chain, Kujawy (Poland) and Swabian Alb (Germany) have been analyzed and compared with the published results. Similar $\delta^{18}O$ values of coeval belemnite rostra and brachiopod shells confirm the necto-benthic habitat of the belemnites studied. Belemnite $\delta^{18}O$ values show relatively constant temperatures (ca. 12ºC) of bottom waters in the Polish Jura Chain basin during a major part of the Late Callovian–Middle Oxfordian (Athleta-mid Tranversarium chrones), except for a short-term cooling (to ca. 9ºC) at the Callovian–Oxfordian transition (latest Lamberti Chron). The cooling is linked to the incursion of a cold bottom current during a sea-level rise. A significant increase in temperature of bottom water (by ca. 4ºC), is noted in all the basins studied during the Submediterranean Late Oxfordian (Bifurcatus–Planula chrones), which is an equivalent of the Boreal Late Oxfordian–Early Kimmeridgian. This phenomenon is linked to both the shallowing of the basins and the global climate warming. Belemnite and brachiopod Mg/Ca and Sr/Ca ratios are disregarded as palaeotemperature proxies because of their weak correlation with $\delta^{18}O$ values.

New and published belemnite and brachiopod carbon isotope data point to the presence of metabolic fractionation of carbon isotopes in belemnite skeleton, which results in a depletion of belemnite calcite in ^{13}C isotope. Despite significant vital effect, belemnite rostra are regarded as a valuable tracer of temporal variations in the carbon isotope composition of oceanic dissolved inorganic carbon (DIC). Belemnite $\delta^{13}C$ data show the presence of two positive excursions in the Upper Callovian (in the Athleta and Lamberti zones) and the Middle Oxfordian (in the upper part of the Plicatilis Zone and the lower part of the Transversarium Zone) in the carbon isotope record of peri-Tethyan carbonates ($\delta^{13}C$ increase during these events to ca. 2‰ and ca. 1.5‰, respectively). The excursions are divided by a Lower Oxfordian (Cordatum Zone) interval characterized by decreased $\delta^{13}C$ values (to. 0.5‰). This is a regional feature of Tethyan isotope record not known from Boreal basins. It is interpreted to have been caused by upwelling, which may have carried waters enriched in the ^{12}C isotope. The appearance of a mixed cold- and warm-water radiolarian assemblage as well as the presence of a diversified ammonite fauna in central European basins at that time confirms intensified seawater circulation. Low belemnite $\delta^{13}C$ values (below 0‰) are also observed in the lower part of the Submediterranean Upper Oxfordian (in the upper part of Bifurcatus Zone and the Hypselum Zone). They are linked to the well-mixed state of seawater in the basins studied. This interval is characterized by a short-term migration event of Boreal ammonites into the Submediterranean ammonite province and mass-occurrences of small necto-pelagic haploceratid ammonites and radiolarians, which might have thrived in eutrophic waters.

The carbon isotope record of bulk carbonates differs from those of belemnites and brachiopods probably because of a strong increase in carbonate production during the Oxfordian and changes in the origin of carbonate mud in the Polish Jura Chain basin. As the Oxfordian acceleration of carbonate production is widely observed in Tethyan and peri-Tethyan basins, it may have affected carbon isotope record of bulk carbonates in various areas.

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Endemic Paratethyan faunas in the Gulf of Corinth, Greece: the utility of Aegean rift basin successions for constraining the ages of endemic Messinian palaeocommunities.

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Early rift settings can offer unique environments for correlation of marine and non-marine sequences during the Messinian. Our work centres on the Gulf of Corinth, a rift whose early history spans the Messinian Salinity Crisis. The Gulf of Corinth Rift is in the back arc of the Hellenic Subduction Zone and forms a marginal basin of the greater Aegean extensional province. Due to its geographic location in the eastern Mediterranean, such Aegean successions hold a key role in the correlation of faunas between the Mediterranean and Paratethyan basins.

The drawbacks of using tectonic environments to constrain global eustatic curves are appreciable. However, a key *advantage* in terms of biostratigraphy lies in the rapidity with which tectono-eustasy alters palaeoenvironmental parameters including basin morphology and its corollaries, water depth and marine connectivity. The result of such rapid palaeoenvironmental changes is that very different marine and non-marine biofacies may be preserved in closely successive stratigraphic units – determined by base-level changes driven by local uplift and subsidence. These successions are likely to contain globally correlatable marine horizons (i.e those containing foraminiferan rich units) closely associated with units containing endemic faunas which would otherwise be difficult to integrate into global or even regional stratigraphic schemes.

Such sections have been identified in the Gulf of Corinth. Mapping and logging of early synrift sediments on the Perachora Peninsula have revealed a complex interplay of eustasy overprinted by local tectonism. These sections contain locally endemic Lymnocardiids and ostracods of Messinian/Paratethyan character interbedded with marine units containing late Miocene ostracods and foraminifera. The application of biostratigraphy to such sections for dating endemic non-marine faunas is significant. In addition, the application of strontium isotope dating to the marine faunas has proven fruitful for further constraining ages.

The tectonic configuration of the Gulf during the late Miocene is still uncertain – but the work presented here is intended to serve as a case-study for similar investigations likely applicable in other peri-Aegean grabens in Turkey and Greece.

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The Coniacian–Campanian Haftoman Formation, a Late Cretaceous epeiric carbonate platform of the northern Yazd Block, central Iran

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The study area is part of the so-called Central-East Iranian Microcontinent (CEIM), the central part of the present-day Iran Plate. During the Mesozoic era, the CEIM was an independent structural unit and detached from the southern margin of Eurasia, consisting (from E to W) of three structural blocks, i.e., the Lut, Tabas and Yazd Block, surrounded by narrow ocean basins that started to open during the early Early Cretaceous. Their formation has often been linked to a post-Triassic rotation of the CEIM around a vertical axis of about 135° with respect to Eurasia, and the peripheral oceans were closed during the latest Cretaceous and Paleogene due to the approaching Arabian Plate and the closure of the Neotethys. The Cretaceous succession of the Yazd Block can reach over 5 km in thickness and has been subdivided into two trangressive–regressive megacycles (TRMs), separated by a major tectonic unconformity in the Upper Turonian (Wilmsen et al. 2015). TRM 1 comprises the Early Cretaceous to Middle Turonian, TRM 2 the Coniacian to Maastrichtian. In the Khur area (northern Yazd Block), TRM 2 starts with the up to 1,000m-thick Haftoman Formation. The base of the formation is characterized by a pronounced unconformity clearly associated with preceding tectonic movements and karstification. The Haftoman Formation has biostratigraphically been dated by means of macro- (inoceramid bivalves, ammonites) and microfossils (larger foraminifera). Above a basal transgression conglomerate, the Haftoman Formation commences with thick-bedded to massive shallow-water carbonates. A careful litho-, micro- and biofacies analysis resulted in the identification of several facies types that can be grouped into four facies associations (FA). FA 1 comprises fine-grained, micritic facies (wacke- to packstones) with open-marine biota (calcispheres, sponge spicules, small foraminifera) that have been deposited in subtidal offshore settings. FA 2 combines well-sorted bio- and intraclastic pack- and grainstones that may show cross-bedding and large-scale clinoformed bedsets. FA 3 includes coarse-grained bioclastic float- and rudstones. FAs 2 and 3 indicate high water energy and may characterize wind- and leeward sub-environments of extensive submarine shoals. FA 4 groups lagoonal facies types (e.g., rudist bafflestones, foraminiferal mud-/wackestones, fenestral mudstones, bindstones) that often have been subject to meteoric diagenesis. The stratigraphic architecture of the Haftoman Formation is dominated by metre-scale shallowing-upward cycles that are stacked upon each other, separated by emergence horizons lined by reddish residual sediments. These high-frequency cycles are embraced by more significant unconformities indicating substantial breaks in sedimentation by means of karstification, mineralization and/or erosion. The near absence of terrigenous input and the widespread, uniform facies development of the Haftoman Formation across wide areas suggest a period of tectonic quiescence and even subsidence during Coniacian–Campanian times. The depositional environment of the Haftoman Formation can be reconstructed from the regional distribution of shallow-water micro- and biofacies as well as the high-frequency shallowing-upward cycles and unconformities. A large-scale epeiric platform environment with open circulation integrates all observations.

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The lower Upper Cretaceous (Cenomanian–Turonian) section at Klieve, southern Münsterland Cretaceous Basin, Germany: integrated stratigraphy and inter-basinal correlation

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In the southern Münsterland Cretaceous Basin (northern Germany), a continuous lower Upper Cretaceous (Cenomanian–Turonian) section has been established based on the succession exposed in and subsurface of the Rinsche quarry at Klieve near Anröchte (TK 4415: Anröchte). The Lower Cenomanian to mid-Upper Turonian has been cored (cored borehole KB 4415/1002 drilled by the Geological Survey of Nordrhein-Westfalen) while the upper Upper Turonian has been studied in the quarry. The section has been subject to an integrated approach applying cm-scale bed-by-bed lithofacies logging, microfacies studies, litho-, bio-, chemo-, event and sequence stratigraphic analyses as well as subsurface geophysical surveys.

The Lower Cenomanian Essen Grünsand Formation rests at 123.60m depth along an angular unconformity with a glauconitic basal conglomerate on grey-green Palaeozoic shales. Up-section, the Baddeckenstedt Formation follows (up to 97m depth) with the Lower Cenomanian Wamel Member (flinty spiculitic marlstones), grading up-section into Middle Cenomanian marl-limestone alternations. The uppermost Middle to mid-Upper Cenomanian pelagic limestones of the Brochterbeck Formation are capped at 81.80m depth by the Kalkknollenbank (*plenus* Bed equivalent). The Cenomanian–Turonian boundary interval is characterized by ca. 2m of dark marls (Hesseltal Formation). The following grey-green bioclastic marls of the Lower Turonian Büren Formation range up to 64.80m depth. The Middle to lower Upper Turonian Oerlinghausen Formation comprises the upper part of the core up to the zero-metre-level. A sedimentological peculiarity is the occurrence of a tongue of the Lengerich Formation in the lower Middle Turonian part between 60–55m depth, consisting of thin-bedded dark marls and white limestones. The marker bed couplet of the Weiße Grenzbank and marl M_{Teuto} (ca. 44–41m depth) subdivides the calcareous Middle Turonian part of the Oerlinghausen Formation (flaser-bedded pelagic limestones) into two approximately equally thick intervals while the lower Upper Turonian segment (from ca.13m depth upwards) gets increasingly marly. The Klieve section continues in the quarry with the 2-m-thick mid-Upper Turonian glauconitites of the Soest Grünsand Member of the Salder Formation which rests with a major unconformity on the Oerlinghausen Formation. Up-section, ca. 20m of marly limestones of the uppermost Turonian–Lower Coniacian Erwitte Formation are exposed.

Macro- and microfossil evidence (inoceramid bivalves and planktic foraminifera) from several levels in the core supports the stratigraphic assignments that have firstly been obtained by regional gamma-ray (GR) and lithostratigraphic correlations to neighbouring well-dated sections. GR correlation turned out as a valuable calibration tool as the log signature allows a save identification of marker beds such as the Weiße Grenzbank and marl M_{Teuto}. High-resolution carbon stable isotope analyses from the mid-Upper Cenomanian to Upper Turonian of the core are correlated to contemporaneous standard curves form northern Germany and the Anglo-Paris Basin, further substantiating the chronostratigraphic calibration of the succession. Argillaceous levels at 29.50m, 12.40m and 3.40m of the core are potential bentonites (T_{C1}, T_{C2} and T_D?) and offer the possibility for additional tephrostratigraphic fine-tuning. Sedimentary unconformities at the 115.80m, 110.40m, 102,30m, 94.70m and 82.30m levels in the Cenomanian as well as at the 64.80m, 41.60m, 10.50m and zero-metre levels in the Turonian give evidence for sea-level changes superimposed onto the early Late Cretaceous overall rise. Their recognition provides clues for inter-basinal sequence stratigraphic correlations and further chronostratigraphic calibration of the Klieve section. In conclusion, the Klieve core provides a high-quality standard section for the lower Upper Cretaceous of the southern Münsterland Cretaceous Basin.

