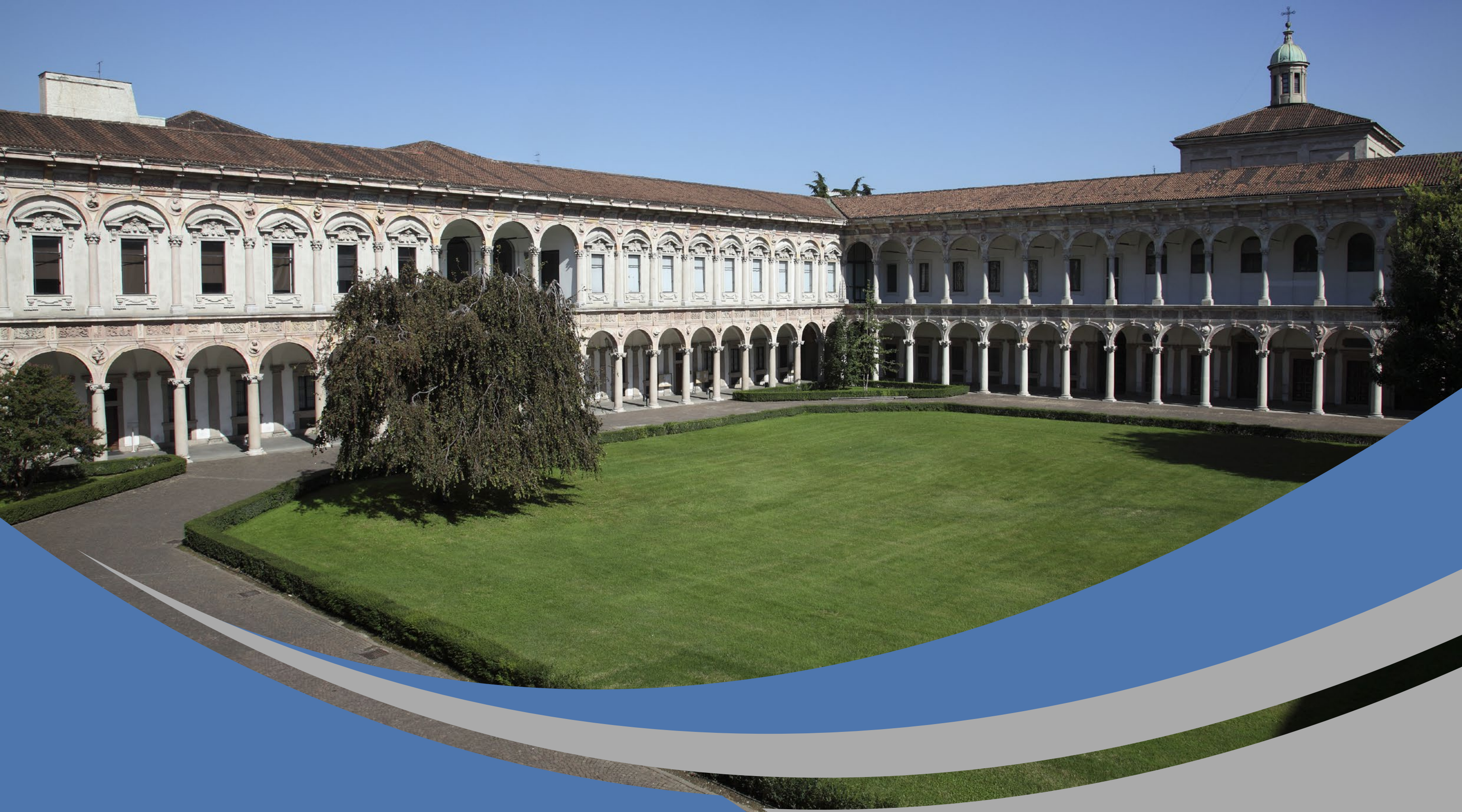
https://doi.org/10.3301/ABSGI.2019.04



Milano, 2-5 July 2019

ABSTRACT BOOK

a cura della Società Geologica Italiana

3rd International Congress on Stratigraphy

3rd International Congress on Stratigraphy
strati 2019
2-5 July 2019, Milano, Italy

IUGS

Commissione Italiana di Stratigrafia

Università degli Studi di Milano

Università degli Studi di Milano
Dipartimento di Scienze della Terra "Ardito Desio"

GENERAL CHAIRS

Marco Balini, Università di Milano, Italy

Elisabetta Erba, Università di Milano, Italy - past President Società Geologica Italiana 2015-2017

SCIENTIFIC COMMITTEE

Adele Bertini, Peter Brack, William Cavazza, Mauro Coltorti, Piero Di Stefano, Annalisa Ferretti, Stanley C. Finney, Fabio Florindo, Fabrizio Galluzzo, Piero Gianolla, David A.T. Harper, Martin J. Head, Thijs van Kolfschoten, Maria Marino, Simonetta Monechi, Giovanni Monegato, Maria Rose Petrizzo, Claudia Principe, Isabella Raffi, Lorenzo Rook

ORGANIZING COMMITTEE

The Organizing Committee is composed by members of the Department of Earth Sciences "Ardito Desio" and of the Società Geologica Italiana

Lucia Angiolini, Cinzia Bottini, Bernardo Carmina, Domenico Cosentino, Fabrizio Felletti, Daniela Germani, Fabio M. Petti, Alessandro Zuccari

FIELD TRIP COMMITTEE

Fabrizio Berra, Mattia Marini, Maria Letizia Pampaloni, Marcello Tropeano

ABSTRACT BOOK EDITORS

Fabio M. Petti, Giulia Innamorati, Bernardo Carmina, Daniela Germani

ABSTRACT INDEX

ST1.1
History of Stratigraphy in Italian environments (17th – 20th centuries)

Conveners and Chairpersons
Ezio Vaccari (Università dell'Insubria)
Andrea Candela (Università dell'Insubria)
Marco Pantaloni (ISPRA)
Luigina Vezzoli (IGG - Istituto di Geoscienze e Georisorse)

Geohistory and history of stratigraphy in the Introduzione alla geologia by the "Huttonian" geologist Scipione Breislak (1750-1826)

Candela A.*

University of Insubria.

Corresponding author email: a.candela@uninsubria.it

Keywords: Scipione Breislak, Plutonism, Hutton, Geohistroy, history of the Earth, Nineteenth-century Italy.

Born in Rome, Scipione Breislak (1750-1826) may be considered one of the most distinguished Italian Vulcanists and then Plutonists between the Eighteenth and early Nineteenth century. In the 1790s, he was professor of Physics at the Military Academy of Nunziatella in Naples, where he also devoted most of his time studying Vesuvius and the Phlegraean Fields, and so becoming acquainted with volcanic phenomena. Breislak's first works on the volcanic areas of Campania revealed how Bergman's theories and Lavoisier's chemistry had affected his belief in the idea that volcanic eruptions were triggered by ignitions of petroleum deposits. After a voluntary exile in Paris, due to the downfall of the Roman Republic, Breislak moved to Milan (1802), where he was appointed Inspector of Gunpowders, and so having the opportunity to keep on studying mineralogy and geology, with a specific attention to Lombardy and to the Alps. During the "Milanese period", he published, in two volumes, the *Introduzione alla geologia* (1811), which may be regarded as the first Italian handbook about the recent science of Geology. In this work, he drew on Huttonian ideas to describe the lithostratigraphical features of crystalline rocks. Without neglecting Breislak's vulcanological hypotheses, the paper aims at analyzing the influence of the Nineteenth-century Plutonist (Huttonian) stratigraphy on the history of the Earth (Geohistory) he depicted in the *Introduzione alla geologia*. The influence of Plutonism – a word which Richard Kirwan (1733-1812) expressly introduced to define James Hutton's geological system (Kirwan, 1810, p. 403), may be also recognized in Breislak's rejection of transition rocks. Indeed, according to him: «nature does not make passages of transitions, and each of its product has a specific and particular way to exist» (Breislak, 1811, pp. 308-309; Vaccari, 1999, p. 34).

Breislak S. (1811) - Introduzione alla geologia. Volume 1: Stamperia Reale, Milano.
Kirwan R. (1810) - Elements of Mineralogy. Volume 1: Mackinlay, London.
Vaccari E. (1999) - Wernerian Geognosy and Italian Vulcanists. In: Albrecht, H. & Ladwig, R., Abraham Gottlob Werner and the Foundation of the Geological Sciences, 26-35, Bergakademie Freiberg.

The De Filippi Expedition and the Cretaceous stratigraphy of Aksai Chin Region (western China)

Fabbi S.*[1], Cestari R.[2], Dominici S.[3] & Sha J.[4]

[1] Sapienza University of Rome, Italy. [2] Strata GeoResearch, Chieti, Italy. [3] Natural History Museum, Firenze, Italy. [4] Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, China.

Corresponding author email: simone.fabbi@uniroma1.it

Keywords: China, Karakorum, Fossil collections.

The De Filippi expedition was a geographic, geological and overall scientific mission carried out in the years 1913-1914 through the Himalayan Range from Kashmir to Baltistan and Xinjiang (then part of the British Empire and China, today belonging to China, Pakistan and India), part of the expedition crossed the remote region of the Aksai Chin with high mountains and highlands more than 5000 meters. Members of the mission were, along with the leader Filippo de Filippi, the geologist Giotto Dainelli and the geographer Olinto Marinelli, who surveyed the topography of the area and collected a large amount of rocks and Paleozoic, Mesozoic and Eocene fossils, now stored at the Natural History Museum of Florence. The fossils were studied by prominent Italian paleontologists such as Gortani, Merla, Parona and Fossa Mancini. A synthesis of the knowledge about the geology and stratigraphy of the area was then published by Dainelli in 1937, and still today represents the first and the only paper about the geology of Aksai Chin. While the western and the southern areas surveyed by the expedition were subsequently traveled and studied by other scientific missions, regarding the Aksai Chin the paleontological collections of the De Filippi expedition, consisting of tens of well-preserved fossils, still nowadays represent the only tool to reconstruct a tentative stratigraphy of the area, as our late Prof. Gaetani pointed out to us. The topographic survey of such uninhabited region was detailed enough, and it has been possible to reconstruct both the route and the sampling localities with good approximation. Some of the toponyms reported on official maps are in fact those (in Italian) assigned to the topographic features during the expedition, such as "Monte della Piega" and "Valle Ignota" ("Fold Mountain" and "Unknown Valley"). Dainelli states in his trip report that fossil localities were abundant, and that based on his preliminary descriptions future geoscientists should easily find fossiliferous localities to investigate the regional stratigraphy, not aware that he would be the only geologist to explore the area for at least more than a century.Besides Paleozoic, Triassic and Jurassic faunas, which were already known in the region, the Cretaceous fossils remarkably represent the first report for that Period in the Trans-Himalayan Range, including bivalves, gastropods, ammonites, brachiopods and echinoderms. Following the descriptions of Parona and Dainelli, the stratigraphy is marked by a >1km-thick succession of Cenomanian to Senonian (sic) limestones and subordinated marls. The stratigraphic attribution was only based on macrofossils, and a revision of the collection has never been undertaken. A re-evaluation of the fauna, also accompanied by thin section analysis carried on small fragments of the samples, will provide new and more accurate data to constrain the Cretaceous stratigraphy of the Aksai Chin and good correlation with other Tethyan palaeobioprovince.

The use of "corsi" in the ancient quarries of the Verona region (NE Italy) and their relevance for the history of stratigraphy

Faccioli M.[1]*

[1]Center for the History of the Mountain, University of Insubria, Italy.

Corresponding author email: mariafaccioli@libero.it

Keywords: history of geology, quarrying, Verona, marble, G. Piccoli, lithostratigraphy.

The quarries of the Verona district, active since ancient times, have been intensely exploited until the 19th century. The excavated materials were used both in civil and religious architecture. The peculiarity that links the Veronese marbles to some aspects of proto-lithostratigraphy, is that each "*corso*" (a rocky layer of the *Scaglia Rossa Veneta*, a limestone also known locally with the name of *lastame*) was used for a specific scope and was named after its main features related to the workability or to the aesthetic quality of the particular lithotypes. Consequently each layer had a different explanatory name: "*corso mato*" (mad layer), "*corso machiato*" (stained layer) and so on. On the other hand, the name of a geological formation could have been derived from the name that the quarrymen historically attributed to the layers of the locally excavated stone. In fact, for example the modern term *Scaglia* comes from the old verb "*scagliare*" (cut in layers), normally used in some extractive sites, as also documented by some 18th century archive papers. This paper intends to summarize and compare various lithostratigrapic columns that have been produced in the mountain area of the Veronese quarries. One of the first lithostratigraphic sequence related to these territories - considered one of the first representation of this kind in the world (Vaccari & Curi 2003) - was published by Gregorio Piccoli in 1739: and many others were elaborated over the years (eg by De Zanche, Gonzato and others), within an area widely studied from the geological and paleontological point of view during the 19th and 20th centuries. The main layers from the Veronese quarries, their properties and the related building and ornamental uses will be then analyzed from a lithographic point of view. Moreover, through a photographic apparatus, practical cases of use of the local stones will be also shown. Finally, a brief reference to the 18th and 19th century quarrying methods will be provided, as well as a table found at the Venice State Archive (*Deputati alle Miniere* Collection), which lists the owners of the stone quarries, the location of the sites, the quality of the "marble" and other important pieces of information about taxes and economic management.

Vaccari E. & Curi E. (2003) - Quarrying and geology in early 18th century Italy: the lithological column of Gregorio Piccoli (1739) - in Geological Resources and History Proceedings of INHIGEO Meeting – Portugal, 417-429, Universidade de Aveiro.

Leonardo da Vinci and the birth of stratigraphy

Ferretti A.*[1], Vezzani F.[2] & Balini M.[3]

[1] University of Modena and Reggio Emilia, Italy.[2] University of Padova, Italy.[3] University of Milano, Italy.

Corresponding author email: ferretti@unimore.it

Keywords: Leonardo da Vinci, Renaissance, stratigraphy, modern geology.

Most geological handbooks associate the birth of stratigraphy to the figure of William Smith in the 18th century, after a brief mention to the pioneer contribution of Nicolas Steno that almost a century before, in his *Dissertationis prodromus* of 1669, had introduced the principles of geometric relationships between strata. On the contrary, Leonardo da Vinci is often related, with other scientists, to the intuition that fossils are remains of living organisms. Da Vinci was indeed much more than that. His excellence in Art has obscured many achievements that Leonardo got in other fields. This is not surprisingly as the same instruction he had, as usual at that time, was an integration of disciplines that now, in modern terms, we call Math, Art, Music, Engineering and Natural Sciences. With this premise, it is somehow limiting to hypothesize that he could have had just "glimpses" of more general concepts. His writings, often hard to decipher for the use both of the Italian language and the application of a specular calligraphy, and his paintings, reveal that all concepts commonly associated to stratigraphy (fossils as age-diagnostic tools, geometric properties and position of strata, stratigraphic correlations, etc.) are deeply-rooted in Leonardo and fully integrated in mature observations of the landscape. Leonardo's contribution as a precursor of modern geology had been already acknowledged by De Lorenzo (1920), who had underlined how Da Vinci, by the use of his sole mind, was able to anticipate global concepts by three centuries. By the analysis of the drawings included in the Codex I and by the accompanying notes, Baucon (2010) recognized evidences of bioerosion and bioturbation structures, among which the first ichnological illustration of *Paleodictyon*. The celebration of the five-hundredth anniversary of Leonardo's death give us the best opportunity just in Milan, where he spent a large part of his life, and just at the International Congress on Stratigraphy, to recognize Leonardo da Vinci as the true founder of modern stratigraphy.

Baucon A. (2010) - Leonardo da Vinci, The Founding Father of Ichnology, Palaios, 25, 361-367.
De Lorenzo G. (1920) - Leonardo da Vinci e la geologia. 204 pp. Nicola Zanichelli Editore, Bologna.

Arturo Issel (1842-1922): the man from Genoa behind the Tyrrhenian Stage of the Pleistocene

Histon K.[1]*

[1]Independent researcher.

Corresponding author email: hiscat@interfree.it

Keywords: History of Geology, Tyrrhenian Stage, Italy, Genoa, biography Issel.

On the 17th May, 1914, Arturo Issel presented a paper at a meeting in Rome of the members of the Reale Accademia dei Lincei, class of natural, physical and mathematical sciences, on his observations and remarks regarding a collection of Quaternary and recent fossils from SW Sardegna. He had received this collection from his good friend and colleague Domenico Lovisato, a tireless explorer of the island. This paper was published in the Atti of the Reale Accademia dei Lincei for 1914 where he outlined his reasons for introducing a new regional denomination for a complex of strata that he referred to as the Tyrrhenian. The latter still stands within modern stratigraphic classification as an Italian Marine Stage for the Mediterranean Sea marking the base of the Late Pleistocene. The scientific importance of Issel's observations, research and interpretations within the geological sciences both nationally and internationally is underlined by the fact that he was a member of 37 national and foreign scientific academies and societies. His malacological studies of the Red Sea and two volume memoirs on the geology and prehistory of Liguria are still considered as major reference works. He also introduced the term of bradyseism regarding slow uplift and subsidence in volcanic areas in an extensive study published in 1883.

But apart from his geological contributions what do we know of the man himself?

He was professor of Geology at the University of Genoa for more than forty years and was renowned for his extensive fieldwork in Liguria that apart from the geology encompassed varied aspects of the territory. He travelled extensively for naturalistic exploration on various voyages to East Africa, the Red Sea and the Mediterranean and was an active member of the Italian Geographical Society. He worked together with Giacomo Doria the founder of the Natural History Museum of Genoa. He was an esteemed figure in Genovese society and while a member of the city council where his judgement was both respected and valued, he was a constant promoter of the sciences in general and established many popular scientific societies. This presentation will provide a short biography of the career, scientific achievements and the wide-ranging interests of this Italian geologist, mineralogist, palaeontologist, geographer, speleologist, paleethnologist and naturalistic traveller.

Issel A. (1914) - Lembi fossiliferi quaternari e recenti nella Sardegna meridionale dal prof. D. Lovisato: Rendiconti Accademia Nazionale dei Lincei, s. 5, v. 23, 759–770.

Giuliano Ruggieri (1919-2002) and the Pleistocene stratigraphy of Santerno Valley (Northern Italy)

Marabini S.*

University of Bologna, Italy

Corresponding author email: stemarabini@libero.it

Keywords: history of geology, Pleistocene, paleontology, stratigraphy.

Giuliano Ruggieri, one of the most important Italian paleontologists and stratigraphers of the 20th century, contributed decisively in defining the chronostratigraphy now officially adopted for the marine Pleistocene. In particular, his name is linked to the proposal of the Emilian and Santernian subplanes in the lower Pleistocene: the latter was reported by Ruggieri in the Santerno valley north of Imola, in the Po Valley side of the Northern Apennines. Ruggieri's interest in the stratigraphy of the Santerno valley dates to the time of his thesis at the University of Bologna, carried out under the direction of Michele Gortani (1883-1966), whose preliminary results were published in 1939 when Ruggieri was still a student. Later, during his long academic career in Sicily (1956-1988) which allowed him to work on the stratigraphy of the Plio-Quaternary deposits of southern Italy, Ruggieri continued for almost sixty years, in several publications, to review and integrate his paleontological and stratigraphic observations in the Santerno valley. In particular, in one of his last works about the summit sandy deposits of the Pleistocene succession of Santerno - the so-called 'Sabbie Gialle' (yellow sands) of Imola - he proposed in 1993, with his typical polemical attitude, to partially recover and reexamine the fossiliferous outcrops that he had studied during his early career and that in the last decades had been obliterated for the construction of the Imola autodrome. The scientific value of Ruggieri's work has been recognized on the occasion of the centenary of his birth, when a geognostic survey was planned by the Scarabelli Museum of Natural History in Imola to precisely locate and resample the outcrop of the 'Sabbie Gialle' studied by Ruggieri in 1939.

Ruggieri G. (1939) - Il Calabriano nell'Appennino romagnolo, Rendiconti Reale Accademia d'Italia serie VII, vol., fasc.1-5, 60-62.

Ruggieri G. (1944) - Il Calabriano e il Siciliano nella Valle del Santerno. Giornale di Geologia, serie 3°, volume XVII, 95-118.

Ruggieri G. (1952) - La limite entre Pliocene et Quaternaire dans la serie Plio-Pleistocene du Santerno. Congres Geologique International, Alger, XV, 235-240.

Ruggieri G. (1975) - Sull'ordine di comparsa degli "ospiti nordici" nella sezione pleistocenica del Santerno. Boll. Soc. Paleont. It., 94, 1603-1611.

Ruggieri G. (1993) - La malacofauna marina delle "sabbie di Imola". Quaderni Studi Naturalistici Romagna, 2, 35-41.

Ruggieri G. & Selli R. (1948) - Il Pliocene ed il Postpliocene dell'Emilia. Giornale di Geologia, serie 3°, volume XX, 1-14.

Ruggieri G. & Sprovieri R. (1983) - Recenti progressi nella stratigrafia del Pleistocene inferiore. Boll. Soc. Paleont. It., 22(3), 315-321.

The historical evolution of the geological knowledge about the UNESCO Matera area (Southern Italy)

Pantaloni M.*[1], Console F.[2], Petti F.M.[3] & Tropeano M.[4]

[1] Servizio Geologico d'Italia, ISPRA, Italy. [2] Biblioteca, ISPRA, Italy. [3] MUSE, Museo delle Scienze di Trento, Italy.
[4] Dipartimento di Scienze della Terra e Geoambientali, Università degli Studi di Bari, Italy.

Corresponding author email: marco.pantaloni@isprambiente.it

Keywords: Matera, calcarenite di Gravina, history of geology.

Matera, in the UNESCO List since the 1993, as well as other villages such as Gravina, Ginosa and Massafra, is located along the western flank of the Apulia Foreland (Southern Italy) and developed on spectacular river valleys slopes (locally "*gravine*"), cut in Plio-Pleistocene carbonate rocks. Due to their exceptional exposure these rocks have been intensively exploited and used as building and ornamental stones. These outcrop localities were the subject of several researches aimed at the definition of their lithological and stratigraphical features. The first scientist who described the lithological characters of these carbonates was Ferrante Imperato, that in his Natural History (1599) introduced the term *Pietra Leccese* to indicate the Cenozoic "soft" carbonate rocks cropping out in Apulo-Bradanic area. Almost two centuries later, Alberto Fortis visited Matera and described for the first time the *outcropping soft rock* and its numerous fossils giving it the name of "tufo duro". Giuseppe Giovene and Michele Milano made a first attempt to establish the stratigraphic position of this lithological unit, and, interestingly, following the plutonist theory then in vogue, defined it as rocks of volcanic origin (note that the term "tufo", introduced for these rocks by Fortis, is normally attributed to volcanoclastic rocks). In 1820, Giovanni Battista Brocchi produced more detailed chronostratigraphic studies, broadly contemporary with the first cartographic representation made by Rodolfo Amando Philippi. The *tufo* attracts the attention of Arcangelo Scacchi, a local scholar who would have later found international fame as mineralogist, and the Russian naturalist Pyotr Alexandrovich Chikhachyov. The interest in this lithostratigraphic unit increased worldwide thanks to the work of the stratigraphist Karl Mayer-Eymar, who defined the sub-stage Materino just "from the city of the Basilicata Region where its marine facies, [...], occurs under the lower Astian blue marls". This attribution opened a wide scientific discussion in which were involved Giovanni Capellini, Cosimo De Giorgi, Giovanni Di Stefano, Carlo Maria Viola and that came up for discussion in Bologna at the 2nd International Geological Congress. After further studies, conducted in the 19th and 20th centuries by Giuseppe De Lorenzo, Francesco Virgilio and Maurice Gignoux (1913), the Materino sub-stage was officially abandoned (Cantelli, 1960; Azzaroli & Cita, 1967). Starting from the geological survey made in the '60s to produce the Geological Map of Italy at 1:100.000 scale in the area of Matera and Gravina, the carbonate Plio-Pleistocene unit cropping out in Matera was officially named "*Formazione della Calcarenite di Gravina*" (Azzaroli, 1968). This work traces the evolution of geological and stratigraphic knowledge and the evolution of scientific thought that turn around this important location of the Italian stratigraphy.

Azzaroli A. (1968) - Studi illustrativi della Carta Geologica d'Italia - Formazioni Geologiche. Servizio Geologico d'Italia, I, 183-185.
Azzaroli A. & Cita B.M. (1967) - Geologia stratigrafica. La goliardica, Milano.
Gignoux M. (1913) - Les formations marines pliocènes et quaternaires de l'Italie du Sud et de la Sicile. A. Rey, Lyon.

The contribution of Henry James Johnston-Lavis to the Monte Somma and Vesuvius Stratigraphy and cartography

Principe C.[1]*

[1]Istituto di Geoscienze e Georisorse - CNR - Pisa, Italy.

Corresponding author email: c.principe@igg.cnr.it

Keywords: Somma-Vesuvius, Jhonston-Lavis, Stratigraphy, Cartography.

Henry James Johnston-Lavis (1856-1914) was one of the key characters of the Vesuvian volcanology of the late nineteenth century. This English doctor arrived in the Neapolitan area in 1880 and devoted himself to the study of Somma-Vesuvius *"in the space time of his profession",* as he said. The results of over 30 years of geological observations were some 30 scientific papers, some of which are still benchmarks in the knowledge of Vesuvius. His description of the 1906 eruption, the geological synthesis of Mount Somma published in the Quarterly Journal of the Geological Society of London in 1884, and the geological map at the scale 1:10,000 of the volcano printed in only 250 numbered copies by himself in 1891, remain unsurpassable. He left also two vulcanological bibliographies, each comprising over 300 pages and thousands of titles, which were compiled together with his wife Antonia, a beautiful Neapolitan noblewoman. The second of these bibliographies was edited after his death, in 1918. As Johnston-Lavis states in the introduction of *The geology of Mount Somma and Vesuvius: "The general form and outline of Monte Somma, the relation of the cone of Vesuvius piled around the recent eruptive axis, to that of the prehistoric one, have so often alluded to by various authors, that the subject might appear exhausted"* (Johnston-Lavis, 1884). Such an observation continues to be valid nowadays for Mount Somma. No papers on Vesuvius seams can start without a brief than generic evolutive history of Mount Somma. In spite to this fact no exhaustive data set are present into the modern literature to describe the geology and chronology of Mount Somma. The best geological description of Somma is still that of Johnston-Lavis, that for the first time describes the presence of the huge *breccia* associated to the nowadays so called Pomici di Base eruption on the north slope of Somma. Johnston-Lavis also deduces from the limited distribution of such a *breccia* that the crater generated from that eruption cannot correspond to the present Somma caldera, but have to be considerably smaller. At the same time, he assumes that a geometrical migration of the following eruptive centers progressively originated that morphological depression. This vision of the Somma growth and its Vesuvius lavas cartography is still valid because of the fact that, it is based on a great number of field data and direct geological observations.

Johnston-Lavis H.J. (1884) - The geology of Monte Somma and Vesuvius, being a Study in Volcanology. Quart Journ Geol Soc London, XL, 35-119.

The geological travels of Achille De Zigno in the Dolomites during the spring of the 1846

Roghi G.*

Istituto di Geoscienze e Georisorse, CNR, Padova.

Corresponding author email: guido.roghi@igg.cnr.it

Keywords: De Zigno, 19th century, Dolomites, Tirol.

The nobleman Achille De Zigno (1813-1892) was an Italian geologist and naturalist who, during the 19th century, extensively studied the geology and paleontology of the Veneto Region and Tirol. His notes in diaries and field notebook were accompanied with a great number of extremely detailed drawings. His eight field notebooks were written between 1841 and 1890, starting when he was 28 until almost his death in 1892. He painted mountains sections and maps, geological outcrops and fossils ink drawings, together with archeological and landscape views, but one of the most impressive feature in the De Zigno's notebooks is the illustrations of a great number of "*strati*". This testifies for his great effort in understanding the age and stratigraphic order of the main geological successions displayed in the visited mountains. In particular, in the spring of 1846 De Zigno crossed the Dolomites and in a thirty-nine pages of one of its notebook described in detail the geology of the area, giving us the unique possibility to understand the state-of-the-art of the Dolomites geology during the middle of the 19th century. Using the geological map of the famous Prussian geologist von Buch, De Zigno travelled from Auer (Ora) to Botzen (Bolzano), walking through all the western Dolomites, including Predazzo village. This former locality, firstly described by Marzari-Pencati in the 1819, is famous for its rock layers relationships not in harmony with the current stratigraphic theory, i.e. the Neptunism. Achille De Zigno's sketch of the *Primitive* granite rocks above the *Stratified rocks,* and thus not placed at the basement of all the other rocks, gave a significant contribution to the history of Geology of the Dolomite of that time.

The development of stratigraphy in Italy between 17th and 18th century: from Steno to Arduino

Vaccari E.[1]*

[1]University of Insubria, Italy.

Corresponding author email: ezio.vaccari@uninsubria.it

Keywords: history of geology, Steno, 17th century, Tuscany, springs.

Between 1667 and 1669, after several explorations and much research on the landforms and rock structures of Tuscany and other parts of northern Italy, the danish anatomist Niels Steensen (Steno), had emphasized the importance of an accurate interpretation of rock strata in the field for the reconstruction of the history of the Earth. In his book *De solido intra solidum naturaliter contento Dissertationis prodromus* (Forerunner to a Dissertation on a solid naturally enclosed within a solid, 1669), Steno outlined (and illustrated in a famous plate) the historical sequence of geological events that occurred in the Tuscan territory after the Creation. This chronological sequence, divided into six stages, may also be considered as his model for the general history of the Earth's surface. This 'revolutionary' approach, also known as 'Stenonian heritage', had a certain influence on the early 18th century studies on the Earth's strata in Italy. In fact, during the early 18th century, the trend of observing the structure of the mountains contributed in focusing many studies on the morphological and lithological differentiation of the strata according to their different forms and rock content. In this context, the debate on the origin of springs was very significant also in Italy for the detailed study of the rock strata in the field. Around the middle of the 18th century, the complexity of the geological characteristics displayed by the numerous regional studies introduced a new problem. The structure of the Earth's surface could no longer be explained only with the statement that the Earth's crust was formed of a regular sequence of strata of sedimentary origin -that is, deposited within seawater. Several different processes seemed to have deposited and later modified the rock strata, and also formed the massive rocks that composed the terrestrial reliefs. The great variety of these rocks and their different shapes and positions also begged the question of their age within the history of the Earth. Consequently, investigations of the composition and formation of mountains and their rock strata expanded rapidly. The first classifications or sub-divisions of mountains, which also included the classification of their different rock types, supported the idea of the relative chronology of the sequence of the studied strata: that is, the most recent or the most ancient formation could be deduced not only from its position within the sequence, but also from its rock type (especially when the order of the strata was confused). In short, the aim was to provide a chronological scheme for the successive formation of different types of rocks that formed different kinds of mountains. The most significant classification of mountains and rock units was that published by Giovanni Arduino (1714–95) in his *Due Lettere sopra varie osservazioni naturali* (Two Letters on various natural observations, 1760), later revised and enlarged in 1774. The classification of mountains can be considered a central topic in the history of 18th century geology because it gradually introduced the idea of geological time connected to a complex history of the Earth - a history made up of a series of important successive changes in the Earth's surface that could be observed in its most prominent geomorphological features: the mountains. The different kinds of rocks, the strata or massive formations that form hills and mountains, therefore became the indispensable keys for recognizing the path of such a long history. This happened well before the systematic use of fossils as chronological indicators, which was an early 19th century achievement and led to what is known today as historical geology or stratigraphy.

ST2.1

Chemo- and biostratigraphy: complementary or antagonistic tools?

Conveners and Chairpersons

Stéphane Bodin (Aarhus University)

Joerg Mutterlose (Ruhr-University Bochum)

High-resolution calcareous nannofossil biostratigraphy for the Lower Cretaceous (Berriasian - Aptian) of the Lower Saxony Basin

Bornemann A.*[1], Erbacher J.[1] & Thöle H.[2]

[1] Bundesanstalt für Geowissenschaften und Rohstoffe. [2] Universität Hannover

Corresponding author email: andre.bornemann@bgr.de

Keywords: Lower Cretaceous, biostratigraphy, chemostratigraphy, calcareous nannofossils.

Lower Cretaceous sediments forming the basinal facies of the Lower Saxony Basin in Northern Germany consist predominantly of monotonous clays and clayey marls. These fine-grained sediments usually provide a moderately to well preserved calcareous nannofloras. Here we studied uppermost Berriasian to lower Aptian sediments comprising the following key events: (a) the Valanginian "Weissert Event", (b) the early Barremian "Hauptblätterton" and (c) the early Aptian "Fischschiefer" (=OAE 1a).

Five drill cores have been investigated over the last years (Frielingen 9, Zuckerfabrik 2, Scharrel 10, Scharnhorst 3) or are currently studied (Wiedensahl 2) with respect to calcareous nannofossils in order to establish a detailed biostratigraphic scheme for northern Germany based on previous works by Bown et al. (1998) and Mutterlose (1991). In total more than 400 samples are being qualitatively studied for calcareous nannofossils allowing to evaluate the applicability of these existing zonation schemes at a high-resolution. Further, high-resolution chemostratigraphy based on XRF core scanning of the drill cores Frielingen 9, Scharrel 10 and Zuckerfabrik 9 allows for testing the synchronicity of appearances or disappearances of marker species on a regional scale.

Bown P.R., Rutledge D.C., Crux J.A. & Gallagher L.T. (1998) - Lower Cretaceous. In Bown P.R. (ed.), Calcareous Nannofossil Biostratigraphy. Kluver Academic Publishers, Dordrecht, Boston, London, 86-131.

Mutterlose J. (1991) - Das Verteilungs- und Migrationsmuster des kalkigen Nannoplanktons in der Unterkreide (Valangin-Apt) NW-Deutschlands. Palaeontographica Abteilung, 221, 27 - 152.

The Aptian GSSP candidate at Gorgo a Cerbara (Central Italy): an alternative interpretation of the bio-, litho- and chemostratigraphic markers

Frau C.[1]*, Bulot L.G.[2], Delanoy G.[3], Moreno-Bedmar J.A.[4], Masse J.-P.[5], Tendil A.J.-B.[5] & Lanteaume C.[5]

[1] Groupement d'Intérêt Paléontologique, Science et Exposition, France. [2] University of Manchester, UK. [3] Nice–Sophia–Antipolis Université, France. [4] Universidad Nacional Autónoma de México, Mexico. [5] Aix Marseille Université, France.

Corresponding author email: camille_frau@hotmail.fr

Keywords: Aptian, GSSP, Integrated stratigraphy, OAE 1a, Gorgo a Cerbara, Italy.

During the *Second International Symposium on Cretaceous Stage Boundaries* held in Brussels in 1995, the Aptian Working Group (ISCS) claimed that no biostratigraphic markers (ammonites, calcareous nannofossils or planktonic foraminiferas) could stand as a proper datum for the definition of the base of the Aptian Stage (Erba 1996). The majority of the Working Group members recommended to use the base of the reverse magnetochron CM0r as the primary marker for the base of the Aptian, and they selected the Maiolica-type Gorgo a Cerbara section (Umbria–Marche Basin, Central Italy) as a possible GSSP. Based on chemostratigraphic correlations between Italy and southeast France, Gradstein et al. (2012) and Ogg et al. (2016) assumed that the base of magnetochron CM0r coincides with the base of the *Deshayesites oglanlensis* Zone that is taken to mark the base of the Aptian in the Mediterranean Tethys by means of ammonites. This statement is based on a short note in the annual report of the Subcommission on Cretaceous Stratigraphy and was never sustained by a proper discussion (Frau et al., 2018). For the time being, no Tethyan section has yielded an accurate calibration to the magnetic zonation with respect to the FO of *Deshayesites oglanlensis*. Moreover, our recent investigation showed that the bio-, litho- and chemostratigraphic events recorded at Gorgo a Cerbara, below, at, and above the magnetochron CM0r fall within the latest Barremian *Martelites sarasini* ammonite zone (Frau et al., 2018). Even if there is no formal historical priority in stratigraphy, to include the *Martelites sarasini* Zone in the Aptian Stage would considerably alter the concept of the Barremian under current use.

Erba E. (1996) - The Aptian stage. In: Rawson, P.F., (ed.), Proceedings of the 2nd International Symposium on Cretaceous Stage Boundaries. Bulletin de l'Institut Royal des Sciences Naturelles de Belgique 66, 31–43.

Frau C., Bulot L.G., Delanoy G., Moreno-Bedmar J.A., Masse J.P., Tendil A.J.B. & Lanteaume C. (2018) - The Aptian GSSP candidate at Gorgo a Cerbara (Central Italy): an alternative interpretation of the bio-, litho- and chemostratigraphic markers. Newsletters on Stratigraphy, 51(3), 311-326.

Gradstein F.M., Ogg J.G., Schmitz M.D., Ogg G.M., (coordinators) (2012) - The Geologic Time Scale 2012. Elsevier, 1174 p. (2-volume book).

Ogg J.G., Ogg G.M. & Gradstein F.M. (2016) - A Concise GeologicTime Scale 2016. Elsevier, 234 pp.

The Santonian-Campanian boundary - historical usage and modern definition

Gale A.S.[1]*

[1]SEES - University of Portsmouth.

Corresponding author email: andy.gale@port.ac.uk

Keywords: Createceous, Stratigraphy, Stages.

The boundary between the Santonian and Campanian Stages has been problematic for stratigraphers to define, largely because of the regional and facies restrictions of faunas and floras at this time in the Cretaceous. The markers discussed at the 1984 Copenhagen symposium included:

– Appearance of the ammonite genus *Submortoniceras* (regionally restricted).
– The *Scaphites hippocrepis* lineage – specifically Scaphites leei III (WI Basin and Gulf Coast).
– The FO of the belemnite *Gonioteuthis granulataquadrata* (only northwest Europe)
– The extinction of the crinoid *Marsupites* (global, but only in chalk facies)
– FO of the nannofossil *Broinsonia parca*
– FO of the benthonic foraminifer *Bolivinoides strigillatus* (diachronous, northwest Europe only)
– The 34-33r magnetic reversal.
– The extinction of the planktonic foraminifer *Dicarinella asymmetrica* (deep marine Tethyan restriction).

In practice, workers in various faunal realms and diverse facies have used regional criteria to define the boundary. Thus; in deep water Tethyan settings, the extinction of *D. asymmetrica,* known to coincide with the magnetic reversal 33r is used; the coincidence of the FO of *Scaphites leei* III with the extinction of *Marsupites* provides a valuable correlation tool between the Western Interior Basin and northern Europe; the discovery of *Marsupites* in the Pacific Realm (British Columbia) allows correlation of the endemic ammonite and inoceramid faunas. The problem has become the correlation between the ammonite: *Marsupites* boundary usage, and the deep Tethyan definition of extinction of *D. asymmetrica* plus the magnetic reversal chron 33r. This can now be resolved using carbon isotope stratigraphy, because a distinctive positive, double excursion, called the Santonian-Campanian Boundary Event, can be identified widely in Tethys, northwest European Boreal chalks and is also found in the Western Interior Basin, and Japan. This event permits the correlation of regional biostratigraphies to a global standard. Use of the well-studied Gubbio Bottacione section for a GSSP, with the primary marker of the 33r magnetic reversal, is a possibility.

New analytic study of Devonian-Permian deposits in the Polar Urals (Kozhim River) and Pay-Khoi (Yugorsky Peninsula)

Kossovaya O.L.*[1], Petrov E.O.[1], Evdokimova I.O.[1], Shmanyak A.V.[1], Zhuravlev A.V.[2], Leontiev D.I.[1], Berbenev M.O.[3] & Yudin S.V.[1]

[1] Russian Geological Research Institute, Russia. [2] Institute of Geology, Komi Scientific Center, Uralian Branch RAS. [3] LLC "RN-Shelf-Arctica".

Corresponding author email: olga_kossovaya@vsegei.ru

Keywords: Upper Paleozoic, U-Pb dating, δ^{13}*C*carb., Yugorsky Peninsula, Polar Urals.

Two Upper-Paleozoic key sections Upper Paleozoic sections in Uugorsky Peninsula and Polar Urals were the main purpose of the first done study with usage of a wide spectrum of geochemical methods. Testing was goaled to verification of stratigraphic boundaries unlike previous researchers, who mainly studied the biostratigraphy in detail. For the first time various geochemical criteria such as f $\delta^{13}C_{carb}$, Sr/Ba, absolute age of detrital zircons of sandstone, etc. were used for facies interpretation, determination of stratigraphic boundaries and testing the abiotic signals at the selected boundaries. In the Pay-Khoi section, the determination of Sr/Ba together with lithological data allowed the identification of depositional environment of four formations - deep-water Khabarovsk Fm. (O_3), coastal-marine Pyrkov Fm. (D_3fr), shallow-water Bolvansky Fm., (C_1v_2 –C_2b), and Chaiyka reef (C_2m-C_3k). The Ba/Ga ratio confirmed the coastal-marine genesis of the siliciclastic rocks of the Pyrkov Fm. interpreted as a bar complex with possible periodical influx of freshwater. In the Kozhim section, the specimens were divided into two groups based on the values of B and the B/Ga ratios.

The Devonian and Silurian sediments were accumulated in a shallow water basin with normal salinity. Coal-bearing samples of the Inta and Kozhimrudnik fms. (P_1k) showed low concentrations of B. Facies are corresponded to desalinate coastal conditions or peat marches located along the coasts. Drastic change of $\delta^{13}C_{carb}$ was found at the S/D, D/C, and Mississippian/Pennsylvanian boundaries. The anomalies were used to clarify the stratigraphic position of boundaries and comparison with global $\delta^{13}{}_{Ccarb}$ curve. The C_2 boundary was specified in the monotonous carbonate deposits of the Bolvanskyi Fm. in the Pay-Khoi section. There $\delta^{13}C_{carb}$ gradually decreased from 2,5 ‰ to 1, 5‰ and later increased up to 3‰. The boundary is confirmed by new biostratigraphic data as well. The first results of the U-Pb dating of zircons were obtained from the sections studied (Isotopic Centre of VSEGEI, SHRIMP II). The maximal number of zircons shown Visean - Lower Bashkirian age: 316–351 ± 3 Ma (18 grains). In the Polar Urals the Upper Devonian-Lower Carboniferous volcanoclastic deposits are known in Voikar paleo-arc. In addition, the western Magnitogorsk volcanic Arc stretched out to 70 N.L. (Puchkov, 2018). The zircon provenance seems to be the acid intrusions formed at the final stage of the collisional volcanic activity via the subduction of Uralian Ocean. According the U-Pb dating of zircons extracted from sandstone of the Gusinaya Fm. (P_1a) its age is 252.4–289.6 ± 1.2 Ma (8 grains). Permian zircons were also selected from sandstones of the Kozhimrudnik and Inta fms., which accumulated in the Pre-Uralian foredeep. The provenance area was probably in the north of the Urals-Siberian Large Igneous Province (Puchkov, 2018).

Puchkov V.N. (2018) - The Plumes – a new word in Geology of the Urals. Lithosphere, 18(4), 483-499.

Integrated bio and chemostratigraphy of the late Barremian - early Aptian interval from southwestern Iran (Zagros Basin)

Mahanipour A.*[1], Mutterlose J.[2] & Eftekhari M.[3]

[1] Department of Geology, Faculty of Science, Shahid Bahonar University of Kerman, Iran. [2] Institute for Geology, Mineralogy and Geophysics, Ruhr-Universität Bochum, Germany. [3] Department of Geology, Faculty of Science, Shahid Bahonar University of Kerman, Iran.

Corresponding author email: a_mahanipour@uk.ac.ir

Keywords: Calcareous nannofossils, stable isotopes, Aptian, Taxy episode, OAE 1a, Iran.

Calcareous nannofossils and stable isotopes have been investigated from a Cretaceous (late Barremian - early Aptian) pelagic section in southwestern Iran (Zagros Basin). The studied sediments mainly consist of marls, marly shales and radiolarian black shales. Based on calcareous nannofossil findings, the studied interval is spanning nannofossil zones NC5C to NC7B following the scheme of Roth (1978). The most important bio-events observed are the first occurrences (FO) of *Rucinolithus irregularis* and *Eprolithus floralis* which subdivide the studied interval into biozones NC5, NC6 and NC7. Our $\delta^{13}C_{Carb}$ record and calcareous nannofossil biostratigraphy corresponds to stratigraphic schemes of other parts of the Tethys Realm, though certain differences have been observed. Based on our data, the FO of *Rucinolithus irregularis* is the most reliable event for defining the Barremian - Aptian boundary. Near this bioevent a positive and a subsequent negative excursion has been recorded. A slight negative excursion near the Barremian - Aptian boundary, which has been reported from other parts of the world, is here interpreted to reflect an oceanic anomaly, the Taxy Episode. The causes of this anomaly are seen in increased submarine volcanic activity of the Ontong Java in the Pacific. During the humid Taxy Episode, anaerobic conditions developed in the Tethys (Föllmi, 2012), which are recorded by black to dark gray marly shales. In the Kabir-Kuh section, studied here, dark shales go along with an increase in the number of temperate and eutrophic nannofossil taxa. Eutrophication resulted from the humid climate and gave way to anaerobic conditions. A decline of nannoconids occurring during this interval are supporting our interpretations. The Taxy Episode is followed by the early Aptian OAE 1a, which is marked by the onset of a negative $\delta^{13}C_{Carb}$ excursion. The C3 to C7 segments of the OAE 1a have been identified. Following the nannoconid crisis, the relative abundance of narrow canal nannoconids never exceed 1%, but the number of wide canal forms shows an increasing trend.

Föllmi K. (2012) - Early Cretaceous life, climate and anoxia. Cretaceous Research, 35, 230-257.

Roth P.H. (1978) - Cretaceous nannoplankton biostratigraphy and oceanography of the northwestern Atlantic Ocean. Initial Reports of the Deep Sea Drilling Project, 44, 731-759.

Integrated conodont, graptolite, and δ13C bio-chemostratigraphy of the Silurian of the Illinois Basin: A complimentary approach

McAdams N.E.B.*[1], Cramer B.D.[2], Bancroft A.M.[3], Melchin M.J.[4], Devera J.[5] & Day J.E.[6]

[1] Texas Tech University, USA.[2] University of Iowa, USA. [3] Indiana University Bloomington / Indiana Geological and Water Survey, USA. [4] St. Francis Xavier University, Canada. [5] Illinois State Geological Survey Prairie Research Institute, USA. [6] Illinois State University, USA.

Corresponding author email: neo.mcadams@ttu.edu

Keywords: chemostratigraphy, biostratigraphy, conodont, graptolite, carbon isotope, Midcontinent.