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Eustatic and tectonic controls on Cretaceous carbonate systems of the Yazd Block, Central Iran

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Cretaceous strata are widespread and well exposed in the Khur and Yazd areas of the Yazd Block, Central Iran. From the Late Barremian to the Maastrichtian, marine deposition prevailed in the wider area, and a few carbonate depositional systems developed and died away. Due to their significance for the reconstruction of climate and sea-level changes as well as their importance as hydrocarbon reservoirs, the Cretaceous carbonate systems of the Yazd Block are picked out as a central theme here.
The uppermost Barremian–Aptian Shah Kuh (Khur area) and Taft formations (Yazd area) form the first fully marine deposits of the first sedimentary megacycle in the Cretaceous of the Yazd Block (Wilmsen et al. 2015). They reach over 1 km in thickness and consist predominantly of micritic, thick-bedded shallow-water carbonates rich in (orbitolinid) foraminifera, dasycladalean algae and rudists. The carbonate system of the Shah Kuh and Taft formations started as a narrow, high-energy shelf that developed into a large-scale, flat-topped rudist platform without marginal rim or steep slope. Both formations are part of an even larger depositional system of shallow-water carbonates that characterized wide parts of present-day Iran during Late Barremian–Aptian times. Their biofacies is very similar to contemporaneous deposits from the western Tethys/eastern Arabia, and they form an important, hitherto poorly known component of the Tethyan warm-water carbonate platform belt. Their demise started in the late Early Aptian (drowning of the Shah Kuh Formation) while shallow-water deposition persisted in the Yazd area into the mid-Late Aptian. The top-Taft unconformity comprises the remaining part of the upper Aptian and is onlapped by Albian deep-water marls.
The Upper Albian–Middle Turonian Debarsu Fm. of the Khur area is an up to 600-m-thick unit of skeletal shallow-water limestones interfingering with marly basinal deposits. The depositional setting was a carbonate ramp as indicated by the absence of gravitationally redeposited sediments and generally smooth facies transitions. Decametre-scale shallowing-upward cycles capped by karst unconformities are evidence of significant sea-level changes that most likely have been formed by eustatic variations. In contrast to the numerous intra-formational unconformities, the major unconformity at the base of the overlying Lower Coniacian–Campanian Haftoman Fm. was formed by tectonic processes: along uplifted blocks, up to two kilometres of erosion locally took place in a geologically short time span during the Late Turonian (Wilmsen et al., 2015). This tectonic event caused the demise of the carbonate system of the Debarsu Formation.
The up to 1 km-thick Coniacian–Campanian Haftoman Fm. of the Khur area onlaps the tectonic unconformity created by the Late Turonian tectonic event and seals the existing palaeo-relief. It consists of shallow-water carbonates. Numerous stacked metre-scale shallowing-upward platform cycles capped by emergence horizons indicate high-frequency, low amplitude sea-level oscillations while occasionally occurring palaeo-karst surfaces indicate major falls. Taking all (bio-)facies and stratigraphic data into account, the Haftoman Fm. is interpreted as a large-scale epeiric carbonate platform. The near absence of terrigenous input, the widespread, uniform facies development and the comparably low thickness across wide areas suggest a period of tectonic quiescence and uniform subsidence during Coniacian–Campanian times. A deepening trend during the Late Campanian is indicated by marly facies towards the top of the formation which is overlain by shallow basinal deposits of the Maastrichtian Farokhi Fm.

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A progress report on the selection of a Tithonian/Berriasian (Jurassic/Cretaceous) boundary level

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Since the setting up of a new Berriasian Working Group in July 2007, there has been a new phase of activity on refining Tithonian and Berriasian correlations, directed towards addressing the outstanding issue of the choice of a Jurassic/Cretaceous boundary. The J/K boundary level is one where long range correlation is difficult. Both austral and boreal regions were isolated and far from Tethys, had more impoverished biotas; also, extensive areas of the world were then land with non-marine sedimentation and biotas. Therefore, there has always been much effort put into trying to improve correlation between marine to non-marine areas and from the core area of oceanic Tethys to isolated seas, seaways and landlocked basins towards the two poles.

A decision was made early by the Berriasian WG to dispense with previous diversions and pre-occupations, and to direct all energies towards factual matters that would promote a decision on selecting a primary marker for the base of the Berriasian. Therefore, the WG has concentrated on the detailed documentation of known key sections and seeking out new useful localities, giving special attention to integrating data from as many fossil groups as possible, preferably calibrated with magnetostratigraphy. Numerous sites, from California and Mexico to Tibet and the Russian Far East, have been studied and assessed. Past decisions dictate that a Tithonian/Berriasian boundary and a GSSP should be defined in marine sequences in Tethys. Tethys was the largest geographical entity at that time, and thus many sites in western Tethys have received special attention. Work in the last several years has concentrated on calibration of markers in an attempt to construct a useful matrix that will constrain a boundary level near to the base of the Berriasella jacobi Subzone, in mgnetozone M19n. Unlike some upper Cretaceous stages, where one fossil taxon is the only useful tool for definition of a GSSP, in the Tithonian/Berriasian boundary interval in Tethys several groups may be present and complement one another, so that calpionellids, calcareous nannofossils, radiolarians and ammonites may all contribute to give an integrated matrix.

Prior to 2007, J/K correlation had already shifted away from a concentration on ammonites. This was because widespread endemism in ammonites had been been repeatedly recognised as an obstacle to correlation, even in western Tethys. Various authors have attempted definition of the boundary level using calpionellids, nannofossils, radiolaria etc, and magnetostratigraphy. In recent times, calpionellids have been seen as the most useful fossil group, and the turnover from *Crassicollaria* species to small orbicular *Calpionella alpina, Crassicollaria parvula and Tintinopsella carpathica* has been documented consistently as a widespread marker in the middle part of M19n.2n. This level lies in the interval traditionally labelled as the “Berriasella jacobi Subzone” (though the ammonite faunas are being radically revised), and it is constrained also by the FADS of species of nannofossil (*Cruciellipsis cuvillieri, Nannoconus wintereri, Hexalithus geometricus* and *Nannoconus globulus globulus*). Work focuses also on finding proxies for these key marker species in biotically impoverished the boreal and austral regions and in non-marine areas. A decision by the Berrriasian Working Group on the primary marker for the Tithonian/Berriasian boundary is expected soon and the choice of a contender GSSP in 2016.

The Santonian-Campanian transition at Göynük, NW-Turkey

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Deposits at Göynük section record the Santonian-Campanian boundary. Hemipelagic to pelagic deposits close to the village of Göynük (NW Turkey) were examined in respect to nannofossil and foraminiferal biostratigraphy, magnetic susceptibility, as well as magnetic polarity. Originally situated on the Sakarya continent (between the intra-Pontide Ocean and northern a branch of the Tethys), deposits from the Mudurnu-Göynük basin display an Upper Cretaceous, northern Tethyan setting. The stratigraphically older part of the Göynük section (i.e. “Road-outcrop”) is characterised by uniform limestone. Strata recorded in the older “Road-outcrop“ can be correlated to the stratigraphically younger part of Göynük section (“Jandarma-outcrop”); Towards the top, the section displays marls and marly limestones with frequent tuff intercalations.
As Göynük section represents a hemipelagic to pelagic environment well above the CCD, planktonic foraminifera prevail in numbers and represent a typical Santonian to Campanian planktonic foraminifera community. Benthic foraminifera are sparse. An increase in absolute abundance of foraminifera in the Jendarma-outcrop can be witnessed. Biostratigraphic data suggest an age from the late Santonian *Dicarinella asymetrica* to the early Campanian *Globotruncanita elevata* planktonic foraminifera zone (nannofossil zones CC16-CC18). By investigation of magnetic polarity, the older part of Göynük can be assigned to the Santonian C34 normal, while the base-Campanian reversal C33r is evident in the upper part of the section.
Results from the assessment of magnetic susceptibility give evidence for Milankovitch cycles. We witness a strong signal for what we assume resembles the 20kyr precession and 100kyr eccentricity signals upon the examination of magnetic susceptibility values from the younger part of the section (“Jendarma- outcrop”). Signals recorded in the “Road-outcrop” are less significant as this part of the section displays a total thickness of only 10 metres (compared to 30 metres at the Jendarma outcrop).The Campanian interval measured at Göynük section shows unusually high values for magnetic susceptibility. Compared to the older part of the section, we find values twice as high in the younger interval. As evidence for volcanic activity is frequent in the Campanian part of the section, the abrupt shift in the magnitude of magnetic susceptibility values may be explained by volcanic admixture. Apart from implications for biostratigraphy and palaeoenvironments, the record of frequent volcanic activities in this Santonian- Campanian boundary section might also provide insights in the history of volcanic events in the North-western Tethyan realm.

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The characteristics of rock minerals of the 7th shale of Jurassic Dameigou formation in Qaidam Basin

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Shale gas is an unconventional natural gas, which occurs free in natural fractures or inter-particle pores, or adsorbed in the surface of organic matter and clay particles. It was thought that the shale in the 7th Member of the Middle Jurassic Dameigou Formation in Qaidam Basin was regarded as the main part of the Northwest Jurassic source rocks, with characteristics of a high abundance of organic matter, high degree of evolution and high generation of hydrocarbon volume. To explore the shale rock mineral property of Dameigou formation provides the scientific basis for the evaluation of shale gas resources and the optimal selection of exploration blocks. Based on the test method of rock mineral identification, mineral-XR diffraction, whole rock test, pressure test and mercury adsorbed gas test, this paper analyzed the difference of brittle minerals, shale content of organic matter abundance and maturity degree of evolution. The analysis results show that shale in the study area include laminated shale, laminar subcarbonate shale, laminar subsilt shale, laminar carbonaceous shale, laminated sand dolomitic shale, laminar carbonate silty shale and laminated silty shale. The clay mineral assemblage contains mostly kaolinite, illite smectite, illite and chlorite, in which kaolinite ranges from 30.9% to 70% with the highest content and an average of 53.6%. The content of illite smectite ranges from 30.9% to 70.0%, with an average of 21.1%. The content of illite ranges from 11.0% to 21.0% with an average of 14.1%. The content of chlorite ranges from 0% to 16%, with an average of 8.6%. According to the clay mineral assemblage we can deduce the diagenetic stage. Generally, appearance and changes from disorderly to orderly mixed with mixed layer of illite mixed layer minerals. The content of authigenic clay minerals such as kaolinite and chlorite increased relatively. The characteristics above can act as the basis for the conclusion that diagenetic stage in this region was the late diagenetic stage A. On the basis of the three terminal element classification systems, we detailed the classification and description of the 7th Member of the Middle Jurassic Dameigou Formation in Northern Qaidam Basin. Its thickness is 35 – 94 m, and it occurs under semi-deep or deep lacustrine sediments. The main rock types are laminar shale, laminated carbonate silty shale and laminated sand shale. Organic rich black shale are high siliceous, with ahigh content of clay minerals, but the carbonate content is low. The kaolinite and illite smectite clay minerals in the mixed layer content is high. The average content is 54.23% and 22.79%, respectively. Diagnetically, to push off the area for shale is the late diagenesis stage.