The Illinois Basin was a major Paleozoic depocenter in the Midcontinent region of the USA that recorded a thick succession of Silurian strata. However, poor surface exposures of the units limited litho- and chronostratigraphic studies and confounded correlation. We initially approached the study by collecting samples for carbon isotopes and conodont (graptolites where present) biostratigraphy under the idea that modern high-resolution methods would allow synthesis of the new data into a regionally useful framework. However, the number of accessible outcrops has dwindled since the last major studies in the 1970s, and carbon isotope curves from our sampled outcrops were initially inconclusive. The Illinois State Geological Survey agreed to support this project and drill a core through the Silurian interval. Intensive bio-chemostratigraphic work on the Schlamer #1 Core establishes an integrated, high-resolution framework that places the Illinois Basin Silurian units in global chronostratigraphic context. The succession spans the Aeronian–Pridoli and records the Ireviken, Mulde, and Lau positive carbon isotope excursions (the first published record in a single section from North America). The total available biostratigraphic, chemostratigraphic, and lithostratigraphic data complement each other and enable correlation into the global Silurian framework. Furthermore, regional correlation among outcrops in Illinois and Missouri is now possible, even for outcrops with limited data or previously inconclusive data. This work has also enabled establishment of a well-defined and usefully subdivided nomenclature for the units. The most notable change is a reassignment of the 'Bainbridge Formation' to the Bainbridge Group, composed of the Seventy-Six, St. Clair, and Moccasin Springs formations. Future work remains to determine if the St. Clair of the Illinois Basin is correlative with that of the type area in Arkansas, although preliminary results suggest that it may be distinct. The oldest Silurian unit in the Illinois Basin, the Sexton Creek Formation, also remains enigmatic.

Dating potential and age accuracy of U-Pb geochronology by LA-ICP-MS applied to lacustrine carbonates

Montano D.*[1-2-3], Gasparrini M.[1], Gerdes A.[2], Rohais S.[1], Della Porta G.[4] & Albert R.[2]

[1] IFP Energies nouvelles, France. [2] Goethe University Frankfurt, Germany. [3] Sorbonne University, France.
[4] Università degli Studi di Milano, Italy.

Corresponding author email: damaris.montano@ifpen.fr

Keywords: geochronology, lacustrine carbonates, U-Pb carbonates dating, LA-ICP-MS, Ries Crater, Yacoraite Fm.

Chronostratigraphy of continental carbonates is a problematic issue since these deposits commonly lack biostratigraphic markers, and the presence of datable layers (i.e. volcanic ash layers) inter-fingered within the sedimentary sequences is uncommon. Moreover, the site-specific geochemistry of continental fluids hinders the use of proxies ($\delta^{18}O$, $\delta^{13}C$, $^{87}Sr/^{86}Sr$) conventionally applied to marine carbonates to perform correlations between time-equivalent lateral facies. Recent advances in laser ablation (LA-ICP-MS) carbonate U-Pb geochronology have opened up the possibility to date a range of previously undateable geological materials. Consequently, absolute U-Pb geochronology of continental carbonates from pedogenic, palustrine, lacustrine and fluvial environments, is becoming a present day challenge in carbonate geochemistry research. Here we present an application of this new method to the Nördlinger Ries Crater basin (Langhian-Serravallian, middle Miocene, south Germany) and to the Yacoraite Fm. (Maastrichtian-Danian, late Cretaceous-early Paleocene, north-west Argentina). This study aims at evaluating the U-Pb geochronology potential and accuracy on lacustrine carbonates. The two case studies were chosen because they include carbonate deposits with a well-constrained chronostratigraphy. The Ries Crater and Yacoraite Fm. carbonates were deposited in a time window of ca. 2 and 4 Ma, respectively. An accurate petrographic analysis allowed selecting micrites, microbial carbonates, early lacustrine and meteoric cements not affected by later diagenesis. The geochronology dataset so far achieved is in agreement with the sedimentation timing known from literature (Marquillas et al., 2011; Rohais et al., 2014; Schmieder et al., 2018), though ages uncertainties are variable. Micrite and microbial carbonates produced the most accurate and precise ages, with uncertainties (2σ) down to 1% (14.46±0.16Ma and 65.7±0.8Ma for the Ries Crater and Yacoraite Fm., respectively), whereas most ages obtained from other carbonate types (lacustrine cements and ooids) are associated with uncertainties of 3-10%. The age precision obtained in this study from lacustrine carbonates suggests the possible use of U-Pb geochronology as a chronostratigraphic tool within the time resolution of the third order sequences. This method may therefore result particularly useful in continental settings where high resolution chronostratigraphic data are mostly lacking. In these settings, specific attention should be given to micrites and microbial carbonates, which seem to provide the most precise and accurate ages.

Marquillas R.A., Salfity J.A., Matthews S.J., Matteini M., Dantas E. (2011) - U-Pb zircon age of the Yacoraite Formation and its significance to the Cretaceous-Tertiary boundary in the Salta Basin, Argentina. Cenozoic Geology of the Central Andes of Argentina, 227-246.

Rohais, S., Hamon, Y., Deschamps, R., Gasparrini, M., Beaumont, V., Kohler, E., Barbier, M., Doligez, B. (2014) - Final report: Phases III – Cretaceous Outcrop analog from Argentina for Microbial Pre-salt Atlantic Series: JIP COMPAS – YEAR 3. IFPEN Report 65622.

Schmieder M., Kennedy T., Jourdan F., Buchner E., Reimold W. U. (2018) - A high-precision $^{40}Ar/^{39}Ar$ age for the Nördlinger Ries impact crater, Germany, and implications for the accurate dating of terrestrial impact events. Geochimica et Cosmochimica Acta, 220, 146-157.

Improvement of chronology for Cenozoic pelagic brown clay by osmium isotope stratigraphy

Ohta J.*[1-2-3], Nozaki T.[3-2-4-1], Takaya Y.[5-1-3], Yasukawa K.[2-1], Fujinaga K.[1-2], Nakamura K.[2], Kimura J.-I.[3], Chang Q.[3] & Kato Y.[1-2]

[1] Chiba Institute of Technology, Japan.[2] The University of Tokyo, Japan. [3] Japan Agency for Marine-Earth Science and Technology, Japan. [4] Kobe University, Japan. [5] Waseda University, Japan.

Corresponding author email: junichiro.ota@p.chibakoudai.jp

Keywords: Cenozoic, Osmium isotope stratigraphy, deep-sea sediments, Pacific Ocean.

Pelagic brown clay is one of the major sediment types covering a large portion of seafloor in the Pacific Ocean (Dutkiewicz et al., 2015). The pelagic brown clay is a mixture of slowly accumulating materials such as eolian, hydrogenetic, and authigenic components. Thus, it can be a favorable recorder of long-term geochemical cycles through the Ocean. However, it has been difficult to determine depositional ages of pelagic brown clays due to poor preservations of calcareous and siliceous microfossils, and magnetic reversals. Another approach to determine the depositional ages is the marine osmium (Os) isotope stratigraphy (Peucker-Ehrenbrink & Ravizza, 2012). $^{187}Os/^{188}Os$ ratio in seawater has fluctuated reflecting a balance between Os fluxes from riverine, hydrothermal, and extraterrestrial sources (Peucker-Ehrenbrink & Ravizza, 2000). Reconstructed seawater $^{187}Os/^{188}Os$ curve through the Cenozoic era shows several positive and negative shifts, some of which have been attributed to contemporaneous geological events (Burton, 2006; Peucker-Ehrenbrink & Ravizza, 2012). These features of the seawater $^{187}Os/^{188}Os$ curve can be stratigraphic markers which help developing chronology of the marine deposit whose ages are difficult to be determined by paleontological or paleomagnetic methods. In this study, we measured seawater $^{187}Os/^{188}Os$ ratios recorded in a pelagic brown clay core, KR13-02 PC04, collected from the western North Pacific Ocean. The seawater $^{187}Os/^{188}Os$ ratio at the core top showed a value near the present seawater value of ~1 (Sharma et al., 1997), and it gradually decreased towards the bottom with some negative excursions. Then, it showed the minimum value at ~8 meters below seafloor. These features corresponded to those of the seawater $^{187}Os/^{188}Os$ curve from the latest Eocene to present (Burton, 2006; Peucker-Ehrenbrink & Ravizza, 2012). Thus, this core could continuously record the depositional history from the latest Eocene to present. The depositional age of this core can be determined by fitting the $^{187}Os/^{188}Os$ data to the seawater curve with helps of lithostratigraphy and biostratigraphy by ichthyolith, an age-diagnostic fossil remains preserved in pelagic brown clay.

Burton K. W. (2006) - Global weathering variations inferred from marine radiogenic isotope records. J. Geochem. Exp., 88, 262-265.

Dutkiewicz A., Müller R. D., O'Callaghan S. & Jónasson H. (2015) - Census of seafloor sediments in the world's ocean. Geology, 43, 795-798.

Peucker-Ehrenbrink B. & Ravizza G. (2000) - The marine osmium isotope record. Terra Nova 12, 205-219.

Peucker-Ehrenbrink B. & Ravizza G. (2012) - Osmium isotope stratigraphy. In: Gradstein F. M., Ogg J. G., Schmitz M. D. & Ogg G. M. (eds.), The Geologic Time Scale 2012, 145-166. Elsevier.

Sharma M., Papanastassiou D.A. & Wasserburg G.J. (1997) - The concentration and isotopic composition of osmium in the oceans. Geochim. Cosmochim. Acta, 61, 3287-3299.

Linking Coniacian inoceramid diversification with paleoenvironmental instability

Todes J.[1]* & Walaszczyk I.[1]

University of Warsaw, Poland.

Corresponding author email: j.todes@student.uw.edu.pl

Keywords: Inoceramid, Cretaceous, Coniacian, carbon isotopes, bioevents.

A series of well defined, apparently rapid evolutionary and migratory events recognized within the *Inoceramidae* characterize the Coniacian Stage. These events provide a basis for the definition of the stage, substage boundaries, and further zonal subdivision, yielding a high-resolution framework resolved to within tens of thousands of years (10-100 kyr). The dynamic turnover and rapid diversification of inoceramids in the Coniacian often coincide with intervals of carbon cycle instability. At first appearance, three events in particular stand out: (1.) The rapid taxonomic turnover from the late Turonian *Mytiloides*-dominated fauna to the latest Turonian-early Coniacian *Cremnoceramus*-dominated fauna occurs penecontemporaneous with the Navigation Event, a globally recognized ca. -1‰ $\delta^{13}C_{carb}$ excursion. It is of particular interest that the peak Navigation negative excursion coincides with the *Didymotis* II Biovent*,* which promptly follows the first appearance of the genus *Cremnoceramus*. (2.) The demise of *Cremnoceramus*, the emergence of the *Inoceramus gibbous* fauna, and the delayed diversification of the genera *Platyceramus* and *Volveceramus* occurs during the early-middle Coniacian transition, coeval with the prolonged onset of Ocean Anoxic Event 3 (OAE3, ca. 2‰). In the Western Interior, trace metal and phosphorus geochemistry suggest the middle/late Coniacian was broadly characterized by intermittent euxinia and elevated nutrient availability. (3.) The appearance of the *Magadiceramus* (lower latitudes) and *Sphenoeramus (*higher latitudes) fauna occurs in close correlation with the Kingsdown Event. There seems to exist a broad correspondence between genus-level inoceramid turnover and paleoenvironmental instability during the Coniacian. However, the further development of geochemical/paleontological datasets would be beneficial for further hypothesis testing. First, there is a need for further joint inoceramid-$\delta^{13}C$ records: while such sections from northern Europe and North America are reasonably available, those from the Tethyan realm and the southern hemisphere are severely underrepresented. Second, high-resolution geochemical records would help to unravel the dynamic setting in which these massive transitions occurred: in particular, Fe speciation, trace metal, and $\delta^{34}S$ records would be quite useful. Third, a better understanding of inoceramid paleobiogeography and paleoecology would help to ascertain the influence of environmental perturbations upon this clade. Overall, this work underscores the need for the integrated analysis of biological, geochemical, and geologic features to unravel the nature of unique paleoecological shifts.

A high-resolution chemo- and biostratigraphy through the latest Toarcian to Early Aalenian units in northern Switzerland

Wohlwend S.*[1], Bernasconi S.M.[1] & Deplazes G.[2]

[1] ETH Zürich, Switzerland.[2] Nagra, Switzerland.

Corresponding author email: stephan.wohlwend@erdw.ethz.ch

Keywords: Opalinus Clay, Staffelegg, Toarcian, Aalenian, T-OAE, Opalinum.

The upper Staffelegg Formation and the overlying Opalinus Clay were deposited in a shallow epicontinental shelf sea during the Late Toarcian to Aalenian time. The sedimentary succession can be investigated today in outcrops and drill cores from northern Switzerland. The Liassic sediments of the Rietheim Member (Staffelegg Fm.) consist of dark black bituminous to silty marls deposited during the Toarcian Oceanic Anoxic Event (T-OAE) which is overlain by dark grey to black calcareous and silty claystone belonging to the Opalinus Clay. The 80 to 120 m thick succession of the Opalinus Clay (decompacted 180-270 m) was deposited during a short time interval with a high sedimentation rate of 0.4 to 0.7 m/ka (Wetzel & Allia, 2003). Based on mineralogy and grain-size, the Opalinus Clay can be further divided into sub-units. The extent of these decametre scale sub-units can be investigated by comparing the records of different outcrops and drill cores. To predict potential lateral facies changes within the Opalinus Clay, the depositional environment must be investigated applying a compositional but also a chronological differentiation.

Biostratigraphy based on ammonites and palynomorphs is a frequently applied method to establish a chronology in these clay rich Jurassic sediments. Previous studies indicate that the top of the Staffelegg Fm. and thus the onset of the Opalinus Clay is diachronous (e.g. Feist-Burkhardt & Pross, 2010; Hostettler et al., 2017). However, the resolution of these biostratigraphic tools is mostly not high enough to differentiate the sub-units of different drill cores within the Opalinus Clay. Therefore, in this study the potential of high-resolution carbon isotope chemostratigraphy measured on carbonates and on organic matter will be presented. The established C-isotope measurements from the different drill cores document the prominent T-OAE negative excursion, which can be followed throughout the drill cores from Lausen, Riniken, Weiach to Benken over about 70 km. In the hanging Opalinus Clay an additional negative excursion is present in the C-isotope measured from the bulk (carbonates) as well as from the organic matter. The stepwise negative shifts can also be correlated throughout the investigated drill cores. The interval covering the upper negative excursion can be dated by palynomorphes and ammonites as early Opalinum Subzone of the Opalinum Zone. This earliest Aalenian excursion documented in the lowermost part of the Opalinus Clay may therefore reflect an additional global variation in the C-isotope record.

Feist-Burkhardt S. & Pross J. (2010) - Dinoflagellate cyst biostratigraphy of the Opalinuston Formation (Middle Jurassic) in the Aalenian type area in southwest Germany and north Switzerland. Lethaia, 43, 10-31.

Hostettler B., Reisdorf A.G., Jaeggi D., Deplazes G., Bläsi H., Morard A., Feist-Burkhardt S., Waltschew A., Dietze, V. & Menkveld-Gfeller U. (2017) - Litho- and biostratigraphy of the Opalinus Clay and bounding formations in the Mont Terri rock laboratory (Switzerland). Swiss Journal of Geosciences, 110, 23–37.

Wetzel A. & Allia V. (2003) - Der Opalinuston in der Nordschweiz: Lithologie und Ablagerungsgeschichte. Eclogae Geologicae Helvetiae, 96(3), 451-469.

The base of the Campanian: isotopes, magnetostratigraphy and biostratigraphy – who's accurate?

Wolfgring E.*, Wagreich M. & Sames B.

University of Vienna.

Corresponding author email: erik.wolfgring@univie.ac.at

Keywords: stable isotopes, planktonic foraminifera, calcareous nannofossils, Santonian/Campanian boundary.

A possible reference section for the Santonian/Campanian boundary in the northwestern Tethys, the Postalm section (Northern Calcarous Alps, Austria) was investigated for palaeomagnetic and stable isotope data, planktonic foraminifera and calcareous nannoplankton biostratigraphy, and strontium isotope stratigraphy, together with published correlated ammonite, crinoid and inoceramid data. The Postalm section shows a deepening trend from upper Santonian conglomerates and grey shelf marls to pelagic bathyal red marly limestones of mainly Campanian age. The end of the Long Cretaceous Normal Polarity Chron (the palaeomagnetic reversal from Chron 34n to C33r) is considered a primary marker for the Santonian/Campanian transition and marks the base of the Campanian at the Postalm section. Bioevents suggested to pinpoint the Santonian/Campanian transition include the last occurrence (LO) of the planktonic foraminifera *Dicarinella asymetrica* and the first occurrence (FO) of the nannofossil marker *Broinsonia parca parca.* Both events are documented in close proximity to the magnetic reversal; *B. parca parca* appears 1.66m and *D. asymetrica* shows its LO 1.24m above the magnetic reversal. At the Postalm section, the δ13C signature shows a distinct positive excursion shortly after the palaeomagnetic reversal (with a peak at ~1.5m). This event is interpreted as representing the Santonian/Campanian Boundary Event (SCBE). Upon comparing the position of bioevents, the position of the SCBE and end of the Long Cretaceous Normal Polarity Chron at Postalm to other sections, differences in the succession of events around the Santonian/Campanian boundary are evident. Other reference sections show the SCBE right below the palaeomagnetic reversal (e.g., Bottaccione, Lägerdorf). Also the micro-/nannofossil record shows some diachroneity: In contrast to its LO at the Postalm section, the Bottaccione record shows the LO of *D. asymetrica* still within Chron C34n implying diachroneity of the bioevent. The position of the FO of *B. parca parca* is either recoreded within the SCBE (Lägerdorf) or above the positive δ13C excursion (Bottaccione, Bocieniec and Postalm). These slightly different levels of the SCBE and the different first and last occurrences of micro – and nannofossil markers point out the importance of high-resolution palaeomag sampling around critical reversals to provide stable and synchronous chronostratigraphic markers and section points for golden spikes.

ST2.2
Conodonts as tools for biostratigraphy, chronostratigraphy, chemostratigraphy and evolution

Manuel Rigo (University of Padova)
Xulong Lai (China University of Geosciences, Wuhan)

Quantitative stratigraphic correlation of Tethyan conodonts across the Smithian-Spathian (Early Triassic) extinction event

Chen Y.L.*[1-2], Richoz S.[2-3], Krystyn L.[4] & Zhang Z.F.[1]

[1]Northwest University, China. [2]University of Graz, Austria. [3]Lund University, Sweden
[4] University of Vienna, Austria.

Corresponding author email: chenyanlong4304103@hotmail.com

Keywords: Tethys, biostratigraphy, Oman, South China, Slovenia, unitary association.

Three small-scale extinctions occurred in the Early Triassic with one of them recognized close to the Smithian-Spathian boundary. In the last two decades, the end-Permian mass extinction as well as the subsequent recovery have been intensively studied throughout the Tethys region, but correlations within the Early Triassic are difficult due to conodonts endemism. Here we use paleontological and geochemical methods to document a high-resolution biostratigraphy of the Smithian-Spathian boundary interval from two sections of Oman. In combination with previously published data from both South-Central Europe and South China, a quantitative stratigraphic correlation has been achieved with 7 conodont UA Zones recognized using the unitary association method. Based on conodonts and carbonate carbon isotope data, the Smithian-Spathian boundary is identified in the interval from UAZ4 to UAZ5 close to the last occurrence of *Nv. pingdingshanensis* in Oman and South China, and within the range of *P. inclinata*, *Ns. planus*, *Pl. regularis*, and *Pl. corniger* in South-Central Europe. UAZ7 fauna displays a clear diachronism as it starts from South China, arrives a bit later in Oman and even later in western Tethys. *Foliella gardenae* and *Icriospathodus zaksi* are reported from Oman for the first time and thus expand the geographical distribution of these rarely reported species.

First documentation of *Astropentagnathus* in China: Progress of Silurian conodont studies in the East Qinling

Chen Z.Y.*[1], Männik P.[2], Wang X.[3-4] & Li C.[5]

[1] Nanjing Institute of Geology and Palaeontology and Center for Excellence in Life and Paleoenvironment, Chinese Academy of Sciences, China. [2] Department of Geology, Tallinn University of Technology, Estonia. [3] State Key Laboratory of Continental Dynamics, Shaanxi Key Laboratory of Early Life Institute and Environments, Department of Geology, Northwest University, China. [4] Centre for Orogenic Belt Geology, CGS, Xi'an Center of China Geological Survey, China. [5] CAS Key Laboratory of Economic Stratigraphy and Palaeogeography, Nanjing Institute of Geology and Palaeontology and Center for Excellence in Life and Paleoenvironment, Chinese Academy of Sciences, China.

Corresponding author email: zychen@nigpas.ac.cn

Keywords: Conodont, Telychian, East Qinling.

The early Telychian (Silurian) conodont *Astropentagnathus* has been reported from Austria, UK, US, Canada, Australia, Greenland, Estonia, and Latvia (see Chen et al., 2017 for overview). Two species, *A. araneum* and *A. irregularis* were included in this genus, and one species, *A.*? *retroramus*, was tentatively assigned to this genus (see Chen et al., 2017 for overview). The genus was widely distributed and has been reported from many palaeoplates, but not from China so far. However, recently the genus was discovered in the Baiaiya Formation at the Tianbacun section of Langao, Shaanxi, China. The area is located in the Qinling orogenic belt which formed the margin of the South China block in the Silurian (Meng et al., 2005). Conodont genera occurring together with *Astropentagnathus* include *Aulacognathus*, *Distomodus*, *Oulodus*, *Ozarkodina*, *Pseudolonchodina*, and *Pterospathodus*. Almost all elements of *Astropentagnathus* in our collection are twisted, probably caused by tectonics (by clockwise rotation of the South China block in the Mesozoic; Meng et al., 2005). Occurrence of *Atropentagnathu*s suggests the *Pterospathodus eopennatus* ssp. n. 1 Biozone for the strata. This agrees with the results of previous investigations in the region reporting Telychian–early Sheinwoodian faunas from the Wuxiahe Formation (Tang et al., 2015) overlying the interval in the present research.

Chen Z.Y., Männik P. & Fan J.X. (2017) - Llandovery (Silurian) conodont provincialism: An update based on quantitative analysis. Palaeogeogr. Palaeoclimatol. Palaeoecol., 485, 661-672.

Meng Q.R., Wang E. & Hu J.M. (2005) - Mesozoic sedimentary evolution of the northwest Sichuan basin: Implication for continued clockwise rotation of the South China block. Geol. Soc. Am. Bull., 117, 396-410.

Tang P., Wang J., Wang C.Y., Wu R.C., Yan K., Liang Y. & Wang X. (2015) - Microfossils across the Llandovery–Wenlock boundary in Ziyang–Langao region, Shaanxi, NW China. Palaeoworld, 24, 221-230.

The evolutionary process from *Mockina bidentata* to the genus *Parvigondolella*: the evidences from Pizzo Mondello Section

Du Y.X.*[1], Rigo M.[1], Onoue T.[2] & Williams I.[3]

[1] Department of Geoscience, University of Padova, Italy. [2] Department of Earth and Planetary Sciences, Kyushu University, Japan. [3] Research School of Earth Sciences, The Australian National University, Canberra, Australia.

Corresponding author email: yixing.du@phd.unipd.it

Keywords: Triassic conodont.

Conodont plays an important role in biostratigraphic study in the Upper Triassic during the last few decades, mostly as a biostratigraphic tool for dating and global correlations. Conodont *Mockina bidentata* has been regarded as the ancestor of genus *Parvigondolella* in many previous works (e.g. Kozur & Mostler, 1971) but the evolutionary process from *Mockina bidentata* to *Parvigondolella andrusovi* needs to be illustrated in detail. Two transitional forms, the one with only one denticle on the anterior margin and the other one with no denticle and characterized by a platform reduced in bulge shape, were recognized in the samples from Pizzo Mondello Section. Furthermore, genus *Parvigondolella* was regarded as morphological variants or ecostratigraphic morphotypes of *Mockina bidentata* (Krystyn et al., 2007; Pálfy et al., 2007). We thus investigated the oxygen composition of biogenic apatite (conodonts) during the phylogenic transition between genera *Mockina* and *Parvingondolla*, excluding that this evolution process could be related to temperature variation. Genus *Parvigondolella* should be thus accepted as an independent genus due to its morphologic differences comparing with *Mockina bidentata,* since it is characterized by the completely absence of the platform and ornamentation. Moreover, the genus *Parvigondolella* has a relatively worldwide distribution, which has been reported occurring in Italy, Austria, Hungary, Slovenia, Canada, America, Mexico, Russia, Japan and China (Kozur & Mostler, 1971; Mazza & Martínez-Pérez, 2015; Rigo et al., 2005, 2018).

Kozur H. & Mostler H. (1971) - Probleme der Conodontenforschung in der Trias. Geol. Palaont. Mitt. Ibk., 1(4),1-19.

Krystyn L., Bouquerel H., Kuerschner W. & Gallet S.R. (2007) - Proposal for a candidate GSSP for the base of the Rhaetian stage. In: Lucas S.G., Spielman J.A. (eds.), The global Triassic. New Mexico Museum of Natural History and Science Bulletin, 41,189-199.

Mazza M. & Martínez-Pérez C. (2015) - Unravelling conodont (Conodonta) ontogenetic processes in the Late Triassic through growth series reconstructions and X-ray microtomography. Bollettino della Società Paleontologica Italiana, 54(3), 161-186.

Pálfy J., Demény A., Haas J. Carter E.S., Görög Á., Halász D., Oravecz-Scheffer A., Hetényi M., Màrton E., Orchard M.J., Ozsvárt P., Véto I. & Zajzon N. (2007). Tria Triassic–Jurassic boundary events inferred from integrated stratigraphy of the Csővár section, Hungary. Palaeogeogr., Palaeoclimatol., Palaeoecol., 244, 11-33.

Rigo M., De Zanche V., Gianolla P. Mietto P., Preto N. & Roghi G. (2005) - Correlation of Upper Triassic sections throughout the Lagonegro Basin. Boll. Soc. Geol. It., 124, 293-300.

Rigo M., Mazza M., Karadi V. & Nicora A. (2018) - New Upper Triassic conodont biozonation of the Tethyan realm. In: Lawrence H. Tanner (eds.), The late Triassic world. Springer, 189-235.

The asynchronous extinction of conodonts: new constraints from Triassic-Jurassic boundary sections

Du Y.X.*[1], Rigo M.[1-6], Pálfy J.[2], Karádi V.[3], Onoue T.[4], Tomimatsu Y.[5], Chiari M.[6] & Roghi G.[6]

[1] Department of Geoscience, University of Padova, Italy. [2] Department of Geology, Eötvös Loránd University, Hungary. [3] Department Palaeontology, Eötvös Loránd University, Hungary. [4] Department of Earth and Planetary Sciences, Kyushu University, Japan. [5] Department of Earth and Environmental Sciences, Kumamoto University, Japan. [6] Institute of Geosciences and Earth Resources (IGG - CNR)

Corresponding author email: yixing.du@phd.unipd.it

Keywords: Triassic-Jurassic Boundary, conodont, extinction.

The End-Triassic Extinction event (ETE) has been recognized in numerous sections worldwide and it is usually marked by three carbon isotope excursions, named precursor, initial and main negative excursions. These three carbon isotope excursions are significant characteristics of this time interval, and they are thought to be related to the emplacement of the Central Atlantic Magmatic Province (CAMP) that is considered the main trigger of the ETE (Marzoli et al., 2004). Stable carbon isotope perturbations, commonly related to biotic turnovers and extinctions, play an important role in stratigraphic correlations, particularly around the Triassic/Jurassic boundary (TJB). This interval is marked by the disappearance of conodonts, elements of a feeding apparatus belonging to marine organisms that populated the Paleozoic-early Mesozoic seas and which became extinct across the TJB. At present, there are no unambiguous clues about the extinction of conodonts, including their Highest Occurrence (HO), which can help to understand the main cause(s) that could have led to their disappearance. Comparison of integrated data of six TJB sections from different areas (NW Tethys *vs* Japan) and different depositional environments (shallow water *vs* deep water) (Pálfy et al., 2001; Hesselbo et al., 2002; Zaffani et al., 2018) seem to testify that conodonts tried first to take refuge from shallow water to open marine environments before becoming extinct.

Hesselbo S.P., Robinson S.A., Surlyk F., Piasecki S. (2002) - Terrestrial and marine extinction at the Triassic-Jurassic boundary synchronized with major carbon-cycle perturbation: a link to initiation of massive volcanism?. Geology, 30, 251-254.

Marzoli A., Bertrand H., Knight B.K., Cirilli S., Buratti N., Vérati C., Nomade S., Renne P.R., Youbi N., Martini R., Allenbach K., Neuwerth R., Rapaille C., Zaninetti L. & Bellieni G. (2004) - Synchrony of the Central Atlantic magmatic province and the Triassic-Jurassic boundary climatic and biotic crisis. Geology, 32, 973-976.

Pálfy J., Demény A., Haas J., Hetényi M., Orchard M. J. & Veto I. (2001) - Carbon isotope anomaly and other geochemical changes at the Triassic-Jurassic boundary from a marine section in Hungary. Geology, 29, 1047-1050.

Zaffani M., Jadoul F. & Rigo M. (2018) - A new Rhaetian $\delta^{13}C_{org}$ record: Carbon cycle disturbances, volcanism, End-Triassic mass Extinction (ETE). Earth-Sci. Rev., 178, 92-104.

Early Anisian (Middle Triassic) species of the conodont *Neogondolella* from China and Romania, with comments on their role in the recognition and correlation of the base of the Anisian

Golding M.L.*

Geological Survey of Canada

Corresponding author email: martyn.golding@canada.ca

Keywords: Anisian, Triassic, China, Romania, Conodont, Biostratigraphy.

The base of the Anisian stage (early Middle Triassic) is currently undefined. There are two potential GSSP sections at Guandao, Guizhou Province, South China (Orchard et al., 2007b), and at Deşli Caira, North Dobrogea, Romania (Grădinaru et al., 2007). At both sections, the conodont *Chiosella timorensis* has been proposed as a possible index for recognition of the base of the Anisian (Orchard et al., 2007a, b). Subsequently, this conodont has been discovered with ammonoids of Spathian age in Nevada (Goudemand et al., 2012), and the suitability of this species as an indicator of the Anisian has been cast into doubt. In spite of continued studies of the geochronology and stratigraphy of the section at Guandao (e.g. Lehrmann et al., 2015; Li et al., 2018), there has been little new work on the Olenekian and Anisian conodont faunas at either section since the study of Goudemand et al. (2012). New species of conodont belonging to the genus *Neogondolella* were recently described from the Anisian of British Columbia, Canada (Golding and Orchard, 2016). Some of these species have subsequently been recognized more widely in western Canada (Henderson et al., 2018). In light of the updated taxonomy of Anisian *Neogondolella*, collections from the Olenekian-Anisian boundary sections at both Guandao and Deşli Caira have been re-examined to assess the range of diversity of *Neogondolella* in the samples, previously described as *Neogondolella* spp. (Orchard et al., 2007a, b). This re-appraisal has led to the recognition of several species of *Neogondolella* present in British Columbia, as well as two new species that allow correlation between the two sections. This is the first record of these species outside of North America. In Guandao, the early Anisian *N.* cf. *dilacerata* is recognized in sample OU-9, where it occurs with specimens of *Chiosella timorensis*, *Cratognathodus* sp. A and sp. B, *Triassospathodus* ex gr. *homeri*, and the first specimens of *Gladigondolella tethydis*. Above this level, *N. curva* occurs in sample OU-11 and OU-21, as well as in sample 204/5 in Deşli Caira. In both sections, *N. curva* occurs with *C. timorensis* and *G. tethydis*, and allows correlation of the two sections. *N.* n. sp. B is recognised in sample OU-21 at Guandao, whereas *N.* n. sp. A occurs in both sections, in samples OU-29 and OU-30 at Guandao, as well as samples 9043 and 612 at Deşli Caira. Near the top of both sections, the late early Anisian to late Anisian conodont *N. hastata* occurs, in sample OU-30 at Guandao, and samples 612, 9048, and 615B at Deşli Caira. In both sections, *N. hastata* occurs with *C. timorensis* and *G. tethydis*. All of the species of *Neogondolella* described above are early Anisian in age, and allow a more refined division of this time period. They also allow greater precision in the correlation of the Tethyan sections with those in North America and higher latitudes, where typical early Anisian species such as *Chiosella timorensis* and *Gladigondolella tethydis* are rare or absent. The oldest species of *Neogondolella* recognized in the Guandao and Deşli Caira sections occur above the first appearance of *C. timorensis*. If this species is considered to be unsuitable as an index for the base of the Anisian due its co-occurrence with Spathian ammonoids, then one of the *Neogondolella* species may be a suitable alternative. Regardless of whether or not a *Neogondolella* species is chosen as the index for the boundary, it is hoped that the recognition of these species and the improvement in early Anisian correlation demonstrates the benefit of further work on the conodont faunas of the GSSP candidate sections. Additional work on other sections where the late Olenekian or early Anisian is preserved, and on conodont species outside of those traditionally assumed to be indicative of the boundary, will be necessary to ensure the selection of a natural GSSP for the base of the Anisian in the future.

Golding M.L. & Orchard M.J. (2016) New species of the conodont *Neogondolella* from the Anisian (Middle Triassic) of northeastern British Columbia, Canada, and their importance for regional correlation. Journal of Paleontology, 90, 1197-1211.

Goudemand N., Orchard M.J., Bucher H. & Jenks J. (2012) - The elusive origin of *Chiosella timorensis* (Conodont Triassic). Geobios, 45, 199-207.

Grădinaru E., Orchard M.J., Nicora A., Gallet Y., Besse J., Krystyn L., Sobolev E.S., Atudorei N.-V. & Ivanova, D. (2007) - The Global Boundary Stratotype Section and Point (GSSP) for the base of the Anisian Stage: Deşli Caira, North Dobrogea, Romania. Albertiana, 36, 54-67.

Henderson C.M., Golding M.L. & Orchard M.J. (2018) - Conodont sequence biostratigraphy of the Lower Triassic Montney Formation. Bulletin of Canadian Petroleum Geology, 66, 7-22.

Lehrmann D.J., Stepchinski L., Altiner D., Orchard M.J., Montgomery P., Enos P., Ellwood B.B., Bowring S.A., Ramezani, J., Wang, H., Wei, J., Yu, M., Griffiths, J.D., Minzoni, M., Schaal, E.K., Li, X., Meyer, K.M. & Payne, J.L. (2015) - An integrated biostratigraphy (conodonts and foraminifers) and chronostratigraphy (paleomagnetic reversals, magnetic susceptibility, elemental chemistry, carbon isotopes and geochronology) for the Permian-Upper Triassic strata of Guandao section, Nanpanjiang Basin, South China. Journal of Asian Earth Sciences, 108, 117-135.

Li M., Huang C., Hinnov L., Chen W., Ogg J. & Tian W. (2018) - Astrochronology of the Anisian stage (Middle Triassic) at the Guandao reference section, South China. Earth and Planetary Science Letters, 482, 591-606.

Orchard M.J., Grădinaru E. & Nicora A. (2007a). A summary of the conodont succession around the Olenekian-Anisian boundary at Deşli Caira, North Dobrogea, Romania. In, Lucas, S.G. & Spielmann Eds., The Global Triassic. New Mexico Museum of Natural History and Science Bulletin 41, 341-346.

Orchard M.J., Lehrmann D.J., Jiayong W., Hongmei W. & Taylor H. (2007b) - Conodonts from the Olenekian-Anisian boundary beds, Guandao, Guizhou Province, China. In, Lucas, S.G. & Spielmann Eds., The Global Triassic. New Mexico Museum of Natural History and Science Bulletin 41, 347-354.

Revised multi-element apparatus of genus *Novispathodus*: new evidences from the Early Triassic conodont clusters at the Zuodeng section of Guangxi, South China

Jiang H.*[1] & Ye Q.[2]

[1] State Key Laboratory of Biogeology & Environmental Geology, School of Earth Sciences, China University of Geosciences, Wuhan, China. [2] Non-ferrous Metals Geological Exploration Bureau of Zhejiang Province, Shaoxing, China

Corresponding author email: jiangliuis@163.com

Keywords: Zuodeng Section; Early Triassic; conodont cluster; multielement apparatus; genus Novispathodus

Nine conodont clusters are collected from the Early Triassic conodont *Novispathodus pingdingshanensis* Zone at the Zuodeng Section of Tiandong County, Guangxi, South China. These clusters were analysed using micro-computed tomography (micro-CT) facilities. Cluster 1 and cluster 2 both consist paired segminate P_1 elements of *Novispathodus pingdingshanensis*. Cluster 3 consists 7 elements, including 1 alate S_0 element, 2 digyrate S_1 element, 3 digyrate S_2 element, and 1 broken $S_{3/4}$? element. Cluster 4 consists 1 segminate P_1 element of *Novispathodus pingdingshanensis* and 1 bipennate $S_{3/4}$ element. Cluster 5 consists 7 elements, including 1 digyrate S_1 element, 2 digyrate S_2 element, 1 bipennate S_3 element, 1 broken bipennate S_4 element and two broken pieces cannot be identified. Cluster 6 consists 1 segminate P_1 element of *Novispathodus pingdingshanensis* and 1 digyrate S_1 element. Cluster 7 consists 8 elements, including 1 alate S_0 element and 1 bipennate S_3 element, paired digyrate S_1 element, S_2 element and segminate P_1 element. Cluster 8 also consists 8 elements, including paired segminate P_1 element and P_2 element and 1 bipennate S_3 element, 1 bipennate S_4 element, 1 markellate M element and 1 broken process of M ? element. Cluster 9 consists 1 markellate M element and 1 digyrate S_1 element. These new materials, combined with the previous reconstruction of Triassic conodont apparatus (Orchard, 2005; Goudemand et al., 2012), suggest genus *Novispathodus* has a composition of 15 elements: a rostral array of 9 S and 2 M elements, two pairs of P elements located caudally. Besides the P_1 position is a pair of segminate elements, our evidence show that the P_2 position is occupied also by a pair of segminate elements, but not angulate elements as suggested before (Orchard, 2005; Goudemand et al., 2012). However, comparing the steady rostral array of 9S and 2M elements, our materials show the variation of P_1 and P_2 elements in the genus *Novispathodus*.

Goudemand N., Orchard M.J., Tafforeau P., Urdy S., Bruehwiler T., Brayard A., Galfetti T. & Bucher H. (2012) - Early Triassic conodont clusters from South China: revision of the architecture of the 15 element apparatuses of the superfamily Gondolelloidea. Palaeontology, 55, 1021–1034.

Orchard M.J. (2005) - Multielement conodont apparatuses of Triassic Gondolelloidea. Spec. Pap. Palaeontol., 73, 73–101.

The Lower/Middle Norian (Upper Triassic) transition: conodonts of the Dovško succession, Slovenia

Karádi V.*[1], Kolar-Jurkovšek T.[2] & Jurkovšek B.[2]

[1] Department of Palaeontology, Eötvös Loránd University, Budapest, Hungary. [2] Geological Survey of Slovenia, Ljubljana, Slovenia.

Corresponding author email: kavik.geo@gmail.com

Keywords: conodonts, biostratigraphy, Upper Triassic, Lacian/Alaunian transition, Slovenia.

Conodonts of the Middle Norian (Alaunian) substage are very poorly known, especially from the Tethyan Realm. The reason is complex: 1) the Alaunian parts of many successions show tectonic or sedimentary disturbance; 2) Alaunian conodont faunas indicate a high rate of juvenile mortality; 3) Tethyan conodont literature is, in most cases, characterized by an over-simplified taxonomy and inadequate illustration of the conodont elements. Consequently, the Alaunian conodont biostratigraphy in the Tethyan Realm is strongly hampered by these biases. Recent studies, both from the Tethys and from western North America, presented rich and well-preserved conodont faunas and revealed the main characteristics of the Lower/Middle Norian faunal turnover. A similar conodont fauna, representing the Lower/Middle Norian transition, was recently recovered from E Slovenia near the village Dovško. The succession, exposed by a road cut and the adjacent creek, is ca. 65 m long and is composed of grey, cherty limestone. The section is situated in the Transitional area between the External and Internal Dinarides, and was located at the eastern part of the Slovenian Basin during the Late Triassic. The lower 28 m of the succession is Lower Norian (Lacian) in age based on the presence of *Epigondolella quadrata*, *E. rigoi*, *E. uniformis*, *E. triangularis* and *Metapolygnathus mazzai*. The uppermost sample of this interval contained *E.* aff. *spatulata*, previously reported from the uppermost Lacian of the Canadian Cordillera. The next 31 m above this level is still dominated by the Lacian-type epigondolellids, in some samples also by *Norigondolella hallstattensis*. However, conodont specimens characterized by a forward-shifted pit in front of the platform mid-length, a posteriorly prolonged keel and a prolonged posterior carina behind the cusp first appear in this part of the succession. These conodonts are assigned partly to *Mockina* ex gr. *matthewi* and partly to *Mockina* spp. and represent the evolutionary transition towards Alaunian species. The dominance of *N. steinbergensis* and the morphologically diverse species of genus *Mockina* indicate Alaunian age for the upper 6 m of the section. The conodont species *E. triangularis* and *E. rigoi* are still present in this interval, which clearly proves that characteristic species of the Lacian range up to the Alaunian in the Tethyan Realm, contrary to western North America. The conodonts recovered from the Dovško succession are of great importance for the understanding of the Lower/Middle Norian transition. However, further research on other abundant assemblages is necessary in order to refine the Alaunian conodont biozonation of the Tethyan Realm, and to enable an accurate regional and, perhaps, global correlation.

Evolution of the genus *Misikella* through the Norian-Rhaetian interval

Karádi V.*[1]

[1]Department of Palaeontology, Eötvös Loránd University, Budapest, Hungary.

Corresponding author email: kavik.geo@gmail.com

Keywords: conodonts, Rhaetian, Norian, evolution.

For the Upper Triassic, conodonts are one of the primary tools utilized in biostratigraphic investigations. For a more effective biostratigraphic zonation, the species should be constrained by clear phylogenetic relationships, in which the stratigraphic ranges and taxonomy are reliable. Unfortunately, a phylogenetic framework for the Upper Triassic pectiniform conodonts is partially missing, except for particular intervals, such as the Carnian/Norian boundary. The purpose of this study was to examine the uppermost Norian and Rhaetian pectiniform conodonts in detail in an attempt to determine their phylogenetic relationships, by applying novel phylogenetic methodologies that incorporate both morphological and stratigraphic data. This work was based on the conodont assemblages from the Upper Triassic strata of the Lagonegro Basin (southern Apennines, southern Italy) and the Csővár area (north-central Hungary), complemented with considerable data from the literature. Only figured specimens with exact positions on stratigraphic logs were utilized from previous studies (Karádi et al., 2019). The calibrated phylogenetic analysis of the uppermost Norian and Rhaetian conodonts supports a two-step evolutionary history. The first radiation includes the development of the *Parvigondolella* species and *Misikella hernsteini*, the first representative of the genus *Misikella*, in the Late Norian (~211-210 Ma). The second radiation phase took place in the Norian-Rhaetian boundary interval (~206.5-205 Ma) and led to the f inal radiation of the *Misikella* species. The refinement of their phylogenetic relationships and stratigraphic ranges allowed the subdivision of the upper Sevatian hernsteini Zone to two subzones (Rigo et al., 2018; Karádi et al., 2019). The lower boundary of Subzone 2 is marked by the first appearance datum (FAD) of *Misikella koessenensis* and *Misikella kolarae*. Even if rare in the latest Sevatian, the appearance of these species just before the FAD of *Misikella posthernsteiniis* a good proxy for the Norian-Rhaetian boundary interval. The morphocline between *Misikella hernsteini* and *Misikella posthernsteiniin* this interval was observed also in the successions of the Csővár area. This makes the FAD of *Misikella posthernsteini* easy to recognize and enables precise global correlation. This datum is therefore strongly supported to be the most suitable for defining the base of the Rhaetian Stage.

Karádi V., Cau A., Mazza M. & Rigo M. (2019) - The last phase of conodont evolution during the Late Triassic: integrating biostratigraphic and phylogenetic approaches. Palaegeography, Palaeoclimatology, Palaeoecology. (accepted).

Rigo M., Mazza M., Karádi V. & Nicora A. (2018) - New Upper Triassic Conodont Biozonation of the Tethyan Realm. In: Tanner L.H. Ed., The Late Triassic World: Earth in a Time of Transition. Topics in Geobiology, 46, 189-235.

The East Mediterranean Triassic Gondwana-Land margin of the Tethyan oceans

Kilic A.M.*[1], Sengor A.M. C.[2] & Hirsch F.[3]

[1] Department of Geological Eng., Balikesir University, Turkey. [2] Istanbul Technical University, Eurasia Institute of Earth Sciences and Department of Geology, Istanbul, Turkey. [3] Laboratory of Geology, Faculty of Sciences, Naruto University, Naruto, Japan.

Corresponding author email: alimurat@balikesir.edu.tr

Keywords: Triassic, conodont, province, Turkey, Taurides.

Triassic conodont faunal assemblages define provinces that witness the plate amalgamation of the present Turkish landmass and beyond. During the last twenty years, samples were collected from Triassic outcrops in the Kocaeli Peninsula, the Karaburun Peninsula, the Central Pontides and the Taurus Belt in Turkey belonging to different tectonic units. A comparison of the conodont fauna of these four realms points to the following statements up; The conodont *Pseudofurnishius murcianus* characterizes the Sephardic faunal Province (Hirsch, 1972), the northern border of which was first found in the Pisidian Triassic, sweeping Lake Beysehir. Lately it can be traced southwards as far as Northern Cyprus and westwards till Fethiye, where its presence in the Lycian Nappes gives a new meaning to the faunal province in the Taurides (Kilic et al., 2017). This suggests that the entire Menderes-Taurus Block was a part of the sephardic facies realm, as the Lycian nappes stem from the western part of this block. Contrary to earlier views, west of Lake Beysehir a continuation of the Tethyan Biofacies does not penetrate within the Sephardic Biofacies. In the Karaburun Peninsula, which is part of the Bornova Flysch, a part of the Neo-Tethyan northern sutures, the red pelagic limestone Laleköy Formation is characterized by Late Anisian conodonts that represent the complete multielement apparatus of *Gladigondolella tethydis*, thus of Tethyan affinity. In Cesme (Izmir), the conodont *Kamuellerella* occurs. New data from the Anisian - Carnian pelagic Kayabasi Limestone (Hallstatt facies of the Küre Complex), Central Pontide Supercomplex (CPS), put in evidence *Gladigondolella tethydis.* Never a conodont was given a better name, as this taxon typifies the low latitude pelagic Tethys environment. *G. okayi*, provides the CPS a local touch within the Hallstatt Kayabasi that is so far unique in the Tethys. This locality was a part of the Palaeo -Tethyan oceanic realm. The Kocaeli Triassic of the Istanbul Zone is a part of the North Tethyan Intra - Pontide Ocean. Here, the type locality of the Bithynian substage (Lower Anisian) yields a conodont fauna that is similar to the Golobardo fauna in Bulgaria, in which the group of *Paragondolella bulgarica* is dominant. The unprecedented Bithynian- Early Pelsonian appearance of *Kamuellerella – Ketinella – Gedikella* (KKG), unexplained without paleoclimatic data, suggests a Middle Triassic (Bithynian) *Propontis Faunal Sub-province* as a part of the Northern Neo-Tethyan Intra–Pontide Ocean. Next to *Nicoraella kockeli*, both *Paragondolella* and *Gladigondolellid* apparatus elements are present. The latter suggest a pelagic environment, whereas the small size of most of the fauna and a high rate of endemic taxa may be the result of exceptionally warm conditions.