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Subdivisions of the Ediacaran System: Integrating biostratigraphic and chemostratigraphic data

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The integration of biostratigraphic, chemostratigrpahic, paleoclimatic, paleoenvironmental, and geochronological data is critical for the subdivision and correlation of the Ediacaran System. Acanthomorphic acritarchs, macroscopic Ediacara fossils, carbon isotopes, strontium isotopes, glaciations, and oceanic oxidation events are useful criteria for the correlations of Ediacaran strata. Applied singularly, however, each of these criteria has its own limitations, because of taphonomic biases in fossil preservation, lithofacies control on and diagenetic alteration of chemostratigraphic signals, and regional variations in climatic and redox conditions. Thus, in order to achieve global correlation, it is important to integrate all stratigraphic data and to establish the relative stratigraphic relationships between biostratigraphic and chemostratigrpahic markers, as well as their relationship with paleoclimatic and paleoenvironmental events.

It is an attractive proposal to divide the Ediacaran System into two series, with the lower series characterized by Doushantuo-Pertatataka acanthomorphs (DPAs), and the upper series characterized by macroscopic Ediacara fossils. Possible proxies for the boundary between these two series include the Shuram negative carbon isotope excursion or the ~580 Ma Gaskiers glaciation. However, DPAs are not universally distributed, their full stratigraphic range has not been established, and their stratigraphic relationships with the Shuram excursion and the Gaskiers glaciation have not been unambiguously resolved. Recent data from Siberia tentatively indicate that the stratigraphic range of DPAs overlap with the Shuram excursion and may even extend into the basal Cambrian, but these relationships have not been formally scrutinized or tested in other basins. Here we integrate Ediacaran acanthomorph biostratigraphic and carbon isotope chemostratigraphic data from South China and northern India to show that the stratigraphic range of certain DPA elements do overlap with the Shuram excursion. Thus, the basis for a simple division of the Ediacaran System into two series needs to be reconsidered, and more nuanced taxonomic and biostratigraphic investigation of Ediacaran acanthomorphs is needed to make them useful in the subdivision and correlation of Ediacaran strata.

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Latest Permian radiolarian fauna from Rencunping Section, Hunan Province, South China and its paleoecological implication

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The Permian-Triassic boundary section at Rencunping, Sangzhi County, Hunan Province, was situated in a deep-water facies (basinal facies) on the outer shelf and contains abundant uppermost Permian radiolarian fossils. We studied the radiolarian fauna based on the detail sampling, examination and statistics. 26 species belonging to 15 genera have been identified from the Talung Formation at this section. The aim is to reconstruct the changing trend of paleo-waterdepths and sea-level changes, providing insight to the Permian-Triassic mass extinction. The Changhsingian paleo-waterdepths of the Rencunping Section have been studied based on the abundance-diversity-assemblage of the radiolarian fauna, the lithological feature, sedimentary structures and minerological features. And the Changhsingian paleo-waterdepths at Rencunping are compared with the counterpart at Meishan, it is revealed that firstly, sea-level curve respectively based on radiolarians and lithology are in substantial agreement; secondly, the sea-level changes from both sections during the Changhsingian can be roughly correlated and the paleo-waterdepths during the early Changhsingian is generally deeper than the counterpart in the late Changhsingian. The sea-level falling is one of the controlling factors which led to the end-Permian mass extinction (including radiolarian extinction).

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The New Vauxiid Sponge from the Kaili Biota (Cambrian Stage 5), Jianhe, South China

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Porifera is the earliest metazoan, be believed original Precambrian and common in Cambrian. Sponge fossils from calcareous mudstone of the Kaili Biota (Cambrian Stage 5), Jianhe area, Guizhou, South China, represent a new species, *Vauxia sinensis*. Energy Dispersive Spectrometer (EDS) analysis indicates the presence of silica in the skeleton of *V. sinensis*, suggesting that its skeleton consists of spicules. This is the first confirmation of siliceous skeletal elements in fossils of the family Vauxiidae, and it lends support for the hypothesis that some early demosponges possessed biomineralized siliceous skeletons, and later in their evolutionary history silica was replaced by spongin. Combining with the morphology of spicules, Vauxiid sponge should be replaced back the Lithistida of the Demospongia. These new specimens provide additional information bearing on the nature of Vauxiid sponges. Such exploration is important not only to prompt a re-examination of its phylogenetic position and let us to a better understanding of demosponge evolution, but also to elucidate historical diversity and the early evolution of sponges.

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Late Pleistocene of the Caspian Sea: New data

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The event scheme of the Caspian Late Pleistocene includes Late Khazarian and Khvalynian transgressive epochs, separated by the Atelian regression. Many questions of a paleogeography of these events are debatable. We studied the sequences of the boreholes up to 100 m drilled in the Northern Caspian Sea. They opened thickness of late Pleistocene deposits with difficult construction. Studying of the structure of the section and spatial correlation of lithological-stratigraphical thicknesses are executed by means of seismoacoustic profiling and static sounding. The sediments of the cores are studied by lithological, malakofaunistic and geochronological methods. Among mollusks we mainly focused on the brackish water species of genus *Didacna* Eichw. Members of this genus are endemic and index species for the Caspian Sea. This genus is known for its high evolutionary rates at the species and subspecies levels, which highlight its significance for the stratification of the marine Pleistocene of the Caspian and for paleogeographic reconstructions of the Caspian basins.

The structure of the cores studied by us showed that between two regressive thicknesses (Chernoyarsk and Atel) two thicknesses of the marine deposits are located. The lower part of the late Khazar deposits is most fully presented on northern structures. Sandy sediments in the basis of the studied sequences are characterized by domination of fresh-water species (*Corbicula fluminalis, Lymnaea stagnalis*) with impurity of the slightly brackish water species. They characterize the shallow warm-water almost fresh-water basin existing on the place of modern central part of the Northern Caspian Sea. Sediments of higher intervals contain the malakofaunistic complex, which feature - a combination of two thermophilic species belonging to different types of fauna: *Didacna nalivkini* and *Corbicula fluminalis,* and also rare *D. surachanica, D. vulgaris*, *D. pallasi*, with obviousness testifying to late Khazar age of the complex. It characterizes the brackish water shallow warm-water basin with inflow of fresh waters. The described layers reflect different phases of development of the late Khazar transgression.

The following stage of development of the Caspian Sea is presented by sandy-clay deposits. Feature of its faunistic complex is the abundance of *D. subcatillus,* the occurrence of *D. cristata* and species of Khazar type *D. pallasi, D. shuraosenica, D. subcrassa*. According to our conclusion the described thickness belong to Girkan transgression. ^{14}C datings received by scintillation method, showed result >42 ky (calibrated age >45 ky); AMS datings >54 ky.

Atel regressive sediments are well expressed in the cores. They transformed by subaeral environment, deposits include the fresh-water mollusks and the vegetable remains. ^{14}C dating showed result 37-41 ky.

The Atel regression was followed by the Khvalynian transgression with the most significant sea-level rise in the late Pleistocene history of the Caspian. Drilling material showed the Khvalynian section begins by a layer of marine sediments with mollusks among them the *Didacna subcatillus* are predominated; ^{14}C age is 28.5-31.5 ky. Evidently the first stage of the Khvalynian transgression took place during the MIS 3. Above it in the boreholes accumulation of sandy and dusty sediments was noted. They correspond to fall of level of the Khvalynian Sea. Age interval of this event was 22-19 thousand years ago. The regression answered the LGM. In northern areas of the Caspian Sea this stage is fixed in the cores structure by washouts. This pack of deposits is blocked by the clay sediments of brown coloring with thick up to 5 m, according to ^{14}C dating its age interval is 17645-16075. Transgression development occurred during the degradation of the glaciation. The Khvalynian cycle of deposits comes to the end with marine-deltaic sediments in the northern part of the Northern Caspian Sea and sandy sediments in its southern part. The regressive Mangyshlakian deposits (sapropel and peat) have the ^{14}C age 8.8-9.6 ky. It corresponded to the climate continentalization of the early Holocene.

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Palynological Record of Early Pliocene Vegetation and Climate in Central and Western Anatolia

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In Pliocene the Earth stepped into a more variable climatic conditions. During Early Pliocene, evaluated climate records from a variety of areas indicate that climate was often warmer than modern climate. On the other hand in Late Pliocene it was arid-cold and climatic oscillations has relatively increased. As a consequence, ice sheets have grown in the Northern hemisphere.

In this study, we evaluated Early Pliocene climatic conditions of Anatolia using palynological data from published research and ongoing studies from western and central Anatolian localities (Çankırı, Cappadocia, Afyonkarahisar). The identified climatic changes are then correlated with global and regional climatic changes.

Anatolia which lies at the intersection point of Asia, Africa and Europe has many large Neogene basins filled with thick terrestrial and marine deposits. Palynological analysis mainly conducted on terrestrial deposits show abundance of mid-to-high altitude coniferous forests and in some restricted localities mixed mesophytic forest, wetland and riparian vegetation was also present. The coniferous forests were dominated by *Pinus* together with *Cedrus, Cathaya* and lesser *Tsuga, Abies* while mesophytic forest was characterized by coniferous trees together with *Fagus* and *Carpinus*. The forests have widespread herbaceous understory (Poaceae) which is interspersed with, sometimes wide, open areas that occupied by Asteraceae. The changes in abundances of some arboreal and non-arboreal plants show temperature fluctuations and precipitation oscillations within Pliocene.

The identified Pliocene flora of western and central Anatolia reflects a subtropical to warm-temperate humid climate in accordance with global warm climate of the Early Pliocene. However there are also some pollen record indicating presence of open vegetation and arid climatic conditions possibly related to intense volcanic activity in the central Anatolia.

Campanian deep-marine conglomerates in the Mudurnu-Goynuk Basin (NW Anatolia): responses to small-scale and large-scale sea level changes

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Within the siliciclastic deep marine succession of the Mudurnu-Goynuk Basin (Turkey), we distinguished basin-wide submarine fan systems characterized by channels and lobe complexes in the Campanian.

The submarine fan system with ca. 100 m thicknesses extends more than 70 km, particularly in the SE of the basin around the Nallıhan town, and the Goynuk town in the north west of the basin. Two measured stratigraphic sections, the Goynuk and Yakapinar-Nallihan sections, have been studied in detail. They consist of 2 gravelly sandstone and conglomerate units separated by thick mudstone or thinner sandstone-mudstone alternations.

The lowermost submarine fan unit comprises 20 m thick thin-bedded sandstone-mudstone alternation within thick basinal marls having abundant nannofossils assigning the early Campanian age. According to nannofossil biozones, the conglomerates lie within the CC21-UC15c zones in the Nallihan-Yakapinar section, underlying grey and black shales lie within the CC19-20 biozones. In the Goynuk Section, the conglomerates lie within CC22a/c - UC15d-eTP zones and black shales and turbidites can be seen within CC21?. They all take place within the G. ventricosa-G. calcarata zones of planktonic foraminifera.

In the lower part of the successions, the mudstones and black shales alternate with each other and thin sandstones beds intercalates in between. Sandstones include current ripples, slump structures and can present only Tcd parts. Conglomerate beds display scoured base and always clast supported in the Goynuk section.

This sequence is overlain by gray mudstone succession with occasional black shales including inoceramid shell accumulations. Just below the conglomerate beds, sandstone beds are often amalgamated. Individual beds of 15 – 20 cm thick show Ta-b elements and typically topped by thin (<2 cm) coalified organic levels including abundant plant fragments.Clast supported conglomerate cut massive pebbly sandstone with 2m incision. Overlying unit include debris flow deposits with blocks from underlying turbidites, conglomerates, mudstones. Sandy turbidites transitionally overly the debris flow deposits and includes plant debris.

Beds in Goynuk comprise nearly monomict conglomerates composed mainly of limestone pebbles and cobbles with different facies and ages. In contrast, conglomerates in Nallihan are more oligomict, and include pebbles from basement rocks too.

The submarine fan system introduced herein records at least two important relative base level drops and subsequentsea level rises in the Campanian in the Mudurnu – Göynük Basin. Turbidite beds may correspond to high frequency relative sea level changes and conglomerate levels can be interpreted as low frequency and third order changes. However, their shiftingspatial positions in different biozones may also indicate a basin wide tectonic control. Even it might have indirect effect on adjacent basins. Coincidence of conglomerate stratigraphic positions withthe global sea level change curve may still indicate a tectono-eustatic effect.

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Early–middle Cambrian palynomorph microfossils and related geochemical events in South China

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The earliest Cambrian acritarch '*Asteridium – Heliosphaeridium – Comasphaeridium*' assemblage and the early Cambrian ('Chiungchussuan') acritarch '*Skiagia ornate – Fimbriaglomerella membranacea*' assemblage in South China can be correlated with assemblages from synchronous strata elsewhere in the world. We have studied early–middle Cambrian acritarchs and other palynomorphs from several sections in southeastern Guizhou Province. In the Wuliu–Zenjiaya section, Series 2 is recognized as the *Leiomarginata simplex–Fimbriaglomerella membranacea* assemblage and Series 3 is characterized by the *Cristallinium cambriense – Heliosphaeridium nodosum – Globosphaeridium cerinum* assemblage. Furthermore, many 'Burgess Shale−type' small carbonaceous fossils have been found from shale of Series 3 age in the Kaili Formation. Recent geochemical study and biomarker evidence further confirm a biostratigraphic change between Cambrian Series 2 and Series 3 and support the recognition of a major geological and biotic event during this time interval.

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Sedimentary Dynamics and Structural Evolution of the Constantinois Platform During the Cretaceous

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The synthesis of stratigraphic and structural data of Constantinois limestone massifs has allowed refining of the southern Tellian series at *Nummilites* stratigraphy and proposing a structural model. The most significant sites and less disturbed by tectonics are the Taxas syncline and southern flank of the Guerioun massif, exactly at the Djebel Ras Rihane.

Also, at the level of Taxas syncline, and surmounting the hard ground which ended the Aptian neritic limestone, the marly levels had provided a Cenomanian microfauna: *Favusella washitensis*, *Rotalipora appenninica*, *R. cushmani*, *R. brotzeni*, *Hedbergella* sp., and *Praeglobotruncana stephani*.
On the southern reverse of Djebel Ras Rihane, at the level of Chaabet Ras Chiboub notch, we can observe, on the hardground that terminates the Aptian nerititic limestones, a clayey Cenomonian over one hundred meters of thickness.
The samples from these clays have provided many *Hedbergella*, *Rotalipora brotzeni*, *R. cushmani*, *R. globotruncanoides* and *Praeglobotruncana* gr. *stephani*.
The top of these clays has provided Coniacian foraminifera and reworked Cenomanian *Rotalipora.* The study of the stratigraphic series of these neritic massifs allowed the refining of our predecessor's results.
The yellow marls stratigraphically surmounting the terminal Aptian - basal Albian through a hard ground represent the Cenomanian-Turonian.
Microscopic analysis of samples from this hardground highlights sedimentological phenomena that attest the emersion of Constantinois platform during the terminal Aptian - basal Albian.
In the Constantinois limestone massifs, "the southern Tellian units at Nummilites" represent the normal marly cover of the neritic limestones.

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Geodynamic Events and Drowning History of Jurassic Carbonate Shelf, Case Study: Aurès Basin (NE Algeria)

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This study focuses on an area located at the southern fringe of the Alpine Belt external zones. The objective of this work is to reconstruct the drowning history of the Jurassic carbonate shelf, and discuss its relationship with the geodynamic evolution of the Southern Tethyian margin.
The identification and interpretation of drowning events in the platforms can help significantly to the reconstruction of the depositional, tectonics and eustatic history of these shelf.
The stratigraphic interpretation and correlation of the study area Jurassic series from a few cross-sections, have allowed the highlighting of the platform physiography during this geological period and individualizing three stratigraphic units.
The synthesis of bio-sedimentological data reveals diversified facies, involving various deposits environments ranging from supratidal to deep pelagic peleoenvironments. These facies have evolved within subsidante carbonate ramp. Thereof has experienced drowning (Toarcian) and filling (Tithonian, Berriasian) phases, in relation with the eustatic sea level changes at the global scale and regional tectonic.

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Notes on the ontogeny of *Ovatoryctocara granulata* Tchernysheva, 1962 and phylogeny of *Ovatoryctocara* Tchernysheva, 1962 (Trilobita) in the Late Duyunian (Cambrian Series 2, Stage 4)

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The ontogeny, their relationships and occurrences of *Ovatoryctocara granulata* Tchernysheva, 1962 have been discussed in detail. During the ontogeny, the following morphological changes can be observed: in early meraspides the cranidium is subcircular to subelliptical in outline; in later meraspides it is long trapezoidal; whereas in holaspides it became trapezoidal; in early meraspides glabella is long narrow cylindrical in outline and parallel-sided; in later meraspides it is parallel-sided posteriorly, slightly inflated medially, gently expanded anteriorly; whereas in holaspides it became cudgel-shaped or clavated in outline; in early meraspides the glabellar furrows are very shallow, transversal connecting with axial furrow; in later meraspides they show circular pits near but isolating from the axial furrow, of which S1-S3 are connecting with transglabellar furrows; whereas in holaspides they became circular pits, of which S1 or S2 are connecting with or without shallow transglabellar furrow and with or without longitudinal furrow; in early meraspides eye ridge is faint and long, slightly slanting from the anterior corner of glabella, preocular field almost absent, palpebral lobe is rather short (exsag.), situated more anteriorly; in later meraspides eye ridge is distinct and shorter than it in early meraspides, slanting slightly behind anterior corner of glabella, preocular field narrow (exsag.), palpebral lobe is longer than it in early meraspides (exsag.), situated anteriorly; whereas in holaspides eye ridge is more distinct and short, slightly slanting distinctly behind anterior corner of glabella, preocular field wider than eye ridge (exsag.), palpebral lobe is long (exsag.), situated at anterior to midpoint opposite to glabella; in early meraspides fixigenae between palpebral lobes are about 1.2 times wider than glabella (tr.); in later meraspides fixigenae between palpebral lobes are 0.7 to 0.8 times as wide as glabella; whereas in holaspides fixigenae between palpebral lobes are 0.3 to 0.4 times as wide as glabella; in early meraspides posterior area of fixigenae is extremely wide (tr.) and long (exsag.), subtrapezoidal in outline, about 0.6 to 0.7 times as long as cranidium, in later meraspides posterior area of fixigenae is wide and long, subtriangular in outline, about 0.4 to 0.5 times as long as cranidium, whereas in holaspides posterior area of fixigenae is wide and narrow, banded, about 0.3 to 0.38 times as long as cranidium; the shape of pygidium changed little during ontogeny; pygidial axis is tapering backward, with 7-8 axial rings plus terminal piece, while the length of pygidial axis became shorter and wider from early meraspides to holaspides, whereas pleural region became narrower (tr.); in early meraspides the shield is smooth; in later meraspides granules began to appear on the surface; in holaspides exoskeleton covered with finer, coarser closely–spaced granules.

Up to date, the following species of *Ovatoryctocara* have been established: *Ovatoryctocara ovata* (Tchernysheva, 1962), *O. angusta* Tchernysheva, 1962 including its subspecies *O. angusta snegireae* (Suvorov, 1964), *O. granulata* Tchernysheva, 1962, ?*O. majensis* (Suvorov, 1964), *O. doliiformis* Shabanov et Korovnikov 2008, *O. yaxiensis* Yuan, Zhao, Peng, Zhu et Lin, 2009, *O. sinensis* sp. nov. from the lower part of the Kaili Formation, *O. pristina* sp. nov. from middle-upper part of the "Tsinghsutung F."), of which *O. pristina* represents the earliest species of the genus and *O. sinensis* the latest. The evolutionary lineage is *O. pristina* - *O. yaxiensis*- *O. angusta*- *O. ovata*- *O. granulata* - *O. doliiformis* - *O. sinensis*. Putative synapomorphies include presence of narrow fixigenae between palpebral lobes, slightly expanded glabella medially having four pairs of glabellar furrows that evolved from slits or linear groves (*O. pristina*) via chevron-shaped excavations (*O. yaxiensis*, *O. angusta*), ovoid or rounded pits near axial furrow (*O. ovata*- *O. granulata* - *O. doliiformis*) to rounded pits away from axial furrow (*O. sinensis*); facial suture proparian. Paedomorphorphic reduction in the number of thoracic segments from *O. pristina* (6 to 7), via *O. angusta*- *O. ovata* (5) , *O. granulata* - *O. doliiformis* (4) to *O. sinensis* (2 to 3), and was accompanied by progressive increase in size of pygidium from micropygous to isopygous (*O. sinensis*).

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Revision of the Biostratigraphy of oryctocephalid trilobites from South China

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Based on a revision of the oryctocephalid genera *Arthricocephalus* Bergeron, 1899, with type species *A. chauveaui* Bergeron,1899, *Oryctocarella* Tomashpolskaya et Karpinski, 1962,with type species *Oryctocara sibirica* Tomashpolskaya in Khalfin, 1960, *Ovatoryctocara* Tchernysheva, 1962, with type species *Oryctocara ovata* Tchernysheva in Kryskov et al., 1960, the Kaili Formation, the"Tsinghsutung Formation" or the Wuxun Formation and the Balang Formation can be divided into 5 trilobite zones in descending order:
Oryctocephalus indicus Zone
Bathynotus kueichouensis-Ovatoryctocara sinensis Zone
Protoryctocephalus wuxunensis Zone
Arthricocephalus intermedus Zone
Arthricocephalus chauveaui Zone
The FAD of *Oryctocephalus indicus* is definding the base of Cambrian Series 3, Stage 5. *Oryctocephalus indicus* Zone occupied the middle part of the Kaili Formation (85.0m to 134 m in thicknes), containing various oryctocephalid trilobites: *Oryctocephalus indicus*, *O. elongatus*, *Curvoryctocephalus taijiangensis, Euarthricocephalus taijiangensis, E. similis, Metarthricocephalus spinosus, Metabalangia yupingensis, Oryctocephalites guizhouensis*. In the lower portion of *Oryctocephalus indicus* Zone the pygidium of *Oryctocephalus* has one to two pairs of marginal spines, whereas In the upper portion of *Oryctocephalus indicus* Zone the pygidium of *Oryctocephalus* has three or four pairs of marginal spines. In the lower portion of *Oryctocephalus indicus* Zone the *Euarthricocephalus* has seven thoracic segments, whereas in the upper portion of *Oryctocephalus indicus* Zone *Euarthricocephalus* has five to six thoracic segments.
Bathynotus kueichouensis-Ovatoryctocara sinensis Zone occupied the lower part of the Kaili Foemation (40 m to 52.8 m in thickness). oryctocephalid trilobites include *Oryctocephalops guizhouensis*, *Protoryctocephalus wuxunensis*, *P. balangensis*, *Ovatoryctocara sinensis*, *Arthricocephlus* sp. This zone represents uppermost Duyunian Stage. LADs of *Redlichia*, *Bathynotus, Protoryctocephalus, Arthricocephalus* and *Ovatoryctocara* can be observed, of which *Ovatoryctocara sinensis* has only two or three thoracic segments, whereas *Arthricocephalus* sp. has only 4 thoracic segments.
Protoryctocephalus wuxunensis Zone (or *Protoryctocephalus arcticus* Zone) occupied the upper part of the"Tsinghsutung Formation" or the Wuxun Formation (70 m to 120 m in thickness). Oryctocephalid trilobites contain *Protoryctocephalus wuxunensis*, *P. arcticus*,
Ovatoryctocara yaxiensis, *O.* sp., *Feilongshania* sp. nov., *Duyunaspis* sp., *Changaspis* sp. of which *Ovatoryctocara* has 6 to 7 thoracic segemnts representing FAD of *Ovatoryctocara*.
Arthricocephalus intermedus Zone occupied the lower part of the"Tsinghsutung Formation" or the Wuxun Formation and upper part of the Balang Formation (about 120 to 150 m in thickness) consisting of the following oryctocephalid trilobites: *Arthicocephalus intermedius* Zhou in Lu et al., 1974, including its synonyms *A. jishouensis* Zhou in Zhou et al., 1977, *A. taijiangensis* Yin in Yin et Lee, 1978, *A. tongrenensis* Yin i Yin et Lee, 1978?, *A. pulchelus* Zhang et Chien in Zhang et al., 1980, *Balangia balangensis*, *Duyunaspis duyunensis*, *Protoryctocara* sp.
Arthricocephalus chauveaui Zone occupied the middle-upper part of the Balang Formation (about 15 to 20 m in thickness). *Arthricocephalus chauveaui* including *Arthricocephalites xinzhaiheensis* has very short biostratigraphical range and an association with *Duyunaspis duyunensis, Balangia balangensis*.
Below *Arthricocephalus chauveaui* Zone whether to establish a new trilobite zone is under consideration.