This study was supported by Tubitak Grant 116Y374.

Hirsch F. (1972) - Middle Triassic conodonts from Israel, southern France and Spain. Mitteilungen der Gesellschaft der Geologie- und Bergbaustudenten, Innsbruck, 21, 811-828.

Kilic A.M., Cam G. & Senturk S. (2017) - Distribution of acuminate Gondolellidae (Conodonta) in the para-autochthonous Triassic of Southern Turkey. 18th Paleontology-Stratigraphy Workshop, September 28-30 2017, Abstracts Book, Chamber of Geological Engineers of Turkey 2017, 75-76.

Triassic conodont zonation of Slovenia

Kolar-Jurkovšek T.*[1] & Jurkovšek B.

[1] Geological Survey of Slovenia, Ljubljana, Slovenia.
[2] Independent researcher.

Corresponding author email: tea.kolar-jurkovsek@geo-zs.si

Keywords: Triassic conodont zones, Permian-Triassic boundary, Luka section, Slovenia

Conodont studies in Slovenia included extensive sampling of the Triassic marine carbonate rocks of the Southern and Eastern Alps, External Dinarides and the transitional area between the External and Internal Dinarides. A total of 34 Triassic conodont zones and two subzones have been distinguished. The Permian-Triassic boundary (PTB) interval strata are characterized by the genera *Hindeodus* and *Isarcicella*, and very rare presence of gondolellids. The Luka section represents a key section to define the PTB strata in Slovenia, as well as in the wider Dinarides area. Dienerian and Smithian strata are marked by the genera: *Eurygnathodus, Foliella, Hadrodontina, Pachycladina* and *Platyvillosus*, whereas in the Spathian *Triassospathodus* prevails. Following Lower Triassic zones can be recognized: *parvus, lobata, isarcica-staeschei, postparvus, aequabilis, anceps, costatus, obliqua, gardenae, corniger, regularis, hungaricus, symmetricus, homeri-robustispinus* in *triangularis* Zones. The Middle and Upper Triassic zones are largely comparable to conodont zones elsewhere in the world. Middle Triassic faunas are indicated by the presence of *Budurovignathus, Neogondolella* and *Paragondolella,* which enable the recognition of the following zones: *bulgarica, bifurcata, constricta, trammeri, hungaricus* and *mungoensis* Zones. In the Longobardian strata of central Slovenia *Pseudofurnishius murcianus* occurs, which designates the zone with the same name. This species is a typical element of the Sephardic province characterized by partly endemic faunas of the western Tethys and its marginal seas. *P. murcianus* is therefore an important paleobiogeographic marker. The distingushed Carnian zones are based on *Carnepigondolella, Paragondolella* and *Quadralella*, in a succession follow: *polygnathiformis, praelindae, tuvalica-carpathica* and the *pseudodiebeli-zoae* Zones, which are comparable to the zones of the standard conodont zonation. The only difference is the Julian-?early Tuvalian zone, with monofauna of *Nicoraella* **?** *budaensis* which designates the *budaensis* Zone and indicates the stressful conditions of the Carnian Pluvial Event; the species is an important regional marker. From the lower Norian until the end-Triassic, a noticeable decline in conodonts is demonstrated in the cycle *Epigondolella, Mockina, Parvigondolella* and *Misikella*. The following succession of the zones was identified: *rigoi-quadrata, triangularis, postera, bidentata, andrusovi-hernsteini, posthernsteini* (divided into the *hernsteini-posthernsteini* and *koessenensis* Subzones) Zones and one Unnamed Zone. The latter corresponds to the *ultima* Zone, which to date has been documented in the eastern part of the Dinarides area.

Kolar-Jurkovšek T. & Jurkovšek B. (2019) - Konodonti Slovenije / Conodonts of Slovenia. Geološki zavod Slovenije, Ljubljana, 260 pp.

Clusters of *Pseudofurnishius murcianus* in the Triassic strata of Slovenia

Kolar-Jurkovšek T.*[1], Martínez-Pérez C.[2-3], Jurkovšek B.[4] & Aljinovi D.[5]

[1] Geological Survey of Slovenia, Ljubljana, Slovenia. [2] Cavanilles Institute of Biodiveristy and Evolutionary Biology, University of Valencia, Spain. [3] School of Earth Sciences, University of Bristol, United Kingdom. [4] Independent researcher. [5] Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Croatia.

Corresponding author email: tea.kolar-jurkovsek@geo-zs.siì

Keywords: Triassic, central Slovenia, conodont biostratigraphy, conodont clusters, apparatus reconstruction.

We report a recovery of an abundant monospecific conodont association with *Pseudofurnishius murcianus* from the strata at Prikrnica in the central Slovenia that have been known to yield conodont clusters (Krivic & Stojanovič, 1978; Ramovš, 1978; Kolar-Jurkovšek et al., 2018). Triassic limestones with *Pseudofurnishius* were deposited at the southern edge of the Slovenian Basin. The Prikrnica section is situated in the transitional region between the External and Internal Dinarides. More than 3500 conodont elements, including over 300 clusters, provide evidences of exceptional preservation due to sudden burial by gravity flow redeposition processes. The environment conditions, together with the high sedimentation rates, and probably the presence of microbial mats at the sea floor, identified in several parts of the section, could have favored low decay rates, increasing the chances of the clusters preservation. The strata were deposited in a relatively deep, pelagic environment of the Slovenian Basin located in the western part of the Tethys. The age of the strata with clusters is within the stratigraphic range of the species *P. murcianus*, the marker of the late Ladinian-earliest Carnian *murcianus* Zone (Kolar-Jurkovšek & Jurkovšek, 2019). Triassic strata of central Slovenia show a great potential for the finding of new complete clusters that are very rare from the Triassic record of the world and are an important source of information for apparatus reconstruction. Together with the application of novel tomographic techniques finding of complete clusters would allow reconstruction of the *P. murcianus* apparatus in the future.

Kolar-Jurkovšek T., Martínez-Pérez C., Jurkovšek B. & Aljinović D. (2018) - New conodont clusters of *Pseudofurnishius murcianus* from the Middle Triassic of Slovenia (Dinarides). In: Over D.J. & Henderson C.M. Eds., Conodont Studies Dedicated to the Careers and Contributions of Anita Harris, Glen Merrill, Carl Rexroad, Walter Sweet, and Bruce Wardlaw. Bulletins of American Paleontology, 395-396, 149-163.

Kolar-Jurkovšek T. & Jurkovšek B. (2019) - Konodonti Slovenije /Conodonts of Slovenia. Geološki zavod Slovenije, Ljubljana, 260pp.

Krivic K. & Stojanovič B. (1978) - Konodonti v triadnem apnencu pri Prikrnici/Conodonts from the Triassic limestone at Prikrnica. Geologija, 21, 41-46.

Ramovš A. (1978) - Mittleltriassische Conodonten-clusters in Slowenien, NW Jugoslawien. Paläontologische Zeitschrift, 52, 129-137.

Conodont biostratigraphy and Carbon isotopic excursions from uppermost Permian to Lower Triassic at Yiwagou Section from Tewo, Gansu Province, northwestern China

Li H.X.[1], Zhang M.H.[1], Chen Y.L.[2], Donghan X.S.[1], Jiang H.S.[1], Wignall P.B.[3], Wu B.J.[1], Zhang Z.T.[1], Ouyang Z.M.[1] & Lai X.L.*[1]

[1] China University of Geosciences, China. [2] Northwest University, USA. [3] University of Leeds, UK.

Corresponding author email: xllai@cug.edu.cn

Keywords: conodont, early Triassic, Yiwagou, Qinling, MRBs.

The period from end Permian to early Triassic was a special time marked by a series of biotic crisis and environmental changes. The ~252-Ma end-Permian mass extinction, which was the most severe one in the geological history, removed the majority of marine organisms and led to the collapse of Paleozoic ecosystem. Afterwards, a delayed and sluggish ecosystem recovery of early Triassic ecosystem was hindered by the repeated biotic crises, especially around the Smithian-Spathian transition, ~1.5 million years later. During this period, the Qinling area was a major seaway between the South China and Northern China blocks. The studied Yiwagou Section was located in a shallow-water, carbonate platform on the southern ridge of the Qinling area and also at the northern margin of South China Block. 160 conodont samples and 298 carbon isotopic samples were collected from the upper Changhsing Formation (P_{3ch}), the Zhalishan Formation (T_{1z}), and the lower Maresongduo Formation (T_{1m}) at Yiwagou, which enables us to establish a conodont biostratigraphic framework with six zones, they are in ascending order, *Hindeodus parvus* Zone, *Eurygnathodus costatus* Zone, *Novispathodus waageni*-*Scythogondolella mosheri* Assemblage Zone, *Pachycladina*-*Parachirognathus* Assemblage Zone, *Triassospathodus triangularis*-*Triassospathodus hungaris* Assemblage Zone and *Neospathodus robustispinus* Zone. There is a blank interval about 190 meters where no conodont samples were collected between *Hindeodus parvus* Zone and *Eurygnathodus costatus* Zone. According to obtained conodonts and carbon isotopic excursions, the Permian/Triassic boundary should be located at the base of *Hindeodus parvus* Zone, the Dienerian/Smithian boundary could be approximately put in *Eurygnathodus costatus* Zone or lower, and the Smithian/Spathian boundary is in the upper part of *Pachycladina*-*Parachirognathus* Assemblage Zone. Unexpectedly, some *Hindeodus postparvus* survived into Dienerian or even early Smithian, probably due to the special environments at Yiwagou.

The peak warmth and anoxia in early Triassic are considered to coincide with the middle/late Smithian boundary where, however, is represented by oxic Marine Red Beds (MRBs) at Yiwagou. A small number of MRBs first appear within the lower Zhalishan Formation in Induan. Then in Smithian, the MRBs roughly increase upwards, and almost occupy the whole middle/late Smithian horizon, along with a negative excursion in $\delta^{13}C$ with values from +7.29‰ to -1.31‰, and MRBs gradually interrupt around the Smithian/Spathian boundary when the $\delta^{13}C$ begin to shift positively. The $\delta^{13}C$ values increased to the maximum of +6.48‰ in early Spathian, and MRBs emerge again at large scale in Maresongduo Formation later in Spathian. These phenomena likely record fluctuating water depth and well ventilated seawater in the southern Qinling Basin.

Late Eifelian (Middle Devonian) Geoevent: timing and characterizing of the Kačák Episode in the Iberian Peninsula (Spain)

Liao J.-C.*[1], Valenzuela-Ríos J. I.[1], García-López S.[2] & Carls P.[3]

[1] University of Valencia, Spain. [2] University of Oviedo, Spain. [3] University of Braunschweig, Germany.

Corresponding author email: jau.liao@uv.es

Keywords: Conodont, global geoevent, Kačák Episode, Late Eifelian, Middle Devonian, Iberian Peninsula.

The Late Eifelian Geoevent is marked by some physical and biotic changes in the marine realm. The most recognized globally are the *Kačák* Event (House, 1985) and the *Otomari* Event (Walliser, 1985). Walliser & Bultynck (2011) proved that the *Kačák* Episode (KE) recorded in south-eastern Morocco contains two different levels: Late Eifelian Event 1 and 2 (LEE 1, LEE 2). The thickness of this interval varies from 0.5 to 2.5 meters. A Middle Devonian conodont database from three selected areas in the Iberian Peninsula, allows the recognition of similar lithologic and associated biotic changes, which is the characteristic expression of the KE. The analysis of each event is based on the extinction, surviving and innovation of conodont species. The precise biostratigraphical age control in each section allows the description of the faunal content from the uppermost Eifelian (*kockelianus-ensensis* zone) to the base of the Givetian (*hemiansatus* zone) interval. Six successions from the Central Pyrenees (Renanué, Re and La Guàrdia d'Ares, LGA), the Palentine Domain (Las Verdes, LV, El Calero, C-CAL and Monderrío, MR) and the Iberian Range (Camino de Molino, CMOL) have been studied. 63 conodont samples yielded 26 taxa grouped into five genera. In the Central Pyrenees, only the Re section shows lithological changes; there, the upper event level, LEE2 is identified, meanwhile in the LGA section, both event levels are recognized. In the Palentine Domain, the three sections show the most significant lithologic and biotic changes within the Man Mb. The fossil record suggests that LEE 1 is identified in two sections, MR and LV. LEE 2 is identified only in MR section. In the Iberian Range, the CMOL section exhibits the lithological change and shows a slightly evidence of part of LEE 2 at the lower part of the outcrop. The *Polygnathus angusticostatus* group becomes extinct earlier in the Palentian and Iberian Range sections (LEE 1) than in the Pyrenean ones (LEE 2). *Icriodus regularicrescens* disappears earlier in MR (LEE 1) than in Re (LEE 2). *I. struvei* and *I. amabilis* are survival species and cross LEE 1, or reach slightly above LEE 2, in the three areas. The *Po. pseudofoliatus* group becomes extinct in LEE 2 or higher in the three areas. *Po. hemiansatus* and *I. obliquimarginatus* are innovative species with first occurrences in LEE 2 or above and this innovation pattern is similar in the three areas.

House M.R. (1985) - Correlation of mid-Palaeozoic ammonoid evolutionary events with global sedimentary pertubations. Nature, 313, 17-22.

Walliser O.H. (1985) - Natural boundaries and Commission boundaries in the Devonian. Courier Forschungsinstitut Senckenberg, 75, 401-408.

Walliser O.T. & Bultynck P. (2011) - Extinctions, survival and innovations of conodonts species during the Kačák Episode (Eifelian-Givetian) in south-eastern Morocco. Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, Sciences de la Terre, 81, 5-25.

Conodont faunas across the Kasimovian-Gzhelian boundary (Late Pennsylvanian) in South China

Qi Y.*[1], Barrick J.[2], Hogancamp N.[3], Chen J.[1], Hu K.[1] & Wang Q.[1]

[1] Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, China.
[2] Texas Tech University, USA. [3] Hess Corporation, USA.

Corresponding author email: ypqi@nigpas.ac.cn

Keywords: Conodonts, Kasimovian-Gzhelian boundary, South China.

Although the first appearance of *Idiognathodus simulator* has been selected to mark the base of the Gzhelian Stage (Heckel et al., 2007), a GSSP has yet to be selected. One hindrance to the selection of a GSSP has been the lack of stratigraphic sections in which the lineage leading to *I. simulator* can be demonstrated. The type material of the species *I. simulator* is from the Heebner Shale in the North America Midcontinent region, and the species of the *I. simulator* group from the Heebner have been well studied (Barrick et al., 2008; Hogancamp et al., 2016), and the species concepts better defined. However, no potential ancestral forms to *I. simulator* occur in the immediately underlying units (Barrick et al., 2013; Hogancamp & Barrick, 2018). Conodont faunas across the Upper Pennsylvanian Kasimovian-Gzhelian boundary interval in Guizhou Province, South China, comprise a mixture of the endemic and cosmopolitan species. The Naqing and Narao sections preserve continuously deposited successions of deep water, slope to basinal carbonates. A newly recognized group of endemic late Kasmiovian to early Gzhelian species of *Idiognathodus,* with new species *I. luosuensis, I. naraoensis*, *I. fengtingensis, I. luodianensis,* and *I. naqingensis*, display increasing asymmetry in P_1 element pairs across the K-G boundary. Platform landmark analysis demonstrates that the South China species differ in morphological features from co-occurring cosmopolitan species of the *I. simulator* group, which also possess asymmetrical P_1 element pairs. Just below the level where the index for the base of the Gzhelian, *I. simulator,* appears, $\delta^{13}C$ falls 2‰. Just above the $\delta^{13}C$ excursion, many Kasimovian species disappear and several species first appear with *I. simulator*, including two new endemic species of *Streptognathodus, S. nemyrovskae* and *S. zhihaoi,* and three of the endemic *Idiognathodus* species, *I. fengtingensis, I. luodianensis,* and *I. naqingensis* The association of the negative $\delta^{13}C$ excursion with the abrupt faunal turnover in the South China sections suggest that an oceanic event may occur at the K-G boundary. This boundary event may be an example of a widespread and correlatable "natural boundary" (Walliser, 1985; Lucas, 2018) that could be used to best define the base of the Gzhelian. This boundary level could be correlated from the South China sections using either biostratigraphy or chemostratigraphy, and one of the South China sections would be an appropriate location for the GSSP.

Barrick J.E., Heckel P.H. & Boardman D.R. (2008) - Revision of the conodont Idiognathodus simulator (Ellison, 1941), the marker species for the base of the Late Pennsylvanian global Gzhelian Stage. Micropaleontology, 54, 125–137.

Barrick J.E., Lambert L.L., Heckel P.H., Rosscoe S.J. & Boardman D.R. (2013b) - Midcontinent Pennsylvanian conodont zonation. Stratigraphy, 10, 1–18.

Heckel P.H., Alekseev A.S., Barrick J.E., Boardman D.R., Goreva N.V., Nemyrovska T.I., Ueno K., Villa E. & Work D.M. (2007) - Cyclothem ("digital") correlation and biostratigraphy across the global Moscovian–Kasimovian–Gzhelian Stage boundary interval (Middle–Upper Pennsylvanian) in North America and Eastern Europe. Geology, 35, 607–610.

Hogancamp N.J. & Barrick J.E. (2018) - Morphometric analysis and taxonomic revision of North American species of the Idiognathodus eudoraensis Barrick, Heckel & Boardman, 2008 group (Missourian, Upper Pennsylvanian conodonts). Bulletins of American Paleontology, 395/396, 35-69.

Hogancamp N.J., Barrick J.E. & Strauss, R.E. (2016) - Geometric morphometric analysis and taxonomic revision of the Gzhelian (Late Pennsylvanian) conodont Idiognathodus simulator from North America. Acta Paleontologica Polonica, 61, 477-502.

Lucas S.G. (2018) - The GSSP Method of Chronostratigraphy: The GSSP Method of Chronostratigraphy: A Critical Review. Frontiers in Earth Science, Published online 06 November 2018. https://doi.org/10.3389/feart.2018.00191

Walliser, O.H. (1985) - Natural boundaries and the Commission boundaries in the Devonian. Courier Forschungsinstitut Senckenberg, 75, 401-408.

A high resolution (<10 Ka) record of Pridoli conodont ecological dynamics in relation to bioevents

Spiridonov A.*[1-2], Gečas T.[1], Brazauskas A.[1], Kaminskas D.[1], Kaveckas T.[1], Stankevič R.[1], Bičkauskas G.[1], Meidla T.[3], Ainsaar L.[3] & Radzevičius S.[1]

[1] Vilnius University, Lithuania. [2] Nature Research Centre, Lithuania. [3] University of Tartu, Estonia.

Corresponding author email: s.andrej@gmail.com

Keywords: Conodonts, recurrence plots, cyclostratigraphy, biotic events, macroecology, biotic transitions.

Pridoli, the final epoch of Silurian period, was a transformational time where significant changes in conodont and gnathostome vertebrate communities occurred. The conodont record is punctuated at least by two events: Klev at the beginning, and Klonk near the end of the time interval. The $\delta^{13}C$ excursion is associated with the latter biotic turnover, which indicates grand changes in biogeochemistry and climate. In the late L. Jeppsson's works it is suggested that there are possibly two more putative conodont biotic events: in the early Pridoli and in the middle of the epoch. In order to test the presence, and the effects of known and hypothesized events, we gathered massive stratigraphic time series of 400 conodont collections (samples) from Milaičiai-103 core which span the whole Pridoli and continue in to Ludlow. Conodonts were studied from the standpoint of taxonomic and total abundance changes. The presented conodont material is accompanied by the gamma ray log, total organic carbon (TOC) estimates and other physical/chemical environmental proxies. The numerical analyses revealed the complex hierarchies of cycles in both environmental variables (e.g. TOC) and also in total conodont abundances. Nevertheless, even though cyclic patterns of change could be observed in conodonts and environmental proxies, the dominant component differs. Changes in conodont abundance are strongly modulated by long term periodicities (> 1 Ma). In addition our data support the occurrence of hypothesized Jeppsson's event in the middle and especially in the early part of the Pridoli. There is almost complete absence of conodonts in a prolonged (many hundreds of Ka) interval despite very insignificant changes in facies at the middle part of the early Pridoli.

This study was supported by the grant from Lithuanian Science Foudation 09.3.3-LMT-K-712-02-0036.

Early and Middle Triassic at the peri-Gondwana margin: integrated bio-chemostratigraphy, sedimentology and trace metal geochemistry at Spiti, Indian Himalaya

Sun Y.D.*[1], Richoz S.[2], Krystyn L.[3], Joachimski M.M.J.[1] & Grasby S.E.[4]

[1] GeoZentrum Nordbayern, Universität Erlangen-Nürnberg. [2] Department of Geology, Lund University. [3] Department of Palaeontology. [4] Geological Survey of Canada.

Corresponding author email: yadong.sun@fau.de

Keywords: Spiti, Early Triassic, Middle Triassic, conodont biostratigraphy, carbon isotope chemostratigraphy.

The Lilang Super Group in the Spiti area, Indian Himalaya documented a continuous sedimentation from the earliest Triassic to the Late Triassic, offering a unique window for Triassic research at the East Gondwana margin. This study focuses on the Mikin and Kaga formations at Muth and Guling of the Pin Valley. The studied strata represent a condensed, mixed carbonate and siliciclastic basinal setting and range from the Griesbachian to the Longobardian (Late Ladinian). Shales are the main type of siliciclastic rock and developed mainly in the Dienerian, Smithian and Aegean. Carbon isotope ratio of carbonate (δ13Ccarb) of the studied interval shows an increase from -2.6 to 0 ‰ from the Griesbachian to the Dienerian-Smithian transition. This is followed by a negative excursion to -3 ‰ in the Smithian and a large positive excursion from -3.0 to 3.5 ‰ across the Smithian-Spathian (S-S) boundary. A short negative shift to -1 ‰ is registered in the early Spathian and followed by a secular positive trend from ~-1 to 1 ‰ in the middle Triassic, with several minor excursions occurring in the Aegean. Carbon isotope ratio of total organic carbon (δ13Corg) co-varies with δ13Ccarb, suggesting both likely represent the original isotopic signatures. The Mo/Al ratio, a proxy for redox variations, decreases from ~0.92 to ~0.12 from the Griesbachian to the Dienerian and remains at low values <0.1 up-section, indicating a dysoxic to possibly fully oxygenated environment from the late Dienerian onward. Ti/Ca ratio, a proxy for continental input, increases in the later Dienerian and the S-S transition, coinciding with the development of two shaly intervals. The Anisian of Spiti saw occurrences of phosphate nodules—a feature which is absent globally in the Early Triassic but also seen in the Anisian of Spitsbergen and Canadian Arctic. The reoccurrence of phosphate nodules in the Middle Triassic likely suggests a global decrease of anoxic water, in which phosphorus is often released and recycled from sediments. Compared to coeval sections at equatorial latitudes, the Muth and Guling successions contain much more diverse ammonoid and conodont faunas. This may attribute to the more southern positioned setting of the region and oxygenated water provided a more favourable habitat for groups with higher mobility to escape the harsh environments at the equatorial low latitudes.

Comparison of the chemical and isotopic composition of Lower Palaeozoic conodonts and the grasping spines of chaetognaths

Szaniawski H.*[1], Wierzbowski H.[2] & Blażejowski B.[1]

[1] Institute of Paleobiology, Polish Academy of Sciences, Warsaw, Poland.
[2] Polish Geological Institute - National Research Institute, Warsaw Poland.

Corresponding author email: szaniaw@twarda.pan.pl

Keywords: Conodonts, Chaetognaths, Cambrian, Ordovician.

Co-occurring at the boundary of the Cambrian and Ordovician, the conodont genus *Cordylodus* and the grasping spines of chaetognaths of the genus *Phakelodus* were investigated using an electron (CAMECA SX100) and an ion microprobe (SHRIMP IIe/MC) at the Micro-area Analysis Laboratory of the Polish Geological Institute - National Research Institute. The studies have revealed that the *Phakelodus* spines are built of a thin (up to ca. 10 µm), outer layer which consists of densely arranged pure fluorapatite crystals and a much thicker middle layer (perhaps with traces of the inner layer) comprising a loosely bound, clouded structure whose composition is similar to that of diagenetic apatite infillings occurring in some parts of the open, internal voids of the spines. It is worth noting that a dense outer layer, corresponding to the cuticle of modern forms, which might have been precipitated during the growth of the animal, seems not to be present in all samples. The ion microprobe analyses of 5 *Phakelodus* samples have shown low and variable δ18O values, which range from 7.4 to 13.5‰ VSMOW. They are much lower than those of co-occurring conodonts of the *Cordylodus* genus (14.5 to 16.0‰ VSMOW). These studies confirm a separate systematic affiliation of the grasping spines of Phakelodus and conodonts, which was postulated earlier by Szaniawski (1982, 2002).

This study has been supported by the Polish National Science Center, grant No. 2016/21/B/S10/02334.

Szaniawski H. (1982) - Chaetognath grasping spines recognised among Cambrian protoconodots. Journal of Paleontology, 56, 806-810.
Szaniawski H. (2002) - New evidence for the protoconodont origin of chaetognaths. Acta Palaeontologica Polonica, 47, 405-419.

Conodonts as a tool for challenging Geodynamic interpretations: two examples from the Devonian of the Spanish Pyrenees

Valenzuela-Ríos J.I.* & Liao J.-C.

University of Valencia

Corresponding author email: jose.i.valenzuela@uv.es

Keywords: Conodonts, structural geology tools, Spanish Pyrenees.

Conodonts have been proven to be excellent tools for applied Geology (bio and chronostratigraphy, thermal maturity, global correlations, palaeoenviromental interpretations,…) This report shows one further application for testing and controlling Regional Geology interpretations. Structural geologists working in the Pyrenean Palaeozoic considered for a long time that the development of black facies, composed mainly of black shales with subordinate black limestone, were restricted to the Silurian, and consequently, the Devonian started with the overlain clear colour, well bedded limestone. Moreover, they considered this black facies as a Silurian detachment level upon which they based they reconstructions on the Pyrenean basin. Detailed conodont studies across this facies shift have proven it to be diachronic and always happening in the upper part of the lower Lochkovian or the lower part of the middle Lochkovian (Lower Devonian). Consequently, these conodont data force Structural Geologists to change their interpretations. A second case is more locally identified and we are only aware of it in the Segre thrust sheet of the Compte Subfacies. The Middle and Upper Devonian of this subfacies is characterised by a continuous sequence of nodular condensed limestone with variegated colours being grey and red dominant. The marked grey to red change coincides with the base of La Mena Formation, developed in the typical "griotte facies" and, although diachronic as conodonts demonstrate, is always placed in the Lower Famennian. A detailed conodont study in one quarry demonstrates the presence of a paraconformity between the underlain Comabella Fm. and the succeeding La Mena Fm. Conodonts prove that the highest stratigraphic level of the Comabella Fm. is Givetian in age (rhenanus/*varcus* Zone), while the immediately higher level of the La Mena Fm. rendered Famennian conodonts (between the upper *crepida* and lower *rhomboidea* Zones). This information demonstrates the presence of a large gap in time, which is not evident by the apparent continuity of strata, comprising the Middle and Upper Givetian, all Frasnian and part of the Lower Famennian and, therefore, urges the revision of former interpretation considering an overall continuos sedimentation for Middle and Upper Devonian strata in the Pyrenean basin.

Landmark based geometric morphometric analysis of selected Lower Norian conodonts

Virág A.1, Szabó B.2 & Karádi V.*2

[1] MTA-MTM-ELTE Research Group for Paleontology, Budapest, Hungary. [2] Department of Palaeontology, Eötvös Loránd University, Budapest, Hungary.

Corresponding author email: kavik.geo@gmail.com

Keywords: Lower Norian, conodonts, landmark analysis.

Conodont taxa that are applied for biostratigraphic subdivision of the Lower Norian in the Tethyan Realm are relatively long-ranged and morphologically variable species. The most critical is the case of *Epigondolella rigoi*, which is basically a wastebasket taxon for those specimens that have a triangular, posteriorly unornamented platform. Landmark analysis, rarely applied on Triassic conodonts, is a promising method that might help revealing intraspecific variability and significant shape differences in such issues. Since the shape of the conodont elements varies greatly (e.g. number of denticles, presence or absence of the anterior trough margin, shape of the keel termination), a sufficient number of traditional anatomical landmarks is hard to find. Instead, we focused mainly on type II (geometrically defined points) and type III (points registered equidistantly on the outline) landmarks. These were digitized automatically using a program developed for this purpose in a software environment called R (v. 3.5.2). Points were registered on scanning electron micrographs of lateral and lower views of 38 conodont specimens. To understand if and how the method is able to separate taxa, first we compared *E. quadrata* with *Metapolygnathus mazzai*, which differ on a generic level. In the second phase, other representatives of genus *Epigondolella* were added, *E. rigoi, E. triangularis* and *E. uniformis*, respectively. To eliminate unnecessary variation in position of the points, as well as in size, and orientation of the specimens, the raw landmark configurations were superimposed on each other using the centroid as a fixed reference point. The centred configurations were then rescaled to the same size and rotated until the minimum sum of squared distances between the landmarks and their corresponding sample average position is reached. The resulting coordinates are the Procrustes shape coordinates, on which a principal component analysis (PCA) was performed. The method was able to clearly separate *M. mazzai* from *E. quadrata* based on the number of denticles in the posterior carina behind the cusp, and the position of the pit and the cusp relative to the centre of the platform. When combining the data of all five taxa, the most important factors of the separation are the width of the posterior platform relative to the anterior part, and the overall width of the entire platform. The shape of the posterolateral corners (from rectangular to rounded) also plays an important role. Combining the data obtained from both the lateral and lower views reduces the overlaps between the morphospaces that each species occupies separately. Presumably, by improving the data acquisition method and by raising the sample numbers, a more accurate separation can be achieved. This might help solving some taxonomic issues that hamper the development of the Norian conodont biostratigraphy.

This study was funded by the NKFIH FK 128741 project.

Upper Norian to Rhaetian conodont biostratigraphy of the Panthalassic Ocean and the final extinction of conodonts at the end-Triassic

Yamasaki K.*[1], Tomimatsu Y.[1], Onoue T.[2] & Rigo M.[3]

[1] Kumamoto University, Japan. [2] Kyushu University, Japan. [3] University of Padova, Italy

Corresponding author email: 187d8164@st.kumamoto-u.ac.jp

Keywords: Conodont, Triassic, Rhaetian, bedded chert, Japan, Panthalassa.

The Rhaetian stage was characterized by intense biological, climatic, and environmental changes, ending with the break-up of the supercontinent Pangaea and the end-Triassic mass extinction (ETE), one of the five Phanerozoic mass extinctions. Notably, the ETE appears to be associated with significant δ13C perturbations, commonly linked to the CAMP (Central Atlantic Magmatic Province) eruptive phases. The stratigraphic record of these environmental changes has been documented in Upper Triassic bedded chert successions in Japan, deposited within a Paleo-Pacific (Panthalassa) deep basin. The chronology of the Rhaetian pelagic sediments in the Panthalassic Ocean is based on radiolarian zones, which are well established in the Upper Triassic bedded chert successions in the Mino Belt, central Japan. Although accurate calibration of the chronostratigraphic stages and substages is based mainly on ammonites and conodonts, most of the Japanese radiolarian zones have been calibrated through correlation with zonal schemes established in other regions, lacking a direct calibration with conodont biostratigraphy. Here we present the Upper Norian to Rhaetian conodont biostratigraphy of an Upper Triassic bedded chert succession from the Mino belt, central Japan, where the radiolarian biostratigraphy has been investigated. Based on the stratigraphic distributions of marker species, four conodont zones are defined: the *Mockina bidentata*, *Misikella hernsteini*, *M. posthernsteini*, and *M. ultima* zones (in stratigraphic order). These conodont zones are comparable to the standard Upper Norian and Rhaetian conodont zones of the western Tethys. The Norian/Rhaetian boundary in the study section is tentatively placed between the last occurrence of a Norian radiolarian species (*Betraccium deweveri*) and first occurrences of Rhaetian conodont species (*M. posthernsteini*). The conodont–radiolarian biostratigraphy from this section accurately calibrates the radiolarian zones in Japan with standard chronostratigraphic stages and substages.

Late Triassic (Norian) multielement reconstruction of conodont apparatus (*Mockina*) base on clusters from Yunnan Province, southwestern China

Zeng W., Jiang H.* & Zhang M.

State Key Laboratory of Biogeology & Environmental Geology, School of Earth Sciences, China University of Geosciences, Wuhan, China.

Corresponding author email: jiangliuis@163.com

Keywords: Mockina, Conodont cluster, Norian, Yunnan, China.

Conodont clusters are known to provide the direct evidence for component, orientation and arrangement of conodont apparatus and thus play a significant role in reconstructing multielement taxonomy and skeletal architecture. In recent years, there have been increased reports of conodont clusters and natural assemblages in the Early and Middle Triassic, which are rather rare in the Late Triassic. Here, for the first time, nineteen fused conodont clusters were collected from upper Norian limestone beds of the Nanshuba Formation in Baoshao, Yunnan province, southwestern China. Based on well-preserved conodont clusters and associated discrete element collections, the composition and architecture of *Mockina* apparatus have been reconstructed. *Mockina* apparatus consists of seven distinct types of elements: a single alate (hibbardelliform) S_0 element, paired breviform digyrate (grodelliform) S_1 and (enantiognathiform) S_2 elements, paired bipennate (hindeodelliform) S_3 and S_4 elements, paired breviform di gyrate (cypridodellifrom) M elements, paired angulate (cratognathodontiform) P_2 elements and segminiplanate (mockiniform) P_1 elements. The orientation, position and arrangement of the S-M series in *Mockina* apparatus are well reconstructed from the *in-situ* preservation of Cluster L. The reconstructed 15-element skeletal structure of *Mockina* apparatus is similar as the ozarkodinid-style architecture and is in accord with that of some other conodont apparatuses in the superfamily Gondolelloidea, confirming the positional homology of grodelliform S_1 and enantiognathiform S_2 elements as well as demonstrating more details in the respect of relative position of elements.

Radiolarians and associated conodonts through the D-C boundary from bedded cherts of Bancheng section, Qinzhou city, southeastern Guangxi, South China

Zhang N.*[1], Jiang H.[1-2] & Wang G.[1]

[1] School of Earth Sciences, China University of Geosciences, Wuhan China.
[2] State Key Laboratory of Biogeology and Environmental Geology, School of Earth Sciences, China University of Geosciences, Wuhan, China.

Corresponding author email: zhangn@cug.edu.cn

Keywords: Devonian-Carboniferous boundary, radiolarians, conodonts, Hangenberg event, bedded chert, South China.

Through a section crossing the Devonian–Carboniferous (D-C) boundary, a radiolarian *Holoeciscus* 3 assemblage Zone and three interval zones including *Archocyrtium protowangi*, *Ar. wangi*, and *Albaillella paradoxa* zones were identified from the bedded cherts at Bancheng of Qinzhou City, southeastern Guangxi, South China. Seven associated conodont levels were recognized from the same section, which mark at least four conodont standard zones comprising Lower-middle **paesulcata,** Upper **paesulcata, sulcata,** and **duplicata** zones. The D-C boundary might be temporarily determined at the base of **sulcata** Zone. Since the **sulcata** and **duplicata** zones overlap the *Ar. protowangi* Zone and *Ar. wangi* Zone in principle, a radiolarian boundary would be identified at the base of Bed 125-5 by the first appearance of *Ar. protowangi*, which is the only 20 cm below of the conodont G-L boundary. Both boundaries are closely spaced and overlie a biotic barren horizon of reddish shale. This barren horizon is suggested to be equivalent to the Hangenberg event horizon.

Integrated conodont biostratigraphy, $\delta^{13}C_{carb}$ chemostratigraphy and U-Pb zircon chronology of Carnian in southwestern China

Zhang Z.T.[1], Sun Y.D.*[2] & Lai X.L.[1]

[1] China University of Geosciences (Wuhan), China. [2] Universität Erlangen-Nürnberg, Germany

Corresponding author email: yadong.sun@fau.de

Keywords: Conodont, carbonate carbon isotope, chronology, Carnina, South China.

Chronostratigraphic subdivisions of Late Triassic in South China were difficult to establish due to a lack of detailed studies in biostratigraphy, chemostratigraphy and radiometric chronology. We carried out conodont biostratigraphy, carbonate carbon isotope ($\delta^{13}C_{carb}$) chemostratigraphy and zircon U-Pb chronology studies in the Changdi and Caizitang sections at eastern Yunnan Province of South China. The sections consist of Zhuganpo and part of lower Wayao formations. The age of lower part of Zhuganpo Formation remains an open question because of the paucity of age-diagnostic conodont. The upper part of Zhuganpo Formation from both sections yield abundant and diversified conodonts, which dominated by the genera of *Pargondolella*, *Quadralella* and *Gladigondolella*, indicating an early Carnian age. Zircons from a volcanic ash bed in the upper Zhuganpo Formation of Changdi section were dated to 233.4±2.7 Ma. $\delta^{13}C_{carb}$ from Changdi are characterized by two minor negative fluctuations and a large negative perturbation, with $\delta^{13}C_{carb}$ values range from -5.2‰ to 3.6‰. The two minor negative perturbations of ~1-1.5‰ were registered in the lower part of Zhuganpo Formation, with $\delta^{13}C_{carb}$ values fluctuate between 0.2‰ and 2.7‰. The large negative excursion of ~7‰ is registered in the middle part of the Zhuganpo Formation, with $\delta^{13}C_{carb}$ values decrease from ~2‰ to -5.2‰. This is followed by a steady increase in $\delta^{13}C_{carb}$ from ~1.5‰ to ~2.8‰ until the uppermost of the Changdi section. $\delta^{13}C_{carb}$ from Caizitang section are characterized by two negative perturbations, with $\delta^{13}C_{carb}$ values range from -0.4‰ to 3.2‰. The first $\delta^{13}C_{carb}$ negative excursion of ~3‰ was recognized in the middle Zhuganpo Formation at Caizitang section. And the age of the first $\delta^{13}C_{carb}$ perturbation should not younger than early Carnian, constrained by the early Carnian conodont fauna in the overlying strata. The second $\delta^{13}C_{carb}$ negative shift of ~2.4 ‰ coincided with the transition from the nodular limestone of the Zhuganpo Formation to the black shale of the Wayao Formation at Caizitang, with $\delta^{13}C_{carb}$ decrease from 2‰ to –0.4‰. These marked the Carnian Humid Episode in the region. Our radiometric dating age of 233.4±2.7 Ma can provide additional age constraints for Carnian and roughly limits the lower age of Carnian Humid Episode in southwestern China.

ST2.3
Applications of cyclostratigraphy in understanding Earth history

Conveners and Chairpersons
Matthias Sinnesael (Vrije Universiteit Brussel)
Christian Zeeden (Leibniz Institute for Applied Geophysics)
Frits Hilgen (Utrecht University)

Grand cycles and Events in Earth's climate during the past 115 million years: a potential link

Boulila S.*[1-2]

[1] Sorbonne Université, CNRS, Institut des Sciences de la Terre Paris, ISTeP, Paris, France.
[2] ASD/IMCCE, CNRS, Observatoire de Paris, PSL University, Sorbonne Université, Paris, France.

Corresponding author email: slah.boulila@sorbonne-universite.fr

Keywords: Climate events, multi-Myr cycles, the last 115 Myr, benthic foraminifera $\delta^{18}O$.

Geological sediment archives document a rich periodic series of astronomically driven climate, but record also abrupt, severe climatic changes called events, the multi-Myr boundary conditions of which have generally been ascribed to acyclic processes from Earth's interior dynamics. These events have rarely been considered together within extended time series for potential correlation with long-term (multi-million year, Myr) cycling. Here I show a coupling between events and multi-Myr cycles in a temperature and ice-volume climatic proxy of the geological past 115 Myr. I use Cenozoic through middle Cretaceous climatic variations, as recorded in benthic foraminifera δ18O, to highlight prominent ~9 and ~36 Myr cyclicities. These cyclicities were previously attributed either to astronomical or tectonic variations. In particular, I point out that most of the well-known events during the past 115 Myr geological interval occur during extremes in the ~9 and ~36 Myr cycling. One exception is the early Cenozoic hyperthermal events including the salient Paleocene-Eocene Thermal Maximum (~56 Ma), which do not match extremes in long-period cyclicities, but to inflection point of these cycles. Specific focus on climatic events, as inferred from δ18O proxy, suggest that some "events", marked by gradual trends within the ~9 and ~36 Myr cycle extremes, would principally be paced by long-term cycling, while "events", recorded as abrupt δ18O changes nearby cycle extremes, would be rather induced by acyclic processes. The connection between cyclic and acyclic processes, as triggers or feedbacks, is very likely. Such link between cycling and events in Earth's past climate provides insight into celestial dynamics governing perturbations in Earth's surface systems, but also the potential connection between external and Earth's interior processes (Boulila, 2019).

Boulila B. (2019) - Coupling between Grand cycles and Events in Earth's climate during the past 115 million years. Scientific Reports, 9(1), 327. https://doi.org/10.1038/s41598-018-36509-7.

Rhythmic bedding in pelagic carbonates: long distance correlation of strata and their significance for the calibration of the Ladinian (Middle Triassic)

Brack P.*, Storck J.C. & Wotzlaw J.-F.

Department of Earth Sciences, ETH Zurich

Corresponding author email: peter.brack@erdw.ethz.ch

Keywords: Middle Triassic, calibrating sections, strata organization.

Rhythmic patterns in bedded pelagic sediments are often used for the temporal calibration of Cenozoic and Mesozoic stratigraphic intervals. However, only in few cases the lateral persistence and reproducibility of patterns has been tested at a bed scale. Here we report an unusual example from the Middle Triassic basinal Buchenstein Formation in the Southern Alps. The 30-70 m thick pelagic portion of this formation comprises fairly regularly bedded siliceous nodular limestones representing a time interval > 3 Ma (Storck et al., 2019). Distinct decimetric bedding potentially records periods of precession (Wotzlaw et al., 2018). Numerous sections hosting these decimetric beds as well as subsets of thinner strata can be traced over more than 150 kilometres and are scattered across irregularly shaped branches of variably but up to 900 m deep basins separated by high-relief carbonate platforms. Correlation of sections is further controlled by distributions of pelagic fossils, volcanic ash layers and magnetic reversals. Thickness of correlated sections varies by up to a factor of 2.5 while the proportions of stratigraphic intervals remain surprisingly stable. This variation seemingly depends on the distance of the basin positions relative to coeval carbonate platforms while individual beds and patterns persist almost to the toes of the slopes of the high relief features.

Except for the volumetrically subordinate remains of organisms including shells of macrofossils and remnants of foraminifera, the origin of the micritic carbonate remains as yet unknown. The systematic variations in thickness of individual layers (Maurer & Schlager, 2003) and entire stratigraphic intervals point to the carbonate platforms as an important source for exported muds. However, the volumes of platform derived carbonate redistributed in the coeval Buchenstein basins must have been small. A portion of this material could have been removed by currents but no sinks for such carbonate are evident. The identification of identical bedding patterns in different basin portions independent of the volume of accumulating material, suggests that local factors had little effect on the organization of strata. If time-periodic changes of climate and/or sea-level were indeed governing parameters these patterns may precisely calibrate the timing of these fluctuations.

Maurer F. & Schlager W. (2003) - Lateral variations in sediment composition and bedding in Middle Triassic interplatform basins (Buchenstein Formation, Southern Alps, Italy). Sedimentology 50, 1–22.

Storck J.C., Brack P., Wotzlaw J.W. & Ulmer P. (2019) - Timing and evolution of Middle Triassic magmatism in the Southern Alps (northern Italy). J. Geol. Soc. London, 176(2), 253-268.

Wotzlaw J.F., Brack P. & Storck J.C. (2018) - High-resolution stratigraphy and zircon U–Pb geochronology of the Middle Triassic Buchenstein Formation (Dolomites, northern Italy): precession-forcing of hemipelagic carbonate sedimentation and calibration of the Anisian–Ladinian boundary interval. J. Geol. Soc. London, 175(1), 71–85.

Precession and obliquity length extracted from a Devonian record from New York State, U.S.

Da Silva A.C.*1, Zeeden C.2, Hilgen F.J.3, Brett C.E.4, Bartholomew A.5, Ver Straeten C.6 & Dekkers M.J.3

[1] Liege University. [2] Hannover University. [3] Utrecht University. [4] Cincinnatti University. [5] New Palz University. [6] New York State Museum Albany.

Corresponding author email: ac.dasilva@uliege.be

Keywords: Milankovitch, Devonian, Precession.

Astronomical insolation forcing plays an important role in pacing Earth's climate (history) including (paleo)climate dynamics; its imprint can be seen in various geoarchives. The effects of insolation often show up in geological records through the expression of typical rhythmic patterns. While especially the 405 kyr component is stable through Earth history, the precession- and obliquity periods are expected to have been shorter further back in time. This is due to the conservation of momentum of the Earth-Moon system and the moon's increasing distance from Earth. Recently a new model was developed to extract the frequency of precession and obliquity, and also the underlying precession constant p, with their respective uncertainty from datasets, more specifically from their periodograms. Here we test this new model through its application to a remarkable dataset from the Devonian in New York State (U.S.A.). This record is spectacular because it shows very nice groups of 6-7 cycles (interpreted as precession) bundled into larger cycles (interpreted as short eccentricity). Magnetic susceptibility was measured at high resolution along this record. It allows to compare the results from spectral analysis to outcrop bundling results. This lends more confidence into the interpretation of the periodograms. The periodograms are subsequently processed through the model to extract the frequencies of precession and obliquity, as well as the precession constant. These results will be compared with other Devonian records.