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Small benthic foraminiferal behavior across the Cretaceous-Paleogene transition interval in northern Tunisia

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In several sections crossing continuous and complete Cretaceous-Paleogene transition intervals in Tunisia (El Melah, El Kef, Ellès, Oued Smara, Oued Abiod) small benthic foraminifera constitute various assemblages showing diverse species and morphotypes. They are rich in taxa defining the "Velasco fauna" which characterizes the bathyal and abyssal zones. Based on the species richness and relative abundance into each assemblage containing more than 300 specimens obtained from >63 µm residue fractions (using an Otto splitter) and their interpreted microhabitats these assemblages show obvious changes across the studied interval. Across the upper Maatrichtian in all the studied sections the assemblages are highly diverse. They indicate upper –middle bathyal environment and mesotrophic condition. Their species richness may reach more than 100. The diverse endobenthic morphotypes are dominant; they represent more than 60 % and may exceed 85 % like as in El Melah section. At the K/Pg boundary all the fauna disappeared temporary (the Ir-rich layer is free of fossils). After the boundary, across the lower Danian (from *Guembelitria cretacea* Biozone to *Parasubbotina pseudobullodes* Biozone of planktonic foraminifera), the small benthic foraminiferal assemblages show a noticeable decrease in species richness. This is due to sudden decrease to ca 45 species immediately after the boundary then gradual disappearances of the major part of the remaining Maastrichtian species. Especially the calcareous endofaunal species show a drastic decrease in relative abundance but few species from the calcareous epifauna became dominant, e.g., *Nutallides truempy*i and *Cibicidoides* spp. except in El Melah section characterizing the deepest environment. Concurrently, those having an agglutinated test show a brief increase through the black boundary layer ranging *Guembelitria cretacea* Biozone. Thus, the species crossing the K/Pg event are assigned to need oligotrophic conditions. These changes in benthic biota are related to the K/Pg cosmic event triggering mass extinction of calcareous primary producers and subsequent collapse of the food supply to the sea floor.

In addition, delayed small endobenthic restitution and epifauna rise including new taxa appearances suggest also that mesotrophic conditions had been recovered at the upper part of the *Parasubbotina pseudobullodes* Biozone . This means that the recovery was not completely established more than 200 kyr after the K/Pg boundary event.

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The Paleocene/Eocene boundary global warming impact on the foraminifera in northern Tunisia

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The Paleocene-Eocene transition deposits outcropping in Tunis city suburban close to Kharouba quarry, as well as in Jebel Goraa nearby Teboursouk city, are rich in planktonic and benthic foraminifera. Quantitative analysis based on representative residue fractions from samples spaced 10 cm close to the Paleocene/Eocene boundary (P/E) and 15 to 50 cm beyond. These fractions, containing at least 300 planktonic specimens and 300 benthic specimens across 10 m and 20 m respectively below and above the boundary, allow to inform on the P/E global warming impact on these different microorganisms.

Across the *Morozovella velascoensis* Biozone (characterizing the upper Paleocene) the morozovellids and subbotinids are equally abundant. Each one of these groups represents 39 to 45% of the planktonic assemblages, but the acarinids are less frequent (10 to 2 %). Through the *Acarinina sibaiyaensis* Biozone (characterizing the lowest Eocene) among planktonic foraminifera the acarinids show an obvious increase and may reach more than 50% of the planktonic assemblages. In contrast large morozovellids and subbotinids underline an important decrease.

About the benthic foraminifera, the assemblages are rich in Velasco fauna indicative of a bathyal environment above the CCD (e.g., *Aragonia aragonensis, Nutallides truempyi, Stensioeina beccariiformis*). Below the P/E boundary the calcareous endobenthic morphotypes are dominant. Above the boundary through the *Acarinina sibaiyaensis* Biozone the benthic foraminifera show a drop in their species diversity and Fisher index. This is due to gradual species disappearances. Beyond, although the species diversity and Fisher index increase, such disappearances continue in order to obtain ca. 50% of the total species loss. These species mass disappearances characterize the Benthic Extinction Event (BEE). The Shannon and Equitability indexes show minor changes. Besides, most of calcareous species are altered by dissolution. In contrast, agglutinated taxa underline an important increase and dominate the benthic foraminiferal assemblages.

All these changes in planktonic and benthic foraminiferal assemblages are related to the Initial Eocene Thermal Maximum (IETM).

Correlation of the Jurassic-Cretaceous boundary interval in Eurasia and North America by Buchias

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There are two limitations which do not allow to perform direct correlations of the Jurassic-Cretaceous boundary beds in the Northern Hemisphere by ammonites: 1) strong biogeographic provincialism of the biota; 2) scarcity of ammonite record in some regions. These problems can be negotiated with help of bivalves belonging to the genus *Buchia*. These bivalves are widespread in the Northern Hemisphere and are met anywhere to the north of 45° in Eurasia and to the north of 40° in North America. At both continents successions by *Buchia* are principally the same, not influenced by any strong provincialism. *Buchia* also do not correlate with facies, as they are known from different types of terrigenous (clays, silts, sands, gravels) and carbonate sediments, both shallow and deep water. The most complete sequences of *Bucha*-zones for the Upper Jurassic and lowermost Cretaceous are established in East Siberia, Russian Far East, western British Columbia and NW California.

Totally, zonal sequence by buchias covers 7 stages – Callovian, Oxfordian, Kimmeridgian, Volgian (Tithonian), Ryazanian (Berriassian), Valanginian and Hauterivian. The present investigation covers only three of them - Volgian (Tithonian), Ryazanian (Berriassian) and Valanginian. This interval is characterized by the following *Buchia*-zones, established for the northern part of East Siberia: *Buchia obliqua, B. unschensis, B. okensis, B. jasikovi, B. tolmatschowi, B. inflata, B. keyserlingi, B. sublaevis*. The same sections in East Siberia were also used as reference for ammonite scale and for direct Boreal-Tethyan paleomagnetic correlations. The current investigation is focused on zonal correlations of North Siberia sections with those located in Northern California. American authors established the following *buchia* zonation for the Jurassic-Cretaceous sequence of Paskenta series: *B. elderensis* Zone (Lower Tithonian), *B. piochii* Zone (Middle-Upper Tithonian), *B.* aff. *okensis* Zone (Upper Tithonian), *B. uncitoides* Zone (Berriassian), *B. pacifica* Zone, *B. keyserlingi* Zone (Lower Valanginian), *B. crassicollis solida* Zone (Upper Valanginian). We have revised this succession based on our own detailed study and collections from two reference sections of Upper Tithonian – Valanginian interval in Northern Califronia, Grindstone Creek and McCarty Creek.

We offer to improve the existing scheme by buchias, by introducing the following stratigraphic units by buchias for Paskenta series: Beds with *B.* aff. *volgensis-B.unschensis* (between *B. piochii* and *B. okensis* Zones; Tithonian and lowermost Berriassan), *B. okensis* Zone (instead of former *B.* aff. *okensis* Zone in the Lower Berriassian); *B. inflata* Zone (lower part of *B. pacifica* Zone, now restricted to its upper part); *B. sublaevis* Zone – Upper Valanginian (between *B. keyserlingi* and *B. crassicollis solida* Zones). All the units, newly established in California, are included into zonal standard for North Siberia, and thus provide direct intercontinental correlations.

Also intervals characterized by the presence of transitional varieties between two index species of adjoining zones ("stratoecotones") were found. Such intervals were observed between *B. piochii* and *B. okensis* Zones; *B. okensis* and *B. uncitoides* Zones (in the Grindstone Creek section); *B. uncitoides* and *B. inflata*, *B. inflata* and *B. pacifica*; *B. keyserlingi* and *B. sublaevis* Zones (in the McCarty Creek section). Also, positions of zonal boundaries were considerably specified: for example, the age of former *B.* aff. *okensis* Zone is Berriassian, while the top of *B. keyserlingi* Zone is still Lower Valanginian, contrary to the data of previous authors.

As a result of our study, a new zonal correlation of the Tithonian-Valanginian interval of the Paskenta series with Upper Volgian – Valanginian interval of North Siberia is proposed. This work was supported by the Russian Foundation for Basic Research, project no.15-05-03149.

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The first finding of *Biplanispira* (Foraminiferida) in the Middle Eocene of south-western Armenia

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The stratigraphic significance of the genera *Pellatispira* and *Biplanispira* (Pellatispiridae) is determined by their narrow stratigraphic range from the upper Bartonian to the upper Priabonian. Genus *Pellatispira* is widely distributed in the Tethys from Spain in the west to the Central Indo-Pacific in the east. Representatives of *Biplanispira*, firstly established in Borneo, are for a long time considered to be the characteristic forms for middle or upper Eocene of Central Indo-Pacific, being badly studied for their rarity. Cole (1970) considered that *Biplanispira* should be referred to the redefined genus *Pellatispira*. He believed that the aberrant growth of test in "*Biplanispira*" is connected with high density of *Pellatispira* populations leading to their high morphological diversity. The heteromorphic structure of *Biplanispira* tests with three types of chambers and chamberlets, and bifurcation of spire allowed distinguishing these genera. In the Mediterranean this genus was found in NE Spain (Igualada area, Ebro basin) (Romero et al., 1999, Costa et al., 2013). There, in association with *Biplanispira*, the new genus *Serraia*, morphologically close to *Biplanispira* was described by Matsumaru (1999). In Armenia, the specimens of *Pellatispira* were described by Grigoryan (1979). *Biplanispira* are discovered in last years in the upper Bartonian nummulitic limestone of Urtsadzor section in association with larger foraminifera: *Nummulites maximus* (A), *N. chavannesi, N. incrassatus, Heterostegina reticulata helvetica, Pellatispira madaraszi*, *Discocyclina augustae, Asterocyclina stella praestellaris* (common), *N. biarritzensis, N. orbignyi, Operculina* ex gr. *gomezi, Assilina schwageri* (single and rare). Although the similar stratigraphic and geographic distribution of *Pellatispira* and *Biplanispira* were mentioned by many authors, our data shown that *Pellatispira* is distributed wider from the upper Bartonian to the upper Priabonian in most localities of southern Armenia, but *Biplanispira* is found only in narrow interval of the upper Bartonian, currently in one section. At the same time the most abundant *Pellatispira* are really found together with *Biplanispira*. The specimens found have the same form of test, arrangement and shape of primary and secondary chambers and chamberlets, size of the proloculus as in *Biplanispira* from Ebro basin of Spain, attributed to *B. absurda.* The accompanied assemblage of larger foraminifera in beds with first Pellatispirids and *Heterostegina* in Ebro locality differs from the Armenian one mainly by the absence of giant *Nummulites*, as well as some radiate forms (*N. orbignyi, N. stellatus, N. biarritzensis*), which however are present below, in Igualada formation. The beds with *Pellatispira* and *Biplanispira* of Igualada basin, situated above of the NP19/20 zone, was interpreted to be latest Bartonian (Costa et al. 2013). In Armenia such beds situated below of NP18 zone, include abundant giant *Nummulites* of *N. millecaput* group, characteristic for Mediterranean lower-middle Bartonian and obviously older than in NE Spain. Therefore, this finding confirms the evident connection of Mediterranean and Trans-Caucasian basins as well as the diachronous appearance of common taxa in them. This work was supported by Russian Fund for Basic Research (project no. 15-55-05102).