An integrated magneto-bio-cyclostratigraphy of a new section from Gubbio disentangles the middle Eocene orbital tuning and sets a prospective Bartonian Stage GSSP

Dinarès-Turell J.*[1], Intxauspe-Zubiaurre B.[2] & Payros A.[2]

[1] Istituto Nazionale di Geofisica e Vulcanologia, Italy
[2] Univerity of the Basque Country, Spain

Corresponding author email: jaume.dinares@ingv.it

Keywords: Astronomical tuning, LLTM hyperthermal, stratotype, nannofossils.

The middle Eocene portrays the beginning of the transition from the warm, high-diversity greenhouse of the early Eocene to the icehouse conditions of the early Oligocene and had been orbitally tuned from deep-sea sequences in the Atlantic Ocean (ODP Sites 1260, 1263, and Hole 702B), closing a gap in the Paleogene astronomical time scale (Westerhold & Röhl, 2013; Westerhold et al., 2015). Equatorial ODP Site 1260 constitutes the only oceanic record where paleoceanographic variability in the precession band is recorded. However, a recent study of drift sediments from the North Atlantic Newfoundland Ridge (IODP Sites U1408 and U1410, Boulila et al., 2018) that has identified a putative obliquity amplitude modulation cycle of ~173 ky duration, has challenged chron durations for the Eocene targeted interval (C18n.1n to C21n, ~38-48 Ma) entailing reassessment of the astronomical tuning of the previously studied Atlantic records. In particular, chron C19 duration, which is relevant for the Lutetian/Bartonian transition chronostratigraphy, has been increased by ~680 ky following the Newfoundland study. Here, we present a high-resolution magnetostratigraphy and cyclostratigraphy from a new Scaglia Variegata section near Gubbio spanning the upper part of C20n up to C18n.1n that is resolved at precession level. The analysis of the cyclic stacking pattern allows tuning to astronomical solutions and correlation to the Atlantic deep-sea records in line with the outcome from a section in Cantabria (Dinarès-Turell et al., 2018). The new data from Gubbio elucidates the middle Eocene chron C19 duration and orbital tuning conundrum evidencing the flawed and untenable outcome from the Newfoundland cores. Calcareous nannofossil biostratigraphy based on 60 samples, as part of an ongoing integrated stratigraphy, has been established rendering the new unveiled Umbrian section as a firm prospective candidate to host the Bartonian base GSSP.

Contribution to project CGL2015–65404-R (MINECO/FEDER, EU).

Boulila S., Vahlenkamp M., De Vleeschouwer D., Laskar J., Yamamoto Y., Pälike H., Kirtland Turner S., Sexton P.F., Westerhold T. & Röhl U. (2018) - Towards a robust and consistent middle Eocene astronomical timescale. Earth Planet. Sci. Lett., 486, 94–107.

Dinarès-Turell J., Martínez-Braceras N. & Payros A. (2018) - High-resolution integrated cyclostratigraphy from the Oyambre Section (Cantabria, N Iberian Peninsula): Constraints for orbital tuning and correlation of middle Eocene Atlantic deep-sea records. Geochem., Geophys., Geosys., 19, 787–806.

Westerhold T. & Röhl U. (2013) - Orbital pacing of Eocene climate during the Middle Eocene Climate Optimum and the chron C19r event: Missing link found in the tropical western Atlantic. Geochem., Geophys., Geosys., 14, 4811–4825.

Westerhold T., Röhl U., Frederichs T., Bohaty S. M. & Zachos J.C. (2015) - Astronomical calibration of the geological timescale: closing the middle Eocene gap. Climate of the Past, 11, 1181–1195.

Correlation of the Ordovician depositional sequences: regional and global aspects

Dronov A.*

Geological Institute of Russian Academy of Sciences, Russia.

Corresponding author email: avdronov@gmail.com

Keywords: Ordovician, depositional sequences, sea-level changes, eustacy, tectonic.

It is suggested that Ordovician sea-level changes are of eustatic nature and could be traced all over the world. Comparative analysis of the Ordovician succession of the Siberian and North American platforms demonstrates a striking similarity in the long-term lithological changes and sea-level curve interpretation (Dronov, 2013; Dronov, 2017). 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. As for the Baltica, there are two different sea-level models for this palaeocontinent. One demonstrates close similarity to the North American model while the other 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, 2017). If one interpret invasion of carbonate facies into the black shale realm as "highstand shedding" (Schlager, 2007), Baltica also follow the Gondwanan sea-level patterns. As a result instead of one global sea-level curve for the Ordovician (Haq & Shutter, 2008) 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.

Dronov A. (2013) - Late Ordovician cooling event: Evidence from the Siberian Craton. Palaeogeography, Palaeoclimatology, Palaeoecology, 389, 87-95.

Dronov A.V. (2017) - Ordovician Sequence Stratigraphy of the Siberian and Russian Platforms. In: Montenari M. Ed. Advances in Sequence Stratigraphy. Special Issue. Stratigraphy & Timescale. Volume 2, 187-241.Elsevier.

Haq B.U. & Schutter S.R. (2008) - A Chronology of Paleozoic Sea-Level Changes. Science, 322, 64-68.

Munnecke A., Calner M., Harper D.A.T. & Servais T. (2010) - Ordovician and Silurian sea-water chemistry, sea-level, and climate: A synopsis. Palaeogeography, Palaeoclimatology, Palaeoecology, 296, 289-413.

Schlager W. (2007) - Carbonate sedimentology and sequence stratigraphy. In: Crossey, L.J. Ed. Concepts in Sedimentology and Paleontology N. 8, SEPM.

Obliquity forcing of lake levels in the Early Jurassic high-latitude continental Junggar Basin, NW China

Fang Y.*[1], Sha J.[2] & Olsen P.[3]

[1] CAS Key Laboratory of Economic Stratigraphy and Palaeogeography, Nanjing Institute of Geology, Chinese Academy of Sciences, China. [2] State Key Laboratory of Palaeobiology and Stratigraphy, Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, China. [3] Lamont-Doherty Earth Observatory of Columbia University, USA.

Corresponding author email: ynfang@nigpas.ac.cn

Keywords: Chaos, Cyclostratigraphy, Early Jurassic, High-Latitude, Junggar Basin.

The Late Triassic to Early Jurassic Newark rift basin located in the tropical Pangea show a unique example that lake levels were strongly paced by earth's obits (Olsen et al., 1996). Mainly base on these recovered lake levels, a Geological Orrery used to map chaos in the solar system was successfully built (Olsen et al., 2019). However, Newark data can only decipher the frequencies of precession of perihelion. To truly understand the chaotic dynamical behavior of the solar system, a contemporaneous high-latitude geological archive recording obliquity pacing of climate is urgently needed. The Junggar Basin, NW China has become a continental basin since the Late Paleozoic and was located at around 60º~70ºN during Late Triassic to Early Jurassic. Thousands of meters thick continuous Late Triassic to Early Jurassic shallow lacustrine deposits are well exposed along the southern margin of the Junggar Basin, providing an excellent opportunity to investigate the effects of earth's orbits on high-latitude continent. A scale of lake depth, based largely on grain size, color, sedimentary structures and fossil types termed the depth rank index, was built in the Lower Jurassic Sangonghe Formation in the southern Junggar Basin. Multitaper method (MTM) power spectra of the depth rank index show thickness periods of 200-70 m, 54-28 m, 14-10 m, 5-2.5 m and 2.5-1.5 m, within which the most strong periodic signal is between 54 m and 28 m. Based on the sedimentary rates of Lower Jurassic along the southern Junggar Basin, the 54-28 m cycles were probably caused by the 405-ky eccentricity cycle related to the gravitational interaction of Jupiter and Venus (g_2-g_5 cycle). The 405-ky tuned depth rank index express clear Earth's orbital parameters of ~1.2-Ma obliquity modulator, 405-ky long eccentricity, ~109-ky short eccentricity, and ~40-ky obliquity. Moreover, the peak of the filtered ~1.2-Ma obliquity modulator is consistent with fluvial channel sandstone, while the trough is consistent with lacustrine fine-grained deposits. We interpret that the bigger Earth obliquity resulted in growing summer and associated timing and magnitude of precipitation and evaporation, favoring developing of big lakes, and vice versa. However, the latest Triassic to earliest Jurassic in the southern Junggar Basin show ~819-ky obliquity modulator (Sha et al., 2015), which is different with the ~1.2-Ma in the Sangonghe Formation, probably indicating chaos behavior.

Olsen P. & Kent D.V. (1996) - Milankovitch climate forcing in the tropics of Pangaea during the Late Triassic. Palaeogeogr., Palaeoclimatol., Palaeoecol., 122, 1-26.

Olsen P., Laskar J., Kent D.V., Kinney S.T., Reynolds D.J., Sha J., Whiteside J.H. (2019) - Mapping solar system chaos with the geological orrery. PNAS, in press.

Sha J., Olsen P., Pan Y., Xu D., Wang Y., Zhang X., Yao X., & Vajda V. (2015) - Triassic-Jurassic climate in continental high-latitude Asia was dominated by obliquity-paced variations (Junggar Basin, Urumqi, China). PNAS, 112, 3624-3629.

Are shallow water carbonates reliable archives of astronomical forcing?

Kemp D.B.*[1] & Van Manen S.[2]

[1] China University of Geosciences, Wuhan
[2] The Open University

Corresponding author email: davidkemp@cug.edu.cn

Keywords: Milankovitch, shallow water carbonates, model, astronomical forcing.

Shallow water carbonate successions are sensitive archives of past environmental conditions, and a great deal of previous work has focused on the utility of such successions as recorders of astronomical climate forcing. In particular, exposure-bound metre-scale cycles are a common phenomenon, and astronomically forced changes in sea level (Milankovitch cycles) may have been a primary driver of these cycles. Nevertheless, this view is contested, and carbonates are in any case poor recorders of both the amplitude and frequency of sea level changes (e.g. Eberli, 2013). A mechanistically simple and stochastic model of carbonate accumulation can be used to illustrate how metre-scale cycles can form under purely random sea level variations. In this model, deposition is controlled primarily by emergence or submergence of a platform, which is itself controlled by stochastic (random walk) changes in sea level. The cycles produced by this model are exposure-bound sequences similar to those observed in real strata. They also have mean recurrence times close to known Milankovitch periods, despite the absence of any astronomical control on their formation. Metre-scale cycles effectively self-generate as an emergent product of the interplay between sea level change and accumulation, and this occurs regardless of either the amplitude of sea level change or the rates of subsidence or accumulation. Metre-scale cycles (~0.5-3 m thickness) are generated even when subsidence and accumulation rates are allowed to vary by an order of magnitude. Under conditions of very high subsidence and accumulation rates, the metre-scale cycles generated by the model have sub-Milankovitch durations (i.e. <3 k.y.). This finding may help shed light on the origin of similarly short-duration metre-scale cycles from the Middle Triassic Latemar platform of Northern Italy. Sensitivity tests of the model show that shallow water carbonates may be sensitive to weak astronomical forcing of sea level. Notably, strong statistical evidence for astronomical cycles in modelled successions can be preserved even if astronomical forcing contributes <1% of sea level variance. Nevertheless, deposition close to sea level in all the simulations ensures that the probability of a complete succession being preserved (i.e. with every astronomical cycle recorded) is very low. This has implications for the use of shallow water carbonates for constructing astronomical timescales. Taken together, shallow water carbonates may be sensitive, but also ambiguous and unreliable, recorders of astronomical forcing.

Eberli G.P. (2013) - The uncertainties involved in extracting amplitude and frequency of orbitally driven sea-level fluctuations from shallow water carbonate cycles. Sedimentology, 60, 64-84.

Milankovitch cycles in Banded Iron Formations (BIFs) around 2.5 Ga

Lantink M.[1], Davies J.[2-3], Mason P.[1], Schaltegger U.[2] & Hilgen F.J.*[1]

[1] Utrecht University. [2] University of Geneva. [3] Université du Québec à Montréal

Corresponding author email: F.J.Hilgen@uu.nl

Keywords: Palaeoproterozoic, Milankovitch, Banded Iron Formation, Kuruman Formation, South Africa.

Large-scale deposition of banded iron formations (BIFs) between 2.8 and 1.9 billion years ago has been explained in terms of various processes, primarily hydrothermal plume activity, continental growth and the dynamic rise of oxygen in the ocean and atmosphere. By contrast, not much attention has been paid so far to climatic variability and its role in the formation of BIFs. Yet, Milankovitch forcing linked to Earth's orbital and inclination parameters and the resultant climate oscillations on the 10^4 – 10^6 year scale must have been operative at that time and may explain rhythmic layering that has previously been observed in BIFs. However, this hypothesis has never been tested, partly as a consequence of the large uncertainties in BIF depositional rates. For this reason, we carried out an integrated stratigraphic study of Paleoproterozoic BIF in the Kuruman Formation of the Griqualand West Basin in South Africa, combining cyclostratigraphic analysis with high-precision TIMS U-Pb zircon dating of several ash intervals interbedded in the BIF. In the field, a distinct hierarchical cycle pattern could be identified in the weathering profile of the Kuruman Fm, which could be traced over a distance of 250 km and explained by the superposition of two cycles. Combined with the results of time series analysis, the period ratio of these two cycles can be explained in two possible ways, namely by the combination of short (~100-kyr) and long (405-kyr) eccentricity, and of long and very long (2.4-Myr) eccentricity with the period of the last cycle being shortened by the chaotic behavior of the Solar System. The much improved U/Pb ages in terms of accuracy and precision show that the latter interpretation is preferred. Next steps in the search for Milankovitch cycles in the BIF will focus on the Dales Gorge Mb assumed to be the temporal equivalent of the Kuruman in Australia, the unnoticed expression of short eccentricity and precession, and the nature of the astronomical-induced climate oscillations.

Mechanisms of Preservation of the Eccentricity and Longer-term Milankovitch Cycles in Detrital Supply and Carbonate Production in Hemipelagic Marl-Limestone Alternations

Martinez M.[1]*

Université de Rennes, France.

Corresponding author email: mathieu.martinez@univ-rennes1.fr

Keywords: marl-limestone alternations, eccentricity, Milankovitch cycles, Cretaceous, detrital supply, carbonate production.

Marl-limestone alternations are spectacular witnesses of the insolation cycles linked to the changes in the Earth's orbital parameters. These alternations are often grouped into bundles of 5 or 20 alternations, respectively linked to the 100-kyr and the 405-kyr eccentricity. In spectra of sedimentary and palaeoclimatic series, the eccentricity cycles show high variances, while in the insolation series, their variance is carried by the amplitude of the precession cycles. I analyse here results from the Subbetic Domain (Spain), Gerecse Mounts (Hungary) and the Vocontian Basin (France), three Tethyan basins recording hemipelagic marl-limestone alternations during the Early Cretaceous to understand the reason why the long cycles are directly preserved with high amplitudes in the sedimentary record. In these three basins, higher sedimentation rates are observed in marls, suggesting that detrital supply control the sedimentation rate at time scales of 405 kyr and 2.4 myr. In the Subbetic Domain, proxies related to the detrital supply only show higher power in the 405-kyr cycle, while proxies including the carbonate production show an attenuation of this cycle. In the Gerecse Mounts, the 405-kyr cycle dominate the spectra of the magnetic susceptibility and the spectral gamma-ray, while the δ13Cbulk shows higher power in the 100-kyr band. In the Vocontian Basin, humid peaks occur every 2.4 myr and are associated to much more clayey sedimentation. Proxies linked to detrital supply thus tend to record longer Milankovitch periods, while proxies related to carbonate production tend to favour the expression of shorter cycles. Pedogenetic and erosion processes are strongly governed by diffusion processes which tend to disrupt the amplitude modulation of the precession cycles. This acts as a mechanism of transfer of power from the precession to the eccentricity cycles. Much pedogenesis under more humid climate have higher diffusion time favouring the record of the long Milankovitch cycles. Conversely, changes in the type of carbonate producers may reverse the response of the sedimentary system to the orbital cycles, which tend to suppress the amplitude of the long Milankovitch cycles. Together with bioturbation, it results in a dominance of the 100-kyr cycle in more carbonate-dominated marl-limestone alternations.

A high-precision numerical time scale for the Toarcian Stage: implications for timing of the marine Toarcian Oceanic Anoxic Event (T-OAE) and Karoo-Ferrar volcanism

Ruhl M.*[1-2], Hesselbo S.P.[3], Al-Suwaidi A.[4], Xu W.[1-2], Thibault N.[5], Jenkyns H.C.[2], Mac Niocaill C.[2], Riding J.B.[6] & Ullmann C.V.[3]

[1] Department of Geology, Trinity College Dublin, The University of Dublin, Ireland. [2] Department of Earth Sciences, University of Oxford, UK. [3] Camborne School of Mines and Environment and Sustainability Institute, University of Exeter UK. [4] Petroleum Institute, Khalifa University, UAE. [5] Department of Geosciences and Natural Resource Management, University of Copenhagen, Denmark. [6] British Geological Survey, UK.

Corresponding author email: micha.ruhl@tcd.ie

Keywords: Jurassic, Toarcian, time-scale, Oceanic Anoxic Event, cyclostratigraphy, large igneous province volcanism.

The Early Toarcian is marked by one of the largest global climatic and ocean-redox change events of the Mesozoic Era, termed the Toarcian Oceanic Anoxic Event (T-OAE; ~183 Ma). It is also characterized by major perturbations in global (bio)geochemical cycles, including the global exogenic carbon cycle. The combined massive release and sequestration of isotopically light carbon, and relative changes in the intricate balance between the two, resulted in major positive and negative shifts in organic and inorganic, marine and terrestrial $\delta^{13}C$ records. The widespread development of anoxic–euxinic conditions, combined with global warming, had major repercussions for marine ecosystem stability, resulting in global marine mass extinction. This major global change event is thought to be causally linked to the emplacement of the Karoo-Ferrar Large Igneous Province (LIP). Although much research has focused on the climatic and environmental consequences of carbon release at this time, the duration and rate of carbon-cycle change, and the temporal and causal link to Karoo-Ferrar LIP volcanism are poorly understood. Here, we present a high-precision astronomical time-scale for the entire Toarcian Stage in the Mochras Borehole (Wales, UK). Integrated with bio-, chemo-, and magnetostratigraphy of the same borehole and radio-isotopic constraints, this allows for important inferences on the temporal link between Karoo-Ferrar LIP volcanism and the Early Toarcian global change event.

The Cyclostratigraphy Intercomparison Project (CIP): consistency, merits and pitfalls of cyclostratigraphy

Sinnesael M.*[1], De Vleeschouwer D.[2], Zeeden C.[3], Claeys P.[1] & CIP-Participants

[1] Analytical, Environmental and Geo-Chemistry, Vrije Universiteit Brussel, Belgium. [2] MARUM — Center for Marine Environmental Sciences, University of Bremen, Germany. [3] LIAG - Leibniz Institute for Applied Geophysics, GEOZENTRUM HANNOVER, Germany.

Corresponding author email: matthias.sinnesael@vub.be

Keywords: astronomical climate forcing, cyclostratigraphy, methodology.

Cyclostratigraphy is an important tool for understanding astronomical climate forcing and reading geological time in sedimentary sequences, provided that an imprint of insolation from Earth's orbital eccentricity, obliquity and/or precession is preserved (Milankovitch forcing). Numerous stratigraphic and paleoclimate studies have applied cyclostratigraphy, but the robustness of the methodology and dependence on the investigator have not been systematically evaluated. Here, we present an experimental design of three artificial cases with known input parameters. Each case is designed to address specific challenges that are relevant to cyclostratigraphy. Case 1 simulates the situation of a scientist onboard a research vessel: for his/her analysis, nothing more than a drill-core photograph and the approximate position of a stage boundary is available. Case 2 is a proxy record with clear nonlinear cyclical patterns, which interpretation is complicated by the presence of a stratigraphic gap. Case 3 represents a modeled Late Devonian proxy record, with a low signal-to-noise ratio and no specific astronomical solution available for this age. Each case was analyzed by 17 to 20 participants as part of the Cyclostratigraphy Intercomparison Project (CIP). The test group was heterogeneous in terms of experience and dedicated time and self-reflected on the results during a meeting in Brussels, Belgium. The analyses demonstrate that not every participant came to the correct solution. However, the median solution of all submitted analyses accurately approached the correct solution in all three cases and some participants obtained the exact correct answers. This experiment demonstrates that cyclostratigraphy is a powerful tool for deciphering time in sedimentary successions, and importantly, it is a trainable skill. Systematically better performances were obtained for cases that were closer in type and stratigraphic age to the experience of individual participants. Finally, we emphasize the importance of an integrated stratigraphic approach and provide a set of guidelines on what good practices in cyclostratigraphy should include. With the CIP, we cannot provide a quantitative measure of reliability and uncertainty of cyclostratigraphy. Instead, our case studies provide valuable insight in current common practices in cyclostratigraphy, their merits and pitfalls. Therewith, CIP is a starting point for further discussions on how to move this maturing field forward.

StratigrapheR: an R package for integrated stratigraphy

Wouters S.*[1], Da Silva A.C.[1], Boulvain F.[1] & Devleeschouwer X.[2]

[1] University of Liège. [2] Royal Belgian Institute of Natural Sciences

Corresponding author email: sebastien.wouters@doct.uliege.be

Keywords: R Cyclostratigraphy, magnetostratigraphy, integrated stratigraphy.

StratigrapheR is an open-source integrated stratigraphy package. It is available in the free software environment R (https://CRAN.R-project.org/package=StratigrapheR) and is designed to manage the large amount of data needed to perform cyclostratigraphy. As this discipline can be carried out by visual analysis on lithological observations and by time-series analyses, StratigrapheR endeavours to link the two by allowing the semi-automated generation of lithologs, the processing of stratigraphical information, and the visualisation of any plot along the lithologs in the R environment. The basic graphical principle behind StratigrapheR is the incremental addition of elements to a drawing: a plot is opened, and graphical elements are successively added. This allows compartmentalisation of the drawing process, as well as the superposition of different plots for comparison. For instance a litholog of a single section can be written as a single function including all the drawing sub-functions, and be integrated in a larger plot, for instance to be correlated to other sections or to show proxy data. The StratigrapheR package is designed for efficient work, and minimum coding, while still allowing versatility. The lithological information of beds (upper and lower boundary, hardness, lithology, etc.) is converted into polygons. All polygons are drawn together using a single function, and each polygon can have its personalised symbology allowing to distinguish lithologies. A similar workflow can be used for plotting proxies while distinguishing each sample by their lithology. Vector graphics can be imported as SVG files, and precisely drawn with the lithologs to serve as symbols or complex elements. Every type of symbol is plotted by calling one single function which repeats the drawing for each occurrence of the represented feature. This illustrates that the amount of work invested to make lithologs using StratigrapheR is related to their complexity rather than their length: a long but monotonous litholog (e.g. of marl-limestone alternations) only takes a few lines of code to generate. The StratigrapheR package also allows basic visualisation and processing of oriented data used for magnetostratigraphy: efficient functions are provided for stereographic projections, Zijderveld plots, conversion between data conventions and reorientation (sample correction, bedding correction, rotation). It also provides a set of functions to deal with selected stratigraphic intervals (for instance in the [0,1[form): they allow simplification, merging, inversion and visualisation of intervals, as well as identifying the samples included in the given intervals, and characterising the relation of the intervals with each other (overlap, neighbouring, etc.). StratigrapheR includes PDF and SVG generation of plots, of any dimension. The generated PDF can even store multiple plots in a single file (each plot on a different page) to document data processing comprehensively.

Towards systematic probing for Milankovic cycles in borehole logging data and complex settings

Zeeden C.*[1], Sinnesael M.[2], Li M.[3], Ulfers A.[1] & Wonik T.[1]

[1] LIAG, Leibniz Institute for Applied Geophysics, Germany. [2] AMGC, Vrije Universiteit Brussel, Belgium.
[3] Department of Geosciences, The Pennsylvania State University, USA

Corresponding author email: christian.zeeden@leibniz-liag.de

Keywords: cyclostratigraphy, evoluitive methods, ICDP, time series analysis.

Cyclostratigraphy is an integral part of many scientific studies on the age and duration of outcrop- and core material from sedimentary geoarchives. Yet, borehole data are not systematically assessed using cyclostratigraphic methods. This has various reasons, including (a) a specific resolution and commonly no possibility to increase data resolution after logging, (b) logging proxy data cannot be connected to the sedimentary environment as easily as core investigations, (c) commonly cyclostratigraphic studies focus on one lithostratigraphical unit, but borehole logs may comprise several (d) some data generated from core material (e.g. stable isotope ratios) cannot be acquired in boreholes directly. Also some complex settings allow for different cyclostratigraphic interpretations. To obtain a reliable understanding of (long) borehole logging datasets, and data from complex settings, a good understanding of the potential and specifics of relevant (time/depth) evolutive methods in cyclostratigraphy are an essential prerequisite. Therefore, we test a suite of evolutive cyclostratigraphic methods using several artificial datasets consisting of modelled Milankovic signals and noise. The principles of spectral moments, or other types of signal characterizations, can be used for initial assessment of signal properties over the entire record, and sometimes allow interpretations regarding sedimentation rate or changes in the climate system. Wavelet analysis and evolutive harmonic analysis (EHA) represent windowed approaches of assessing cyclicity, where wavelet analysis and evolutionary spectral analysis can also assess amplitude variations. Evolutive average spectral misfit (eASM) and evolutionary correlation coefficient analysis (eCOCO) assess the similarity of power spectra (eCOCO) and significant cyclic variations (ASM) in geological datasets against Milankovic targets, being conceptionally similar but technically different. The TimeOpt method investigates precession- and eccentricity amplitude modulations and aims at finding a best fit through assessing various sedimentation rates. Aim of our work is the comparison of different evolutive cyclostratigraphic methods for an understanding of which methods perform good under specific conditions. Once artificial datasets are discussed, we apply these methods to rather well understood real data. A discussion of the possible issues and potential of especially uncommon methods gives insight in further potential of cyclostratigraphy.

ST2.4

Ammonoids in stratigraphy

Conveners and Chairpersons

Arnaud Brayard (Universite de Bourgogne)

Claude Monnet (Université de Lille)

The Bithynian (Middle Anisian) ammonoid record of Aghdarband (Kopeh-Dag, NE Iran): from taxonomy to revised chronostratigraphy

Balini M.*[1], Marchesi R.[1], Nicora A.[1], Hosseinyoon M.[2], Soleimani S.[3] & Norouzi M.[3]

[1] University of Milano, Italy.
[2] Geological Survey of Iran, Mashhad, Iran.
[3] Geological Survey of Iran, Tehran, Iran.

Corresponding author email: marco.balini@unimi.it

Keywords: Middle Triassic, Middle Anisian, Ammonoids, Taxonomy, Chronostratigraphy.

Aghdarband in NE Iran is an important key-area, well known for the thick Triassic sedimentary succession deposited in a back-arc setting along the southern margin of Laurasia. One important unit of this succession is the Nazar-Kardeh Formation, a mixed calcareous and sandy unit, rich in ammonoids, that was deposited in basinal conditions. Few ammonoids from the Nazar-Kardeh Formation where collected in the 1970s by A. Ruttner (Ruttner, 1991) and studied by Krystyn & Tatzreiter (1991). This first collection was not done with a bed-by-bed approach, but the authors could distinguish two faunas, assigned to the *Nicomedites osmani* and the *Aghdarbandites ismidicus* zones of the Bithynian substage of the Anisian. The area was visited several times by us (Zanchi et al., 2016; Balini et al., 2019) and the field works included the bed-by-bed sampling of several fossiliferous localities of the Nazar-Kardeh Formation. Four stratigraphic sections have been sampled in the tectonic units 1, 2 and 3, and a total 645 ammonoids have been collected. The most complete and fossiliferous sections are Agh25 in tectonic unit 1 and Agh37 in tectonic unit 3. The first section provides the best record of the *Nicomedites osmani* zone, while section Agh 37 is the only one where both the bithynian zones are documented. Fourteen genera have been identified: *Norites*, *Acrcochordiceras*, *Ismidites, Nicomedites*, *Aghdarbandites*, *Kocaelia*, *Pseudohollandites*, *Japonites*, *Gymnites*, *Costigymnites*, *Leiophillites*, *Monophyllites*, *Phyllocladiscites* and two new genera. A total number of 25 species (8 new) have been recognized. *Nicomedites* and *Aghdarbandites*, the most common genera of the *N. osmani* and *A. ismidicus* zones, respectively, show a much wider diversity than reported in literature. The correlations with the most important bithynian sections of Gebze (Turkey), Nakhlak (Central Iran) and Spiti (Tethys Himalaya, India) are discussed.

Balini M., Nicora A., Zanchetta S., Zanchi A., Marchesi R., Vuolo I., Hosseiniyoon M., Norouzi M. & Soleimani S. (2019) - Olenekian to Early Ladinian stratigraphy of the western part of the Aghdarband window (Kopeh-Dag, NE Iran). Riv. It. Palaeontol. Strat., 125, 283-315.

Krystyn L. & Tatzreiter F. (1991) - Middle Triassic ammonoids from Aghdarband (NE-Iran) and their Palaeobiogeographical significance. In: Ruttner A.W. (ed.), The Triassic of Aghdarband (AqDarband), NE-Iran and its pre-Triassic frame. Abh. Geol. Bund., 38, 139-163.

Ruttner A.W. (1991) - Geology of the Aghdarband Area (Kopet Dag, NE-Iran). In: Ruttner A.W. (ed.), The Triassic of Aghdarband (AqDarband), NE-Iran and its pre-Triassic frame. Abh. Geol. Bund., 38, 7-79.

Zanchi A., Zanchetta S., Balini M. & Ghassemi M.R. (2016) - Oblique convergence during the Cimmerian collision: evidence from the Triassic Aghdarband Basin, NE Iran. Gondwana Res., 38, 149-170.

Principles of Devonian ammonoid zonations

Becker R.T.*

Westfälische Wilhelms-Universität Münster, Germany

Corresponding author email: rbecker@uni-muenster.de

Keywords: Devonian, ammonoids, zonal scales, phylogeny, events.

The research history of Devonian ammonoid zonations goes back for more than hundred years. Especially in the Upper Devonian, zones with a duration of only a few hundred thousand years have been established and correlated internationally. However, based on the studies of ontogenetic morphometry and intraspecific variability, it became evident in recent years that many ammonoid faunas of separate regions contain similar and related, but different taxa. This requires a new look at the principles of zonation systems and their correlation.

In general, regional Devonian ammonoid successions are distinctive and not simply duplicated in separate basins, each with individual facies developments and palaeoecological conditions. Despite their open shelf, pelagic lifestyle, ammonoids were highly facies-sensitive although the type of environmental control on population differences is mostly unknown. The following zonal types are recognized:

- Phylozones, defined by evolutionary change within a non-endemic, branching lineage (e.g. middle Frasnian Beloceratidae).
- Endemozones, defined by the FADs of endemic taxa (e.g. regionally different Frasnian Virginoceratidae or Famennian Prolobitidae).
- Migrozones, defined by FADs related to the sudden immigration of a lineage with a longer evolutionary history elsewhere (e.g. Triainoceratidae in Europe-North Africa-North America).
- Cryptozones, defined by FADs of taxa with cryptogenic ancestry (e.g. Frasnian Devonopronoritidae in the Altai Mts. and Iran).
- Ecozones (s.str. or acme zones), defined by sudden blooms of specific taxa, for example in event beds (e.g: *"Archoceras"* in Upper Kellwasser Beds).
- Desaster zones, defined by sudden LADs in the course of significant extinction events (e.g. *Postclymenia evoluta* Zone after the Hangenberg Extinction).
- LAD zones, defined by individual LADs (e.g. upper *Anarcestes* Zone in the upper Emsian).

Internationally, the best correlation is achieved using genozones, which are characterized by the FAD of an index genus (or closely related genus group), but with different oldest species in different regions. This implies a mixture of phylogeny and migration. Global events led to global disaster zones (e.g. Frasnian-Famennian boundary extinction) and, sometimes, also to pantropical ecozones. Further detailed studies are required to document global phylozones based on speciation within pantropical genepools. Examples are the supposed congruent evolutionary changes in the far apart Upper Devonian of North America, North Africa, Germany, and NW-Australia (e.g. Frasnian *Prochorites*, Famennian sporadoceratids).

The analysis of regional/global zonal schemes holds important clues to understand the interaction of evolution and regional/global environmental change.

Ammonoid and *Daonella* zonation of the Sasso Caldo quarry (Besano Formation, Middle Triassic)

Bindellini G.*[1], Balini M.[1], Teruzzi G.[2] & Dal Sasso C.[2]

[1] Dipartimento di Scienze della Terra "A. Desio", Università degli Studi di Milano, Italy.
[2] Museo di Storia Naturale di Milano, Italy.

Corresponding author email: g.bindellini@gmail.com

Keywords: Ammonoids, Monte San Giorgio, Middle Triassic, Anisian/Ladinian boundary, Nevadites zone, Besano Formation.

With this contribution we show the preliminary results of the ammonoid and *Daonella* zonation of the Besano Formation (Anisian/Ladinian boundary) at Sasso Caldo (SC) quarry section on the Italian side of Monte San Giorgio (NW Lombardy). The Besano Fm is the most fossiliferous unit of the Middle Triassic succession of the Monte San Giorgio site (UNESCO WHL), which de facto has provided one of the best preserved record of marine life in the Triassic period. During the excavations led by the Natural History Museum of Milan (MSNM) at SC (from 1985 to 2003, directed by G. Teruzzi) almost 2000 specimens, including plant remains, vertebrates and invertebrates, have been collected. This contribution is part of a PhD project held at the Earth Sciences Department "A. Desio" of the "Università degli Studi di Milano", in cooperation with the MSNM. The project aims to the (1) publication of a biostratigraphic log, and (2) study of the vertebrate fauna recovered at SC, with particular focus on the holotype of *Besanosaurus leptorhynchus.* The collection stored at the MSNM includes 60 specimens of *Daonella* and more than 200 ammonoids. These specimens, whose stratigraphic importance have been proved in the past years (i.e. Rieber, 1969, 1973), have never been studied since now. During the excavation, the sedimentary succession was divided into several "strata". Usually each stratum includes a couplet of layers, typically a (lower) dolomitic and an (upper) bituminous layer. The "strata" have been numbered in increasing order from top to bottom. Relatively good specimens range from stratum 88 to stratum 50. The genus *Repossia* ranges from st. 82 to st. 80; *Stoppaniceras* is present from st. 80 to st. 73, but also a single specimen of *S. variabilis* has been found at st. 88; *Nevadites* ranges from st. 71 to st. 57; *Serpianites* ranges from st. 67 to 62, but *S. airaghii* is completely lacking. About the bivalve *Daonella*, *D. vaceki* is present in strata 83 and 82; *D. airaghii* occurs in st. 80; *D. pseudomoussoni* ranges from st. 80 to st. 76; *D. fascicostata* ranges from st. 75 to st. 66; *D. luganensis* occurs in st. 66. All of these taxa document the *N. secedensis* zone from st. 88 to st. 47. Thanks to this zonation, a precise bed-by-bed correlation of the SC section to Middle GBZ exposed at Mirigioli (Punkt 902) is proposed. Eventually we point out that, whereas the ranges of the *Daonella* species match perfectly with the already published Swiss material, the ranges of ammonoids genera seem to be wider than previously thought.

Rieber H. (1969) - Daonellen aus der Grenzbitumenzone der mittleren Trias des Monte San Giorgio (Kt. Tessi, Switzerland). Eclogae Geol. Helv., 62, 657-683.

Rieber H. (1973) - Die Triasfauna der Tessiner Kalkalpen. Cephalopoden aus der Grenzbitumenzone (Mittlere Trias) des Monte San Giorgio (Kt. Tessin, Switzerland). Schweiz. Palaeontol. Abh., 93, 1-96.

The Red rock region and the Minette ironstone stratigraphy (upper Toarcian – Aalenian) in southern Luxembourg: protection and valorization of a geological heritage

Di Cencio A.*[1-2-3] & Weis R.[1]

[1] National Museum for Natural History Luxembourg, Palaeontological Department. [2] Studio Tecnico Geologia e Paleontologia Technical Studio, San Casciano Val di Pesa (FI).
[3] Gruppo Avis Mineralogia e Paleontologia Scandicci (FI).

Corresponding author email: andreadicencio@geologiaepaleontologia.eu

Keywords: Aalenian, Biostratigraphy, Geological heritage, Luxembourg, Red Rock Region, Toarcian.

The Red rock region, the type locality of the Minette Ironstone formation, has been a very important mining centre in the southern Luxembourg, close to the French border. Thanks to the presence of iron minerals and elements in several oolithic beds, in fact, the Minette-type rocks have been quarried over the years to produce this important metal for the iron and steel industries. The entire formation has been studied by geologists and mining engineers and both underground and opencast mines operated everywhere in the area. As a side-effect of the iron mining, important paleontological associations of ammonites, belemnites and other invertebrates have been found during the last one and a half centuries. In the literature, several authors studied the fossils emerged from this area (e.g. Branco, 1879; Benecke, 1905; Maubeuge, 1947) and several new species have been identified on material originating from the Minette. Fossils have been originated from very condensed and relatively thin levels. Nevertheless, the material is well preserved and it is possible to perfectly study the European biostratigraphic sub-division of those beds, especially concerning the upper Toarcian Aalenis Zone and upper Aalenian Murchisonae Zone. Most of the palaeontological collection of fossils from Red Rock region is currently stored at the Natural History Museum of Luxembourg, thus becoming a regional and international reference collection for the span of time between lower and middle Jurassic. Although all the mines are now abandoned and partially protected as national nature reserves, it is still possible to study the stratigraphic sequence at several places. The Minette appears very important not only from an industrial, geological, stratigraphical and palaeontological point of view, but it also represents a fundamental (strategic) place to study the interaction between the human and industrial history on the one hand, and the local geology, natural resources and landscapes on the other one. This is a noteworthy point for the realization of a UNESCO biosphere reserve (Man and biosphere program), which aims at protecting and valorising the entire area, including its geological heritage.

Branco W. (1879) - Der Untere Dogger deutsch-lothringens. Abh. Z. Geol., II.

Benecke E.W. (1905) - Die Versteinerungen der Eisenerzformation Deutsch-Lothringens und Luxemburgs. Ver. Geol. Land.,1-598. Strassburg.

Maubeuge P.L. (1947) - Sur quelques ammonites de l'"Aalénien Ferrugineux" du Luxembourg et sur l'échelle stratigraphique de la formation ferrifère franco-belgo-luxemburgeoise. Inst. Grand Ducal de Luxembourg, Section Sci. natur., XVII, 73-87, 2 pl. Luxembourg.

Biochrones, the introduction of a new biostratigraphic tool: the Toarcian test

Di Cencio A.*[1-2-3]

[1] National Museum for Natural History Luxembourg, Palaeontological Department. [2] Geologia e Paleontologia Technical Studio, San Casiano Val di pesa (FI). [3] Gruppo Avis Mineralogia e Paleontologia Scandicci (FI).

Corresponding author email: andreadicencio@geologiaepaleontologia.eu

Keywords: Biostratigraphy, Biochrone, Biozone, Chronozone, Toarcian.

Biostratigraphy is the science which subdivides rocks by their paleontological content. Its fundamental unit is the biozone, which is characterized by the stratigraphic distribution of a marker. Biozones are bounded by bioevents and they are separable in sub-biozones. A biostratigraphic survey is characterized by several phases: sampling fossils layers by layers, study and classify them at specific level, recognize markers and bioevents, establish biozones, edit the local biostratigraphic scale and correlate it with Standard ones. This is a very complex work that needs a specialist to be realized. The result of a biostratigraphic study is a sequence of biozones which gives a relative age to the studied rocks. When the bioevent is dated in absolute way, the biozone corresponds to chronozone (Salvador, 1994). Starting from the biostratigraphic survey, the specialist proposes a possible evolution: the method of biochrones. It starts by the concept of chrone with some little differences. The so-called biochrone is established on couples of well-defined bioevents, identifying one or more biozones. A co-evoluted and well-identified paleontological association is required for each biochrone. The association is studied at genus level choosing the genera with very clear and univocal taxonomical features. This paper aims at testing the biochrones' method on Toarcian stage given its biostratigraphic importance. The ammonites are chosen as reference fossils. After a classic biostratigraphic study with all connected phases and the identification of appropriate bioevents, four biochrones have been recognized. They cover the entire age. The first biochrone is instituted on the Tenuicostatum and Serpentinus biozones, the second on the Bifrons zone, the third on the Variabilis, Thouarsense and Dispansum zones, the fourth on the Pseudoradiosa and Aalensis Zones. With these new units, the number of choosen taxa decreases and the studied features permit an easier approach, making the method easy to accessible also to not specialists. Using biochrones, the correlation between coeval but different geological sequences does not loose definition, but it relied on less complicated methods, adding value to the entire science of datation with fossils.

Salvador A. (1994) - International Stratigraphic Guide. A guide to stratigraphic classification, terminology, and procedure, The International Union of Geochrological Sciences and the Geological Society of America (eds.), 214 pp.

Early Jurassic tectonic-sedimentary evolution of the Longobucco Basin: ammonoid biostratigraphy provides new constraints

Innamorati G.[1]*, Fabbi S.[1] & Santantonio M.[1]

"Sapienza", University of Rome, Italy.

Corresponding author email: giulia.innamorati@uniroma1.it

Keywords: Early Jurassic, ammonite biostratigraphy, Calabria, rift basin.

The Early Jurassic rifting phase is an event widely described all across the Western Tethyan region. In the Longobucco Basin (northeastern Calabria, Sila Greca), such tectonic phase controlled the sedimentation of a thick succession, unconformably resting on an Hercynian metamorphic and igneous basement. The Longobucco Basin stratigraphy documents the rapid subsidence of a continental margin which evolved from an alluvial plain characterized by fluvial red beds (Rhaetian/Hettangian boundary) to a shallow marine shelf with hybrid carbonates, to a deep sea basin characterized by siliciclastic and hybrid turbidites (Pliensbachian/Toarcian), and finally to a pure pelagic basin (Middle Jurassic onward). Paroxysmal tectonics, also marked by huge megaclastic deposits, first occurred at the Sinemurian/Pliensbachian boundary, producing intrabasinal highs and steep basin margins. Footwall blocks made of exhumed portions of Hercynian basement were ephemerally colonized by shallow water limestones with an abundant siliciclastic content. These carbonate bodies drowned diachronically around the Pliensbachian/Toarcian boundary as a consequence of a second main tectonic phase.

Pliensbachian and Lower Toarcian ammonite assemblages have been found at different stratigraphic levels and in different positions of the investigated basin. Ammonite biostratigraphy allowed to reconstruct the evolution of a such underinvestigated area. In particular it has been possible to constrain the following main tectono/sedimentary events:

- age of the megaclastic deposits associated with the first tectonic pulse (Lower Pliensbachian – base of the Ibex Zone)
- age of a condensed guide level in the basinal deposits, marking a regional highstand phase (Upper Pliensbachian – Lavinianum Zone)
- age of drowning of the carbonate bodies (where reliable biostratigraphic markers are scarce) (Late Pliensbachian/Middle Toarcian – Emaciatum Zone/Bifrons Zone)
- age of the second tectonic phase (Late Pliensbachian/Middle Toarcian – Top Algovianum Zone/Bifrons Zone)

The studied ammonite assemblages also provide interesting palaeobiogeographic information, being composed of taxa showing either a European or a Mediterranean affinity; this fact point out the existence of a faunal mixing in the Pliensbachian, which is considered a stage characterized by marked provincialism between Mediterranean and European ammonite faunas.

The Unitary Associations method in ammonoid biostratigraphy

Jattiot R.*[1], Bucher H.[2] & Brayard A.[1]

[1] Biogéosciences, UMR 6282, CNRS, Université Bourgogne Franche-Comté, France. [2] Paläontologisches Institut, Universität Zürich, Switzerland.

Corresponding author email: romain.jattiot@u-bourgogne.fr

Keywords: ammonoids, quantitative biochronology, Early Triassic, Cretaceous.

Owing to their abundance, high evolutionary rates and widespread geographical distribution, ammonoids represent major biostratigraphical fossils. In biostratigraphical works, ammonoid zones are usually defined as interval zones, which correspond to continuous zones generally bounded by the first occurrence (FO) and/or last occurrence (LO) of an index species. However, the local range of any particular ammonoid by itself is not necessarily informative and accurate in time, since the fossil record is incomplete, discontinuous and reflects ecological partitioning. Furthermore, the main disadvantage of interval zones is the time lag that can exist between the true evolutionary origination of a species (i.e., its First Appearance Datum) and its local FO, which also depends on local ecological conditions, sampling effort and selective preservation. Thus, the use of interval zones often leads to diachronous correlations and biostratigraphical contradictions. Differing from interval zones, the Unitary Associations method (Guex, 1991) is based on discrete, discontinuous zones defined by the occurrence of characteristic species or of characteristic pairs of species. Thus, this method is much more robust for detecting and solving biostratigraphical contradictions in a given dataset, and it also provides a laterally constant sequence of zones without any crossings, whatever their resolution. We will show some examples where this method has already been proved to be very efficient in providing robust quantitative ammonoid biostratigraphical schemes in the Triassic and in the Cretaceous. Additionally, we will present a project whose prime objective is to reassess uppermost Albian biostratigraphy by means of the Unitary Associations method. Utilizing for the first time this method in the debate over the highly controversial Vraconnian stage, this project is expected to yield unprecedented results towards disentangling this biostratigraphical conundrum. We also aim to subsequently decipher couplings between major palaeoecological and environmental changes observed during this time interval.

Guex J. (1991) - Biochronological Correlations. Springer.

A new Lower Jurassic ammonoid locality from the Death Valley National Park (California, USA) and its biostratigraphic implications

Kostka Zs.*[1], Ferlicchi M.[2], Santucci V.[3] & Pálfy J.[1-4]

[1] Department of Geology, Eötvös Loránd University. [2] Basin Research Institute, Death Valley National Park
[3] National Park Service, Geologic Resources Division. [4] MTA-MTM-ELTE Research Group for Paleontology

Corresponding author email: kostkazs@gmail.com

Keywords: Death Valley National Park, North America, Hettangian, ammonoid, biostratigraphy.

The number of Jurassic ammonoid localities known from western North America is far less than those in Europe and their fauna remains less studied. However, analysis of faunal assemblages may add crucial information to our understanding of the tectonically complex orogen of the North American Cordillera. The new locality presented here contributes to our knowledge of the Early Jurassic Eastern Pacific ammonoid faunas and their paleobiogeographic distribution. Biostratigraphic assignments help to test the applicability of a regional standard zonation (Taylor et al., 2001). The new data may also be used to constrain reconstructions of paleogeography and tectonic history.

The study area is located within the Basin and Range Province, where Cenozoic extension created pull-apart basins and horst-and-graben structures. The Death Valley National Park, near the border of California and Nevada, features bedrocks ranging in age from the Neoproterozoic to present. The new locality at Butte Valley exposes the Mesozoic formation of the same name, first described by Johnson (1957). The age of the formation was thought to be Triassic, on the basis of a few poorly preserved ammonoids. However, here we present newly obtained fossil collections of Jurassic age from the topmost part of the formation.

In 2018, 190 specimens were collected at a locality informally referred to as "Ammoniteville". Most specimens are flattened internal and external molds. Although species-level identification is hampered by the poor state of preservation, ammonite biostratigraphy allows assignment of the studied section to the early-middle Hettangian. The lower part falls into the Polymorphum Zone, whereas the upper part represents the Coronoides Zone of the North American regional zonation. The genera present in the collection are best compared with those from the Gabbs Valley area in Nevada (Guex, 1995) and Haida Gwaii (Queen Charlotte Islands) in British Columbia (Longridge et al., 2008). At each of the three areas cosmopolitan genera (e.g. *Kammerkarites* and *Franziceras*) dominate the assemblages, supplemented by few other East Pacific taxa (e.g. *Eolytoceras*). The revised Early Jurassic, rather than Early Triassic age of the uppermost Butte Valley Formation requires reconsideration of some depositional, paleogeographic and tectonic models of the Mojave Desert region.

Guex J. (1995) - Ammonites hettangiennes de la Gabbs Valley Range (Nevada, USA). Mém. Géol. (Lausanne), 27, 1-131.

Johnson B.K. (1957) - Geology of a part of the Manly Peak quadrangle, southern Panamint Range, California. Univ. Calif. Publ. Geol. Sci., 30, 353-423.

Longridge L.M., Pálfy J., Smith P.L. & Tipper H.W. (2008) - Middle and late Hettangian (Early Jurassic) ammonites from the Queen Charlotte Islands, British Columbia, Canada. Rev. Paléobiol., 27, 191-248.

Taylor D., Guex J. & Rakus M. (2001) - Hettangian and Sinemurian ammonoid zonation for the western Cordillera of North America. Bull. Géol. Lausanne, 350, 381-421.

New ammonoid faunas from the Lower Carnian of China Mountain (Upper Triassic, Tobin Range, Nevada)

Marchesi R.*[1], Balini M.[1] & Jenks J.F.[2]

[1] Dipartimento di Scienze della Terra "A. Desio", Università degli Studi di Milano, Italy.
[2] Independent researcher.

Corresponding author email: ruben.marchesi@unimi.it

Keywords: Upper Triassic, Carnian Stage, Desatoyense Zone, Ammonoids, Nevada.

New Lower Carnian ammonoid faunas from China Mountain (Tobin Range, Nevada) are described. The area was investigated in the early 1970s as part of the PhD work of K.M. Nichols (1972). Nichols collected ammonoids from two sites (localities #1251 and #1311, Nichols, 1972), but did not report bed-by-bed collection data. These collections are presently stored at the USGS Core Research Center (Lakewood, CO), but they have not been described. Nichols & Silberling, 1977, referred to the locality and assigned the ammonoid faunas to the Desatoyense Zone. The authors visited the area in October 2018 and noted the location of the fossiliferous interval in the uppermost part of the Smelser Pass Member of the Augusta Mountain Formation, a few meters below the erosional base of the Cane Spring Formation. Two new fossiliferous sites were located and sampled bed-by-bed from exposed beds, and float specimens were collected from the two sites, taking careful note of their stratigraphic position. Stratigraphic sections were measured and a total of 758 specimens were collected from these two new localities. An attempt was made to find locality #1251 (Nichols, 1972), but was unsuccessful due to the lack of precise locality information. Ammonoids by far make up the majority (+95%) of the specimens, with the remaining 5% consisting of bivalves and brachiopods. The ammonoid faunas are dominated by *Daxatina* belonging to at least two new species that are not present in South Canyon (type locality of the no-longer valid Desatoyense Zone). These new species have a simple ceratitic suture line and are morphologically similar to the *Daxatina* that occur in the middle-upper sedimentary succession of South Canyon. The upper part of the fossiliferous interval is characterized by the appearence of *Perrinoceras*, and the occurrence of very rare specimens of *Silenticeras* cf. *schencki*, *Clionitites* cf. *reesidei* and ?*Trachyceras* also suggests correlation with sections D2, E and the lower part of section F of South Canyon.

Nichols K.M. & Silberling N.J. (1977) - Stratigraphy and Depositional History of the Star Peak Group (Triassic), Northwestern Nevada. Geol. Soc. Am. Spec. Pap., 178, 1-73.

Nichols K.M. (1972) - Triassic depositional history of China Mountain and vicinity, north-central Nevada. [Ph.D dissert.] Stanford Calif., Stanford Univ., 142pp.

ST2.5

Big data in stratigraphy

Conveners and Chairpersons
Michael Stephenson (British Geological Survey)
Junxuan Fan (Nanjing University)

A new database for the correlation of core data in the Mediterranean Sea

Amezcua-Buendia R., Diamantini C., Potena D. & Negri A.*

Polytechnic University of Marche, Italy

Corresponding author email: a.negri@univpm.it

Keywords: Big data analytics, database, Mediterranean sea, sapropel, S1.

Science advances and with it the storage of large amounts of data. The need to use this data efficiently, quickly and safely is possible thanks to the Big data analytics that allows us storage and relationship data in order to obtain new knowledge. Here we present a new database (BEyOND) that provides a wide variety of organized and standardised paleoproxies relative to the last 20.000 years of Mediterranean Sea history and that we plan for the future to make it available to all researchers, with open access, in order to extract and, more importantly, to add data (extending to other intervals of time) in a way that favours the exchange of knowledge. Our presentation focus on the way we built the database, focusing on a specific interval of time corresponding to the deposition of the most recent sapropel (S1) and the possibilities offered by it. BEyOND contains 139 sediment cores data (97 cores in the Mediterranean sea) from 82 scientific papers and a total of 1.750 proxies that have been categorised in: geochemistry, isotopes, pollen, sediment grain size, coccolithophore, dinoflagellate and foraminifera. Our work highlights the development of a new method to correlate the data also in case of missing precise age control for each core. Our database highlights the potential of using data analytics to extract hidden patterns and new knowledge also in various fields of the marine geology.

Big Data, Old data, New Data, Linked Data: A Geological Survey perspective on "Stratigraphic Data Science"

Condon D.*, Woods M., Heaven R., Howe M., Harrison M., Stewart M., Walsh J., Newell A. & Wilby P.

British Geological Survey.

Corresponding author email: dcondon@bgs.ac.uk

Keywords: Stratigraphy, data science, geological data sets.

Stratigraphic frameworks, developed using a range of stratigraphic data types, can be used to integrate a range of geological data sets, including paleontological, sedimentological, physical properties, composition etc. For research related to deciphering the stratigraphic record to understand the evolution of the Earth System, it is routine to develop integrated datasets specific to a time slab of interest, and focused on the stratigraphic data that is directly pertinent to the research topic being addressed. National geological surveys use stratigraphy to address a range of issues, from the increasing use of the subsurface for resource abstraction (water, energy), storage of waste (CO_2, radioactive) and energy, and infrastructure development (e.g., below cities). These varied use cases, and longer-term perspectives, require national geological surveys to take a different approach to dealing with stratigraphic data, compared to more academic research endeavors, and a more open approach compared to industry. In this presentation we outline ongoing efforts at the British Geological Survey to better develop the systems, skills and expertise to deploy and apply stratigraphic information within the applied geosciences realm. This focus builds upon >150 years of systematic stratigraphic data collection, decades of regional synthesis (UK sector and internationally) and involvement in national and international data driven initiatives, and is driven by the varied use cases outlined above. The long-term nature of data in geological surveys poses a range of challenges, related to managing and linking legacy data, capturing and linking new data, and making these data readily discoverable and accessible to users, and the deployment of stratigraphic information to help facilitate progress in key geoscience challenge areas. We will outline a range of ongoing activities, include the development of tools for intelligent data discovery, linked data efforts, and international partnerships related to the deployement of BGS burgeoning data into systems, and driving their development and inter-connections, and discuss future areas for application.

OXeAP_RDB, a new Database of Late Jurassic-Early Cretaceous Rudist bivalves

Fabbi S.*[1], Cestari R.[2] & Sha J.[3]

[1] Sapienza University of Rome, Italy. [2] Strata GeoResearch, Chieti, Italy. [3] Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, China.

Corresponding author email: simone.fabbi@uniroma1.it

Keywords: Rudist bivalves, Oxfordian, Updated Database, Aptian.

In the late Jurassic and Cretaceous the shallow and warm water seas were marked, among other benthic marine organisms, by rudist bivalves, a peculiar group of fossils that originate in the late Jurassic and became exinct at the end of the Cretaceous. Rudist occurrences reported in three publicly available databases (Paleotax, PaleobioDB and Paleo-reefs) have been integrated with the most recent information in literature, critically examined and improved with original notes, allowing to check their distribution in carbonate successions since the origin of these bivalves in the Oxfordian (late Jurassic) up to their first main extinction event in the early Aptian (early Cretaceous) corresponding to the OAE1a (Selli level). Such data were used to evaluate the control exerted by geodynamic factors, such as the opening of new gateways that modified the oceanic circulation patterns, on the diffusion and evolutionary history of these benthic bivalves. The extraction and validation of data sourced from different databases was a massive work, that confirms how web databases are useful, even if data need a large amount of work by researchers to be used for scientific purposes. Moreover, databases need continuous updating which is only possible with a great effort of researchers and technicians. Paleotax for example is updated to the year 2000, while PaleobioDB and Paleo-Reefs have largely incomplete collections of papers and occurrences regarding rudist bivalves. One of the byproducts of our work was, thus, the production of a new database (Oxfordian-early Aptian Rudist DB, OXeAP_RDB), freely available on request at www.stratageoresearch.com. The DB was created in .xls format and is structured to easily find the palaeontological information necessary for any stratigraphical and geological application. OXeAP_RDB is updated to January 2019, is critically revised and is easy to be accessed, but unfortunately it doesn't provide a webgis application for the location of entries on a map. The next step will be the production of a Database including all the rudist occurrences from the Oxfordian to the Maastrichtian, though the data that needs to be checked are by far more numerous and massive.

http://www.paleotax.de/rudists/intro.htm
https://paleobiodb.org
https://paleo-reefs.pal.uni-erlangen.de/reefs/searchreef_public.php
http://www.stratageoresearch.com

DDE Stratigraphy: an online platform for the online share and service of stratigraphic data and tools

Fan J.X.[1]*, Yang J.[1] & Hou X.D.[1]

School of Earth Sciences and Engeering, Nanjing University, China.

Corresponding author email: jxfan@nju.edu.cn

Keywords: Deep-time Digital Earth, stratigraphy, FAIR, time dimension, database.

The Deep-time Digital Earth (DDE), the IUGS recognized Big Science Program, was formally launched on February 26, 2019 by 13 international organizations and national geological surveys such as International Commission on Stratigraphy (ICS), International Association on Sedimentologists (IAS), and British Geological Survey. The Deep-Time Digital Earth is an international consortium aiming to develop a platform of connected geoscience informatics efforts with FAIR data (Findable, Accessible, Interoperable, and Re-usable) with adequate quality control linking various Earth's spheres in geological history (Wang et al., 2019). The DDE is a 4D system, including one dimension of geological time and three dimensions of paleo-location. It provides the possibility of linking those multi-source heterogeneous data of existing geological databases through the 4D concept. DDE Stratigraphy, aiming on the time dimension for the DDE system, is the platform for the sharing of stratigraphic data and tools. Many existing stratigraphic databases, such as Geobiodiversity Database (http://www.geobiodiversity.com/Main.aspx; Fan et al., 2013) and Macrostrat (https://macrostrat.org/; Peters, 2005) can be linked to each other through the DDE Stratigraphy platform. Those tools, such as TS Creator for stratigraphic visualization, SinoCor and CONOP for quantitative stratigraphy, Geological Virtual World for virtual reality (VR) can be freely accessed by any users through the online system or even apps in the mobile phone.

Fan J.X., Chen Q., Hou X.D., Miller A.I., Melchin M.J., Shen S.Z., Wu S.Y., Goldman D., Mitchell C.E., Yang Q., Zhang Y.D., Zhan R.B., Wang J., Leng Q., Zhang H. & Zhang L.N. (2013) - Geobiodiversity Database: a comprehensive section-based integration of stratigraphic and paleontological data. Newsletters on Stratigraphy, 46(2), 111-136.

Peters S.E. (2005) - Geologic constraints on the macroevolutionary history of marine animals. Proceedings of the National Academy of Sciences U.S.A., 102, 12326-12331.

Wang C.S., Shen S.Z., Zhou C.H., Hou Z.Q., Cheng Q.M., Oberhansli R. & Stephenson M., (2019) - Preface: Decodification of Earth evolution in Deep-time. Acta Geologica Sinica (English Edition), 93(S3), 1-2.

Electronic stratigraphy dictionary of Russian Phanerozoic

Oshurkova M., Zbukova D., Gorshenina V.*, Baranov I., Berezyuk N. & Chetverova V.

A. P. Karpinsky Russian Geological Research Institute (FGBU "VSEGEI")

Corresponding author email: Vera_Gorshenina@vsegei.ru

Keywords: information system, database, stratigraphy.

Department of stratigraphy and paleontology VSEGEI (Russian Geological Research Institute) runs an information system "Electronic stratigraphy dictionary of Russian Phanerozoic" (IS). The first version of IS was released under Data base management system (DBMS) Paradox 9.0 (Oshurkova et al., 2002). Actual version is working under DBMS Oracle 11g. It has two interfaces: web-interface for internet users (http://stratdic.vsegei.ru/) and internal application for IS editor. To enter information into the data bank (DB), a unified form has been developed containing a complete set of features for diagnosing a stratigraphic unit (Straton). Reference books and dictionaries were created to provide the necessary clarity and completeness of descriptions. Each description contains the following details: name of Straton with etymology of name and author, rank and links. The data on the stratotype of the Straton (with geographical coordinates) are given; the lithological and paleontological characteristics of the Straton are also available. Stratigraphic position of Straton includes system, epoch, stage and biostratygraphical zonation as well as reginal units and members, relations with underlying and overlapping deposits, geographical expansion (with geological map binding, where this Straton is being used). Isotopic, paleogeomagnetic and paleoclimatic data are notified also for Stratons where it is available. Graphical data shown as columns are used as Straton description. Straton's description in the rank of horizon lists the local stratigraphic units (series, suites and strata) that it includes. Straton's description in the rank of series lists combine retinue suites and thickness. DB allows to search by name of Straton, or its geographical, stratigraphic position. To start using IS it is enough to enter in system through "Reports" form and receive a Word-document with full description of Straton. IS is updated and actualized permanently. Two-side linked dynamical interaction with "Legend of serial State Geological Maps of Russian Federation" provides the access to full scope of information. Two key parameters are used for linking: name of Straton and it's stratigraphical position (in GTS – geological time scale). In the database becomes available information about belonging of the Straton to a specific legend and taxon of structural-formation zoning. DB is intended for operative support by paleontological and stratigraphical information during mapping and geological research works.

Oshurkova M.V., Avdontsev S.N. & Zbukova D.V. (2002) - Information System "Electronic Stratigraphic Dictionary of the Phanerozoic of Russia" // Reg. geol. and metallogeny, 16, 61-68.

NSB, a Big Data tool for chronostratigraphic syntheses of the deep-sea sediment record

Renaudie J.*[1], Lazarus D.[1] & Diver P.[2]

[1] Museum für Naturkunde Berlin. [2] Divdat Consulting.

Corresponding author email: johan.renaudie@mfn.berlin

Keywords: micropaleontology, paleoceanography, evolution, databases, age models.

The deep-sea sedimentary record is the primary source of materials for paleoceanography and marine micropaleontology. Early studies of Quaternary-Recent sediments, e.g. CLIMAP used piston cores and broad geographic syntheses of single time interval data. Pre-Quaternary paleoceanographic studies mostly use sediments recovered by the deep-sea drilling projects (DSDP, ODP, IODP), and have mostly focussed on multiple proxy data time-series from a few sections, with new proxies and increasing time resolution as primary research directions. Many scientific questions in paleobiology and earth system science however benefit from, or require, a global perspective, with integration of data from many sections in different oceans and environments. This in turn requires a global chronostratigraphic framework, applied to each section, and access to both the individual section chronostratigraphy and section-linked data for studies. The drilling programs do not provide this, instead capturing and archiving primary metadata and raw (unstandardized) individual study report data files, indexed to depth-in-section via their own and allied databases, e.g. the Pangea earth sciences archive system. The Neptune database was begun at the ETH in Zürich in the early 1990s to provide a global deep sea age-modeled section framework linked to marine microfossil occurrence data, for taxonomic and paleobiologic studies. The initial implementation was in a pre-sql, offline rdbms supported by offline apps in True Basic. The database migrated to modern sql and the web via the Chronos project (USA) in the early 2000s and was re-incarnated as NSB in the 2010s at its current home at the MfN in Berlin. Along the way the data content expanded by >300% to current values of nearly 800K occurrence records for 9K taxa names from >300 globally distributed age-modeled drill sites. The large majority of the data is from the Cenozoic, but some Cretaceous data is held as well. NSB re-wrote the complex, multiple computer-language heritage stack to a more maintainable (by undertrained, over-committed regular scientists) implementation in Python and SQL. A major extension of NSB added chronostratigraphic data: events in individual sections (28K records), and their reference calibrations in deep sea sections (2.7K records), plus age scales. Neptune and NSB have primarily been used for paleobiologic and evolutionary studies, but paleoceanographic use of the chronostratigraphic content has increased rapidly in the last few years. This is probably due to more visibility via a recently created data link to the popular micropaleontology taxonomy website Mikrotax. More deep-sea data, land section data, older geologic time intervals, stronger links to allied databases and archives (GBDB, Pangea, DDE), integration online of currently offline tools (e.g. ADP, used to generate age models for sections), and more analytic tools, including AI, are all possible directions for future NSB development.

A needful preparation for quantitative biostratigraphy with big data: taxonomy examination by image analysis

Shi Y.K.*

Nanjing University, China

Corresponding author email: ykshi@nju.edu.cn

Keywords: taxonomy examination, image analysis, fusulinids, PCA, CVA.

Under the circumstance of big data, a composite standard sequence (CSS) containing all geological events in an appropriate order will become a more necessity among researchers, especially new joiners, to understand the geological history. This sequence could be constructed through various quantitative stratigraphic techniques such as graphic correlation (Shaw, 1964) and constrained optimization (CONOP, Sadler & Cooper, 2003), and need to be recognized by the wide geological school, firstly of all, paleontologists. Biostratigraphy, based on The Principle of Faunal Succession, plays a key role for constructing CSS and in return the CSS need to be tested by the common fossil occurrence sequence. However, there is a long existed argue among paleontologists that when fossil data from amounts of sections are compiled the inconsistency on taxonomy would become the primary bias. Geobiodiversity database (GBDB, Fan et al., 2013) made significant effort to avoid this issue, such as setting the taxonomy opinion function for taxonomists to provide professional critics, and inviting taxonomists to examine the data before Paleozoic CSS of South China was constructed. With the paleontological data increase under the international science project of Deep-time Digital Earth, fossil data from all over the world will accumulate and it's impossible to rely on any single taxonomist or even a group to do the taxonomy examination. Image analysis technique will provide a solution and here I apply it to fusulinid foraminifera thin section images as a pilot analysis. Thin section images include all details for fusulinid taxonomists to commonly assign the taxa. The analysis consists of 119 images belonging to six genera. All images are standardized with regard to size, gray scale, shade and orientation. Linear multivariate analyses, i.e. principal component analysis and canonical variant analysis, are employed to distinguish the images and the result exhibits high consistency with the author's identification. The procedure displays the power of image analysis, and with nonlinear analysis and artificial intelligence technique involved in the future, taxonomy examination assisted by image analysis will be quick and accurate for CSS construction.

Fan J.X., Chen Q., Hou X.D., Miller A.I., Melchin M.J., Shen S.Z., Wu S.Y., Goldman D., Mitchell C. E. & Yang Q. (2013) - Geobiodiversity Database: a comprehensive section-based integration of stratigraphic and paleontological data. News. Stratigr., 46(2), 111-136.

Sadler P. M. & Cooper R.A. (2003) - Best-fit intervals and consensus sequences. In: P. J. Harries ed., High-resolution approaches to Stratigraphic paleontology, 49-94. Kluwer Acadeic Publishers, Dordrecht, Boston, Paris.

Shaw A. B. (1964) - Time in stratigraphy. McGraw-Hill, New York.

Assisted Biostratigraphic Interpretation: an Example of Machine Learning in Petroleum Geoscience

Simmons M.D.[1], Adeyemi O.[1], Bidgood M.D.[2], Maksymiw P.[1], Osterloff P.[3], Possee D.[4], Routledge C.[5], Saunders B.[1], Prince I.[3] & van Buchem F.S.P.*[1]

[1] Halliburton. [2] GSS (Geoscience) Ltd. [3] Shell. [4] University of Southampton. [5] University College London.

Corresponding author email: thevanbuchems@hotmail.com

Keywords: Biostratigraphy, assissted machine learning, petroleum geoscience.

The application of data science and machine learning are transforming petroleum geoscience workflows. Routine yet time-consuming and important tasks can be made more efficient by the application of machine learning-based assisted interpretation, freeing the geoscientist to perform tasks with greater value. Accuracy, reproducibility, and understanding of uncertainty are also improved and greater insight can be gained. Biostratigraphic data is common in the industry but requires deep specialist knowledge and significant time to interpret, hence it can be underutilized. However, the form of the data makes it suitable for the application of machine learning techniques. The applications of machine learning on biostratigraphic data from a set of typical industry wells were tested to facilitate the interpretation of biozone/age and paleoenvironment. The data was from three wells from anonymous West African locations. Two wells form training data, with a third well the target for machine learning based interpretation. Numerous samples had been analysed from each well and rich and diverse assemblages of foraminifera and calcareous nannofossils were present over an interval that ranged in age from Cretaceous to Neogene incorporating 60 biozones. In total, the three wells contained 768 species within 710 samples. However, to capture a full range of possible bioevents, the industry wells were supplemented with data from published sources [e.g., International Ocean Drilling Programme (IODP) reports on 16 wells with relevant stratigraphy] to form a more comprehensive training dataset. The data was provided without interpretation, thus an initial task was to carry out a human interpretation of biozone/age and palaeoenvironment. This then provided the context to develop the training dataset and a target to measure the success of the machine learning technique against. To facilitate both human and machine learning based interpretation, it was found useful to identify and eliminate spurious data, for example, that resulting from reworking or caving. Such data was identified by reference to species dictionaries that identify the broad stratigraphic range of species and through statistical screening. Application of Random Forest and Naïve Bayesian algorithms achieved results comparable to standard human interpretation, and pre-processing of the data proved beneficial. Important to the success of the project was the close working relationship between data scientists and subject matter experts to capture the nuances of biostratigraphic data and its interpretation. The work forms a case study for application to other geoscience data types.

The Uses and Benefits of Big Data for Geological Surveys

Stephenson M.H.*

British Geological Survey

Corresponding author email: mhste@bgs.ac.uk

Keywords: 'Long tail' data, geological survey, International Union of Geological Sciences.

'Long tail' data is the difficult-to-get-at data that sits in libraries, institutes and on the computers of individual scientists. Informatics specialists like to contrast it with the smaller number of large, more accessible data sets. The name 'long tail' derives from graphs drawn of the size of data sets against their number: there are relatively few large datasets and a lot of smaller ones. Geological science has more long tail data than sciences like physics or meteorology, probably because historically it has been less associated with big science infrastructure and sensors. Much of this 'long tail' data resides in geological surveys – institutes created by nations to survey and 'inventorise' geological resources. For many large and long-established geological surveys, improving the discoverability and ease of compilation (interoperability) of 'long tail' geoscience data involves making historical paper data available to cyberspace. A unique collaboration between the British Geological Survey (BGS) and computer scientists of the GeoBiodiversity Database (GBDB) is opening up some of this data. The BGS has an abundance of biostratigraphical data collected over almost two centuries associated with about 3 million fossils and thousands of localities and stratigraphic sections, to exacting and consistent standards. The data has great potential for science, but much of it is contained within paper documents or simple document scans and so is inaccessible to big data tools. It needs lifting from the page and into cyberspace. The BGS began working recently with GBDB (the official database of the International Commission on Stratigraphy (ICS)) which is almost unique in being the only large database to hold sequences of fossils tied to sections, rather than just spot collections. Another aspect of 'long tail' geoscience data in geological surveys is well-organized data in digital 'islands'. These need to be brought together between and within institutions, made interoperable, and georeferenced both in a palaeogeographical and modern geographical sense. The Deep-time Digital Earth (DDE), the first 'Recognised Big Science Program' of the International Union of Geological Sciences (IUGS) aims to link digital 'islands'. Through DDE, data will be made available in easily used 'hubs' providing insights into the distribution and value of earth resources and materials, as well as earth hazards. Data brought together in new ways may provide novel glimpses into the Earth's geological past and its future.

Using the Mikrotax web-taxonomy system as a platform for envisioning and exploring stratigraphic occurrence data from the Neptune database

Young J.R.*[1], Bown P.R.[1], Huber B.T.[2], Lazarus D.B.[3], Pedder B.E.[1] & Wade B.S.[1]

[1] University College, London, UK. [2] Smithsonian Institution, Washington, USA.
[3] Museum für Naturkunde, Berlin, Germany.

Corresponding author email: jeremy.young@ucl.ac.uk

Keywords: micropalaeontology, biodiversity, web-database, ocean-drilling.

Micropalaeontology is a data-rich branch of the earth sciences. Individual samples can contain thousands of specimens and it is quite normal for micropalaeontologists to identify, collect, image or measure tens or even hundreds of thousands of specimens during the course of a research project. However, these data are relatively difficult to systematise and data mining techniques have been relatively poorly used, at least outside the industrial biostratigraphy sector. Probably the most useful exception to this is provided by the data from deep sea drilling, where enormous numbers of samples have been studied under a relatively uniform framework through more than 50 years of research. The prime compilation of these data is provided by the Neptune database, which now includes ca 800,000 species occurrence records and this has been extensively used for palaeobiodiversity studies. More recently in the context of the Mikrotax project we have been developing the potential of the Neptune database as a source of relatively objective, quantitative, data on the stratigraphic and biogeographic occurrence of individual species of planktonic microfossils. We have found that the *occurrence-frequency* of individual species (i.e. the proportion of samples they are recorded in from a given time interval) provides a useful proxy for species abundance change, and so can be used to investigate changing distribution patterns through space and time significantly better than using simple presence-absence data. Further by summing the occurrence-frequencies of individual species we can obtain the *observed-diversity* of higher taxa (i.e. the average number of species observed in a sample of a given age). This *observed-diversity* is arguably more useful than total recorded diversity, and has the advantage of being much less susceptible to skewing from rare species and taxonomic splitting. Plotting data from the Neptune database is now a core part of the Mikrotax system, complementing the other data on microfossil taxonomy, morphology and biostratigraphy. The system currently provides definitive data for two major groups - calcareous nannofossils (Nannotax website) and planktonic foraminifera (pforams@mikrotax website), with extension to other groups (e.g. radiolaria and acritarchs) in progress. The Neptune occurrence data are presented as plots of occurrence-frequency through time for individual species, with additional tools available to plot occurrence-frequency data on palaeogeographic maps, on a time-latitude grid, and on custom plots comparing different taxa. These tools are invaluable for Mikrotax-users seeking reference information on individual taxa. It has also, however, proven significant that they provide tools to visualise the raw data of the Neptune database. By doing so they expose problems with the database which are otherwise easily overlooked, and so allow us to improve it. This has led to us significantly revising the age models for numerous sites and to revising synonymy interpretations. Following this we are better able to understand the strengths and weaknesses of the Neptune data compilation and use it as a basis for planning larger scale data integration within micropalaeontology.

ST2.6

Does the Golden Spike still glitter?

Conveners and Chairpersons
David Harper (Durham University)
Philip Gibbard (University of Cambridge)
Brian Huber (Smithsonian Museum of Natural History)

The GSSP is Dead! Long Live the GSSP!

Cramer B.*

University of Iowa

Corresponding author email: bradley-cramer@uiowa.edu

Keywords: GSSP, biostratigraphy, conodont, graptolite, timescale.

The original decision to utilize the boundary-statotype concept for chronostratigraphic divisions of Earth history in the form of Global Boundary Stratotype Sections and Points (GSSPs) was not without controversy. The advantages of the boundary-stratotytpe concept with regards to gaps and overlaps when compared to the unit-stratotype concept notwithstanding, there has remained a persistent disquiet among stratigraphers with the practicality and function of the GSSPs as chosen and utilized in the past four decades. Today, a growing chorus of discussion has begun regarding the demise of the GSSP. I would like to posit that the difficulties with the practical function of many, if not most, of the GSSPs currently designated are not the fault of the GSSP as a concept, but rather the decisions that were made by the subcommissions in selecting the GSSP positions in the first place. The typical over-reliance on single-taxon biozone biostratigraphy and the *a priori* assumption that the first appearance of an index species in a lineage zone will 'approach synchronicity' is at the core of many current GSSP issues. The solution to this problem is not to overthrow the concept of the GSSP, but rather, to better constrain our objectives to include events in Earth history, not solely the positions identifiable by a single clade of biostratigraphers.

Fallacies regarding GSSPs

Finney S.*

California State University, Long Beach

Corresponding author email: Stan.Finney@csulb.edu

Keywords: GSSP, correlation, criticisms.

Fifty-two years since the International Commission on Stratigraphy was established, ICS has approved and the IUGS has ratified 71 of the 102 GSSPs that define boundaries of a single, hierarchal set of global stages, series, systems, and erathems for the Phanerozoic Eonthem. During these 52 years, methods of stratigraphic correlation improved considerably, and knowledge of stratigraphic successions worldwide expanded greatly. Although the basic concept of the Global Stratotype Section and Point is known throughout the stratigraphic community, it often is misrepresented, and critics of the GSSP process chose to ignore it successes. Ager's (1981) pronouncement that it does not matter where the golden spike is hammered in so long as it is done and that we can then move on to the much more difficult task of correlation is most unfortunate. Too many GSSPs, such as those defining most of the stages and series of the Silurian, were placed without concern for correlation. They proved to be seriously deficient and now must be replaced. Correlation must precede definition; in fact, demonstrated widespread, reliable correlation is the primary requirement for ensuring a successful GSSP decision. Determination of a single marker that defines the GSSP and possibly secondary markers is well known. But these markers cannot be taken as infallible. In fact, the marker(s) only has value in terms of its position relative to all other stratigraphic signals within an extended boundary interval. Correlation is not a process of simple discovery of the marker in other sections; it always is an interpretive process that evaluates the position of the primary and secondary markers with regard to all other stratigraphic signals in an extended stratigraphic interval in both the stratotype section and the section correlated to it. It has been argued that, because a GSSP defines a point in time, two successive GSSPs define an interval of time that is a geochronologic unit and that the strata deposited during that time interval comprise a corresponding chronostratigraphic unit. It has even been argued that for this reason chronostratigraphic units are redundant and unnecessary. However, this argument ignores the fact that two GSSPs can be known to be successive only by means of an already established, extensive chronostratigraphic framework.

Ager D.V. (1981) - The Nature of the Stratigraphical Record, 2nd Ed. MacMillan. Hong Kong.

The Golden Spike still glitters, providing a new platform for chronostratigraphic calibration and global correlations

Harper D.A.T.[1]*

[1]Durham University, UK.

Corresponding author email: david.harper@durham.ac.uk

Keywords: Correlation, Calibration, GSSPs.

The perceptive work of 18th and 19th century geologists developed the concept of geological time and the stratigraphic column. But, as greater precision was required to correlate events and strata globally, it was clear that many of the original boundaries of the geological systems were separated from each other by unconformities. Many, however, are only regional breaks in Europe, not elsewhere, providing a poor basis for global correlation. Nevertheless, the column provided the basis for Darwin's studies (published in 1859) on evolution in deep time and Phillips's pioneering diversity curves for life in the Phanerozoic (published in 1860). A new approach was required, inspired by the International Commission on Stratigraphy (ICS). All the system boundaries have been reinvestigated by working groups of the ICS (all but one is in place), as have many of the series and stage divisions (Cohen et al., 2013). The base of a chronostratigraphic interval is defined in a unique stratotype section, in a type area using the concept of a "golden spike" (Hedberg, 1976). All the usual criteria for a workable stratotype section must be satisfied (Cowie et al., 1986). The golden spike, which represents a point in the rock section and an instant in geological time, is then driven into the section, at least in theory (Holland, 1986); this is a fact. In reality, the spike is usually adjusted to coincide with the first appearance (FAD) of a distinctive, recognizable fossil within a well-documented lineage, though non-biological markers are ever increasingly important. This horizon will then be the Global Stratotype Section and Point (GSSP) and reported on the regularly-updated ICS timescale chart (Cohen et al., 2018, www.stratigraphy.org) now in many different languages. The ranges of all fossils occurring across the boundary, together with geochemical and other proxies, are documented as aids to correlation; correlation, however, is a hypothesis. Improved calibration and correlation of strata with biological data are commonly matched by chemostratigraphy, cyclostratigraphy and magnetostratigraphy together with high precision absolute dates, sometimes with an accuracy of 10 kyr. Successions can be orbitally-tuned using Milankovitch cycles based on eccentricity, obliquity and precession. These data, biological and non-biological, are integrated in the definition and description of chronostratigraphic units. The establishment of the GSSP for the Chattian Stage (Paleogene System) is an elegant exemplar (Coccioni et al., 2018). Shen and Rong (2019) have integrated all available stratigraphic (time-series) data from China, compiled from the Ediacaran to Quaternary.

Cohen K.M., Finney S.C., Gibbard P.L. & Fan J.-X. (2013) - The ICS 823 International Chronostratigraphic chart. Episodes, 36, 199 - 204.

Cohen K.M., Finney S.C., Gibbard P.L. & Fan J.-X. (2013) - The ICS 823 International Chronostratigraphic chart. Episodes, 36, 199 - 204.

Cowie J.W., Ziegler W., Boucot A.J., Bassett M.G. & Reman, J. (1986) - Guidelines and Statutes of the International Commission on Stratigraphy (ICS). Courier Forschungsinstitut Senckenberg , 83, 1-14.

Coccioni R., Montanari A., Bice D., Brinkhuis H., Deino A., Frontalini F., Lirer F., Maiorano P., Monechi S., Pross J., Rochette P., Sagnotti L., Sideri M., Sprovieri M., Tateo F., Touchard Y., Van Siameys S. & Williams G. (2018) - The global stratotype section and point (GSSP) for the base of the Chattian Stage (Paleogene System, Oligocene Series) at Monte Cagnero, Italy. Episodes.

Holland C.H. (1986) - Does the golden spike still glitter?. Journal of the Geological Society, 143(1), 3-21.

Shen S. & Rong J. (Eds.) (2019) - Integrative stratigraphy and timescale of China. Science China: Earth Sciences 62, 1–348.

Tree-ring dating in event stratigraphy: insights to the Northgrippian-Meghalayan boundary from isotope chronology

Helama S.*

Natural Resources Institute Finland, Rovaniemi

Corresponding author email: samuli.helama@luke.fi

Keywords: Dendrochronology, Holocene, chronostratigraphy, climatostratigraphic boundaries, event stratigraphy.

Subdivision of the Holocene Series/Epoch into the Greenlandian, Northgrippian and Meghalayan Stages/Ages has recently been ratified based on stable isotope records from ice-core and speleothem archives (Walker et al., 2018, 2019). The base of the most recent chronostratigraphic unit, corresponding to the Northgrippian-Meghalayan boundary, coincides with the '4.2 ka event' recognised as a drought anomaly in many low-latitude sites. The Global Stratotype Section and Point (GSSP) for the boundary, the oxygen isotope record from the Mawmluh Cave speleothem (India), demonstrates this event with markedly weakened Asian summer monsoon. Here we contribute to the assessments of the geological time scale and the global characteristics of this event by detailing an isotopic excursion in tree-ring carbon isotopes from high-latitude/subarctic Europe. The $\delta^{13}C$ chronology (Helama et al., 2018) demonstrates extremely overcast (wet) conditions, especially between 2190 and 2100 BCE, with anomalous conditions sustaining until 1990 BCE. In addition to demonstrating its exact dating and duration, the $\delta^{13}C$ data also illustrate the two-stage nature of the event and highlight the greater magnitude of the earlier stage. Considering the need to focus on climate records based on well-dated chronologies when defining new climatic events, the isotope record from Finnish Lapland is an ideal time marker as it is reliably converted to calendric timeline using the established tree-ring cross-dating methods (e.g. Speer, 2010). Moreover, the reconstruction of cloud cover variability based on the tree-ring $\delta^{13}C$ demonstrates the value of this isotope chronology to trace the past climatic events present in the recent geological record. Previously, tree-ring records have not served as GSSPs to subdivide formally the geological past. Traditionally most GSSPs utilise lithified and exposed rock outcrops; however, the GSSPs defining the lower boundary and subdivision of the Holocene Series/Epoch are now based on ice-core and speleothem isotope records. Interestingly, there have been suggestions of potential GSSP for the as-yet-undefined Anthropocene particularly in tree-ring. More generally, our results exemplify the potential of tree-ring archives to provide ideal time-stratigraphic marker horizons in terms of event stratigraphy.

Helama S., Arppe L., Timonen M., Mielikäinen K., & Oinonen M. (2018) - A 7.5 ka chronology of stable carbon isotopes from tree rings with implications for their use in palaeo-cloud reconstruction. Global Planet. Change, 170, 20-33.

Speer J.H. (2010) - Fundamentals of Tree-Ring Research. The University of Arizona Press, Tucson.

Walker M., Gibbard P., Head M. J., Berkelhammer M., Björck S., Cheng H., Cwynar L.C., Fisher D., Gkinis V., Long A., Lowe J., Newnham R., Rasmussen S.O. & Weiss H. (2019). Formal division of the Holocene Series/Epoch: a summary. J. Geol. Soc. India, 93, 135-141.

Outcome of the proposal on Unit Stratotypes and Astrochronozones

Hilgen F.J.*[1], Lourens L.J.[1], Pälike H.[2] & Research Support Team

[1] Utrecht University. [2] MARUM.

Corresponding author email: F.J.Hilgen@uu.nl

Keywords: Unit-stratotype, Astrochronozone, global chronostratigraphy, GSSP, Geological Time Scale.

The Global Stratotype Section and Point (GSSP) approach to define stage boundaries leaves the unit or body of the stage undefined. At the same time, former arguments against unit-stratotypes have been invalidated for the Cenozoic through the revolutionary advance in integrated high-resolution stratigraphy and astronomical dating. Combined, these provide unprecedented age control and ensure continuity of sedimentary successions, opening up the possibility to introduce unit-stratotypes for global stages. Last year, we proposed such unit-stratotypes with the entire stage to be formally defined in an astronomically age calibrated deep-marine succession, preferably but not necessarily containing the GSSP. Furthermore, cycles used for the tuning and to build our standard Geological Time Scale could be formally defined as chronozones. In this way, the standard Geological Time Scale and Global Chronostratigraphic Scale would be brought in line with the progress in integrated high-resolution stratigraphy and astronomical dating. The proposal involved separate voting on the formal definition of unit-stratotypes and astrochonozones, as the definition of unit-stratotypes does not necessarily depend on the formalization of astrochonozones. The proposal was submitted to the International Subcomission on Stratigraphic Classification (ISSC) for voting after several rounds of internal discussion with ISSC members. The final revised proposal was sent to ISSC voting members on February 23 last year with the deadline one month later. The outcome of the voting was circulated to ISSC members on April 30 and later to ICS. The proposal on the unit stratotype was declined by ISSC as the needed super majority of 60% of the votes was not reached (57.14%), while the formal definition of astrochronozones was accepted with a majority vote of 64.29%. Looking at the outcome of the vote, we could have continued with a separate proposal on the astrochronozone part for voting in Internation Commission on Stratigraphy (ICS). However, the astrochronozone is intimately linked to the unit-stratotype concept and an exclusive vote on it would be less relevant as a consequence. Note that this would not have been the case if the results of the ISSC vote would have been opposite, as the formalization of unit-stratotypes implies a much more fundamental change in global chronostratigraphic procedures and thinking than that of astrochronozones. Moreover, the most important astrochronozones associated with the stable 405-kyr eccentricity cycle will anyway be numbered from the Recent back in time, although in an informal rather than a formal way. As a moratorium of 10 years does not apply, we aim to resubmit the proposal after Strati2019 and the publication of GTS2020, as these events are anticipated to underline the critical importance of astronomical calibration of continuous deep marine successions not only for building our time scale but also for understanding Earth history.

La Charce (southeast France) - the Global Boundary Stratotype Section and Point (GSSP) of the Hauterivian stage

Mutterlose J.*[1], Rawson P.[2] & Reboulet S.[3]

[1] Ruhr-University Bochum. [2] University of Hull, University College London.
[3] Université de Lyon.

Corresponding author email: joerg.mutterlose@rub.de

Keywords: GSSP, Valanginian/Hauterivian boundary, La Charce.

The La Charce section (Drôme Department, southeastern France) is suggested for the Global Boundary Stratotype Section and Point (GSSP) of the Hauterivian stage. The thick section is well exposed and characterised by continuous sedimendation, without facies changes; the calcareous-marl alternation is favourable for long range correlations; macrofossils (mainly ammonoids) and microfossils (mainly nannofloras) are abundant and well preserved; magnetostratigraphy (weak signal), chemostratigraphy, sequence stratigraphy and gamma ray spectrometry records have been compiled; there is already a permanent protection of the site as it belongs to an Espace Naturel Sensible (ENS) of the Drôme Department; a reception area has been developed allowing a free and permanent access of the site. The base of the Hauterivian should be defined by the first occurrence (FO) of the ammonite genus *Acanthodiscus* which marks the base of the *A. radiatus* ammonite Zone. According to this proposal, the FO of the ammonite species *A. rebouli* in bed number 189 marks the base of the stage. At La Charce, the nannofossil event that best approximates the Valanginian/Hauterivian boundary is the last occurrence of *Eiffellithus windii* (bed number 213). Several other ammonite and calcareous nannofossil events are of inter-regional correlation value and provide valuable secondary markers:

– Bed 217 FO of *Diloma galiciense* (calcareous nannofossil)
– Bed 214 FO of *Saynella mucronata* (ammonite)
– Bed 213 LO of *Eiffelithus windii* (calcareous nannofossil)
– LO of *Tribrachiatus* sp. (calcareous nannofossil)
– Bed 197 FO of *Leopoldia leopoldina* (ammonite)
– Bed 194 FO of *Spitidiscus (*gr. *lorioli-meneghinii)* (ammonite)
– Bed 193 FO of *Breistrofferella castellanensis* (ammonite)
– Bed 190 FO of *Breistrofferella varapensis* (ammonite)
– FO of *Staurolithites mitcheneri* (calcareous nannofossil)
– Bed 189 FO of *Acanthodiscus rebouli* (ammonite) [base of Hauterivian]
– Bed 189 FO of *Teschenites flucticulus* (ammonite)
– FO of *Teschenites pachydicranus* (ammonite)
– Bed 186 LO of *Teschenites callidiscus* (ammonite)

The top of Chron M10Nn.3n coincides with the base of the Hauterivian and may serve as an interregional correlation event. Carbon isotopes from carbonate bulk rock samples show a plateau of around 1.3‰ across the boundary. The main geochemical breaks occur at the base and top of a marly interval (beds 197-203) which lies about 8 m above the boundary.

Stratigraphy in the Anthropocene - nailing down chronostratigraphy

Wagreich M.*, Draganits E. & Sames B.

University of Vienna, Austria.

Corresponding author email: michael.wagreich@univie.ac.at

Keywords: Anthropocene, golden spike, GSSP.

The Anthropocene is now under investigation of the Anthropocene Working Group (AWG) of the Quaternary Subcommission. Whereas the AWG indicates that the Anthropocene is stratigraphically real, and formalization at epoch rank is recommended (Zalasiewicz et al., 2017), other publications disregard any potential for a formally defined chronostratigraphic unit of the Geological Timescale (GTS) for various reasons, including the shortness of its duration or a better attribution to other disciplines like history or politics. In defining an Anthropocene as a chronostratigraphic unit, the AWG is committed to chronostratigraphy and various suggestions for starting points have been published so far. However, no GSSP section was defined yet, and the golden spike primary marker remains undefined, but many suggestions prefer artificial bomb nuclides from 1950 to 1965 (Zalasiewicz et al., 2017).

We notice several interesting points regarding stratigraphy:

(1) The second Copernican revolution brought a new view of the Earth as a single complex system, revolving Earth Sciences into Earth System Sciences, but also reversing the natural sciences progression into a revived anthropocentric view of the world with humans as a prominent natural force.

(2) Uniformitarianism, a first principle of geology, no longer holds true for Anthropocene strata, where we find artificial materials, minerals and chemical compounds never before existing on Earth and geological processes modified by humans, from planetary material fluxes, induced earthquakes to least nuclear fission.

(3) The current method of GSSP chronostratigraphy was perfectly suitable for diffuse and hard to date deep-time boundaries, but becomes more and more questioned by the development of precise and exact numerical dating methods in geochronology and astrochronology. This dilemma is especially exemplified by current stratigraphy effort applied on the Anthropocene aiming for a chronostratigraphic boundary and thus GSSP golden spike point which might be defined in a time frame covered by the unifying and precise time scale of the historical calendar, so historical and geological time scales would meet. This time scale allows for the precision down to splits of seconds and results in the golden spike (or pin) being inaccurate and artificial. A reiteration of the GTS from top (youngest)-down may be the future way. The challenges faced in defining the stratigraphy of the Anthropocene may provide the opportunity for the discussion to change chronostratigraphy into a numerical stratigraphy.

Zalasiewicz J., Waters C.N., Summerhayes C.P., Wolfe A.P., Barnosky A.D., Cearreta A. Crutzen P., Erle E., Fairchild I.J., Galuszka A., Haff P., Hajdas I., Head M.j. Ivar do Sul J.A., Jeandel C., Leinfelder R., McNeil J.R., Neal C., Odada E., Oreskes N., Steffen W., Syvitski J., Vidas D., Wagreicj M. & Williams M. (2017) - The Working Group on the Anthropocene: Summary of evidence and interim recommendations. Anthropocene, 19, 55-60.

Zalasiewicz J., Waters C.N., Williams, M. & Summerhayes, C.P. Eds. 2019. The Anthropocene as a Geological Time Unit. A Guide to the Scientific Evidence and Current Debate. Cambridge University Press, Cambridge.