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Division of Strata Superregions in China

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In terms of the global tectonic setting, all continents of China are grouped into Pan-Cathaysian blocks, Laurasia and Gondwana Continental Margins and three Oceans (Paleoasian Ocean, Tethys Ocean and Pacific Ocean). The continent of China is subdivided into three blocks (North China, Tarim and Yangtze) and eight orogenic belts (Altai – Inner Mongolia – Daxinganling, Tianshan – Junggar – Beishan, Qinling – Qilian – Kunlun, Qiangtang – Sanjiang, Gangdisê, Himalaya, Cathaysia, Eastern Taiwan), based on the process of oceanic-crusts subduction and of the colliding-accreting of continental crusts. Along the orogenic belts, six suture zones, including the Ertix – Xar Moron, south Tianshan, Kuanping – Foziling, Bangong, co – Shuanghu – Nujiang – Changning – Menglian, Brahmaputra, Jiangshao – Chenzhou – Qinfang zones have been recognized, based on the distribution of ophiolites or ophiolites-related mélanges. Correspondingly, the strata of the continent of China are subdivided into 17 strata superregions (SSR): Altai – Inner Mongolia – Daxinganling SSR, Ertix – Xar Moron SSR, Tianshan – Junggar – Beishan SSR, south Tianshan SSR, Tarim SSR, North China SSR, Kuanping – Foziling SSR, Qinling – Qilian – Kunlun SSR, Qiangtang – Sanjiang SSR, Yangtze SSR, Bangong co – Shuanghu – Nujiang – Changning – Menglian SSR, Brahmaputra SSR, Jiangshao – Chenzhou – Qinfang SSR, Gangdisê SSR, Brahmaputra SSR, Himalaya SSR, Cathaysia SSR, Eastern Taiwan SSR.Therefore, tectonically these strata superregions belong to three blocks, six suture zones and eight orogenic belts.

This division is mainly based on 6 key aspects, including the difference of tectonic settings and tectonic evolutions for different blocks, features of convergent-subductional zones and orogenic belts, the timing when the oceanic crusts subducting and the continental crusts colliding, paleobiogeographical features of basins, features of strata sequences.

Study on sedimentary and diagenesis environment of Yubei Yingshan formation

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For the study of physical properties of Yubei Yingshan formation, looking for high quality reservoir of oil and gas, this paper selected 19 rock samples of Yingshan formation in different depth of the study area and tested the carbon and oxygen isotope, by the ancient environment analysis method, combined with the sedimentary environment and diagenetic environment, studied the geochemistry characteristics of sedimentary and diagenesis environment of Yubei Yingshan formation. The test results showed that: $d^{13}C$ and $d^{18}O$ values varied in a small range, the minimum value of $d^{13}C$ is -2.6‰, the maximum is -0.7‰, the average is -1.57‰. The minimum value of $d^{18}O$ is -10.8‰, the maximum is -6.0‰, the average is -7.82‰. The minimum value of Z is 118.4‰, the maximum is 122.6‰, the average is 120.19‰. The minimum value of T is 42.5°C, the maximum is 67.5°C, the average is 51.86°C. Carbon isotope of carbonate in Yubei Yingshan formation is similar to that in normal deposite marine carbonate, oxygen isotope of carbonate rocks in Yubei Yingshan formation bias negative compared with that in normal marine carbonate, mainly due to oxygen isotopic fractionation in the pore water and the affection of leaching and dissolution by atmospheric water in the process of diagenetic. Atmospheric water seriously depleted ^{18}O, carbonate rocks affected by atmospheric water usually have negative impact on $d^{18}O$ values in the rainfall season. Lower $d^{18}O_{PDB}$ corresponding to higher paleotemperature, higher $d^{18}O_{PDB}$ corresponding to lower paleotemperature. The paleotemperature of diagenetic of Yubei Yingshan formation from deep to shallow experienced a process of decline and then raise, which indicate that the burial depth of diagenetic experienced process of increase first and then decrease. The rise of the sea level corresponds to a higher $d^{13}C_{PDB}$, the decline of sea level corresponds to the lower $d^{13}C_{PDB}$, $d^{13}C_{PDB}$ of the first half of Yingshan period was significantly higher than that of the second half, which indicate that the Yingshan period experienced a process of decrease of the sea level. Z value can be as a qualitative reference mark to classify land or sea environment, Z> 120 reflected as a marine environment, Z <120 reflected as a continental environment, Z = 120 is undetermined. Z value can be used as a quantitative index to explain the relative change of paleosalinity in Yubei Yingshan formation only when $d^{13}C$ with Z value and $d^{18}O$ with Z value has a high correlation. $d^{13}C$ with Z value have a high correlation in Yubei Yingshan formation, the correlation coefficient was 0.813. $d^{18}O$ with Z value almost have no correlation, the correlation coefficient is 0.025. Thus, Z value as quantitative indicator to explain the relative change of the paleosalinity has lower accuracy. T value indicates paleotemperature of diagenetic, the paleotemperature of diagenetic is high with the average of 51.86°C. Thermal dissolution of limestone can change the physical properties of rock and that is beneficail to the reservior. The above analysis shows that the deposition conditions of Yubei Yingshan formation is similar to the normal marine conditions, diagenesis improved physical property of the reservoir. Leaching and dissolution of atmospheric water can increase the pore volume, thermal dissolution is also conducive to the improvement of reservoir. Leaching and dissolution of atmospheric water and thermal dissolution are the favorable conditions for the development of reservoir.

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Appearance of trilobites during the Cambrian Explosion: a discussion on the definition of the Cambrian Series 2 and Stage 3

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Subdivision of the Cambrian System into four series and ten stages has been widely accepted by scientific communities. The conterminous bases of Cambrian Series 2 and Stage 3 are expected to be placed at a horizon close to the first appearance of biomineralized trilobites, which marks the onset of the largest phase of the Cambrian explosion. An ideal boundary would be marked by a significant and globally recognizable bioevent that divides the lower part of the Cambrian System into the sub-trilobitic Terreneuvian Series and the first trilobite-dominated Series 2. This biostratigraphically demarcated level needs to be placed in the context of all available information, such as geochronometric and chemo- and magnetostratigraphic brackets, and its correlation potential should be tested through a detailed study of several continuous successions covering the critical interval. The major difficulty is a strong biotic provincialism, a plethora of regional unconformities and facies changes in different paleocontinents during the Terreneuvian–Series 2 boundary interval. However, a few levels provide potential for intercontinental correlation crucial for defining the base of Cambrian Series 2 and Stage 3. These levels include the global FAD of trilobites and other time-equivalent boundaries such as the FAD of certain non-trilobitic species (e.g. SSFs and acritarchs), and non-biostratigraphic markers (e.g. stable carbon isotopic excursion). By comparison with other potential indicators for a boundary, the FAD of trilobites still has advantages for defining the GSSP and hence should be kept as the provisional primary marker before the GSSP is officially established.

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Phosphatized microtubular fossils from the late Ediacaran Dengying Formation of South China

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Complex multicelluar eukaryotes have diversified since the Ediacaran Period, which are well documented in a number of exceptionally preserved biotas in South China, e.g. the Lantian biota, the Weng'an biota, and the Gaojiashan biota. More than 300 microtubular fossils have been recovered from phosphorous dololithite at the base of the late Ediacaran Dengying Formation. The new fossil site is located in the northern margin of South China Plate, within the present-day Zhenba Country, Shaanxi Province. Microfossils are phosphatized and appear as tubular or columnar forms, varying from circular, and square to irregular in cross section and ranging from 150µm to 1300µm in diameter. The maximum preserved length is 1700 µm. The fossils bend frequently, exhibiting apparent surficial growth striations and fine laminations(4-20 µm in thickness) inside, and a couple of specimens exhibit regular segmentations. Some specimens show rounded or conical apex indicating a model of half-closed tube. The tube wall are preserved as phosphoric or/and silicic coatings (3-6 µm). One or several grooves are symmetrically or asymmetrically distributed on many specimens along the longitudinal axis. A well-preserved specimen shows a longitudinal fission, presumably representing an evidence for asexual reproduction. These morphological characters exclude assignment to cyanobacteria and algae, and hence their biological affinities remain uncertain. The new fossils have close resemblance to *Sinocyclogyclicus* and *Quuadratitubus* from the Weng'an biota, but are younger in age.

Cambrian (Stage 3) lophotrochozoa from the Chengjiang Fauna: discovery and progress

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The articulated nature of skeletal elements has provided clues to the behaviors of extinct organisms that are usually unobtainable from shelly and skeletonized fossils alone. Until now, not so many taxa of soft-bodied fossils among lophotrochozoans are known from Cambrian Könservat-Lagerstätten, but include abundant brachiopods and the mollusk-like scleritome-bearing Wiwaxia. Wiwaxiids are a problematic group of scale-covered lophotrochozoans known from Cambrian Stages 3-5. Their imbricating dorsal scleritome of leaf-like scales has prompted comparison with various annelids and molluscs, and has been used as a template to reconstruct the articulation pattern of isolated Small Shelly Fossils. The first articulated specimens of Wiwaxia from the Cambrian Stage 3 Chengjiang Konservat-Lagerstätten show that the Wiwaxia scleritome comprised nine equivalent transverse rows associated with outgrowths of soft tissue, but did not possess an separate zone of anterior sclerites. This metameric construction is fundamentally incompatible with the circumferential disposition of sclerites in early molluscs, but does closely resemble the armature of certain annelids. A deep homology with the annelid scleritome must be reconciled with Wiwaxia's mollusc-like mouthparts and foot; together these point to a deep phylogenetic position, close to the common ancestor of annelids and molluscs. Fundamental differences between the scleritomes of halkieriids and wiwaxiids seemingly contradict their close relationship in a 'halwaxiid' clade.