ST2.8
Sediment archives from ocean drilling: insight into the development and improvement of Biochronology and Time Scales

Conveners and Chairpersons
Jan Backman (Stockholm University)
Ursula Roehl (marum - Zentrum für Marine Umweltwissenschaften)
Thomas Westerhold (University Bremen)

Cenozoic calcareous nannofossils as stratigraphic tools: state of the art, pitfalls and future perspectives

Agnini C.[1]*

[1]University of Padova, Italy.

Corresponding author email: claudia.agnini@unipd.it

Keywords: calcareous nannofossils, IODP, biostratigraphy, biochronology.

Nannofossils are calcareous rests produced by phytoplanktonic algae that in the modern ocean are mostly ascribed to Haptophyta. When they were first be observed in the nineteen century their biological nature was not immediately clear and even when it became obvious, for decades they have been considered a scientific curiosity more that an effective and powerful stratigraphic tool. The collection of an immense dataset from the most important geological archive, the sediments, have allowed scientists to understand that this group has a unique and widespread distribution in space and time. This fundamental step was made possible thanks to two main reasons: the first one is the enormous dataset made available by the ocean drilling projects, the second is the development of micropaleontology in relation to Oil companies. In the seventies it became evident that calcareous nannofossils are essential to biostratigraphy, in other words to assign relative ages to bioevents and produce biostratigraphic schemes for both the Mesozoic and Cenozoic. This represented a revolution in the utilization of this group that has rapidly became one of the most important marine stratigraphic tools. In this view the recent publication of two biozonations, one for the Paleogene and one for the Neogene/Quaternary, if on one hand it surely represents an implementation of the classic Cenozoic biozonations, on the other hand it is the first attempt to apply a quantitative approach to this discipline. Once the spacing and ranking of calcareous nannofossil biohorizons are defined the further step is to relate this relative dating to absolute dating and this has been obtained using magnetostratigraphy and/or cyclostratigraphy. The exceptional bonus of biochronology is in fact that you can use the age estimation calculated for biohorizons to frame sedimentary successions in time when absolute dating tools are not available. In the last decades much has been done, but a lot more still needs to be done because we now want to integrate all the information possibly gathered from different disciplines with the higher possible resolution. Moreover, micropaleontologists have to fully understand the incredible role they can play in the refinement and implementation of these chronologic frameworks but for doing that they have to make an effort in trying to standardize their methodologies and, even more importantly, move from a descriptive-naturalist approach, where the figure of micropaleontologist is a mere data collector, to a modern interdisciplinary approach, where they are able to provide their fundamental contribution on an equal footing with other Earth scientists.

A biostratigraphic and paleoecological analysis of Late Oligocene calcareous nannoplankton of the North Atlantic Ocean

Clark W.*[1], Watkins D.K.[2] & Wagreich M.[1]

[1] University of Vienna. [2] University of Nebraska-Lincloln.

Corresponding author email: wclark38@gmail.com

Keywords: nannoplankton, biostratigraphy, time-scale, paleoecology, Late Oligocene, ocean drilling.

A transect across the North Atlantic Ocean, from ocean drilling Sites 926, 628, 563, U1406, 647, and 918, was analyzed quantitatively to determine the paleolatitudinal distribution of calcareous nannofossils in the Late Oligocene and the effects of that distribution on biostratigraphic resolution. A biochronological analysis utilized Unitary Associations (UA) and divided the assemblage into 6 UAs, correlating with current biostratigraphic schemes. UA 3 and UA 4, defined by the base of *Sphenolithus calyculus*, was not consistently used in existing biostratigraphy, and offers an additional bioevent for the Upper Oligocene. The absence of UA 5 at Hole 926B reveals a disconformity that was not identified previously. Modern zonation schemes cannot be accurately applied to the North Atlantic Ocean north of 53° latitude. The best biostratigraphic resolution is restricted to the upper mid-latitudes, Sites 628, 563, and U1406, or from 27-40°. Detrended Correspondence Analysis (DCA), a Temperature index (TI), and the Shannon Diversity Index (H), were used to examine the paleoenvironmental gradients which exerted primary and secondary control over the distribution of species. The temperature index correlates to DCA 1, suggesting that thermal controls were the primary factor in the distribution of nannofossils in the North Atlantic during the Late Oligocene. Shannon Diversity and the percent abundance of the taxon *Reticulofenestra minuta* correlates significantly to DCA 2, suggesting that surface water mass fertility was the secondary controlling factor.

Magnetostratigraphic framework for IODP Expedition 371 (Tasman Frontier Subduction Initiation and Paleogene Climate)

Dallanave E.*[1], Chang L.[2], Sutherland R.[3], Dickens G.R.[4], Blum P.[5] & Exp. 371 Scientists

[1] University of Bremen, Germany. [2] Peking University, China. [3] Victoria University of Wellington, New Zealand. [4] Rice University, USA. [5] International Ocean Discovery Program, USA.

Corresponding author email: edoardo@uni-bremen.de

Keywords: IODP Exp. 371, Zealandia, magnetostratigraphy, Paleogene, Tonga-Kermadec.

International Ocean Discovery Program (IODP) Expedition 371 (27 July – 26 September 2017) was designed to understand the Tonga-Kermadec subduction initiation (southwest Pacific) through recovery of Paleogene sedimentary records, and also to constrain the regional oceanography and climate evolution since the Paleogene. During the Expedition were drilled 2506 m of sediment and volcanic rock at six sites (U1506–U1511) located in the northern Zealandia and Tasman Sea area east of Australia. Sediments drilled at Sites U1506 to U1510 consist of nannofossil and foraminiferal ooze or chalk that contained volcanic or volcaniclastic intervals with variable clay content. Paleocene and Cretaceous sections range from more clay rich to predominantly claystone. At Site U1511 a series of abyssal clay and diatomite was recovered, with only minor amounts of carbonate. The ages of strata at the base of each site is middle Eocene to Late Cretaceous. To integrate paleomagnetic results from shipboard archive halves and discrete specimens measurements, we collected a total of ~400 standard 8 cm^3 oriented cube specimens from Hole U1507B, U1508C, U1509A, and U1511B. After measuring the anisotropy of magnetic susceptibility (AMS), which gives indication about the sediment fabric and possible presence of drilling-induced deformation, specimens were stepwise demagnetized using both alternate field and thermal demagnetization, and the natural remanent magnetization was measured after each demagnetization step with a 2G Enterprises Cryogenic magnetometer. On-shore base analyses sensibly improve the quality of the magnetostratigraphic dataset, and the examined Holes altogether span from magnetic polarity Chron C5En to C24n, from about 18 Ma to 55 Ma. In the international time scale this corresponds to the Burdigalian–Ypresian (early Miocene to early Eocene), for a total of ~37 Myr of southwest Pacific geological history calibrated with the Geomagnetic Polarity Time Scale. This age-model provides a robust chronological framework for understanding the evolution of the Tonga-Kermadec subduction zone during the Cenozoic and the possible implications on the global climate variations.

Towards a standard radiolarian zonation for the Mesozoic

Goričan Š.*[1], O'Dogherty L.[2], Baumgartner P.O.[3], Carter E.S.[4] & Matsuoka A.[5]

[1] ZRC SAZU, Slovenia. [2] Universidad de Cádiz, Spain. [3] Université de Lausanne, Switzerland
[4] Portland State University, USA. [5] Niigata University, Japan.

Corresponding author email: spela@zrc-sazu.si

Keywords: radiolaria, biochronology, Mesozoic.

Mesozoic radiolarian biochronologic scales have been developed since the 1970s and most reached their present day status in the 1990s. The average degree of temporal resolution corresponds to substage level and is sufficient to provide a meaningful framework for general geological studies. A great majority of zonal schemes were elaborated in low-latitude sections but are applicable in mid to high latitudes as well because an adequate number of species occur worldwide. Oceanic material recovered by DSDP in the 1970's was crucial in constructing the first radiolarian schemes for the Cretaceous and, in a later stage, ODP samples contributed substantially to the improvement of Middle to Upper Jurassic zonations also. Mesozoic radiolarian biochronology remains, however, primarily based on land sections. We recently presented a short historical review and a synthesis of currently used zonations developed in North America, Europe and Asia (Goričan et al., 2018). As proven over the years of their application, reliable radiolarian subdivisions are those based on the assemblage concept. The biochronologically significant assemblages are defined either empirically or quantitatively by using the Unitary Association Method. The more species are included, the easier it is to correlate an assemblage over large geographic distances even with less than optimal preservation. Interval zones defined exclusively with FADs and LADs of marker taxa are not appropriate for the radiolarian stratigraphic record, which is highly incomplete due to facies restrictions and the variable degree of preservation. The ubiquitous presence of many radiolarian taxa allows for a relatively clear inter-regional correlation of assemblages. The existing zonations further confirm that the region where these zonations were established does not limit the geographic area of their applicability. It is thus reasonable to try to assemble the existing zonations, to select and revise the zones with the widest geographic traceability and to construct a composite Mesozoic zonation that would provide a single reference standard for radiolarian dating on a global scale. We are currently preparing such a compiled zonation complemented with newly available age constraints (e.g. stable isotope data) that will consolidate the correlation of radiolarian zones to chronostratigraphic units. This zonation could be an important contribution to a new edition of the Geologic Time Scale considering that radiolarians are the main and often the only fossil group providing age data in deep-marine siliceous deposits. The standard radiolarian zonation for the Mesozoic will be completed in near future and first presented at the 16th InterRad Meeting in September 2020 in Ljubljana, Slovenia.

Goričan Š., O'Dogherty L., Baumgartner P.O., Carter E.S. & Matsuoka A. (2018) - Mesozoic radiolarian biochronology – current status and future directions. Revue de micropaléontologie, 61, 165-189.

From the Caribbean to the JOIDES Resolution – The development of low latitude planktonic foraminiferal biozonations and future implications

King D.J.*[1-2-3], Wade B.S.[1], Liska R.D.[4] & Miller C.G.[2]

[1] Department of Earth Sciences, University College London. [2] Department of Earth Sciences, Natural History Museum. [3] Micropalaeontology Department, PetroStrat Ltd. [4] Independent researcher.

Corresponding author email: david.king.13@ucl.ac.uk

Keywords: biostratigraphy, planktonic foraminifera, Caribbean, evolution, extinction.

The utility of planktonic foraminifera in biostratigraphy was first fully recognised within the Caribbean region during the middle of the 20th century. The area was responsible for the first major biozonations for the microfossil group and remained critical for the subsequent development of the low latitude biostratigraphic schemes. Here we present a historical review of the Oligo-Miocene component of these biostratigraphic schemes from the initial zonation proposed by Cushman & Stainforth (1945) with the work of Hans Bolli and Walter Blow being particularly highlighted due to their heavy influence on the current and established biostratigraphic zonation. These Caribbean-centric schemes typically relied on outcrop samples, providing a relative sense of geological time. With the initiation of ocean research drilling, more complete oceanic sections were recovered and became critical in biostratigraphic zonations. The calibration of these zonations with other stratigraphic frameworks (e.g. magneto- and cyclostratigraphy) allowed for the establishment of numerically aged bioevents. The bioevents applied in the Caribbean zonations are correlated to the modern-day low latitude biogeochronology of Wade et al. (2011) with our synthesis highlighting that a number of bioevents (e.g. Top *Paragloborotalia kugleri* and Top *Catapsydrax dissimilis*) have been applied consistently since the recognition of their biostratigraphic value. This in turn allows us to determine which bioevents are the most and least recognisable (e.g. based on how frequently the bioevents have been applied). The range charts from a number of important Caribbean focused studies have been reassessed to determine whether there was potential to apply a given bioevent, and whether the original author merely did not recognise the biostratigraphic utility of the species or favoured another bioevent. In considering this historical review, a number of amendments to Wade et al. (2011) have been suggested, including the reintroduction of Base *Fohsella lobata* and Base *Globigerinatella insueta* as primary bioevents due to their historical importance in biostratigraphic correlation. In addition, the Miocene to recent datums from Wade et al. (2011) have been recalibrated following more recent updates to the magnetochronology. The overall effect on the planktonic foraminifera biogeochronology is minor, however this becomes the suggested biostratigraphic framework for the low latitudes.

Cushman J.A. & Stainforth R.M. (1945) - The foraminifera of the Cipero marl formation of Trinidad, British West Indies, Cushman Laboratory for Foraminiferal Research Special Publication, 14, 1–75.

Wade B.S., Pearson P.N., Berggren W.A. & Pälike H. (2011) - Review and revision of Cenozoic tropical planktonic foraminiferal biostratigraphy and calibration to the geomagnetic polarity and astronomical time scale. Earth-Science Reviews, 104, 111-142.

ST2.9

Improved reconstruction of geomagnetic field variations from 10Be and paleomagnetic methods: a stratigraphic tool for global synchronization of paleorecords

Conveners and Chairpersons

Quentin Simon (Aix-Marseille University)

Didier L. Bourlès (Aix-Marseille University)

Andrew P. Roberts (Australian National University)

New datation of Neogene series of the Guercif basin (Morocco): a combination between biochronological and magnetostratigraphical data

El Kati I.*[1], Benammi M.[1], Tabyaoui H.[2] & Benammi M.[3]

[1] Ibn Tofail University, Kenitra, Morocco. [2] Polydisciplinary Faculty, Taza, Morocco. [3] Poitiers University, France

Corresponding author email: imadelkati@yahoo.fr

Keywords: magnetostratigraphy, Neogene, Guercif basin, Morocco.

The Guercif basin is the eastern continuation of the Neogene foredeep of the Moroccan Rif Mountains, from which it has been separated by the late Neogene uplift of the Middle Atlas Mountains. Four stratigraphic sections have been analyzed on which 136 samples have been taken for the magnetostratigraphy study. The magnetic characteristics of these rocks show that the magnetization usually results from the presence of magnetite, titano-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). Magnetostratigraphic investigations in Safsafate section in the Messinian deposits show that it could be correlated with chrons C3Br.1n - C3Ar (~ 6.7 - 7.3 Ma). The Ain Guettara and Oued Lahmar sections show a succession of at least seven polarities that are correlated with chrons C3n.4n- C3n.2n (~ 4.5 - 6.0 Ma). These results along with new biostratigraphic studies based on rodent faunas and volcanism permit to establish the age of tectonic activity and deposition.

Ultra-high resolution paleomagnetic and ^{10}Be evidence for complex transitional field behaviour during the Upper Olduvai geomagnetic polarity reversal

Horng C.-S.[1], Roberts A.P.*[2], Zhao X.[2] & Simon Q.[3]

[1] Institute of Earth Sciences, Academia Sinica, Nankang, Taiwan, Republic of China. [2] Research School of Earth Sciences, The Australian National University, Canberra, Australia. [3] CEREGE UM34, University of Aix Marseille, CNRS, IRD, INRA, College de France, Europôle Méditerranéen de l'Arbois, Aix-en-Provence, France.

Corresponding author email: andrew.roberts@anu.edu.au

Keywords: paleomagnetism, Upper Olduvai transition, Taiwan.

We have obtained two nearby ultra-high-resolution, continuously sampled, records of the Upper Olduvai polarity transition from eastern Taiwan. The transition is recorded over the thickest sedimentary interval ever documented for a geomagnetic reversal (~16 m). The paleomagnetic record is carried by detrital magnetite and is not complicated by late diagenetic growth of greigite, which compromised previous attempts to obtain high-resolution sedimentary polarity transition records from Taiwan. The two transitional records can be correlated serially with each other, which lends confidence in the reliability of paleomagnetic recording. In contrast to most published sedimentary polarity transition records, our record resolves stop-and-go features so that they appear as gradual field changes. This demonstrates the exceptional resolution required to fully observe transitional field behaviour. The field underwent a rapid major shift near the beginning of the transition after collapsing to weak intensities, as is evident in both normalized remanence and ^{10}Be records, followed by several large and well-resolved directional swings with virtual geomagnetic poles (VGPs) lingering along "preferred" bands, notably in North America and the North Atlantic at the beginning and the South Atlantic at the end of the transition, respectively. However, the main transition then swings through the Pacific, with a minor VGP cluster south of Hawaii, followed by a cluster near New Zealand. Compilation of existing Upper Olduvai transition records indicates that field behaviour was different from that during the better studied Matuyama-Brunhes transition. This could support inferences from numerical geodynamo simulations that each reversal has a unique character, although the number of paleomagnetically well studied transitions remains small and the resolution of most records is not high. Despite the complex nature of the Upper Olduvai transition, VGP clustering in specific locations provides ongoing evidence for the influence of lateral lower mantle temperature variations on the reversing geodynamo.

An extended record of paleomagnetic direction and paleointensity across the Matuyama-Brunhes reversal from the Chiba composite section, central Japan

Okada M.*[1], Haneda Y.[1], Suganuma Y.[2] & Simon Q.[3]

[1] Ibaraki University. [2] National Institute of Polar Research. [3] Aix Marseille University.

Corresponding author email: makoto.okada.sci@vc.ibaraki.ac.jp

Keywords: Matuyama-Brunhes reversal, relative paleointensity, 10Be, Lower-Middle Pleistocene boundary GSSP.

We report a high-resolution paleomagnetic direction and relative paleointensity records from a continuous marine succession, consisting of 80 meters in thickness, exposed on the Chiba composite section of the Kokumoto Formation, Kazusa Group, Japan (Kazaoka et al., 2015; Suganuma et al., 2018). The Chiba composite section is a candidate for the Lower-Middle Pleistocene boundary GSSP. Our records, consisting of a new record (this study) and data from the previous study (Okada et al., 2017), provide detailed behaviors of the virtual geomagnetic poles (VGPs) and relative paleointensity changes during and after the Matuyama-Brunhes (M-B) polarity transition. The resultant relative paleointensity and VGP records show a significant paleointensity minimum near the M-B boundary, which is accompanied by an apparent "polarity switch" like a change in terms of the paleomagnetic direction. The relative paleointensity record exhibits a consistent variation with a parallel 10Be derived intensity proxy suggesting that our paleomagnetic data are highly plausible as a proxy for the geomagnetic field intensity. The results indicate that the field intensity seems to keep at a low level for ca. 10 thousand years associated with an unstable normal polarity, and then the field intensity recovers up. Our paleomagnetic data represent one of the most detailed records on this geomagnetic field reversal so far obtained from marine sediments and will, therefore, be vital for understanding the dynamics of the geomagnetic dynamo and for calibrating the geological time scale.

Kazaoka O., Suganuma Y., Okada M., Kameo K., Head M.J., Yoshida T., Kameyama S., Nirei H., Aida N. & Kumai H. (2015) - Stratigraphy of the Kazusa Group, Boso Peninsula: An expanded and highly-resolved marine sedimentary record from the Lower and Middle Pleistocene of central Japan. Quat. Int., 383, 116–135.

Okada M., Suganuma Y., Haneda Y. & Kazaoka O. (2017) - Paleomagnetic direction and paleointensity variations during the Matuyama-Brunhes polarity transition from a marine succession in the Chiba composite section of the Boso Peninsula, central Japan. Earth, Planets and Space, 69, 45. https://doi.org/10.1186/s40623-017-0627-1.

Suganuma Y., Haneda Y., Kameo K., Kubota Y., Hayashi H., Itaki T., Okuda M., Head M.J., Sugaya M., Nakazato H., Igarashi A., Shikoku K., Hongo M., Watanabe M., Satoguchi Y., Takeshita Y., Nishida N., Izumi, K., Kawamura K., Kawamata M., Okuno J., Yoshida T., Ogitsu I., Yabusaki H. & Okada M. (2018) - Paleoclimatic and paleoceanographic records of Marine Isotope Stage 19 at the Chiba composite section, central Japan: A reference for the Early–Middle Pleistocene boundary. Quat. Sci. Rev., 191, 406–430.

Multi - proxy global views on geomagnetic field variations over the past 100 ka

Panovska S.*[1] & Korte M.[1]

GFZ German Research Centre for Geosciences, Potsdam, Germany.

Corresponding author email: sanja.panovska@gfz-potsdam.de

Keywords: paleomagnetism, geomagnetic field, excursions, cosmogenic isotopes, global models.

The geomagnetic core field varies on time scales from months, years, centuries, to millennia. These variations can be conveniently studied using empirical spherical harmonic global models of Earth's magnetic field. One characteristic of the long-term variations are geomagnetic excursions - events when field directions deviate strongly from an axial-dipole dominated field, associated with globally low field intensities. Recent empirical modeling progress on long timescales gives us global insight into the field variations over the past 100 ka and the Laschamp excursion, the best globally documented event that happened 41 ka ago. However, the models are limited by data distribution and uncertainties of the paleomagnetic sediment and volcanic data. Since the production rate of cosmogenic isotopes, such as ^{10}Be, depends on the geomagnetic field, these records can also serve as proxies and complement the paleomagnetic data in better understanding the long-term field variations. First efforts are made in including a global compilation of ^{10}Be records in building a model over the past 100 ka. The Laschamp excursion is the most prominent feature in the past 100 ka, recorded globally in the paleomagnetic records, and represented in the ^{10}Be records with the highest peak in production rates. We discuss paleosecular variation, dipole moment and field morphology over the past 100 ka, the potential of the presently available compilation of cosmogenic isotopes records to improve global geomagnetic field models and the use of geomagnetic excursions as stratigraphic markers for correlation purposes.

Cosmogenic ^{10}Be records: a tool to control accuracy of paleomagnetic records during geomagnetic reversals and excursions

Simon Q.[1]*, Thouveny N.[1] & Bourlès D.L.[1]

[1]Aix-Marseille Université, CNRS, IRD, Coll France, Aix en Provence, France.

Corresponding author email: simon@cerege.fr

Keywords: paleomagnersitm, geomagnetic field, cosmogenic nuclide beryllium-10.

Geomagnetic field strength variations during reversals and excursions provide key information on geodynamo regimes and robust stratigraphic markers (see references). However, paleomagnetic records obtained from sediments and lava sequences are biased by uncertainties hampering accurate reconstructions. In order to test and improve the reliability, resolution and precision of paleomagnetic records during rapid field variations, reconstructions of the cosmogenic nuclide beryllium-10 (^{10}Be) atmospheric production rate, inversely proportional to the geomagnetic dipole moment value, have been obtained on several sedimentary sequences. The results obtained on the same samples from both methods are compared to extract accurate features (amplitudes, duration, rates) and discuss field dynamics during reversals and excursions. These features show that most available paleomagnetic records of reversal do not integrate the full field behavior which is problematic to reconstruct their precise dynamics and understand underlying physical processes. However, it does not hamper stratigraphic correlations among most geologic records, especially when using dipolar intensity proxy as global marker.

Simon Q., Thouveny N., Bourlès D.L., Valet J.-P., Bassinot F., Ménabréaz L., Guillou V., Choy S. & Beaufort L. (2016a) - Authigenic ^{10}Be/ ^{9}Be ratio signatures of the cosmogenic nuclide production linked to geomagnetic dipole moment variation since the Brunhes/Matuyama boundary. J. Geophys. Res., 121, 7716–7741. https://doi.org/10.1002/2016JB013335

Simon Q., Bourlès D.L., Bassinot F., Nomade S., Marino M., Ciaranfi N., Girone A., Maiorano P., Thouveny N., Choy S., Dewilde F., Scao V., Isguder G. & Blamart D. (2017) - Authigenic ^{10}Be/^{9}Be ratio signature of the Matuyama–Brunhes boundary in the Montalbano Jonico marine succession. Earth Planet. Sci. Lett., 460, 255–267. https://doi.org/10.1016/j.epsl.2016.11.052

Simon Q., Bourlès D. L., Thouveny N., Horng C.-S., Valet J.-P., Bassinot F. & Choy S. (2018a) - Cosmogenic signature of geomagnetic reversals and excursions from the Réunion event to the Matuyama–Brunhes transition (0.7–2.14 Ma interval). Earth Planet. Sci. Lett., 482, 510–524. https://doi.org/10.1016/j.epsl.2017.11.021

Simon Q., Thouveny N., Bourlès D. L., Bassinot F., Savranskaia T. & Valet J.-P. (2018b) - Increased production of cosmogenic ^{10}Be recorded in oceanic sediment sequences: Information on the age, duration, and amplitude of the geomagnetic dipole moment minimum over the Matuyama–Brunhes transition. Earth Planet. Sci. Lett., 489, 191–202. https://doi.org/10.1016/j.epsl.2018.02.036

New Relative Paleointensity Record of the geomagnetic field for the Holocene from the Central Adriatic Sea

Venuti A.*[1], Florindo F.[1], Vigliotti L.[2], Negri A.[3], Sabbatini A.[3], Spagnoli F.[4] & Morigi C.[5-6]

[1] Istituto Nazionale di Geofisica e Vulcanologia, Roma, Italy. [2] ISMAR, CNR, Bologna, Italy. [3] Università Politecnica delle Marche, Dipartimento di Scienze della Vita e dell'Ambiente, Ancona, Italy. [4] ISMAR, CNR, Ancona, Italy. [5] Dipartimento di Scienze della Terra, Università di Pisa, Pisa, Italy. [6] Geological Survey of Denmark and Greenland, Copenhagen, Denmark.

Corresponding author email: alessandra.venuti@ingv.it

Keywords: Paleomagnetism, secular variations, foraminifera, sapropel, Adriatic Sea, Holocene.

A marine sequence from Central Adriatic Sea (Meson-Adriatic Depression) was analyzed by means of paleomagnetic/rock magnetic analysis then integrated with micropaleontological data (planktonic foraminifera) and AMS^{14}C measurements. The core chronology of the late 3000 years was mostly based on the correlation of paleomagnetic inclinations with those of the UK master curve and supported by radiometric data. The chronology of the lower portion of the core was based on the occurrence of the sapropel S1 (clearly indicated by the concentration magnetic parameters) and of the planktonic foraminifera *Globorotalia inflata*. Magnetic parameters vary within the range that fulfill the criteria for a relative geomagnetic paleointensity (RPI) study. RPI record was obtained by normalizing the intensity of natural remanent magnetization (NRM_{20mT}) by anhysteretic remanent magnetization (ARM_{20mT}). The last 7000 years of the record is in good agreement with (a) the paleointensity record reconstructed by the geomagnetic global model CALS10k.1b (Korte et al., 2011), (b) with the regional models for Europe SCHA.DIF.3k (Pavón-Carrasco et al., 2009) and SCHA. DIF.8K (Pavón-Carrasco et al., 2010). In addition, our record agrees with relative paleointensities from MAD in central Adriatic Sea (new record computed using data from Vigliotti et al., 2008) and Augusta Bay in Sicily (Sagnotti et al., 2011).

Korte M., Constable C., Donadini F. & Holme R. (2011) - Reconstructing the Holocene Geomagnetic Field. Earth Planet. Sci. Lett., 312, 497-505.

Pavón-Carrasco F.J., Osete M.L., Torta J.M. & Gaya-Piqué L.R. (2009) - A regional archeomagnetic model for Europe for the last 3000 years, SCHA.DIF.3K: applications to archeomagnetic dating. Geochem. Geophys. Geosyst., 10, (Q03013).

Pavón-Carrasco F.J., Osete M.L. & Torta J.M. (2010) - Regional modeling of the geomagnetic field in Europe from 6000 to 1000 B.C.. Geochem. Geophys. Geosyst., 11, Q11008.

Sagnotti L., Smedile A., De Martini P.M., Pantosti D., Speranza F., Winkler A., Del Carlo P., Bellucci L.G. & Gasperini L. (2011) - A continuous palaeosecular variation record of the last four millennia from the Augusta Bay (Sicily, Italy). Geophys. J. Int., 184, 191–202.

Vigliotti L., Verosub K.L., Cattaneo A., Trincardi F., Asioli A. & Piva A. (2008) - Palaeomagnetic and rock magnetic analysis of Holocene deposits from the Adriatic Sea: detecting and dating short-term fluctuations in sediment supply. The Holocene, 18(1), 141-152.

ST3.1

Ediacaran Subdivision

Conveners and Chairpersons

Guy Narbonne (Queen's University)

Shuhai Xiao (Virginia Tech)

Marc Laflamme (University of Toronto)

Dima Grazhdankin (Trofimuk Institute of Petroleum Geology and Geophysics)

Ediacaran microbial bioherms capping methane seep networks in the Marinoan cap carbonate of the Kaarta Mountains, Mali

Álvaro J.J.*[1], Bilström K.[2] & Jorge A.[3]

[1] Instituto de Geociencias (CSIC-UCM), Madrid, Spain. [2] The Swedish Museum of Natural History, Stockholm. [3] Museo Nacional de Ciencias Naturales, Madrid, Spain.

Corresponding author email: jj.alvaro@csic.es

Keywords: cap carbonate, methane, microbial, reef.

In the Kaarta Mountains of Mali, the triad (glaciogenic diamictite-cap carbonate-silexite) that marks the Cryogenian-Ediacaran transition shows sharp modifications in facies in short distances (< 10 km). The cap carbonate of the Koniakari Group is representative of quiescent-dominated conditions, locally interrupted by decametre-scale disrupted substrates. The latter are characterized by the onset of fissure and fracture networks, occluded with tabular-and rosette-shaped barite cements and sealed by stromatolitic buildups with barite interlaminae. Detailed petrographic and geochemical analyses reveal barite-rich/free couplets of the stromatolitic patches display $\delta^{13}C$ values ranging from –43.2‰ to –4.8‰ PDB, indicative of a combination of microbial mediation, probably as alternations of methane and photosyntetizer carbon sources. The microbially induced oxidation of methane and input of Ba-rich fluids was coupled to reduction of sulfate derived from seawater. The Sr/S isotope ratio and barite shape and size point to diagenetic barite crystals occluding the fissure network and precipitated as stromatolitic intergrowths in the overlying buildups. Although present-day "chemoherms" commonly occur in deep substrates, under anoxic bottom waters, the cap carbonate of the Kaarta Mountains is representative of shallow waters under normal (oxygenated) conditions.

Cambrian-style biomineralizing animal fossils in the terminal Ediacaran stage

Cai Y.[1], Xiao S.*[2], Li G.[3] & Hua H.[1]

[1] Department of Geology, Northwest University. [2] Department of Geosciences, Virginia Tech.
[3] Nanjing Institute of Geology and Palaeontology.

Corresponding author email: yaopingcai@qq.com

Keywords: Ediacaran, biomineralizing fossil, diversity, evolution, South China.

The origin and radiation of biomineralizing metazoans is an important evolutionary innovation that had a significant geobiological impact. The earliest known skeletal metazoans are from the terminal Ediacaran Period (~550–539 Ma), represented by a few genera of weakly biomineralized tubular and goblet-shaped fossils. In contrast, shelly fossils in the early Cambrian Period (~539–520 Ma) are much more diverse and abundant. Traditionally, skeletal fossils in the terminal Ediacaran and early Cambrian are regarded as two distinct assemblages, with little overlap in stratigraphic distribution and taxonomic composition, implying a possible extinction event at the Ediacaran–Cambrian boundary (ECB) followed by a subsequent radiation event (Darroch et al., 2018; Zhuravlev and Wood, 2018). Recently, it has been shown that some Ediacaran skeletal taxa may have extended into the early Cambrian (Han et al., 2017; Yang et al., 2016; Zhu et al., 2017), indicating evolutionary continuity between these two assemblages. This evolutionary continuity also implies that lineages of Cambrian-style biomineralizing animals may extend below the ECB, a stratigraphic pattern that has long been suspected on the basis of Siberian data (Rogov et al., 2015; Zhu et al., 2017) but has not been confirmed elsewhere. In this study, we test this prediction using biostratigraphic data from the terminal Ediacaran Beiwan Member of the Dengying Formation in southern Shaanxi Province of South China (Cai et al., 2019). Our data show that the Beiwan assemblage consists of diverse skeletal fossils dominated by terminal Ediacaran taxa such as *Cloudina* and *Sinotubulites*, but also contains rare elements that morphologically resemble early Cambrian shelly fossils, particularly *Anabarites trisulcatus*. The new fossils increase the diversity of skeletal animals in the terminal Ediacaran stage. They also suggest that, although a macroevolutionary turnover occurred at the ECB, a small number of skeletal animal lineages did cross this boundary. The recognition of such evolutionary dynamics opens new avenues to characterize survival/extinction selectivity and to assess the roles of environmental changes or ecological interactions as triggers for the evolutionary turnover at the ECB.

Cai Y., Xiao S., Li G. & Hua H. (2019) - Diverse biomineralizing animals in the terminal Ediacaran Period herald the Cambrian explosion. Geology, 47(4), 380-384.

Darroch S.A., Smith E.F. Laflamme M. & Erwin D.H. (2018) - Ediacaran extinction and Cambrian explosion. Trends Ecol Evol., 33, 653 – 663.

Han J., Cai Y., Schiffbauer J.D., Hua H., Wang X., Yang X., Uesugi K., Komiya T. & Sun, J. (2017) - A Cloudina-like fossil with evidence of asexual reproduction from the lowest Cambrian, South China. Geol. Mag., 154(6), 1294-1305.

Rogov V.I., Karlova G.A., Marusin V.V., Kochnev B.B., Nagovitsin K.E. & Grazhdankin D.V. (2015) - Duration of the first biozone in the Siberian hypostratotype of the Vendian. Rus. Geol. Geophys., 56(4), 573-583.

Yang B., Steiner M., Zhu M., Li G., Liu J. & Liu P. (2016) - Transitional Ediacaran–Cambrian small skeletal fossil assemblages from South China and Kazakhstan: implications for chronostratigraphy and metazoan evo Zhu M., Zhuravlev A.Y., Wood R.A., Zhao F. & Sukhov S.S. (2017). A deep root for the Cambrian explosion: Implications of new bio-and chemostratigraphy from the Siberian Platform. Geology, 45(5), 459-462.lution. Precambrian Res., 285, 202-215.

Zhuravlev A.Y. & Wood R.A. (2018) – The two phases of the Cambrian explosion. Sci. Rep., 8, 16656.

Siberian Perspectives for Terminal Ediacaran Stage

Grazhdankin D.V.*[1-2], Rogov V.I.[2], Karlova G.A.[2], Markov G.Ye.[1-2], Dorzhiev M.S.[1-2], Peek S.[3-4], Cui H.[3-5] & Kaufman A.J.[3]

[1] Novosibirsk State University, Russia. [2] Trofimuk Institute of Petroleum Geology and Geophysics, Russia. [3] University of Maryland, USA. [4] United States Geological Survey, USA. [5] Vrije Universiteit Brussel, Belgium.

Corresponding author email: dima.grazhdankin@gmail.com

Keywords: Terminal Ediacaran Stage, Khorbusuonka Group, arctic Siberia, Gaojiashan section, South China.

Gaojiashan section, South China has been regarded as a candidate for the Terminal Ediacaran Stage GSSP. Located 4400 km to the north, a section at the northwestern slope of the Olenek Uplift, arctic Siberia allows a critical evaluation of some of the criteria suggested for definition of the Terminal Ediacaran Stage. The Olenek section is represented by the Khorbusuonka Group comprising the Maastakh, Khatyspyt and Turkut formations. A U–Pb zircon date of 543.9 ± 0.24 Ma for tuff breccia constrains the age of the Turkut Formation (Bowring et al., 1993). The Khatyspyt Formation is exceptionally fossiliferous and contains calcite-cemented macrofossils, carbonaceous compression macrofossils, and meniscate trace fossils *Nenoxites*. If the *Nenoxites* ichnofabric from the Mohyliv Formation in Ukraine and the putative body fossil *Shaanxilithes ningqiangensis* from the Dengying Formation in South China refer to approximately the same structure, then the first appearance datum of this fossil could be as old as 556 Ma (Soldatenko et al., 2019). Internal moulds of tubular skeletal fossils *Cambrotubulus decurvatus* occur throughout the Turkut Formation. Our observations suggest that the fossil *Cambrotubulus* could be an internal mould of a central cavity of the tubular fossil *Cloudina*. The dominance of well-preserved carbonates in the Khorbusuonka Group opens up a possibility of global correlations via chemostratigraphy. $\delta^{13}C_{carb}$ values in the Khorbusuonka Group reflect variations seen elsewhere, featuring (in ascending order) a strong $\delta^{13}C_{carb}$ positive shift to values near 6‰ in the Maastakh and lower Khatyspyt formations, an intermediate interval of relatively little isotopic change with a monotonic decrease in $\delta^{13}C_{carb}$ from 2‰ to near 0‰ throughout most of the Khatyspyt and lower Turkut formations, and a negative excursion to ca. −4‰ in the upper Turkut Formation. The positive excursion of $\delta^{13}C_{carb}$ values in the Khatyspyt Formation is thought to be coeval with a similar magnitude excursion in the Gaojiashan Member of the Dengying Formation; however, strontium isotope ($^{87}Sr/^{86}Sr$) ratio in the Maastakh and Khatyspyt formations is consistently ca. 0.7080, a value not seen anywhere in the terminal Ediacaran. Extensive marine anoxic events during the terminal Ediacaran period potentially can be used in stratigraphic correlation and both the Dengying and Khatyspyt formations provide a record of such events; however, their synchroneity has yet to be established by independent means of correlation.

Russian Science Foundation Grant 17-17-01241.

Bowring S.A., Grotzinger J.P., Isachsen C.E., Knoll A.H., Pelechaty S.M. & Kolosov P. (1993) - Calibrating rates of Early Cambrian evolution. Science, 261, 1293–98

Soldatenko Y., El Albani A., Ruzina M., Fontaine C., Nesterovsky V., Paquette J.-L., Meunier A. & Ovtcharova M. (2019) - Precise U-Pb age constrains on the Ediacaran biota in Podolia, East European Platform, Ukraine. Sci. Rep-UK, 9, 1675.

A proposed global boundary stratotype section and point (GSSP) for the base of the terminal stage of Ediacaran System in the southern Shaanxi, China

Hua H.*[1], Cai Y.[1], Zhou C.[2], Chai S.[1] & Min X.[1]

[1] State Key Laboratory of Continental Dynamics, Shaanxi Key Laboratory of Early Life and Environment, Department of Geology, Northwest University, Xi'an, China. [2] State Key Laboratory of Palaeobiology and Stratigraphy, Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing, China.

Corresponding author email: huahong@nwu.edu.cn

Keywords: terminal Ediacaran stage, GSSP, Gaojiashania stage, FAD of Cloudina, China.

The Global boundary Stratotype Section and Point(GSSP) for the base of the Gaojiashania Stage (stage 6 and the latest stage of Ediacaran System)(Zhou et al.,2019) is defined at the base of a intraclastic limestones layer 36.6m above the base of the Gaojiashan Member, Dengying Formation in the Gaojiashan-Niuluokeng section, about 4 km South of Hujiaba, in Ning Qiang County, southern Shaanxi, China. The GSSP is exposed in a road cut at a position of 32º57' 24.1"N and E:106º27' 48.9" E. The GSSP level contains the lowest occurrence of the cosmopolitan tubular skeleton fossil *Cloudina*, other important markers near the base of the stage include the appearance of highly bioturbation, a significant positive carbonate carbon isotope excursion (up to +6‰) followed by a stable plateau of values around 2–3‰(Hua et al.,2007) and an increase in the abundance and 34S composition of pyrite(Cui et al.,2016). The Dengying Formation in the southern Shaanxi region are sandwiched between the Ediacaran Doushantuo Formation (ca. 635–551 Ma) and the early Cambrian Kuanchuanpu Formation and is subdivided into three intervals, including the Algal Dolomite, Gaojiashan, and Beiwan members, which are generally correlated with Hamajing, Shibantan, and Baimatuo members, respectively, in the Yangtze Gorges area. The Gaojiashan Member is characterized by the abundant occurrence of tubular metazoans and trace fossils, which are subdivided into three biozones: *Shaanxilithes* biozone, *Conotubus-Gaojiashania-Protolagena* biozone, and *Sinotubulites-Cloudina* biozone (Hua et al., 2001, 2007). There are three candidates for the lower boundary of Gaojiashania Stage in the section. One is the first appearance level of *Shaanxilithes ningqiangensis*, which lies at about 12.6m above the base of the Gaojiashan Member. *S. ningqiangensis* has also been reported from upper Ediacaran strata in in the basal Jiucheng Member of the Dengying Formation in eastern Yunnan Province (Zhang et al., 2015) in the Zhengmuguan Formation in Helanshan area of Ningxia and Zhoujieshan Formation at Dachaidan in Qinghai Province (Shen et al., 2007; Zhang et al., 2015), as well as in northwestern India (Tarhan et al., 2014), in southeastern Siberia (Zhuravlev et al., 2009; Wood et al., 2017), and probably also in southern Namibia (Darroch et al., 2016). The second is the first appearance level of tubular fossil *Conotubus hemiannulatus,* 12.8m above the *Shaanxilithes ningqiangensis* biozone. The organic tubes of *Conotubus* has been interpreted as the precursor of the biomineralized *Cloudina* tubes (Hua et al., 2007). Beyond South China, possible *Conotubus* fossils have also been reported from the Esmeralda Member of the Deep Spring Formation in Nevada (Smith et al., 2016), although the taxonomic identification needs to be verified through a systematic investigation. The third, is FAD of the tubular fossil *Cloudina*, about 9.1m above the first *Conotubus* layer. Given its worldwide distribution and unparalleled significance in biological innovation, the first appearance of *Cloudina* has the greatest potential to become the stratigraphic marker for defining a terminal Ediacaran stage, and can be correlated with precision to all paleocontinents. The section fulfills all the requirements for a GSSP, and the horizon can be constrained not only by the primary stratigraphic marker (*Cloudina*) but also with secondary biostratigraphic, chemostratigraphic correlation tools.

The middle Ediacaran Shuram Excursion: Global Diagenetic Conspiracy or Environmental Prelude to the Origin of Animals?

Kaufman A.J.[1]*

University of Maryland Geology Department.

Corresponding author email: kaufman@umd.edu

Keywords: Shuram, excursion, diagenesis, authigenesis, chemostratigraphy, Cloudina.

The Shuram Excursion – the profound negative carbon cycle anomaly preserved in a wide range of middle Ediacaran carbonate facies on multiple continents – stands out as a candidate geochemical marker for the base of the Terminal Ediacaran Stage. First recognized in strata from Oman and South Australia, this deep stratigraphic divide was soon discovered in Ediacaran successions worldwide. With nadir $\delta^{13}C$ values dramatically lower than mantle inputs, its primary nature has long been questioned. Hence, the origin of the Shuram Excursion – with its presumed relationship to glaciation, the rise of oxygen, and the origin of animals – remains one of the great outstanding problems of Ediacaran Earth history. Controversies surrounding the Shuram event, which is coincident with the global increase in seawater alkalinity, include whether it (1) represents a disturbance of the oceanic carbon reservoir due to oxidation of organic matter, (2) reflects conditions conducive to authigenic carbonate precipitation, or (3) results from meteoric or burial diagenesis. While petrographic and isotopic evidence support an authigenic origin for Shuram carbonate nodules in South China and Namibia, the globally-distributed event was most-likely a primary oceanographic phenomenon related to the progressive ventilation of anoxic seawater. The sudden increase in ^{13}C-depleted alkalinity is argued as a direct result of the delivery of nutrients and sulfate during intense weathering of uplifted terrains. These continental fluxes would have stimulated anaerobic microbial sulfate reduction and water column production of carbonate with strongly negative $\delta^{13}C$ compositions. Progressive ocean oxygenation is supported by time-series U and Mo isotope measurements of Shuram equivalent carbonates worldwide. Evidence for intense weathering of the continents and the buildup of oceanic sulfate is provided by time-series analyses of strontium (indicating a significant increase in the delivery of radiogenic ^{87}Sr to the oceans) and sulfur isotope abundances during the unprecedented carbon cycle perturbation. Indeed, given the remarkable coupling of carbon, sulfur, strontium, and uranium isotope change during the event, either the Shuram Excursion represents a global diagenetic conspiracy, or it is an indicator of worldwide environmental change. By the end of the biogeochemical event shallow ocean water would have been oxygenated enough to stimulate the evolution and diversification of the Ediacara biota. These organisms, including *Cloudina* – the oldest known animal with a phosphatic carbonate shell – and many elements of the soft-bodied Nama Assemblage first appear near the end of the Shuram Excursion in southern Namibia. The remarkable juxtaposition of biogeochemical and evolutionary events supports the view that the Shuram Excursion was a global environmental phenomenon, and furthermore, provides coupled geochemical and fossil markers for the base of the Terminal Ediacaran Stage worldwide.

Revisiting the stratigraphic correlation potential of the Ediacaran skeletal organism *Palaeopascichnus linearis*

Kolesnikov A.*[1-2]

[1] Trofimuk Institute of Petroleum Geology and Geophysics of Siberian Branch Russian Academy of Sciences, Russia.
[2] Geological Institute, Russian Academy of Sciences, Russia.

Corresponding author email: anton.kolesnikov@icloud.com

Keywords: Ediacaran, Palaeopascichnus.

Within the span of a little over forty years, palaeopascichnids represented an enigmatic group of macroscopic fossils, which were widespread in Ediacaran sequences and also characterised by substantial differences in preservation leading to no consistent diagnosis for these fossils. Initially, the palaeopascichnid fossils were interpreted as either an ancient trace fossil of detritus feeders. Later, other scholars suggested alternative interpretation for palaeopascichnids is that they were coprolites, algal remains, body fossils of unknown affinity or xenophyophore-like benthic protozoan organisms. A recent study of the new species *Palaeopascichnus linearis* from the Ediacaran Khatyspyt Formation of the North East Siberia as well as a re-examination of other ones, specifically the Southeast White Sea, Central and South Urals revealed compelling evidence of the agglutinated nature of these fossils. As a result, it has been considered that the species *Palaeopascichnus linearis* to be one of the oldest known macro organisms with an agglutinated skeleton; its presence puts emphasis on this organism in terms of biostratigraphy and paves the way for the reexamination of other palaeopascichnid-like fossils, which are important for the stratigraphic correlation potential of Ediacaran sequences. It is probably the only Ediacaran taxon whose stratigraphic range spans almost the entire system. The oldest representative of this species is found in the Lantian Formation in South China in the strata that are referred to as the second Ediacaran Stage. The uppermost occurrence of this taxon has been documented in the Asha Group of South Urals and correlated with the terminal Ediacaran Stage. If so, *Palaeopascichnus linearis* can be regarded as the first recognised Ediacaran index-species. It also contributes significantly in improved understanding of the evolution and survival of the Ediacaran biota in the aftermath of the Kotlinian Crisis. In light of the possible dynamic nature of Ediacaran ocean redox conditions, and by analogy with the Ediacaran fossil taxon *Aspidella* it is suggested that palaeopascichnida represents an opportunistic organism that could quickly take advantage of favourable oxic conditions resulting in the occurrence of remarkably dense populations. These fossils are globally distributed and can be numerically abundant. At the present time, the fossils occur across the entire East European Platform (Finnmark, south-eastern slope of the Baltic Shield, Southeast White Sea area, Moscow and Mezen basins, Central and South Urals, Podolia), as well as in South China, Avalonia (Newfoundland, Wales), Australia (Adelaide Rift Complex), and Siberia (Olenek Uplift, Uchur-Maya Region). Thus, the revisiting the stratigraphic correlation potential of the oldest macroscopic skeletal organism has a short term outlook.

This research was funded by RFBR [grant No. 19-05-00828] and RSF [grant No. 17-17-01241].

The diversity of the Gaojiashan Biota of the latest Ediacaran

Min X.* & Hua H.

State Key Laboratory of Continental Dynamics, Department of Geology, Northwest University.

Corresponding author email: 360446872@qq.com

Keywords: Gaojiashan biota, terminal Ediacaran, calcareous algae, acritarchs.

In recent years, with the deeper research, the diversity of the Gaojiashan biota has been enhanced. More and more various morphologically diverse fossils are recovered. To a great extent, they prove the evolutionary connection during this period. Gaojiashan biota is well-known by the Ediacaran fossil *Cloudina* and tubular fossil *Sinotubulithes*, *Conotubus*, *Shaanxilithes*, as well as *Protolagena*. Three other important types can be recognized. One is Doushantuo-Pertatataka acritarchs including three genera which were thought extinct before. One is calcified cyanobacteria containing five genera that occur in the Early Cambrian and later. One is possible protozoa. These groups extremely not only enrich the biologically diversity of Gaojiashan biota, but also provide new paleontological data on the Ediacaran-Cambrian transition. The discovery as well makes this period much more significant to research the evolution of metazoan.

Formulating a terminal Ediacaran Stage: progress and prospects

Narbonne G.M.*[1] & Xiao S.[2]

[1] Queen's University. [2] Virginia Tech.

Corresponding author email: narbonne@queensu.ca

Keywords: Ediacaran, Neoproterozoic, Cloudina, Shuram, stratigraphy.

The Ediacaran Period was ratified in 2004 and formal discussions towards its subdivision began in 2014. The Terminal Ediacaran Stage Working Group (TES-WG) is mandated to define a GSSP and name for the youngest stage of the Ediacaran Period, immediately below the base of the Cambrian. Ediacaran Subcommission meetings and field excursions in China, South Africa and Namibia, South Australia, Newfoundland, Oman, Nevada, and upcoming meetings in Spain and Brazil provide an overview of key TES sections and stratigraphic indicators worldwide. A summary paper in *Episodes* (Xiao et al., 2016) described the background to Ediacaran subdivision and progress to date. A ballot of Voting Members in July 2018 showed strong support for establishing a GSSP that is marine, fossiliferous, as continuous as possible, suitable for C- and Sr-isotope chemostratigraphy, and < ca. 550 Ma in age. The TES marks the first appearance of shells of biomineralizing animals in Earth history, and Voting Members overwhelmingly regarded the appearance of Ediacaran shelly fossils as the principal criterion for definition and recognition of a TES. Calcareous Ediacaran shells occur abundantly in TES strata worldwide, and typical taxa include *Cloudina*, *Sinotubulites*, and *Namacalathus*; there is some stratigraphic overlap between terminal Ediacaran and Cambrian taxa. Tubular or ribbon-shaped organic compressions such as *Shaanxilithes*, *Corumbella*, *Conotubus*, *Wutubus*, and *Sekwitubulus* also first appear in abundance in this interval and were regarded by Voting Members as a potential second-order criterion for recognizing the TES, but systematic re-evaluation of these taxa is necessary to provide a sound taxonomic framework for their use in biostratigraphy. In contrast with the diverse Ediacaran taxa of the earlier Avalon and White Sea assemblages, the TES contains a depauperate, Nama assemblage of Ediacara-type fossils with only two genera of Ediacara-type impressions (*Ernietta* and *Swartpuntia*) that originated during the TES, and terminal Ediacaran strata are typified by low diversity acritarch assemblages consisting mostly of smooth leiospheres. Globally, Ediacaran shelly fossils and ribbon/tubular organic impressions commonly appear immediately above a major negative carbon anomaly, variably termed the Shuram, Wonoka, or EN3 excursion, that has been dated as older than 550-551 Ma on two continents. Combination of a major biological change immediately following a strong chemostratigraphic signal could be useful in defining the base of the Terminal Ediacaran Stage, but further work on the cause, timing, complexity, and correlation of the Shuram is needed before it can be used with confidence as a global stratigraphic marker.

Xiao S., Narbonne G.M., Zhou C., Laflamme M., Grazhdankin D.V., Moczydłowska-Vidal M. & Cui H. (2016) - Toward an Ediacaran time scale: problems, protocols, and prospects. Episodes, 39, 540–555.

Widespread occurrences of glendonite in the Doushantuo Formation, South China: Implication for Ediacaran climate change and stratigraphic correlation

Wang Z.*[1], Chen C.[1], Wang J.[1], Xiao S.[2], Suess E.[3], Chen X.[4], Ma X.[1] & Wang G.[5]

[1] State Key Laboratory of Biogeology and Environmental Geology & College of Marine Science and Technology, China University of Geosciences, Wuhan, P. R. China. [2] Department of Geosciences, Virginia Tech, Blacksburg, USA [3] GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany. [4] Wuhan Center, China Geological Survey, Wuhan, P. R. China. [5] Academy of Environmental Planning & Design, Co., Ltd., Nanjing University, P. R. China.

Corresponding author email: wungchou@qq.com

Keywords: Doushantuo Formation, glendonite, carbon isotopes, climate cooling, South China.

Silicified glendonite has been reported from Ediacaran inner-shelf deposits of the lower Doushantuo Formation (in association with a positive carbon isotope excursion known as EP1) at a single stratigraphic section in the Zhangcunping area of South China (Wang et al., 2017). Glendonites are pseudomorphs of syndepositional or early authigenic ikaites ($CaCO_3{\cdot}6H_2O$) that form at near-freezing temperatures. Thus, the presence of glendonite in the lower Doushantuo Formation implies a period of cool climate somewhere between ~609 Ma and ~551 Ma based on currently available age constraints. This interpretation predicts a wider geographic distribution of Ediacaran glendonite at consistent stratigraphic horizons in the Doushantuo Formation of South China. To test this prediction, we conducted a systematic survey of Doushantuo glendonites in South China and discovered new occurrences of Doushantuo glendonite at Huji (inner-shelf, drill core), Changyang (intrashelf basin, drill core), and Yangjiaping (shelf margin, outcrop) sections. The new data demonstrate widespread occurrences of Doushantuo glendonite across the continental shelf of the Yangtze Block in South China. In contrast to completely silicified glendonite in the Zhangcunping area, glendonites at the new localities are stellate clusters that are pseudomorphed by calcite spar and sometimes are rimmed with silica, thus allowing for carbon isotope analysis. Calcispar in the glendonites is characterized by negative carbon isotopic signatures, with $\delta^{13}C$ values as low as–37‰, indicating that diagenetic transformation of precursor ikaites to glendonites may be related to anaerobic oxidation of organic matter or methane in sediment. In contrast, carbonate strata that host the glendonites are characterized by positive $\delta^{13}C$, confirming the consistent stratigraphic distribution of Doushantuo glendonites in association with EP1. Ongoing work is aimed at understanding the paleoenvironmental and geochemical controls (particularly redox conditions and porewater phosphate concentrations) on ikaite and glendonite formation, further constraining the age of the glendonite-bearing strata, and determining the chronostratigraphic relationship between Doushantuo glendonites and documented Ediacaran ice ages such as the Gaskiers glaciation. Determining whether a single or multiple glaciations occurred in the Ediacaran Period and how these glaciations are correlated with carbonate carbon isotope excursions are critical to the subdivision and correlation of the Ediacaran System.

Wang Z., Wang J., Suess E., Wang G., Chen C. & Xiao S. (2017) - Silicified glendonites in the Ediacaran Doushantuo Formation (South China) and their potential paleoclimatic implications. Geology, 45(2), 115-118.

A global expansion of oceanic anoxia and the case for a terminal Ediacaran stage

Xiao S.*[1] & Narbonne G.M.[2]

[1] Department of Geosciences, Virginia Tech, Blacksburg, Virginia, USA. [2] Department of Geological Sciences and Geological Engineering, Queen's University, Kingston, Ontario, Canada.

Corresponding author email: xiao@vt.edu

Keywords: Ediacaran, Anoxia, Biostratigraphy.

Redox sensitive trace metal concentrations in fine-grained siliciclastic sediments and uranium isotopic compositions of carbonate rocks both indicate a global expansion of oceanic anoxia in the latest Ediacaran Period, ca. 551–539 Ma (Sahoo et al., 2016; Evans et al., 2018; Zhang et al., 2018; Wei et al., 2018; Tostevin et al., 2019). It is estimated that, during this global expansion of oceanic anoxia, over 20% of ocean floor was covered by anoxic waters (Zhang et al., 2018; Tostevin et al., 2019). This is two orders of magnitude greater than the ~0.2% of ocean floor under anoxic waters in the modern ocean (Helly et al., 2004). Considering that anoxic benthic environment largely occurs where the oxygen minimum zone impinges upon continental shelves (Helly et al., 2004), it is possible that a significant portion of continental shelves was affected by anoxia in the terminal Ediacaran when the area of anoxic seafloor was two orders of magnitude greater than in the modern ocean. Thus, it is likely that terminal Ediacaran animals were directly impacted by an expansion of oceanic anoxia and an increase in redox dynamics. Indeed, integrated geochemical and paleontological data suggest that the distribution of terminal Ediacaran animals was directly limited by anoxia on continental shelves where redox conditions were dynamic both spatially and temporally (Wood et al., 2015; Tostevin et al., 2016; Darroch et al., 2015). Thus, when assessing biostratigraphic markers for the definition and global correlation of the terminal Ediacaran stage, it is important to consider the possible impact of this global expansion of oceanic anoxia on the distribution of animal fossils. With few exceptions (Dong et al., 2008; Hawkins et al., 2017; Carbone et al., 2015), potential index fossils for the definition of the terminal Ediacaran stage (Xiao et al., 2016) are mostly restricted to shallow-water and locally oxic environments. To achieve a global correlation of the terminal Ediacaran Stage, it is critical to develop stratigraphic correlation tools to bridge deep- and shallow-water facies through integrative stratigraphic investigation of shelf-basinal transects in Ediacaran basins (e.g., in South China and NW Canada).

Sahoo S.K., Planavsky N.J., Jiang G., Kendall B., Owens J.D., Wang X., Shi X., Anbar A.D. & Lyons T.W. (2016) - Oceanic oxygenation events in the anoxic Ediacaran ocean. Geobiology, 14(5), 457- 468.Evans S.D., Diamond C.W., Droser M.L. & Lyons T.W. (2018) - Dynamic oxygen and coupled biological and ecological innovation during the second wave of the Ediacara Biota. Emerging Topics in Life Sciences, 2, 223-233.

Zhang F., Xiao S., Kendall B., Romaniello S.J., Cui H., Meyer M., Gilleaudeau G.J., Kaufman A.J. & Anbar, A. D. (2018) - Extensive marine anoxia during the terminal Ediacaran Period. Science advances, 4(6), eaan8983.

Wei G.Y., Planavsky N.J., Tarhan L.G., Chen X., Wei W. Li D. & Ling H.F. (2018) - Marine redox fluctuation as a potential trigger for the Cambrian explosion. Geology 46, 587-590.

Tostevin R., Clarkson M. O., Gangl S., Shields G. A., Wood R.A., Bowyer F., Penny A.M. & Stirling C.H. (2019) - Uranium isotope evidence for an expansion of anoxia in terminal Ediacaran oceans. Earth Planet. Sci. Lett., 506, 104-112.

Helly J.J., Levin L.A. (2004) - Global distribution of naturally occurring marinehypoxia on continental marginsDeep Sea Res. Part I Oceanogr. Res. Pap. 51, 1159-1168.

Wood R.A., Poulton S.W., Prave A.R., Hoffmann K.H., Clarkson M.O., Guilbaud R., Lyne J.W., Tostevin R., Bowyer F., Penny A.M., Curtis A. & Kasemann S.A. (2015) - Dynamic redox conditions control late Ediacaran metazoan ecosystems in the Nama Group, Namibia. Precambrian Res., 261, 252-271.

Tostevin R., Wood R.A., Shields G.A., Poulton S.W., Guilbaud R., Bowyer F., Penny A.M., He T., Curtis A., Hoffmann K.H. & Clarkson M.O. (2016) - Low-oxygen waters limited habitable space for early animals Nat. Comm., 7, 12818.

Darroch S.A.F. Sperling E.A., Boag Thomas H., Racicot R.A., Mason S.J., Morgan A.S., Tweedt S., Myrow P., Johnston D.T., Erwin D.H. & Laflamme M. (2015) - Biotic replacement and mass extinction ofthe Ediacara biota. Proc. R. Soc. B (Biol. Sci.) 282, 20151003

Dong L., Xiao S., Shen B. & Zhou C. (2008) - Silicified Horodyskia and Palaeopascichnus from upper Ediacaran cherts in South China: tentative phylogenetic interpretation and implications for evolutionary stasis. J. Geol. Soc. London, 165, 367-378.

Hawkins A.D., Xiao S., Jiang G., Wang X. & Shi X. (2017) - New biostratigraphic and chemostratigraphic data from the Ediacaran Doushantuo Formation in intra-shelf and upper slope facies of the Yangtze platform: Implications for biozonation of acanthomorphic acritarchs in South China. Precambrian Res., 300, 28-39.

Carbone C.A., Narbonne G.M., Macdonald F.A. & Boag T.H. (2015) - New Ediacaran fossils from the uppermost Blueflower Formation, northwest Canada: disentangling biostratigraphy and paleoecology. J. Paleontol., 89, 281-291.

Xiao S., Narbonne G.M., Zhou C., Laflamme M., Grazhdankin D.V., Moczydłowska-Vidal M. & Cui H. (2016) – Towards an Ediacaran time scale: problems, protocols, and prospects. Episodes, 39, 540–555.

Geochronological framework(s) for the Ediacaran System

Yang C.[1]* & Condon D.[1]

[1]British Geological Survey.

Corresponding author email: dcondon@bgs.ac.uk

Keywords: Ediacaran, Geochronology.

The Ediacaran (635-539 Ma) Period is a critical transitional time interval when the Earth transferred from a microbial-dominated world to a metazoan world. To decipher how life and environment co-evolved, and what caused these fundamental changes during this time interval, requires integration of proxy data within geochronological framework(s). A growing database of radio-isotopic dates are being published from the Ediacaran strata worldwide and a first order chronology of events is established, however resolved framework(s) still remains ambiguous and poorly quantified, thus limiting our ability to integrate data from disparate stratigraphic sections. This is due in part to a lack of radio-isotopic dates for some critical horizons, large uncertainties of some dates, difficulties in age-model interpolation and stratigraphic correlation, and different interpretations. Here we assess the variable quality of the existing geochronological database, integrate absolute dating results with other forms of temporal stratigraphic information, and build the Ediacaran geochronological framework (especially in South China) using Bayesian models (e.g. Bronk Ramsey, 2008; Haslett & Parnell, 2008). In this way we begin to discuss approaches to quantifying uncertainty across the stratigraphic record. Such frameworks provides preliminary time scale of the Ediacaran System, with uncertainties and subject to further changes, and provides a mechanism to test correlation models and integrate data from disparate stratigraphic sections.

Bronk Ramsey C. (2008) - Deposition models for chronological records. Quaternary Science Reviews, 27, 42–60.

Haslett J. & Parnell A. (2008) - A simple monotone process with application to radiocarbon-dated depth chronologies: Royal Statistical Society Journal, series C, 57, 399–418.

Carbon isotopic excursions in the middle Ediacaran of South China

Zhou C.*[1], Xiao S.[2], Ouyang Q.[1], Guan C.[1] & Wang W.[1]

[1] CAS Key Laboratory of Economic Stratigraphy and Palaeongeography, Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, China. [2] Department of Geosciences, Virginia Tech, Blacksburg, USA

Corresponding author email: cmzhou@nigpas.ac.cn

Keywords: Ediacaran subdivision, chemostratigraphy, EN3/Shuram excursion, Gaskiers glaciation.

The middle Ediacaran Shuram excursion is the most pronounced negative carbon isotopic shift in Earth history. Potential equivalents of the Shuram excursion have been reported in many places around the world, indicating that it can be used as a potential chemostratigraphic tool for Ediacaran subdivision and global correlation. However, the age of the Shuram excursion is not tightly constrained. The ~ 551 Ma age from South China is sometimes cited as directly dating the end of the Shuram, although it should be considered as a minimum age constraint. The onset of the Shuram excursion has not been tightly constrained by radiometric dates either, and estimates range from 580 Ma to 560 Ma. The Shuram excursion generally shows a simple stratigraphic pattern with a sharp shift to negative δ13C values followed by a slow recovery to positive values (Grotzinger et al., 2011). The upper Doushantuo Formation around the Huangling Anticline, western Hubei Province, South China, however, gives a more complex picture. Whereas the Shuram excursion is expressed in the upper Doushantuo Formation as a single δ13C negative excursion at some sections in the eastern region of the Huangling Anticline (for example, EN3 at the Jiulongwan section), other sections in the western region contain two negative excursions (the lower JNE or the Jiuqunao δ13C negative excursion, and the upper MNE or the Miaohe δ13C negative excursion) separated by a moderately positive excursion (the DPE or the Diaoyapo δ13C positive excursion). Detailed stratigraphic correlation of the DPE and MNE around the Huangling Anticline is still a matter of debate; however, it has been widely accepted that only the JNE is correlated with EN3 and the Shuram excursion. Strata hosting the JNE are overlain by a black shale (up to 3 m thick), a dolostone (up to 12 m thick), and the Miaohe Member black shale (up to 23 m thick). The ~551 Ma age was reported for an ash bed in the uppermost Miaohe Member. Considering the typically slow deposition rate of black shales, it is possible that both the onset and the end of JNE (=EN3 or Shuram) were much earlier than 551 Ma. This inference is consistent with a recent subsidence model analysis of the Ediacaran Johnnie Formation, showing that the Shuram excursion occurred 585–579 Ma and its termination is coincident with the ~580 Ma Gaskiers glaciation (Witkosky & Wernicke, 2018). If proved globally synchronous, the Shuram excursion can be an ideal chemostratigraphic marker to subdivide the Ediacaran System.

Grotzinger J.P., Fike D.A. & Fischer W.W. (2011) - Enigmatic origin of the largest-known carbon isotope excursion in Earth's history. Nat. Geosci., 4, 285-292.

Witkosky R. & Wernicke B.P. (2018) - Subsidence history of the Ediacaran Johnnie Formation and related strata of southwest Laurentia: Implications for the age and duration of the Shuram isotopic excursion and animal evolution. Geosphere, 14, 2245-2276.

ST3.2

Cambrian stratigraphy, events and geochronology

Conveners and Chairpersons

Per Ahlberg (Lund University, Sweden)

Loren E. Babcock (The Ohio State University)

Terreneuvian skeletonized microfossils from phosphatic interbeds of the Fuentepizarra Formation, Central Iberian Zone, Spain

Álvaro J.J.*[1] & Lorenzo S.[2]

[1] Instituto de Geociencias (CSIC-UCM), Madrid, Spain. [2] Universidad de Castilla-La Mancha, Almadén, Spain.

Corresponding author email: jj.alvaro@csic.es

Keywords: Cambrian, microfossils, phosphate, Iberia.

In the Central Iberian Zone of the Iberian Peninsula, the presence of Terreneuvian phosphorites in the middle member of the Pusa Formation has been the focus of geostrategic interest since the 1980s to estimate the economic potential of phosphate ore reservoirs. The main phosphatic interval is confined to northwest-southeast trending, slope-related palaeochannel, about 130 m thick and exposed for about 20 km, known as the Fontanarejo Bed (Valdelacasa anticline) and with an estimate of ore exploitation close to 5,800,000 tons. Due to early-diagenetic silicification of these channel infills (Álvaro et al., 2016), acid etching has not yielded significant microfossils, and only hexactinellids and demosponges embedded in thromboidal mats are known from thin-section (Reitner et al., 2012). In contrast, lateral equivalent exposures in the Fuentepizarra Formation of the Alcudia anticline have yielded helcionellids, identified as *Anabarella plana* Vostokova (Gubanov *in* Vidal et al., 1999; Gubanov & Peel, 2003). Intensive etching of two *Anabarella*-bearing phosphoritic interbeds, up to 30 cm thick, has completed this previous discovery with the presence of chancelloriids, halkieriids, orthotecid hyoliths and some problematic sclerites resembling corumbellid tube fragments. The stratigraphic range of *A. plana* in the Anabar Uplift of the Siberian Platform (Kouchinsky et al., 2017) allows identification of a time span including the pre-trilobite *Purella cristata* and *Watsonella crosbyi* Zones in Siberia.

Álvaro J.J., Shields G.A., Ahlberg P., Jensen S. & Palacios T. (2016) - Ediacaran-Cambrian phosphorites from the western margins of Gondwana and Baltica. Sedimentology, 63, 350-377.

Gubanov A.P. & Peel J.S. (2003) - The early Cambrian Helcionelloid mollusc *Anabarella* Vostokova. Palaeontology, 46, 1073 -1087.

Kouchinsky A., Bengtson S., Landing E., Steiner M., Vendrasco M. & Ziegler K. (2017) - Terreneuvian stratigraphy and faunas from the Anabar Uplift, Siberia. Acta Palaeontologica Polonica, 62, 311-440.

Reitner J.R., Luo C. & Duda J.P. (2012) - Early sponge remains from the Neoproterozoic-Cambrian phosphate deposits of the Fontanarejo area (central Spain). Journal of Guizhou University Natural Sciences, 29, 184-186.

Vidal G., Palacios T., Moczydłoska M. & Gubanov A.P. (1999) - Age constraints from small shelly fossils on the early Cambrian terminal Cadomian Phase in Iberia. GFF, 121, 137-143.

A Model for Subdividing Cambrian Stages into Substages

Babcock L.E.*[1], Peng S.C.[2], Ahlberg P.[3], Zhang X.L.[4], Zhu M.Y.[2] & Parkhaev P.Yu.[5]

[1] The Ohio State University, USA. [2] Nanjing Institute of Geology and Palaeontology, China. [3] Lund University, Sweden [4] Northwest University, China. [5] Borissiak Paleontological Institute, Russia.

Corresponding author email: babcock.5@osu.edu

Keywords: Cambrian, stage, substage, chronostratigraphy, GSSP

At the 34th International Geological Congress in Brisbane Australia, the International Commission on Stratigraphy (ICS) opened the way for formal definition of substages of the International Chronostratigraphic Chart. It is a way of recognising that we have now obtained high-quality, finely resolved, data through much of the Neoproterozoic and Phanerozoic, and that it is often possible to correlate strata within stages globally on the basis of multiple stratigraphic markers. The process for defining substages is the same as for stages. At present, four Cambrian stages remain undefined by GSSPs. Identification of the best marker horizons for defining substages depends in part on first reaching consensus about the best choices for stage definition in each of these four stages. For this reason, multiple options are indicated in some stages. For provisional stages 2, 3 and 4, the best choice for marking a stage boundary may be influenced in part by options available for substages. We would like to begin discussion on the possibility of subdividing Cambrian stages into formal substages. As a starting point, we would like to advance the following possibilities. The horizons suggested for subdivision are tentative, and further work may be needed to restrict or expand the options. If it becomes desirable to define more than one substage per stage, a numbering system ('Substage 1', 'Substage 2') can be used to refer to the provisional substages until a formal name is ratified. The Fortunian Stage may be subdivided at one or more positions. The options are open, but possibilities for marking a single subdivision are the FADs of *Anabarites trisulcatus* and *Purella antiqua*. Two subdivisions are also a possibility, in which case possible horizons for subdivision include the FADs of *Cambrotubulus decurvatus* (lower level), and *Purella antiqua* or a similar position such as the FAD of a species of *Anabarella* or *Latouchella* (upper level). Possibilities for marking the bases of provisional Stages 3 and 4, and one or more internal subdivisions of each, remain open and require additional study. The base of provisional Stage 2 may be placed at the FAD of either *Aldanella attleborensis* or *Watsonella crosbyi*. The levels of *A. attleborensis* and *W. crosbyi* are similar. If either is selected as the marker for the base of Stage 2, the FAD of *Lapworthella tortuosa*, *Lapworthella bella*, *Skiagia ornata* or *Mobergella radiolata* might be useful as the base of a substage. Options for marking the base of provisional Stage 3 include the FADs of *Microdictyon effusum*, *Pelagiella subangulata*, *Mobergella radiolata* and *Profallotaspis jakutensis*. Possibilities for subdividing the stage into one or more substages include *Microdictyon effusum, P. subangulata*, *Repinaella sibirica*, *Delgadella anabara* or a species of *Pelagiella*. The FAD of an eodiscid trilobite such as *Hebediscus*, *Calodiscus*, *Triangulaspis* or *Serrodiscus*, or alternatively the FAD of an oryctocephalid trilobite such as *Oryctocarella duyunensis* or *Arthricocephalus cheauveaui*, is likely to be selected as the marker for the base of provisional Stage 4. Another possibility, depending on the choice of marker for the base of Stage 3 and the base of a Stage 3 substage, is *P. subangulata*. If any of these taxa are selected to mark the stage base, the FAD of *Ovatoryctocara granulata* would make a convenient horizon for the base of a substage. The FAD of *Ptychagnostus praecurrens* would make a good horizon subdividing the Wuliuan Stage. The FAD of *Ptychagnostus punctuosus* can be used to subdivide the Drumian Stage. The FAD of *Linguagnostus reconditus* can be used to subdivide the Guzhangian Stage. It is uncertain at present what would best serve as a marker for subdividing the Paibian Stage. One possibility is the first appearance of the polymerid trilobite *Erixanium*. The Jiangshanian Stage can be subdivided, perhaps, at the FAD of either *Irvingella major* or *Eolotagnostus decorus*. Finally, Stage 10 is undefined, but its base could be at the FAD of *Lotagnostus americanus* or *Eoconodontus notchpeakensis*. If a stage base coinciding with the FAD of *L. americanus* is ratified, the FAD of *E. notchpeakensis* could be used to subdivide the stage.

Geometric morphometric analysis of *Protoconites* from the early Cambrian Yanjiahe Formation (Fortunian), Yichang, Hubei Province, China

Chen Y.L.*[1], Guo J.F.[2], Song Z.C.[2], Zhang Z.F.[1], Qiang Y.[2], Betts M.J.[1], Zhen Y.J.[2] & Yao X.Y.[2]

[1] Northwest University, China. [2] Chang'an University, China.

Corresponding author email: chenyanlong4304103@hotmail.com

Keywords: Fortunian, Yanjiahe Biota, Protoconites, Geometric morphometrics, morphospace.

The Ediacaran to Cambrian transition is a critical interval of time during which major evolutionary changes occurred. Recently, several macroscopic fossils have been recovered from the silty shales of the Early Cambrian Yanjiahe Formation (Terreneuvian, Fortunian – Stage 2) in the three Gorges area of South China. These fossils represent an important ecological diversification of macroscopic organisms at the onset of the Cambrian. *Protoconites* are a kind of conical carbon compression fossils that could be of cnidarian origin. Herein, geometric morphometric analyses are applied to crack out specimens of *Protoconites* to reveal any cryptic morphological details that have implications for their morphological diversity, ontogenetic process, and taxonomic identification. These statistical analyses revealed a strong relationship between size and shape, which indicates that the overall shape of *Protoconites* was mainly controlled by allometric growth. The smaller specimens are generally wider at the anterior, and more commonly have straight-sides. Larger individuals tend to be narrower at the anterior, with bending more common. Our analysis demonstrated that there are always transitional forms between strongly bended specimens and straight specimens, and no obvious gap between them, suggesting that all the assemblage likely consists a single species.

The family Atopidae (Trilobita) in the upper Marianian (Lower Cambrian) from the Ossa-Morena zone (SW Spain)

Collantes L.*[1-2], Gozalo R.[1], Mayoral E.[2], Garzón I.[2] & Liñán E.[3]

[1] University of Valencia. [2] University of Huelva. [3] University of Zaragoza.

Corresponding author email: luis.collantes.geo@gmail.com

Keywords: Atopidae, Ossa-Morena Zone, Biostratigraphy, Cambrian Stage 4, Cambrian Series 2.

New specimens of the gena *Atops* and *Pseudatops* (Family Atopidae) are described in the lower Cambrian rocks in the north of the province of Huelva (Andalusia, Spain). The studied fossils have been recorded in the "Alternancia de Cumbres" unit; the assemblage trilobite is composed by *Serrodicus*, *Calodiscus*, *Triangulaspis*, *Hicksia***?**, *Atops* and *Pseudatops*. The presence of *Serrodicus* permit us to date this assemblage as upper Marianian (see Liñán et al., 2002). Specimens from the genus *Atops* are assigned to the species *A. calanus* Richter & Richter, while the specimens from the genus *Pseudatops* are described as *P.* aff. *reticulatus* (Walcott). The presence of the genus *Pseudatops* in the upper Marianian rocks at the SW of the Ossa-Morena Zone allows the correlation with other palaeogeographic regions, being this genus present in *Hebediscus attleborensis* Subzone of the *Callavia broeggeri* Zone, in Eastern Newfoundland (see Fletcher, 2006), in the upper part of the *Antatlasia guttapluviae* Zone in Morocco (see Sundberg et al., 2016), and in the *Elliptocephala asaphoides* fauna of the Taconic allochthon. In addition, the trilobite assemblage studied herein suggest an age close to the base of the Cambrian Stage 4 (see Liñán et al., 2006).

Fletcher T.P. (2006) - Bedrock geology of the Cape St. Mary's Peninsula, southwest Avalon Peninsula, Newfoundland (includes parts of NTS maps sheets 1M/1, 1N/4, 1L/6 and 1K/13), Newfoundland. Government of Newfoundland and Labrador, Geological Survey, Department of Natural Resources, Report 06-02, 117 pp.

Liñán E., Gozalo R., Palacios T., Gámez Vinaned J.A., Ugidos J.M. & Mayoral E. (2002) - Cambrian. In: In: Gibbons, W. & Moreno, T. (eds) The Geology of Spain. Geological Society, London, 17-29.

Liñán E., Gámez Vintaned J.A., Gozalo R., Dies M.E. & Mayoral E. (2006) - Events and biostratigraphy in the Lower Cambrian of Iberia. Zeitschrift der Deutschen Gesellschaft für Geowissenschaften, 157, 597-609.

Sundberg F.A., Geyer G., Kruse P.D., McCollum L.B., Pegel T.V., Zylinska A. & Zhuravlev A. (2016) - International correlation of the Cambrian Series 2-3, Stages 4-5 boundary interval. Australasian Palaeontological Memoirs, 49, 83-124.

Early Cambrian (Stage 4) brachiopods from the Shipai Formation in the Three Gorges area of South China

Duan X. & Zhang Z.*

Northwest University.

Corresponding author email: elizf@nwu.edu.cn

Keywords: Brachiopoda, Cambrian, Shipai Formation, South China, fossil assemblages.

A variety of abundant fossils have been reported from the lower Cambrian Shipai Formation in the Three Gores areas of Hubei province, South China, but the brachiopod fauna and their systematic diversity are still far from clear. Herein, we describe 7 genera, 4 species and 4 undetermined species including 4 linguloids (*Palaeobolus liantuoensis*; *Lingulellotreta malongensis*; *Eoobolus* sp. and botsofrdiid. indet.), two acrotretoids (*Eohadrotreta zhenbaensis*; *Hadrotreta* sp.), two Kutorginates (*Kutorgina* aff. *chengjiangensis*, *Nisusia* sp.). The brachiopod assemblage from the muddy siltstone and shales of the Shipai Formationis is dominated in number by acrotretoids. They are mainly yielded from the middle part of this formation (*palaeolenus lantenuisi* trilobite zone), and commonly aggregated as high-density concentrations of shell valves on the same bedding planes. The strata immediately above the acrotretoids horizon contain rich linguloid brachiopods, of which small individual *Eoobolus* is particularly common. Its shell length is about 2mm. At the uppermost part of the Shipai Formation (i.e., *Redlichia meitanensis* trilobite zone), *Kutorgina* and *Nisusia* became the dominated genera. These brachiopods derive from 7 families, each family is represented by monospecific fossils, which signify low-diversity but high-disparity. The brachiopod fauna from the Shipai Formation, Yichang city, Hubei province displays very high similarity with synchronous fauna described from Guanshan biota (Wulongqing Formation), Yunnan province. The shell concentrations of acrotretids in the middle part of the Shipai Formation, Three Gorges area is reminiscent of the numerous accumulations of acrotretids in the middle part of the Wulongqing Formation in the Wuding area, Yunnan province. The similar high-density aggregation of acrotretids shells in the Wulongqing Formation of Wuding area and the Shipai Formation of the three Gorges area suggests that the two depositional sequences are roughly correlated biostratigraphically. Study of the brachiopods from the lower Cambrian Shipai Formation not only makes an important contribution to the diversity of Cambrian brachiopods in south China but also provides biological information on the stratigraphic correlation of the early Cambrian strata.

Upper Cambrian GSSPs and their correlation to regional stratigraphic subdivisions in Asian Russia

Gogin I.Ya.*[1] & Pegel T.V.[2]

[1] Russian Geological Research Institute (VSEGEI), St. Petersburg, Russia. [2] Siberian Research Institute of Geology, Geophysics and Mineral Resources (SNIIGGIMS), Novosibirsk, Russia.

Corresponding author email: Ivan_Gogin@vsegei.ru

Keywords: stratigraphy, Cambrian, trilobites, GSSP, Russia, Eastern Siberia.

At present, the development of the International Stratigraphic Scale for the upper part of the Cambrian system has reached significant progress. The names of the Upper Cambrian series (Furongian) and its two stages (Paibian and Jiangshanan) have been accepted and ratified. However, the problem of tracing the identified levels of global correlation for practical regional geology and the correlation of Russian supra-regional stratigraphic units of the Upper Cambrian with the new international levels still remains challenging. The Siberian craton is the key region for understanding the stratigraphy of the upper part of the Cambrian system in the Asian Russia. It is supported by folded structures of various genesis (Taimyr, Kharaulakh, Sette-Daban folded systems, Igar-Norilsk system of edge dislocations, folded structures of De Long islands). The territory of the Siberian Craton throughout the whole Cambrian period stayed marine basin. Two independent stratigraphic subregional scales, based on the distribution of trilobites and conodonts were developed to separate the Upper Cambrian sediments. One of the scales is used for the subdivision and correlation of open marine sediments - the distal shelf and the slope. The trilobite complexes used to define it have taxa of wide geographic distribution and are primarily agnostid. To a large extent, these taxa also define the divisions of the new international GSSP-based scale of the Cambrian system. This subregional scale is used for global correlations. This area of open sea deepwater sediments includes the sections with one of the most discussed levels of global correlation, which can serve as the lower boundary of the upper stage of Cambrian – FAD of agnostid species *Lotagnostus americanus*. This level is defined in the section of the upper part of the Ogonyor Formation on Khos-Neleger river of Kharaulakh ridge, in the section of the Dzhunyukan Formation, Dzhunyukan river of Sette-Daban ridge, and in the Grustninskaja Formation of Trautfetter river on Taimyr peninsula. In all the sections listed here, the level of the Paibian base (FAD *Glyptagnostus reticulatus*) is also defined. FAD of *Irvingella* and *Agnostotes orientalis* - the level of the base of the Jiangshanan stage is known only in the section of the middle part of the Ogonyor Formation on the Khos-Neleger river, as well as in the sediments of the Tchopko Formation of the Igaro-Norilsk edge dislocations area. The second sub-regional scale is used for the areas of shallow water, reef and lagoon sediments distribution. Predominantly endemic assemblages of shallow water polymer trilobites were used to define it. But this scale has also been used in recent years for correlation purposes while establishing the GSSP of the Upper Cambrian stages. A reliable correlation of different facies strata in Central Siberia with the trilobite and conodonts assemblages in the youngest part of the Cambrian section is carried out only for individual levels. This correlation is based on the study of the marginal sections of the facial subregions, which include individual elements of both the shallow-water and open-sea trilobite assemblages. The cooccurrence of the elements of different facial trilobite assemblages has been established only for some levels. For the additional support of biostratigraphic correlation the δC distribution data obtained in several sections of Upper Cambrian sediments in the last decade are considered. The use of these abiotic factors makes the proposed version of the strata correlation significantly more reliable.

Conclusion: Thus, the most likely correlation levels for the different facies deposits of the Upper Cambrian of Eastern Siberia are the following: 1. The upper part of the Guzhangian, correlating with Chomurdakh regional stage corresponds to the Nganasanyan, Tavgian and Maduian regional stages; 2. The Paibian stage and the lower half of the Jiangshanan stage - the Kutugunian regional stage, corresponds to the Ensian and Yurakian regional stages; 3. The approximate correspondence between the Loparian and the upper part of the Khos-Neleger regional stages and the level of the lower boundary of the Tremadoc in the lower part of the Njaian regional stage.

Trilobites biostratigraphy of the Wuliuan Stage in the Iberian Chains (NE Spain)

Gozalo R.*[1], Chrivella Martorell J.B.[1], Dies Álvarez M.E.[2] & Liñán E.[2]

[1] University of Valencia, Spain. [2] University of Zaragoza, Spain.

Corresponding author email: rodolfo.gozalo@uv.es

Keywords: Iberian Chains, Spain, trilobites, biostratigraphy, Wuliuan Stage, Miaolingian Series.

The Wuliuan Stage has been recently ratified by the ISC. Its lower boundary has been placed in the *Oryctocephalus indicus* FAD and the upper boundary in the previous level to the *Ptychagnostus atavus* FAD. Both species have a wide geographic distribution, but none of them have been recorded in the Mediterranean region, and we need to stablish a confindent correlation. Herein we revise the trilobites biostratigaphy of the Leonian to middle Caesaraugustan (Cambrian regional stages for Spain) that comprise the full Wulian age and the upper part of Cambrian Stage 4 and lower part of Drumian in the Iberian Chains. From a stratigraphic point of view, the trilobites studied have been recorded in the upper part of Valdemiedes, Mansilla and lower part of the Murero Fms andhave been identified nine agonostoid species (four genera) and forty-one polymeroids species (twenty-one genera). It has been subdivided in six zones, biz: *Acadoparadoxides mureroensis*, *Eccaparadoxides sdzuyi*, *E. asturianus*, *Badulesia tenera*, *B. granieri*and *Pardailhania hispida* (see Sdzuy et al., 1999, and Gozalo et al., 2008, 2011). Although the species *O. indicus* has not been found yet in this region, we can stablish a roughly correlation based on the isotopic signal and the entry of agnostoids in the Valdemiedes Fm. (see Gozalo et al., 2013), that indicate a maximum floading in the area, similar to what happens in the interval surrounding the boundary in the stratotype (see Zhao et al., 2016). The base of Wulian Stage could be correlated with the uppermot part of the *A. mureroensis*Zone. While the base of Drumian Stage has been previously correlated with the base of *P. hispida* Zone or below (Gozalo et al., 2011), the new data of acritarch in the Cantabrian Mountains indicates the base in an undetermined level in the upper part of *B. tenera* (Palacios, 2015).

Gozalo R., Liñán E., Gámez Vintaned J.A., Dies Álvarez M.E., Chirivella Martorell J.B., Zamora S., Esteve J. & Mayoral E. (2018) - The Cambrian of the Cadenas Ibéricas (NE Spain) and its trilobites. Cuad.Museo Geominero, 9, 137-151.

Gozalo R., Chirivella Martorell J.B., Esteve J., & Liñán E. (2011) - Correlation between the base of Drumian Stage and the base of middle Caesaraugustan Stage in the Iberian Chains (NE Spain). Bull. Geosci., 86, 545-554.

Gozalo R., Álvarez M.E.D., Vintaned J.A.G., Zhuravlev A.Y., Bauluz B., Subías I., Chirivella Martorell J.B., Mayoral E., Gursky H.J., Andrés J.A. & Liñán E. (2013) - Proposal of a reference section and point for the Cambrian Series 2–3 boundary in the Mediterranean subprovince in Murero (NE Spain) and its intercontinental correlation. Geol. Jour., 48, 142-155.

Palacios, T. (2015) - Acritarch assemblages from the Oville and Barrios Formations, northern Spain: A pilot proposal of a middle Cambrian (Series 3) acritarch biozonation in northwestern Gondwana. Rev. Palaeobot. Palyno., 219, 71-105.

Sdzuy K. Linán E. & Gozalo R (1999) - The LeonianStage (early Middle Cambrian): a unit for Cambrian correlation in the Mediterranean subprovince. Geol. Mag., 136, 39-48.

Zhao, Y. *et al*., 2016. Proposed Global Standard Stratotype-Section and Poin for th base of the Miaolingian Series and Wuliuan Stage (Provisional Cambrian Series 3 and 5). Unpublish. Report prepared for the ISCS.

The gut elements of the Cambrian *Leanchoilia*

Lan T.*[1]

[1]Guizhou Research Center for Palaeobiology, Guizhou University, Guizhou, China.

Corresponding author email: 626990410@qq.com

Keywords: Leanchoilia, Digestive system, Elements, Cambrian, Kaili biota.

Digestive system is the place where enargy transfer into animals body. In this study, we focus on the digestive system of *Leanchoilia*. *Leanchoilia* is worldwide distribute in the Cambrian. The gut glands remarkable differentiate along the AP axis in size of *Leanchoilia* sp. from the Kaili biota of the Cambrian, Wuliu Stage (508 ma). The X-ray fluorescence (XRF) reveals some elements profile of the digestive system of *Leanchoilia* sp. suggest gut traces contain high concentrations of calcium phosphate. The result may suggest the phosphate distribution flactuation within the *Leanchoilia* gut at different stages within the edysis process of *Leanchoilia*.

Distribution and enrichment patterns of trace elements during Ediacaran and early Cambrian in south China

Luo K.-L.*, Long J., Tian X.-L., Ni R.-X. & Zhang S.-X.

Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing, China.

Corresponding author email: luokl@igsnrr.ac.cn

Keywords: Ediacaran and early Cambrian, trace elements, distribution and enrichment patterns, selenium, biological changes, south China.

The Ediacaran and early Cambrian are critical periods for the evolution of multicellular life. To present the distribution and enrichment patterns of trace elements in this period, major and trace elements of 2610 samples from 6 sections of Ediacaran and early Cambrian period in Three Gorges section of Hubei Province, Taoyuan section of Hunan Province, Sanshui section of Guangdong Province, Weng'an section of Guizhou Province, and Meishucun section of Yunnan Province in the South China and Lujiaping section in South Qinling Mountain, Shaanxi Province in central China were analyzed. Compared to the upper continental crust, average selenium (Se) is the most enriched trace elements among 23 analyzed trace elements in the whole Ediacaran and early Cambrian Formations in those 6 sections in the South China Lujiaping section in South Qinling Mountain, and then arsenic (As), molybdenum (Mo), and cadmium (Cd) followed. The concentrations of them vary great. In Three Gorges section, Se from 10^{-5}> to 30.08 mg/kg, As from 10^{-5}> to 196.45, Mo from 0.02 to 288.95, and Cd from 0.02 to 163.05 mg/kg, with average values of 1.34, 1.04, 14.02, and 8.03 mg/kg, and average enrichment factors (EF) of 26.97, 10.66, 9.66, and 5.35, respectively. The distribution and enrichment patterns of trace elements in another 5 sections in south China exhibit similar variation and trends through the Ediacaran and early Cambrian Formations as Three Gorges section in Hubei Province. The Se is the most enriched in Lujiaping Formation black shale of Ediacaran and early Cambrian in south Qinling Mountain, general varied from 10 to 303 mg/kg with the average values of 23 mg/kg in the beds of black shale in Lujiaping Formation, and with average values of 5.21 mg/kg whole Lujiaping Formation. The lowest Se content among 6 sections is in Guangdong Province. The Se and Mo concentration exhibit similar variation and increasing trends through the Ediacaran and early Cambrian Formations, and As exhibit decline trends through the strata. The most enriched Se beds (sequence) is the lower part of Yuanshan Formation (Qiongzhusi) in Yunnan, Niutitang formation in Guizhou, and lower part of upper member Lujiaping Formation in Shaanxi, which just below the horizon of first trilobite occurs bed, can be compared with to base of Series 2 of Cambrian that Se is about 16 mg/kg (in Guangdong)-303 mg/kg (in Shaanxi), followed by the fourth Member of Doushantuo Formation (DST-IV) of Ediacaran(20-76 mg/kg), then the lower part of DST-II, 20-56 mg/kg; the most enriched As bed is the lower part of DST-II , then DST-IV. Mo exhibit same trends as the selenium. The result show that a series of strong enriched sequences of Se, Mo, and As during Ediacaran and early Cambrian sequences in south China are consistent with a series of major biological evolution sequences in Ediacaran and early Cambrian. Compared with the content and enrichment of Se and other elements of marine black shale in other geological periods, such as black shale of Datangpo Formation of Cryogenian, Ordovician–Silurian interval, Devonian- Early Mississippian interval etc., that result show that Se content in Ediacaran and early Cambrian black shale are general 5-20 times or even more times than above period. At same time, the enrichment coefficient of Se is the highest among the all BFs in the black shale of Ediacaran and early Cambrian, but is not the highest in Datangpo and other interval black shales sequences which had not big biological change. It show that the degree of enrichment of selenium seems to be a sensitive indicator of the degree of biological change. The higher the content and enrichment of Se, the greater of the biological change degree. So, that Se, Mo, and As are not a series micronutrient elements that are critical for life in today, but also plays an important role in the early biological radiation and change. The future two science problems need to pay more attention: 1) Evolution of selenium, arsenic, and other bological trace elements (BFs) during geological history, 2) Quantitative relationship between the enrichment level of BFs and biological changes level- occurrence, development, radiation, extinction.

The Miaolingian Series and the traditional 'Middle' Cambrian: implications for Baltoscandian stratigraphy

Nielsen A.T.[1] & Ahlberg P.*[2]

[1] University of Copenhagen, Denmark. [2] Lund University, Sweden.

Corresponding author email: per.ahlberg@geol.lu.se

Keywords: Chronostratigraphy, Cambrian, Miaolingian, trilobites, acritarchs, Baltoscandia.

The Miaolingian Series was ratified in 2018 as the new formal name for Cambrian series 3 (≈ 'Middle' Cambrian). The GSSP for the conterminous base of the Miaolingian and its lowermost stage, the Wuliuan, coincides with the FAD of the widely distributed oryctocephalid trilobite *Oryctocephalus indicus* in the Kaili Formation at the Wuliu-Zengjiayan section, eastern Guizhou Province, China. However, *O. indicus* and associated trilobites have not been recorded from Baltoscandia and hence direct correlation into the Baltic successions is difficult. In Baltica, acritarchs may be used for identifying the base of the Miaolingian, but two problems have to be addressed: 1) Does the GSSP level in China correspond to the FAD of the *Eliasum–Cristallinium* acritarch assemblage?, and 2) how accurately is the incoming of this assemblage identified in Baltoscandian successions, where the underlying sandy strata in general are not particularly productive for acritarchs?