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Diagenetic uptake of rare earth elements by bioapatite, with an example from Lower Triassic conodonts of South China

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The distribution patterns of rare earth elements (REEs) are frequently used as proxies for ancient seawater chemistry or paleomarine environmental conditions. However, recent work has shown that diagenesis can lead to remobilization and inter-elemental fractionation of REEs, and that these effects often occur in conjunction with redox reactions in sediment porewaters. Here, we review existing literature on the diagenetic fluxes of REEs in marine sediments and porewaters in order to systematize existing knowledge on this subject. REEs undergo significant redistribution among sediment phases during both early and late diagenesis as a consequence of adsorption and desorption processes. Remobilization of REEs commonly leads to inter-elemental fractionation, variously leading to enrichment or depletion of the light, middle, or heavy REE fractions. Further, REE remobilization can be facilitated by redox changes, e.g., through reductive dissolution of host phases in suboxic and anoxic porewaters. Characteristic REE distribution patterns develop through these processes: (1) a ‘flat distribution’ signifying predominantly terrigenous siliciclastic influence, (2) a ‘middle-REE bulge’ probably due to adsorption of light and heavy REEs to Mn- and Fe-oxyhydroxides, respectively, and (3) ‘heavy-REE enrichment’ indicative of hydrogenous (seawater) influence (note: all patterns in this paper are normalized to the REE composition of average upper continental crust, or UCC).

In the second part of this study, we undertake an analysis of the REE distributions in conodonts and whole-rock samples from West Pingdingshan, a Permian–Triassic boundary section in South China. Using ΣREE/Th and Y/Ho ratios, we show that almost all of the conodont samples have a strong diagenetic overprint, and that the hydrogenous REE fraction is small and not isolatable. Furthermore, the conodonts contain two diagenetic REE components, one characterized by low ΣREE (100–300 ppm), high ΣREE/Th ratios (>1000), strong middle REE enrichment, and Eu/Eu* ratios of ~1.5–2.0, and the second by high ΣREE (300–2000 ppm), low ΣREE/Th ratios (~20–30), little or no middle REE enrichment, and Eu/Eu* ratios of ~1.0. The first component exhibits a pronounced middle-REE bulge that represents an early diagenetic signature associated with suboxic conditions, possibly related to adsorption of REEs onto Fe–Mn oxyhydroxides in the shallow subsurface environment. The second component shows a flat REE distribution that is similar to both our whole-rock samples and average UCC, indicating derivation from REEs released from detrital siliciclastics (e.g., clay minerals), probably at a range of burial depths from shallow to deep. Failure of the conodont samples to yield an isolatable hydrogenous component demonstrates that bioapatite does not always preserve a primary marine REE signature. Given that bioapatite REEs have been widely used for this purpose, often on the assumption of minimal or no diagenetic influence, our findings are likely to necessitate a re-evaluation of the results of many earlier studies. In general, we counsel caution in inferring a hydrogenous origin for REEs in bioapatite owing to frequent diagenetic alteration of REE distributions.

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Updating the oryctocephalid trilobite zones (upper part of Cambrian Series 2) at the Balang village, Jianhe County, Guizhou, China and its correlation

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The upper part of Cambrian Series 2 and the lower part of Cambrian Series 3 are well developed in the Jianhe area, Guizhou, and in descending order, includes the Kaili and the “Tsinghsutung” formations, both of them contain abundant oryctocephalid trilobites. Based on intensive investigation three biozones and one interval containing *Arthricocephalus (Arthricocephalites) jishouensis* have been recognized (Table 1), in descending order, they are: 1) *Oryctocephalus indicus* Zone; 2) *Bathynotus kueichouensis-Ovatoryctocara sinensis* Assemblage Zone; 3) *Protoryctocephalus arcticus* Zone; 4) undetermined zone contains *Arthricocephalus (A.) jishouensis*. The first two zones belong to the Kaili Formation, and the last two are recognized in the “Tsinghsutung” Formation.
Oryctocephalus indicus Zone can be correlated with *Koanamuites* or *Oryctocephalops reticulatus* Zone at the Molodo River Section in Siberia, the base of the Sydpoasset Formation in Peary Land, North Greenland, and the *Oryctocephalus indicus* Zone and *Amecephalus arrojosensis* Zone in North America (Table 1). Within *Bathynotus kueichouensis*- *Ovatoryctocara sinensis* Ass. Zone, besides abundant *Bathynotus* and *Redlichia*, *Ovatoryctocara* and *Oryctocephalus* yielded from the Molodo River Section also occur in this biozone. *Protoryctocephalus* and *Nangaopis* are common in the lower part of the Kaili Formation.
Protoryctocephalus is abundantly found from the mid-upper parts of the “Tsinghustung” Formation, including *P. arcticus*, *P. elongatus* and *P. balangensis*. *Redilichia*, *Nangaopis*, *Olenoides* and *Ovatoryctocara*? also have been found from that interval, and the trilobite assemblage resembles that of the lower part of the Kaili Formation. The lower boundary of *Protoryctocephalus arcticus* Zone may be correlated with that of *Ovatoryctocara* Zone at Molodo River, Siberia. However given that the stratigraphic ranges of *Protoryctocephalus arcticus* and *Arthricocephalus (A.) jishouensis* are replicated in the lower part of the “Tsinghsutung” Formation, the lower boundary of the *Protoryctocephalus arcticus* Zone should be expressed as dashed line. On the other hand, it recently has been suggested to establish the *Arthricocephalus chauveaui*-*Changaspis elongata* Assemblage Zone in the Balang Formation and the lowermost part of the “Tsinghsutung”Formation, but this suggestion is baseless and unreasonable. However further work seems needed before establishing and approval of these zones.

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Taphonomy and morphologic variation of *Oryctocephalus indicus* from China, Russia and USA

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The effects of taphonomy on trilobite systematics are likely more evident on those taxa which occur in a wide range of lithofacies. These taxa are often the most useful for intercontinental correlations and hence have critical significance for biogeography. This is the case of *Oryctocephalus indicus* which FAD is candidate to define the base of Cambrian Stage 5. Here we discuss the potential effects of taphonomy on the taxonomy and as consequence in the biostratigraphy of three *Oryctocephalus* species from South China, Siberia and western USA.

1) *Oryctocephalus indicus* is abundantly yielded from five sections of the Kaili Formation (*ca.* 1000 specimens). A preliminary taphonomy study of articulated specimens reveals that a small percentage around the 5% of the specimens lack S_2 and S_3; 20% shows very weak S_2 and S_3 and about the 75% of the specimens show well developed glabellar furrows.

2) *Oryctocephalus reticulatus* (Lemontova, 1940) from Cambrian Stage 5 of Siberia is very similar to *O. indicus*, and the latter differs in having poorly developed of the second and third pairs of transglabellar furrows. However, previous taphonomy studies demonstrated that transglabellar furrows in the glabela are subjected to obliteration in specimens preserved in shale. According to the variability seen in *O. indicus* from Kaili we suggest that *O. reticulatus* should be a junior synonym of *O. indicus*, and the variations are due to sampling and taphonomical bias. The previous inaccurate identification of *O. reticulatus* brings misinterpretation of stratigraphic correlation in Siberia.

3) *Oryctocephalus americanus* Sundberg and McCollum, 2003 also resembles *O. indicus*, but differs of the latter in having only one transglabellar furrow (S_1) and two pairs of pygidial marginal spines. *O. americanus* lacks two transglabellar furrows (S_2 and S_3), but we also have observed such obliteration in disarticulated cranidia (n = 135, 20%) from the Kaili Formation. On the other hand, the study of *O. indicus* from South China also shows that the pygidium is high variable and some specimens bears also two pairs of pygidial marginal spines. Therefore *O. americanus* may be a junior synonym of *O. indicus*. *Oryctocephalus americanus* belongs to the *Amecephalus arrojosensis* Zone and its FAD is 4 meters above the extinction datum of *Olenellus*. This implies that the boundary between Cambrian Series 2 and Series 3 should be moved between the extinction level of *Olenellus* and the current FAD of *O. indicus* in North America.

In conclusion, if we followed previous works on *O. americanus* and *O. reticulatus*, both of these morphotypes appeared in the Kaili Formation, it is suggested that their morphologic variations should be contributed by taphonomic alteration rather than biological diversification.

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Biostratigraphy of Oryctocephalid Trilobites from the Cambrian "Tsinghsutung" Formation at Balang, Jianhe County, Guizhou Province, China

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Cambrian Series 2 and 3 at Balang, Jianhe area were deposited in the transitional slope belt, and the "Tsinghsutung" Formation (Cambrian Series 2) exposed in this area is 272 m thick. The lower part of the formation is dominated by limestone; the mid-upper part is composed of gray limestone intercalated with mudstone, and the top of the formation consists of dolomite. Its lithologic characters are distinct from the typical Tsinghsutung Formation in Western Guizhou and different from the coeval Wuxun Formation in Danzhai area, thus we temporarily use "Tsinghsutung" Formation. A new Burgess Shale- type lagerstätte, named as Jianhe Biota, was discovered in the mid-upper part of the "Tsinghsutung" Formation near Balang village. The fossil assemblage includes representatives of porifera, cnidarians, worms (*sensu lato*), brachiopods, mollusks, arthropods, eocrinoids and abundant trilobites (including Ptychopriidae, Redlichiidae and Oryctocaridae), which yielded from multiple beds through the entire formation. We have found 2 genera with 6 species and 1 subgenus of Oryctocaridae: *Protoryctocephalus balangensis* Zhao and Yuan in Yuan et al., 2002, *P. elongatus* Zhao and Yuan in Yuan *et al*., 2002, *P. arcticus* Geyer and Peel, 2011, *Duyunaspis duyunensis* Chang and Chien 1977 *Arthricocephalus* (*Arthricocephalites*) *jishouensis* **(**Zhou in Zhou et al., 1977) and *A.* (*Arthricocephalites*) sp.

The first appearance datum (FAD) of *A.* (*Arthricocephalites*) *jishouensis* is in the underlying Balang Formation, and *A.* (*Arthricocephalites*) *jishouensis* extended to the lower part of the "Tsinghsutung" Formation. The FADs of *P. balangensis* and *P. elongatus* are in the "Tsinghsutung" Formation and the two taxa extended to the lower part of the overlying Kaili Formation. *Protoryctocephalus arcticus* has been found in the lower part of the "Tsinghsutung" Formation, ranging from 135m to 239m above the base. This taxon was described by Geyer and Peel in 2011 based on disarticulated cranidia from the Henson Gletscher Formation of northern Greenland. Based on a great number of specimens collected from this interval, the *P. arcticus* Zone was established. The *Protoryctocephalus arcticus* Zone is limited to the middle and upper parts of the "Tsinghsutung" Formation at Balang village. Here, we suggest that the *P. arcticus* Zone is correlated with the *Eoagostus roddyi-Arthricocephalus chauveaui* Zone in the lower part of the Henson Gletscher Formation in north Greenland. Nevertheless, further fieldwork in the lower part of the "Tsinghsutung" Formation is needed to verify the validity of this new biozone.

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Subdivision of the early Ediacaran

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A distinctive cap carbonate marks the end of the Cryogenian Period and the beginning of the Ediacaran Period (Knoll et al., 2006). Following the deposition of the cap carbonate, the early Ediacaran is characterized by the rapid diversification of both micro- and macro-eukaryotes (Zhou et al., 2007; Yuan et al., 2011), representing a post-glacial bioradiation event. Recently, the Ediacaran Subcommission has established the Second Ediacaran Stage (SES) Working Group, whose main task is to subdivide the early Ediacaran and to define the base of the second Ediacaran Stage using biostratigraphic, chemostratigraphic, and lithostratigraphic tools.

In the Yangtze Gorges area of South China, acanthomorphic acritarchs first appear in the Doushantuo Formation chert nodules ~8 meters above the top of the cap dolostone (Zhou et al., 2007; McFadden et al., 2009; Liu et al., 2014). Approximately at this horizon, the $\delta^{13}C$ values show a positive shift.

The Lesser Himalaya of India is probably another region where the early Ediacaran biostratigraphic and chemostratigraphic data are available. Overlying the Blaini Formation diamictite, the Ediacaran succession in the Lesser Himalaya region consists of the Infra Krol Formation and Krol Group, with facies assemblages and carbonate platform architecture similar to the Ediacaran succession in South China (Jiang et al., 2003). Immediately overlying the cap carbonate, the chert nodules in Infra Krol black shales yield acanthomorphic acriatchs including *Asterocapsoides*, *Ericiasphera*, and *Knollisphaeridium* (Tiwari and Knoll, 1994; Tiwari and Pant, 2004). The Krol A Formation of Krol Group that overlies the Infra Krol Formation yields an acritarch assemblage (Shukla and Tiwari, 2014) and is characterized by positive $\delta^{13}C$ values (Kaufman et al., 2006). The Infra Krol and Krol successions provide an opportunity to test biostratigraphic models developed from the Doushantuo Formation in South China (Zhou et al., 2007; McFadden et al., 2009; Liu et al., 2014).

In the Patom Uplift of East Siberia, a diverse acanthomorphic acritarch assemblage occurs in the Ura Formation (Sergeev et al., 2011; Moczydlowska and Nagovitsin, 2012). This microfossil assemblage can be correlated with the upper acritarch assemblage of the Doushantuo Formation in South China (Liu et al., 2014), and this correlation is consistent with $\delta^{13}C$ variations in both areas. While there are no acanthomorphic acritarchs from the underlying Barakun Formation, which overlies the Cryogenian Dzemkukan Formation diamictite, the siltstones and mudstones in the lower Barakun Formation have potential to yield acritarchs of biostratigraphic significance.

In summary, although there is an urgent need for more high-resolution biostratigraphic and chemostratographic investigations on the early Ediacaran successions in South China, India, Siberia, and other regions, the first occurrence of acanthomorphic acritarchs and simultaneous $\delta^{13}C$ shifts have great potential to define the base of the second Ediacaran Stage.

The Characteristics of Carbonate Cements in the Interbedded Sandbody in ES_4 in Dongying Sag

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Dongying sag is a sub-structural unit of the Jiyang depression. The study area is located in northern Dongying sag. To study the characteristics and origin of carbonate cement, samples from Shahejie Formation in Dongying sag are tested by petrological methods, the content of clay minerals and trace elements. Then the impact of carbonate cements in different periods of hydrocarbon accumulation is described.

The result shows that the main minerals of carbonate cements are calcite, dolomite, ankerite and ferrocalcite. They occur as grain coating carbonate, sparry cement and replacement of quatz and feldspar. The grain coating carbonate cements are located in fan-deltas, which are affected by fresh water and saline water in turn. The average Sr/Ba ratio is 0.85. In this condition, halophilic anaerobic bacteria produce micritic cements. The sparite cements are produced in beach-bars by saline water in which the average Sr/Ba ratio is 2.24. Vertically, they mainly develop in a depth of 1600 – 1900 m and 2500 – 3300 m which are in the eodiagenesis and the mesodiagenesis, respectively.

Calcite cements generated in the eodiagenesis which mainly originate from precipitation of saline water in pores while part of them became later dolomitized. They can weaken the mechanical compaction and protect the reservoir. The illitization also appeared at 1600 m providing Ca^{2+}, Mg^{2+}, Fe^{2+}. Then its content is increasing continuously until 3000 m. The content of chlorite rises obviously at 2600 m and 3200 m, which is a little later than illitization illustrating that the alkali fluids really contain Mg^{2+}, Fe^{2+}. Because of this the content of calcite became reduced while dolomite increased with depth because of the Ca^{2+}, especially below 2600 m. Ankerite and ferrocalcite generated in the mesodiagenesis which is mainly affected by Mg^{2+} and Fe^{2+}. Those ankerite and ferrocalcite will plug pores and throats.

Constructing a Neoproterozoic Seawater Strontium Isotope Curve

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Although strontium isotope stratigraphy is well-established in Phanerozoic studies, its application to the Precambrian is still limited. The strontium isotopic composition of seawater has varied throughout Earth history in response to the balance between Sr isotopic exchange with ocean crust and input of riverine Sr derived from continental weathering. Because of this, seawater $^{87}Sr/^{86}Sr$ highs of the Phanerozoic Eon are interpreted to reflect weathering/erosional events, related to mountain building, while $^{87}Sr/^{86}Sr$ lows are considered to result from low weathering rates due to supercontinent denudation or increased seafloor spreading. Seawater $^{87}Sr/^{86}Sr$ also responds to changes in the isotopic composition of material undergoing weathering with old, continental rocks contributing radiogenic Sr, while the opposite is true for freshly erupted volcanic terrains which are frequently linked to negative excursions in seawater $^{87}Sr/^{86}Sr$. The largest ever increase in seawater $^{87}Sr/^{86}Sr$ took place sometime from approximately 900 Ma to 500 Ma, and was associated with a permanent step shift in baseline $^{87}Sr/^{86}Sr$ composition. The unprecedented size of this increase, its timing and causation remains unconstrained. This study attempts firstly to reconstruct global seawater $^{87}Sr/^{86}Sr$ trends through this increase, using well-preserved carbonate rock samples from the North China craton, calibrated against additional $^{87}Sr/^{86}Sr$ and $\delta^{13}C$ data from Neoproterozoic samples collected from other sections around the world. Sample preparation techniques for bulk carbonate Sr isotope stratigraphy are being honed during the course of this study. Other stable isotope systems ($\delta^{13}C$ and $\delta^{18}O$) and trace elements, including REE have been investigated on the same samples to help to identify pristine samples for Sr isotope analysis and help with the interpretation. The newly obtained data from this study (mainly Huaibei group of Huaibei area), using the excellently preserved early marine calcite cements and some bulk rock samples, confirm that the carbonate strata across the Jiao-Liao-Xu-Huai stratigraphic realm of the North China Craton exhibit the moderately positive $\delta^{13}C$ value and low $^{87}Sr/^{86}Sr$ values that are characteristic of the early Neoproterozoic (Tonian). The results help to recreate the global curve by linking negative excursions in the Shijia (Xuzhou) formations with the global ~ 810Ma 'Bitter Springs Anomaly' or BSNA. The first attempt of a Neoproterozoic strontium isotope curve has been reconstructed using our unpublished data and published data.

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Stratigraphic architecture and age model of the Cryogenian successions of South China

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Stratigraphy and sedimentology of the Cryogenian glacial successions provide primary data for elucidating climatic change of this critical interval. The Cryogenian strata of South China were deposited in a rift basin, and exhibit dramatic facies change from the basin center to margin, which complicates stratigtraphic correlations. Here we present new sedimentological, stratigraphic, geochronological and geochemical data based on the detailed analyses of more than ten well exposed sections along a basinward transect from north-south. In the basin center, Cryogenian strata are about 4000 m thick and characterized by two glaciogenic diamictite units separated by a diamictite-free siliciclastic interval. Initiation of the Chang'an glaciation (Sturtian equivalent) is conformable and gradational with dropstones appearing in siltstone at the basal part of the Chang'an Formation followed by a shoaling-up sequence that is interpreted to represent a glacio-eustatic sea-level fall. In the basin center, >600 m of graded beds of siliciclastic rocks and debrites of the Fulu Formation overlie the Chang'an Formation. The Fulu Formation is succeeded by a thin (<10 m) fine-grained siliciclasitic unit with black shale and manganese carbonate at the base, which is assigned to the Datangpo Formation, and massive glacigenic diamitictite of the Marinoan-age Nantuo Formation. On the basin margin, the Datangpo Formation is up to 300 m thick and is underlain by a glaciogentic diamictite (Tiesi'ao/Gucheng/Dongshanfeng formations). Taking factors of glacial dynamics and active tectonism into account, we develop a facies model to interpret the sedimentology and stratigraphic architecture of these successions.

The stratigraphic architecture is further supported by the new high-resolution zircon U- Pb ages from the top of the pre-Cryogenian successions and the interglacial Datangpo interval both in the basin and shelf areas. Most importantly, these new ages confirms synchroneity and duration of the Sturtian glaciation which initiated rapidly at 716 Ma and ended at 660 Ma. Combined with previously published geochronological data from South China, Namibia, and NW Canada, our new data will permit the development of a more highly resolved age model for the Cryogenian, and provide tests for Cryogenian climatic models.

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Identification and correlation of the Cambrian base: problems and potential solutions

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Since the time of its ratification in 1992, the GSSP of the base of the Cambrian in the Fortune Head section, Newfoundland, Canada, has presented challenges to correlation, and its intended use as a stable, precise horizon for global correlation outside both the stratotype section and the Avalonian paleocontinent has been questioned. Stepping aside from the issues associated with the stratigraphic occurrence and range of *Trichophycus pedum*, and the conceptual model of a Cambrian base coincident with the first appearance or diversification of animals, there are other practical stratigraphic issues to consider. Here we try to assess other possible chronostratigraphic tools for identifying and correlating the Cambrian base. These derive mostly from observations in South China coupled with data from Siberia. Possible chronostratigraphic tools apart from trace fossils include: (1) the FAD of an early small shelly fossil, of which the best candidate taxa are *Protohertzina anabarica* and *Protohertzina unguliformis*; (2) the FAD of an acritarch or the base of an acritarch zone (e.g. the *Asteridium-Heliosphaeridium-Comasphaeridium* assemblage); and (3) the BACE $\delta^{13}C_{carb}$ excursion.

Major questions concerning these chronostratigraphic tools include: (1) Whether FADs of small shelly fossils and acritarchs are facies controlled, and to what extent? (2) What is the stratigraphic relationship among the FADs of *Protohertzina anabarica*, *Protohertzina unguliformis Asteridium-Heliosphaeridium-Comasphaeridium* acritarchs, and *Treptichnus pedum*? (3) Is the BACE $\delta^{13}C_{carb}$ excursion a synchronous global event? If yes, which position (onset or peak) of the excursion is the best for correlation? Whether the prominent multiple excursions in the basal Cambrian recorded in Siberia can be correlated on a global scale or represent just a local signature? Whether the $\delta^{13}C_{carb}$ signature is coupled with or decoupled from the $\delta^{13}C_{org}$ within the BACE event? How reliable will it be to use the $\delta^{13}C_{org}$ excursion for correlation of the Cambrian base in non-carbonate strata?

Geochronological data are an one key to resolving the problems. Based on new and published zircon U-Pb ages from the basal Cambrian of South China, coupled with geochronological data from other areas, we assess potential solutions for precisely correlating the Cambrian base.

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A *Glyptagnostus reticulatus* trilobite faunule from the Cambrian of Qinghai Province, northwest China

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A new trilobite assemblage has been collected from the Heicigou Group of Daliang, Menyuan, northeastern Qinghai Province, northwest China with the globally distributed index fossil *Glyptagnostus reticulatus*, defining the base of Cambrian Paibian Stage, (Furongian Series). The assemblage is comprised of six taxa, including three agnostoid arthropods, namely *Glyptagnostus reticulatus* (Angelin, 1851), *Pseudagnostus josepha* (Hall, 1863), and *Agnostus inexpectans* Kobayashi 1938, and three polymerid trilobites, namely *Baikadamaspis sinensis* (Yang in Zhou et al., 1977), *Aphelaspis qilianensis* Lin et Zhang in Chu et al., 1979, and *Eugonocare* (*Olenaspella*) *transversa* Lin et Zhang in Chu et al., 1979. The assemblage is strongly similar to that from western Hunan, South China and is possibly from deep, outer-shelf to slope setting. This is the first record of *Glyptagnostus reticulatus* from the North China Plate and made it possible to mark the contemporary base of Paibian and Furongian precisely for the Cambrian succession of North China.

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