Comparison of acritarch taxa shared between the GSSP section and Baltica indicates that the GSSP level likely correlates with a level *within* the Baltoscandian *Eliasum–Cristallinium* assemblage zone. Nonetheless, it appears most feasible to consider the base of this zone (i.e. the Kibartian Regional Stage) as the best possible local approximation for the base of the Miaolingian in Baltoscandia. This level equates the traditional lower boundary of the 'Middle' Cambrian as used in the East Baltic area. In much of Scandinavia, the lower boundary of the Miaolingian thus defined falls within the Hawke Bay hiatus. Hence, the Miaolingian largely corresponds to the interval previously assigned to the 'Middle' Cambrian in the region, except that the Miaolingian includes the *Agnostus pisiformis* Zone, which traditionally has been assigned to the 'Upper' Cambrian. In Scandinavia, the Miaolingian/Furongian boundary is very precisely defined, being marked by the lowest occurrence of the cosmopolitan agnostoid *Glyptagnostus reticulatus* and abundant olenid trilobites. In the East Baltic area, the upper boundary of the Miaolingian coincides with a major unconformity.

A chronostratigraphic framework based on index acritarchs for the Cambrian volcanosedimentary Vallehondo and Playón formations of the Cambrian Ossa-Morena Rift (Zafra Syncline, Ossa-Morena Zone, southwest Iberian Massif)

Palacios T.*[1], Álvaro J.J.[2], Jensen S.[1], Santos Zalduegui J.F.[3], Eguiluz L.[3], Corfu F.[4] & Gil Ibarguchi J.I.[3]

[1] Universidad de Extremadura. [2] Instituto de Geociencias (CSIC-UCM). [3] University of the Basque Country
[4] University of Oslo.

Corresponding author email: medrano@unex.es

Keywords: acritarchs, Cambrian, Ossa-Morena Zone, Spain, chronostratigraphy, geochronology.

An extensive record of diagnostic cosmopolitan acritarchs from the volcanosedimentary Vallehondo and Playón formations of the Cambrian Ossa-Morena Rift allows us to establish a fine acritarch-based chronostratigraphy, bracketed between the Cambrian *Serrodiscus*-bearing Series 2 (Stage 4) strata and the Guzhangian (Miaolingian) *Sao* aff. *hirsuta*-bearing beds. Two Cambrian Series 2 acritarch zones (*Skiagia ciliosa* and *Heliosphaeridium notatum* zones) and five Miaolingian (IMC1 to IMC5 zones; Palacios, 2015) are recognized. The IMC1 and IMC2 zones are identified in the La Albuera Member (Vallehondo Formation) rich in felsic volcanic interbeds that have been dated between 512 ± 4 and 502 ± 2 Ma. (Sánchez-García et al., 2008). The IMC1 Zone includes the FAD of *Comasphaeridium longispilosum*, *Eliasum llaniscum* and *Comasphaeridium silesiensis*, diagnostic of the Miaolingian Series and associated with the diagnostic trilobite *Acadoparadoxides* cf. *mureroensi*s. The transition to the IMC2 Zone coincides with ignimbrites dated at 504.5 ± 1.3 Ma (Sánchez-García et al., 2008). This zone is approximately equivalent to the Wuliuan Stage. The IMC2 Zone includes the FAD of *Comasphaeridium francinae* and *Cristallinium cambriense*; its top is interrupted by the last volcanic felsic levels that mark the top of Vallehondo Formation dated by us at 500.9 ± 0.9 Ma (U-Pb SHRIMP). This zone corresponds to most of the Drumian Stage. The latter radiometric age provides a more precise constraint for the end of acid volcanism. The maximum acritarch diversification coincides with the influence of basic volcanism in the Playón Formation, where three latest Drumian-Guzhangian zones have been recognized: (i) the IMC3 Zone includes the FAD of *Adara alea*, *Vulcanisphaera cantabrica*, *Eliasum asturicum* and *Eliasum fombellae*, whose stratigraphic ranges are limited to this zone; (ii) the IMC4 Zone is characterized by the FAD of *Timofeevia* species (such as *T. lancarae*, *T. heteromorpha* and *T. tchedirtiensis*); and (iii) the IMC5 Zone by the appearance of *Cristallinium dubium* and *Symplassosphaeridium cambriensis* (Palacios, 2015). The new data confirm a latest Drumian-Guzhangian age for the basic volcanism in the Playón Formation. The detailed acritarch-based zonation recognized in Iberia is also valid for the Acado-Baltic (biogeographic) Province, and reinforces the great value of acritarchs in Miaolingian chronostratigaphy.

Palacios T. (2015) - Acritarch assemblages from the Oville and Barrios Formations, northern Spain: a pilot proposal of a middle Cambrian (Series 3) acritarch biozonation in northwestern Gondwana. Review of Palaeobotany and Palynology, 219, 71–105.

Sánchez-García T., Quesada C., Bellido F., Dunning G. & González de Tánago J. (2008) - Two-step magma flooding of the upper crust during rifting: the Early Paleozoic of the Ossa-Morena Zone (SW Iberia). Tectonophysics, 461, 72–90.

Revision of the Cambrian stratigraphy of the Bowers Terrane, northern Victoria Land, Antarctica

Park T.-Y.*, Kihm J.-H., Woo J. & Lee J.-I.

Korea Polar Research Institute, Korea Rep.

Corresponding author email: typark@kopri.re.kr

Keywords: Cambrian, stratigraphy, northern Victoria Land, Antarctica.

The Cambrian rocks in Antarctica are well exposed along the Transantarctic Mountains which run along the eastern margin of the continent, and ends in the northern Victoria Land (NVL). The Cambrian sedimentary successions in NVL were formed in association with subduction of the paleo-Pacific plate under the Antarctic continent, and represented by an accretionary complex of sedimentary rocks in three tectonic terranes: the Wilson, Bowers and Robertson Bay terranes, from inboard to outboard. The Bowers Supergroup of the Bowers Terrane is well-known for producing Cambrian trilobites which can be used for biostratigraphic correlation. The original Cambrian stratigraphy of the Bowers Terrane was established on the basis of the materials collected during 1974/75 and 1981/82 expeditions by the New Zealand Antarctic Research Programme (NZARP). Among the fossil-occurring localities of the Bowers Terrane, Edlin Neve and Mariner Glacier represent the northwest and the southeast end points, and are only about 200 km apart. Nevertheless, the Cambrian stratigraphy of the Bowers Terrane was interpreted to show a remarkable lateral facies variation. Korea Polar Research Institute carried out four expedition to the northern Victorian Land from 2012/2013 season to 2015/2016 season, with setting up field camps at Mariner Glacier and Reilly Ridge. A detailed biostratigraphic researches in the area has revealed that the thick Spurs Formation at Mariner Glacier is due to stratigraphic repetitions by tectonic folds, and the Paibian aspect of the Spurs Formation at Reilly Ridge was a result of misidentifications of some taxa. The unusually thick Molar Formation in the Houliston Glacier which is located in the middle part of the Bowers Terrane is likely to be due to misinterpretation of the structurally complicated area. The accordingly-revised Cambrian stratigraphy of the Bowers Terrance shows less lateral facies variation. The remaining issues of the area include 1) the unreliable age of the Eureka Formation which occurs only at Marine Glacier, and; 2) the lower boundary of the Spurs Formation at Mariner Glacier which was covered by snow.

New collection of Sirius Passet biota, Peary Land, North Greenland, and its implication for the age

Park T.-Y.*[1], Lee M.[1], Kihm J.-H.[1], Nielsen M.L.[2], Vinther J.[2] & Nielsen A.T.[3]

[1] Korea Polar Research Institute, Korea
[2] University of Bristol, UK
[3] University of Copenhagen, Denmark

Corresponding author email: typark@kopri.re.kr

Keywords: Cambrian, Sirius Passet, North Greenland, age.

Peary Land of North Greenland is a terrestrial area of the highest latitude in the northern hemisphere, but has received limited attention due to its extreme remoteness. Nevertheless, this area holds a celebrated Cambrian fossil locality, Sirius Passet (82° 47.603′ N, 42° 13.394′ W), which is a Konservat-lagersttäte, producing soft-bodied marine animal fossils of ca. 520 Ma. However, due to the lack of good age-constraining fossil, the precise age of the Sirius Passet fauna remains still contentious; the sole trilobite species Buenellus higginsi is an endemic species, and only provides a rough age constrain of correlating to the Nevadella Zone of Laurentia, which is a relative long-ranging biozone. In 2016, 2017, and 2018 seasons, expeditions to Sirius Passet led by the Korea Polar Research Institute collected about two tons of slabs containing more than 10,000 fossil specimens from the outcrop and screes of the Buen Formation. The new collections include various metazoans, such as sponges, euarthropods, stem-group euarthropods, primitive mollusks, annelids, cycloneuralians including priapulids and loriciferans, gnathiferans, and primitive deuterostomes, which contains not only better-preserved specimens of the previously documented species, but also many new species. Interestingly, the new materials hold some new shelly fossils, such as archaeocyathids, possible brachiopods, and mobergellids. Further studies on the new shelly fossils would provide a better age constraint for the Sirius Passet biota in the future.

Better one-eyed than stone-blind: choosing the index species for the base of Cambrian Stage 3

Parkhaev P.Yu.*, Demidenko Yu.E. & Kulsha M.A.

Borissiak Paleontological Institute RAS, Moscow.

Corresponding author email: pparkh@paleo.ru

Keywords: Cambrian, biostratigraphy, Stage 3, trilobites, SSF, GSSP.

During the last 10-15 years the Cambrian system in the International Chronostratigraphic Chart (ICC) was slowly filled by the toponymical named stages with ratified GSSP at their lower boundaries. Traditional middle and upper Cambrian portions were the first to get their stage-units due to the presence in deposits of many taxa (mostly trilobities) with wide geographic ranges ensuring reliable correlations between various paleocontinents. The lower Cambrian part of the chart is different. This is the time of initial radiation of most skeletal groups of Metazoa, with localized diversifications and rather limited spatial distributions of taxa. Still we do not choose the criteria how to define the globally recognized stages 2, 3, and 4. The situation with Stage 3 is the most difficult (for recent summary see Zhang et al., 2017). Here we discuss the problem of the biostratigraphic substantiation of the lower boundaries the Stage 3 of ICC and of the Atdabanian Stage of the General Stratigraphic Scale (GSS) of Russia. It is believed that the first appearance of trilobites is the main characteristic of these stage units. However, the difficulties in choice of the correlation level for the lower boundary of the Stage 3 on the base of trilobites are clearly shown. It is explained by the different taxonomic composition of the assemblages of the most ancient representatives of this group of arthropods on different paleocontinents and obvious diachronism of the levels of their first appearance. It is proposed to use the species Mobergella radiolata Bengtson, 1968 for definition of the lower stage boundary (Rozanov et al., 2011; Demidenko et al., 2012). The geographical distribution of this SSF species is wider than that of any species among the ancient trilobites. It was shown that on the territory of the Siberian Platform in the stratotype region for the Lower Cambrian stages (the interfluve of Lena and Aldan rivers) M. radiolata appears in sections at the same level as the first Atdabanian archaeocyaths of the Retecoscinus zegebarti Zone do. This allows the use of M. radiolata as the index species for the lower boundary of the Atdabanian Stage of GSS. Finds of M. radiolata in other regions of the Siberian platform (west, north and southeast, interior areas of the platform) make this taxon of microfauna an extremely valuable tool for the Lower Cambrian biostratigraphy, the correlation potential of which is much higher than that of the locally distributed Early Atdabanian archaeocyathes or trilobites.

Study is supported by RFBR 19-04-01027.

Demidenko Y.E., Parkhaev P.Y. & Rozanov A.Y. (2012) - Morphological variability and types of preservation of Mobergella radiolata–a potential index species for the GSSP of Cambrian Stage 3. Journal of Guizhou University, 29, 157–158.

Rozanov A.Y., Parkhaev P.Y., Demidenko Y.E. & Skorlotova N.A. (2011) - Mobergella radiolata—a possible candidate for defining the base of Cambrian Series 2 and Stage 3. Bulletin of Museum of Northern Arizona, 67, 304–306.

Zhang X.L., Ahlberg P., Babcock L.E., Choi D.K., Geyer G., Gozalo R., Hollingsworth J.S., Li G X., Naimark E.B., Pegel T., Steiner M., Wotte T., Zhang Z.F. (2017) - Challenges in defining the base of Cambrian Series 2 and Stage 3. Earth Sci. Rev., 172, 124–139.

Mid-Early Cambrian molluscs from North China and Siberia – East Gondwana correlations

Parkhaev P.Yu.*

Borissiak Paleontological Institute RAS, Moscow.

Corresponding author email: pparkh@paleo.ru

Keywords: Cambrian, biostratigraphy, molluscs, Australia, China, Siberia.

Molluscs assemblages from the middle Early Cambrian of Northern China platform are known since 1980s (Xiao, Zhou, 1984; Zhou, Xiao, 1984; Feng et al., 1994, etc.). Over 30 species (a number of them are synonyms) were described from the Xinji Fm and its equivalents in Anhui, Henan and Shaanxi provinces of China. The ongoing studies bring new data on the taxonomic composition, fauna relations and stratigraphic correlations of these strata (e.g., Li et al., 2014, 2016, 2017, 2018, 2019). During the ICECS-2018 field trip to Shaanxi we collected rock samples from the lower Xinji Fm at Chaijiawa and Zhoujiaqu sections. The subsequent treatment of samples revealed the following mollusc assemblage: *Bemella communis*, *Marocella mira*, *Pararaconus paradoxus*, *Anhuiconus microtuberus*, *Asperconella troyensis*, *Davidonia rostrata*, *Figurina nana*, *Horsegullia horsegulliensis*, *Xianfengella yatesi*, *Anabarella australis*, *Stenotheca drepanoida*, *Watsonella crosbyi*, *Xinjispira simplex*, *Pelagiella madianensis*, *Pojetaia runnegari*. Comparison of this assemblage with that described from the Lower Cambrian of South Australia (Bengtson et al., 1990; Gravestock et al., 2001) shows almost complete similarity of species composition, though the Australian assemblage is even more diverse. Since that the Australian formations containing these species (Parara Lst, Mernmerna Fm, Sellik Hill Fm) and Chinese Xinji Fm are obviously of the same age. In addition to mollusks, various SSF and *Estaingia* trilobites from Xinji Fm suggests its correlation with the middle Canglangpuan of South China and middle Botoman of Siberian platform (Yun et al., 2016). The correlation is also supported by the presence of numerous *Pelagiella madianensis* in Xinji Fm, recently reported (Kouchinsky et al., 2015) from the Botoman (*Calodiscus*–*Erbiella* zone) of the East Anabar region as *Pelagiella* sp. 1, along with *Figurina nana*, *Pararaconus paradoxus* (as *Pararaconus* sp.), and *Pelagiella subangulata* (as *Pelagiella* sp. 2). In Laurentia (NE Greenland) the following species are reported (Skovsted, 2004) from the Bastion Fm of Middle Dyeran (*Bonnia*–*Olenellus* zone): *Davidonia rostrata*, *Asperconella troyensis*, *Pojetaia runnegari*, *Bemella communis* (as *Figurina groenlandica*), and *Anabarella australis*. These strata are confidently correlated with the Botoman stage of the Siberian platform by trilobites (Peng et al., 2012). The find of *Watsonella crosbyi* in the lower Xinji Fm is noteworthy. It confirms the significant time range of the species (i.e., Tommotian–Botoman), and put doubts on new correlation chart elaborated for the Lower Cambrian of South Australia (Betts et al., 2016, 2018) that significantly increase the age of the formations as compared to commonly accepted correlations.

I am thankful to Prof. Zhang Xingliang and his team for organization of the ICECS-2018 and field trips. Study is supported by RFBR 19-04-01027.

Arthropod anomalocarids from the Cambrian Balang Fauna in East Guizhou, South China

Peng J.*, Wang Q., Lan T., Zhang H. & Wang Y.

College of Resource and Environment Engineering, Guizhou University, Guiyang - Guizhou, China

Corresponding author email: gzpengjin@126.com

Keywords: Anomalocarids, Balang Fauna, Cambrian, Guizhou, China.

The Balang Fauna from Guizhou, China yields fossils represented seven invertebrate phyla. It is preserved in middle and upper parts of the Cambrian Balang Formation in Guizhou, South China. The Balang Formation distributes wider in eastern Guizhou and western Hunan, at present, the 9 localities containing the Balang Fauna have found, of which the very fossiliferous the Lazizhai section of the Balang Formation near Lazhizhai village, Jianhe County, eastern Guizhou contains best fossils representatives of eight invertebrate phyla, including sponge and chancelloriids, coelenterates, brachiopods, priapulid worms, hyoliths, arthropods and stalked echinoderms. In addition, still have alga, and a rich ichnofauna. Especially, arthropod assemblages have high diversified, including trilobites, trilobitomorphs, large bivalved arthropod, bradoriids, and anomalocarids. Anomalocarid fossils from the Balang Fauna preserve as frontal appendage and head sclerites. According to their morphology, the fossils are similar to those frontal appendage and head sclerites of anomalocaridids from Chengjiang Biota. It is known that Acanthomeridion commonly in the Chengjiang Biota; of which the important Anomalocaridids includes fossil sclerites both Anomalocaris and Hurdia. Comparison with those frontal appendage and head sclerites of anomalocaridids from Chengjiang Biota, the frontal appendages from the Balang Formation are recognized as a part of the frontal appendages of Anomalocaris, and another head sclerites should be an central elements or dorsal plate and lateral plate of Hurdia. Their exact taxonomy needs more works. The discovery of arthropod anomalocarids of the Balang Fauna indicates that taxa originally present in the shallow water platform of Yunnan migrated eastward to the deep-water area of Guizhou in Cambrian 4 epoch, adapting to a new ecological setting. The new assemblage from the Balang Fuana not only adds new taxonomic records but also provides some new information regarding anomalocaridid palaeoecology, evolution, and geographic distribution. New finds indicate these swimming animals with dispersal capabilities similar to modern pelagic organisms, and provide new essential information to a better understanding of the evolutionary pattern of these taxa in timeline, in terms of geographic distribution. New anomalocaridid taxa from the Balang Fauna are comparable with that of the equivalent Guanshan Biota. Observations of new taxa from the Balang Fauna open a new stratigraphic window on their diversity and early evolutionary history.

Proposed GSSP for Cambrian Stage 10 with multiple stratigraphic markers for global correlation

Peng S.C.*[1], Babcock L.E.[2], Bagnoli G.[3], Shen Y.[4], Mei M.[5], Zhu X.[1], Li D.[4], Zhang X.[4] & Wang L.[5]

[1] State Key Laboratory of Palaeobiology and Stratigraphy, Chinese Academy of Sciences (Nanjing Institute of Geology and Palaeontology), Nanjing, China. [2] School of Earth Sciences, The Ohio State University, Columbus, Ohio, USA. [3] Department of Earth Sciences, University of Pisa, Italy. [4] School of Earth and Space Sciences, University of Science and Technology of China, Hefei, China. [5] School of Earth Sciences and Natural Resources, China University of Geosciences, Beijing, China

Corresponding author email: scpeng@nigpas.ac.cn

Keywords: Proposed GSSP, Cambrian, Stage 10, Waergang section, NW Hunan, China.

A GSSP has been proposed for defining the base of Cambrian Stage 10 (provisional) at the FAD of Lotagnostus americanus in the Wa'ergang section, northwestern Hunan, South China (Peng et al., 2014, 2018), which exposes a thick Cambrian-Ordovician succession in slope facies, known as the Huaqiao and overlying Shenjiawan formations. The proposed stratotype point is 29.65 m above the base of the Shenjiawan Formation. Multiple stratigraphic markers have been studied in the proposed stratotype section in order to correlate the proposed GSSP horizon as widely and precisely as possible.

Agnostoid trilobite biostratigraphy. Three agnostoid zones are recognized in a 32-m-thick interval that includes the proposed GSSP horizon. In ascending order, they are the *Eolotagnostus decorus* Zone, the *Lotagnostus americanus* Zone and the *Micragnostus chiushuensis* Zone. The base of the *L. americanus* Zone is defined by the lowest occurrence of the eponymous species at 29.65 m above the base of Shenjiawan Formation (or 684.65 m above the base of the Huaqiao Formation); this position is proposed as the base of global Stage 10. The cosmopolitan *L. americanus* allows for global correlation, as the species has been recognized from Canada, the Great Basin of the United States, the UK, Sweden, Argentina, Siberia, Kazakhstan, Tasmania and China (South, Northwest and East China).

Polymerid trilobite biostratigraphy. Four assemblage zones of polymerid trilobites are recognized in the Shenjiawan Formation of the Wa'ergang section (Peng, 1984, 1992). The lowermost zone is the *Lotagnostus americanus-Hedinaspis regalis* Assemblage-zone. Extensive collecting in the Wa'ergang section shows that *H. regalis* and another important polymerid trilobite, *Charchaqia norini*, make their first appearances nearly at the FAD of *L americanus*. These two polymerid species have an intercontinental distribution.

Conodont biostratigraphy. As a result of detailed sampling, four conodont zones are recognized in the Shenjianwan Formation of the Wa'ergang section (Bagnoli et al., 2017; Dong and Zhang, 2017) with several species having intercontinental correlation value. C osmopolitan species include *Proconodontus tenuiserratus*, *P. muelleri, P. serratus*, and *Eoconodontus notchpeakensis*. The base of the *P. posterocostatus* Zone, which is marked by the lowest occurrence of *Dasytodus trasmutatus*, nearly coincides with the first appearance of *L. americanus*. In the Wa'ergang section, the FAD of the cosmopolitan *E. notchpeakensis* lies about half way between the FAD of *L. americanus* and the base of Ordovician; this horizon may be useful for subdividing Stage 10 into two substages.

Carbon isotope chemostratigraphy. High-resolution $\delta^{13}C$ analyses in the Wa'ergang section reveal three negative excursions (N1, N2, N3) within the Shenjiawan Formation. The N1 and N2 excursions are older than the HERB/TOCE (N3) excursion, and the N1 excursion begins just above the proposed GSSP horizon (Li et al., 2017). The N1 excursion represents the first significant carbon isotope excursion event following the SPICE excursion, and correlates into sections described from Australia, Argentina, and Laurentia.

Sequence stratigraphy. The Shenjianwan Formation, which is predominantly a carbonate unit, essentially represents a single third-order sequence that embraces 44 meter-scale cycles of the L-M type (Mei et al., in press). This third-order sequence is the uppermost third-order cycle known in the Cambrian. The third-order sequence can be subdivided into 2 fourth-order sequences, each of which is further subdivided into 6 fifth-order sequences. The proposed GSSP horizon lies within the first fifth-order sequence in the lowermost part of the Shenjianwan Formation. The position can also be identified as about 8 m above the conterminous base of the third-order sequence, which is also about 8 m above the base of the lowermost fourth-order and fifth-order sequences.

The combination of the lowermost occurrences of widely distributed agnostoid, polymerid, and conodont species, the first significant negative carbon isotope excursion event upsection from distinctive SPICE positive excursion (in the Paibian Stage), and the first fifth-order sequence of the uppermost third-order sequence known in the Cambrian, allows for confident recognition and correlation of the base of the provisional Stage 10 on a global scale.

Bagnoli G., Peng S., Qi Y. & Wang C. (2017) - Conodonts from the Wa'ergang section, China, a potential GSSP for the uppermost stage of the Cambrian. Riv. It. Paleontol. Strat., 123(1), 1-10.

Dong X. & Zhang H. (2017) - Middle Cambrian through Ordovician conodonts from Hunan, South China. Jour. Paleont. Mem., 73, 1-89.

Li D., Zhang X., Chen K., Chen X., Huang W., Peng S., & Shen Y. (2017) - High-resolution carbon isotope chemostratigraphic record from the uppermost Cambrian stage (Stage 10) in South China, implications for defining the base of Stage 10 and palaeo-environmental change. Geol. Mag., 154 (6), 1232-1243.

Mei M., Wang L., Li Y., Peng S., Zhu X., & Zuo J., in press. Studies on cyclostratratigraphy within the framework of sequence stratigraphy for the Stage 10 of the Cambrian Furongian at the Wa'ergang section, Taoyuan County, Hunan Province. Jour. Strat., 43.

Peng S., (1984) - Cambrian-Ordovician boundary in the Cili-Taoyuan border area, northwestern Hunan with description of relative trilobites. In: Nanjing Institute of Geology and Palaeontology, Academia Sinica (ed.), Stratigraphy and Palaeontology of Systemic Boundaries in China, Cambrian and Ordovician Boundary (1), 285-405. Anhui Sci. Tech. Publ. House, Hefei.

Peng S., (1992) - Upper Cambrian Biostratigraphy and Trilobite Faunas of Cili-Taoyuan area, northwestern Hunan, China. Mem. AAP, 13, 1-119.

Peng S., Babcock L.E., Zhu X., Zuo J., & Dai T. (2014) - A potential GSSP for the base of the uppermost Cambrian stage, coinciding with the first appearance of *Lotagnostus americanus* at Wa'ergang, Hunan, China. GFF, 136, 208-213.

Peng S., Babcock L.E., Bagnoli G., Shen Y., Mei M., Zhu X., L. D., Zhang X. & Wang L. (2018) - Proposed GSSP for the base of Cambrian Stage 10 (Furongian Series) at FAD of *Lotagnostus americanus* in the Wa'ergang section, Hunan, China. In: International Conference on Ediacaran and Cambrian Sciences, Joint meeting of ISCS & ISES, Program, Abstract, 76-78. NW Univ., Xi'an.

The Niutitang Formation from the Cambrian in Guizhou

Yang X.[1]*, Zhao Y., Cao P.[1] & Wei B.[1]

[1]College of Resources and Environmental Engineering, Guizhou University, Guiyang, China.

Corresponding author email: yangxinglian2002@163.com

Keywords: Cambrian, China, trilobites, bradoriids, sponge fossils.

The Niutitang Formation is a stratigraphical unit situated between the underlying Dengying (or Laobao, Gezhongwu, or Taozichong) Formation and the overlying Mingxinsi (or Jiumenchong) Formation, and consisting of black carbargilite, carbonaceous shale, and multi-elemental (e.g., Ni and Mo) ore beds in its lower part, and black carbonaceous shale intercalated with grey-green silty shale in its upper part, which also contains the trilobite Tsunyidiscus, the bradoriid Tsunyiella, and abundant sponge fossils. According to the biostratigraphy, the black silty shale interval below the first appearance of Tsunyidiscus is late Xiaotanian in age, and can be correlated with the Ni-Mo-rich ore layer in the lower part of the Niutitang Formation of the Yankong and Songlin sections, with the upper phosphoric concretionary horizon of the Niutitang Formation in the Duoding section, with the upper part of the Laobao Formation below the lowest stone coal bed with phosphate nodules of the Niutitang Formation of Majiang and Danzhai (and other localities), and with the highly carbonaceous shale with phosphate nodules at the base of the Zhalagou Formation in Sandu. The middle and upper parts of the Niutitang Formation are Chiungchussuan in age. In the transitional slope area of Guizhou, the thick limestone of the Jiumenchong Formation containing Hubeidiscus and located above the black shale of the Niutitang Formation, can be correlated with the lower part of the Mingxinsi Formation in the shallow water area of Guizhou. The ages of these strata range from late Chiungchussuan to early Duyunian.

Distribution and biostratigraphy of the Cambrian chancelloriids: a review

Yun H.[1]* & Zhang X.[1]

[1]State Key Laboratory of Continental Dynamics and Shaanxi Key Laboratory of Early Life and Environments, Department of Geology, Northwest University, China.

Corresponding author email: yunhao@stumail.nwu.edu.cn

Keywords: Cambrian, chancelloriids, distribution, biostratigraphy.

Chancelloriids are a group of cosmopolitan Cambrian animals that mainly distributed in 64 distinct localities. In 54 of them, chancelloriids are preserved as isolated sclerites in skeletal faunas that deposited in carbonate-dominated rocks. In 9 localities, chancelloriids are important members of the *Konservat-Lagerstätten* that characterized by shales and siltstones. Particularly, in the Sekwi Formation of Northwest Territories, Canada, the partially-preserved chancelloriid scleritomes are preserved on the bedding surfaces of carbonates. *Chancelloria*, *Archiasterella* and *Allonnia* are the common chancelloriid genera in most continents. However, other genera are usually restricted in specific regions: *Dimidia* occurs only in South China, Gondwana and Laurentia, *Eremactis* only in East Gondwana and Laurentia, *Cambrothyra* and *Nidelric* only in South China. The distribution of chancelloriids is generally within the tropical and subtropical zones, while a few genera (*Chancelloria* and *Archiasterella*) can survive in the continents with relatively higher latitudes, such as Baltica, Avalonia and south part of Gondwana. The global chancelloriid biostratigraphy indicates that there are three phases corresponding to the evolution of this animal group. The first phase (initial phase) is the early Terreneuvian of Cambrian, when the sclerites of *Chancelloria* and a few *Cambrothyra* occurred in South China, Siberia and Mongolia. The second phase (flourished phase) is from the late Terreneuvian to late Miaolingian, during which the chancelloriid group is remarkably diversified and their distribution is expanded to all continents. The third phase (declined phase) is from the late Miaolingian to early Furongian. In this period, there is only a small number of *Chancelloria* and *Archiasterella* yielded in the skeletal assemblages of South China and Peri-Gondwana. After the Paibian Stage of Furongian, chancelloriids totally went extinct.

ST3.3

Silurian odyssey towards advanced stratigraphy and correlation

Conveners and Chairpersons

Petr Štorch (Institute of Geology of the Czech Academy of Sciences)

Carlo Corradini (Università di Cagliari)

Zhan Renbin (Chinese Academy of Sciences)

The Aeronian succession of the El Pintado section (proposed replacement GSSP for the base Telychian), Seville Province, Spain

Štorch P.*[1], Loydell D.K.[2], Frýda J.[3] & Gutiérrez-Marco J.C.[4]

[1] Institute of Geology of the Czech Academy of Sciences. [2] University of Portsmouth. [3] Czech Geological Survey. [4] Instituto de Geociencias (CSIC–UCM), Facultad de Ciencias Geológicas

Corresponding author email: storch@gli.cas.cz

Keywords: graptolite, biostratigraphy, Silurian, Aeronian, Telychian, GSSP candidate section.

The North-East shore of the El Pintado reservoir in Seville Province, Spain exposes several continuous sections of dominantly anoxic graptolitic hemipelagites which altogether range from the lower Rhuddanian to the Lochkovian (Jaeger & Robardet, 1978). A richly graptolitic section through the Aeronian/Telychian boundary described by Loydell et al. (2015) may be considered as a promising candidate for a new boundary stratotype for the Telychian Stage. Herein we describe the lower part of the structurally simple El Pintado section comprising Rhuddanian/Aeronian boundary interval and middle and upper Aeronian strata. A uniform succession of black shale referred to the *cyphus* and lower *triangulatus* graptolite biozones is interrupted by a prominent disconformity in the middle of the *triangulatus* Biozone which is overlain by the middle Aeronian *leptotheca* Biozone. Lower Aeronian strata, correlatable with the upper *triangulatus*, *pectinatus* and *simulans* biozones of central Europe (Štorch et al., 2018), are missing. The *leptotheca* Biozone is overlain by the *convolutus*, *sedgwickii* and *halli* biozones without any evidence of another disruption of sedimentation apart from a 5 cm thick rusty siltstone in the lower *sedgwickii* Biozone and the absence of a positive *sedgwickii* C_{org} isotope excursion. The overall thickness of the Aeronian succession is 7.9 m. More than 100 graptolite species, including all biozonal index taxa and other stratigraphic marker species, enable high-resolution correlation with other Aeronian sections in Europe and elsewhere. The isotope record fluctuates little in the Aeronian part of the section. No significant C_{org} isotope excursions have been recorded even in the *sedgwickii* Biozone despite the remarkable decrease in graptolite species richness. The Aeronian succession contributes to a solid foundation of the ongoing proposal of the El Pintado section as a candidate for the base Telychian GSSP.

Jaeger H. & Robardet M. (1979) - Le Silurien et le Dévonien basal dans le nord de la Province de Séville (Espagne). Géobios, 12, 684–714.

Loydell D.K., Frýda J. & Gutiérrez-Marco J.C. (2015) - The Aeronian/Telychian (Llandovery, Silurian) boundary with particular reference to sections around the El Pintado reservoir, Seville Province, Spain. Bull. Geosci., 90, 743–794.

Štorch P. Manda Š. Tasáryová Z. Frýda J. Chadimová L. & Melchin M.J. (2018) - A proposed new global stratotype for Aeronian Stage of the Silurian System: Hlásná Třebaň section, Czech Republic. Lethaia, 51, 357–388.

Update on the Wenlock-Ludlow transition in the Timan-northern Ural region

Antoshkina A.I.* & Shebolkin D.N.

N.P. Yushkin Institute of Geology, Komi Science Center, Ural Branch, RAS.

Corresponding author email: a.antoshkina@bk.ru

Keywords: Wenlock-Ludlow boundary, facies, fauna, isotope data.

The Timan-northern Ural region represents the north-eastern margin (in modern co-ordinates) of the European Platform. Mid-Silurian sedimentation took place on an extensive carbonate platform covered by shallow epicontinental sea. On the carbonate platform margin were developed shallows with reefs restricted a circulation of water in the shelf. The low-diversity fauna is represented by species typical of shallow-water with low hydrodynamics. The Wenlock-Ludlow boundary deposits of the region have been studied via outcrops from the Subpolar Urals, Chernyshev and Chernov swells. The Homerian-Gorstian is represented by the interval where ostracodes fauna was widespread and distinctly changes in depositional environments are expressed (Subpolar Urals, 2000). The regressive phase of the end-Homerian is identified by ooid-stromatolite associations often with ostracodes and siliciclastic material sometimes forming siltstones or sandstones beds. In the lowermost Gorstian clay limestones include ostracodes, rare brachiopods and tabulate corals. Carbon isotopic values data derived from brachiopods shown the positive excursion in 1.6‰ during the late Homerian and the negative one in 0.7‰ during the early Gorstian (Modzalevskaya & Wenzel, 1999). Carbon isotopic values data derived from rock samples from the Subpolar Urals and Chernyshev Swell sections shown the same situation: in the upper Homerian beds the positive excursions are in 1.1-1.8‰ or in 1.2-2.0‰ and in the late Homerian beds the negative excursions are in 0.4-0.5‰. The ostracodes data as the most typically fauna correlating with the graptolite biozones *ludensis* and *nilssoni* (Abushik, 2000) available suggest that the $\delta^{13}C$ excursions from this interval are of the same (late Homerian-early Gorstian) age. It should be noted that during the interval is marked a short-time extinction event. Siliciclastic material transported to basin during late Homerian relative sea low-stand was promoted to increasing of a microbial activity and disturbing of benthic ecosystems. The absent of ooid-stromatolite associations at the onset of transgressive event of the early Gorstian suggests that the factors, such as a water depth and trophic conditions changed for benthic ecosystems towards better.

Abushik A. (2000) - Silurian-earliest Devonian ostracode biostratigraphy of the Timan-Northern Ural region. Proc. Est. Acad. Sci. Geol., 42(2), 112-125.

Modzalevskaya T.L. & Wenzel B. (1999) - Biostratigraphy and geochemistry of Upper Silurian brachiopods from the Timan-Pechora region (Russia). Acta Geol. Pol., 40(2), 145–157.

Subpolar Urals Field Trip Guidebook (2000) - In: Antoshkina A., Malysheva E. & Mannik P. Eds., Suppl. to Spec. Publl. 6 of Ichtyolith Iss. Syktyvkar: Geoprint, 1-119.

Integrated High Resolution Stratigraphy of the Llandovery Succession of Anticosti Island

Braun M.G.*[1-2] & Desrochers A.[1]

[1] University of Ottawa. [2] University of Iowa.

Corresponding author email: mgbraun@uiowa.edu

Keywords: Llandovery, Chemostratigraphy, Lithostratigraphy, Cyclostratigraphy, Carbon Isotope Excursions.

The Silurian Period was one of the most volatile intervals in Earth's history. The Period was marked by a series of short-lived climatic events, strong sea level fluctuations, and oceanic turnovers, all of which are commonly associated with moderate scale extinctions and perturbations of the global carbon cycle. Seven major positive isotopic carbon excursions are recognized in the Silurian, occurring in association with biotic turnovers. Historically, most Silurian research has focussed on the large excursions present in the Wenlock, Ludlow, and Pridoli epochs whereas the smaller Llandovery excursions remain understudied and more poorly known. The storm-dominated palaeotropical carbonate succession superbly exposed on Anticosti Island in Eastern Canada represents one of the most complete, thickest, and well-preserved successions in the world of Upper Ordovician and lower Silurian strata. This study develops a new integrated high resolution litho-, cyclo-, and chemostratigraphic framework for the upper Hirnantian to lower Telychian succession on Anticosti, by examining ~450 m of strata from a recent stratigraphic drill core supplemented by an additional ~120 m of strata from outcrop. Through a lithofacies analysis, four facies assemblages and three time-specific facies were identified in this succession; all facies are interpreted to have been deposited below fairweather wave base on a storm dominated carbonate ramp. Temporal facies shifts appear to be controlled by both long-term and short-term sea level fluctuations and can be organized into three orders of superimposed transgressive-regressive cycles. Isotopic curves for $\delta^{13}C$ and $\delta^{18}O$ were produced by sampling well-preserved bulk micrite at a resolution of 0.5-1 m per sample; in total 611 samples were taken from outcrop and core. Four distinct positive carbon isotope excursions are recognized in the succession; the upper Hirnantian (+5‰), Lower Aeronian (+2‰), Upper Aeronian (+6‰) and Valgu (+3.5‰) excursions. Multi-ordered $\delta^{18}O$ trends are recognized to occur in association with $\delta^{13}C$ trends and likely controlled by glacio-eustatic fluctuations.

Sequential Lower Aeronian, Upper Aeronian, and Valgu positive isotopic carbon excursions have only been reported in the Wisconsin subsurface and the Moose River Basin in northern Canada. These Llandovery excursions are now recognized in the more complete and thicker succession of Anticosti Island with higher peak values; including the highest magnitude ever recorded for the Upper Aeronian excursion. This study represents a comprehensive high resolution Llandovery stratigraphic framework integrating litho-, cyclo-, and chemostratigraphic data that provides meaningful insights into the driving forces behind these Silurian positive $\delta^{13}C$ excursions.

High Resolution $\delta^{13}C$ and $\delta^{18}O$ Chemostratigraphy Across the Ordovician-Silurian Boundary: New Insights from Anticosti Island, Eastern Canada

Braun M.G.*[1-2], Mauviel A.[1], Daoust P.[1-3] & Desrochers A.[1]

[1] University of Ottawa. [2] University of Iowa. [3] McGill University.

Corresponding author email: mgbraun@uiowa.edu

Keywords: Ordovician-Silurian Boundary, Chemostratigraphy, Carbon Isotopes, Oxygen Isotopes, Carbon Isotope Excursions.

The early Paleozoic Icehouse, which spans the Ordovician-Silurian (O/S) boundary, comprises a series of climatic shifts and sea level fluctuations driven by the advance and retreat of the Gondwana ice sheets. The storm-dominated paleotropical carbonate succession superbly exposed on Anticosti Island in Eastern Canada represents one of the most complete, thickest, and well-preserved successions in the world spanning the O/S boundary. Recent work on Anticosti has produced a high resolution chemostratigraphic framework by sampling ~320 m of strata from nearly complete costal outcrops and cliff faces along the west coast of the island, ~700 m of strata from two recent stratigraphic cores, and ~120 m of strata along cliffs and river banks in the south-central portion of the island; in total nearly 1500 data points (sampled at a 0.5-1.0m interval) for $\delta^{13}C$ and $\delta^{18}O$ were collected, corresponding to the entire exposed late Katian to mid Telychian succession of Anticosti Island. Four distinct positive carbon isotope excursions are recognized in the succession; the upper Hirnantian (+5‰), Lower Aeronian (+2‰), Upper Aeronian (+6‰) and Valgu (+3.5‰) excursions. Each of these excursions is recorded in at least two different localities on the island, and provide a distinct geochemical signal useful for local, regional, and global scale correlations with age equivalent strata. Anticosti Island is the only section in the world known to record sequential Hirnantian, Lower Aeronian, Upper Aeronian, and Valgu excursions; additionally, with peak values of +6‰, the Anticosti succession records the highest magnitude ever documented for the Upper Aeronian Excursion. Much like the Quaternary $\delta^{18}O$ marine signal, our $\delta^{18}O$ record is tightly coupled with multi-order cyclic facies changes. The tight coupling between lithologic and oxygen isotopic data suggests the Anticosti succession was influenced by glacio-eustatic fluctuations both during and following the end-Ordovician glacial maximum.Primary isotopic signal preservation is supported by the lack of significant covariance between $\delta^{13}C$ and $\delta^{18}O$, by microfabric preservation of both macro and microfossils in petrographic, cathodoluminescence, and SEM microscopy, and by little or no diagenetic resetting as suggested by the trace element geochemistry. Although unusual in deep geological time, this is possible when lithification occurs shortly after deposition in a closed diagenetic system.

Integrative stratigraphic research on the Late Ordovician to Llandovery (Silurian) black shales in South China

Chen Q.*[1], Fan J.X.[2], Chen X.[1] & Sun Z.Y.[3]

[1] Nanjing Institute of Geology and Palaeontology and Center for Excellence in Life and Paleoenvironment, Chinese Academy of Sciences, China. [2] Nanjing University, China. [3] Chengdu University of Technology, China.

Corresponding author email: qchen@nigpas.ac.cn

Keywords: Biostratigraphy, Wufeng and Lungmachi Formations, black shale, Silurian, South China.

From late Katian (Late Ordovician) to early Telychian (Llandovery, Silurian), the Wufeng and Lungmachi black shales (interbedded with a thin bed of limestone in middle Hirnantian, named Kuanyinchiao Bed) were widely distributed in the Upper Yangtze Platform, South China. The stratigraphic research about these two formations started from the early 20th century (Lee & Chao, 1924; Sun, 1931; Yin, 1943; Mu, 1945), and with several decades of efforts, the graptolite biozonation of the black shales has been established and could be correlated globally (Chen et al., 2000; Fan et al., 2011). The Wufeng Formation includes four biozones, i.e., the *Dicellograptus complanatus*, *Dicellograptus complexus*, and *Paraorthograptus pacificus* biozones of the upper Katian Stage, and the *Metabolograptus extraordinarius* Biozone of the lower Hirnatian Stage. The Lungmachi Formation includes nine biozones, i.e., the *Metabolograptus persculptus* Biozone of the upper Hirnantian Stage, the *Akidograptus ascensus*, *Parakidograptus acuminatus*, *Cystograptus vesiculosus*, *Coronograptus cyphus* biozones of the Rhuddanian Stage, the *Demirastrites triangulatus*, *Lituigraptus convolutus*, *Stimulograptus sedgwickii* biozones of the Aeronian Stage, and the *Spirograptus guerichi* Biozone of the lower Telychian Stage. In recent years, significant breakthroughs have been made in the exploration and production of shale gas from the Wufeng and Lungmachi black shales in South China. In order to investigate the temporal and spatial distribution models of these two formations, precise biostratigraphic work has been widely applied to many drilling cores and sections in this area. Meanwhile, some preliminary studies on the organic carbon isotope stratigraphy, cyclostratigraphy and quantitative stratigraphy have been carried out, in order to construct a high-resolution stratigraphic scheme for regional correlation. Based on that, the circumjacent distribution pattern of the black shale in the bordering area of eastern Chongqing, western Hubei and northwestern Hunan (Chen et al., 2017), and the stage-progressive distribution from the northern Guizhou to the southern Chongqing (Chen et al., 2018) have been recognized, which are important basis for the future research work, exploration and site selection of the shale gas.

Chen X., Chen Q., Zhen Y.Y., Wang H.Y., Zhang L.N., Zhang J.P., Wang W.H. & Xiao C.H. (2018) - Circumjacent distribution pattern of the Lungmachian graptolitic black shale (early Silurian) on the Yichang Uplift and its peripheral region. Science China Earth Sciences, 61(9), 1195–1203.

Chen X., Fan J.X., Wang W.H., Wang H.Y., Nie H.K., Shi X.W., Wen Z.D., Chen D.Y. & Li W.J. (2017) - Stage-progressive distribution pattern of the Lungmachi black graptolitic shales from Guizhou to Chongqing, Central China. Science China Earth Sciences, 60, 1133–1146.

Chen X., Rong J.Y., Mitchell C.E., Happer D.A.T., Fan J.X., Zhan R.B., Zhang Y.D., Li R.Y. & Wang Y. (2000) - Late Ordovician to earliest Silurian graptolite and brachiopod biozonation from the Yangtze region, South China, with a global correlation. Geological Magazine, 137, 623–650.

Fan J.X., Melchin M.J, Chen X., Wang Y., Zhang Y.D., Chen Q., Chi Z.L. & Chen F. (2011) - Biostratigraphy and geography of the Ordovician-Silurian Lungmachi black shales in South China. Science China Earth Sciences, 54, 1854–1863.

Lee J.S. & Chao Y.T. (1924) - Geology of the Gorge District of the Yangtze (from Ichang to Tzekuei) with special reference to the development of the Gorges. Bulletin of the Geological Society of China, 3, 351–391.

Mu A.T. (1945) -. Graptolite faunas from the Wufeng Shale. Bulletin of the Geological Society of China, 25, 201–209.

Sun Y.C. (1931) - Graptolite-bearing strata of China. Bulletin of the Geological Society of China, 10, 291–299.

Yin T.H. (1943) - On the Lungmachi Shale. Geological Review, 8, 1–8.

Integrated stratigraphy of the Silurian of the Carnic Alps

Corradini C.*[1], Corriga M.G.[1], Ferretti A.[2], Pondrelli M.[3], Serventi P.[2] & Simonetto L.[4]

[1] University of Cagliari, Italy. [2] University of Modena and Reggio Emilia, Italy. [3] University of Chieti-Pescara, Italy
[4] Museo Friulano di Storia Naturale, Italy.

Corresponding author email: corradin@unica.it

Keywords: Carnic Alps, lithostratigraphy, biostratigraphy, conodonts, graptolites.

The Carnic Alps are located across the Italian-Austrian border. Here, one of the best exposed and most complete Palaeozoic successions in the world, ranging from the Middle Ordovician to the Upper Permian, occurs. Even if Silurian outcrops are irregularly distributed in the region, some reference sections for Silurian global studies (e.g., Cellon, Rauchkofel Boden, Oberbuchach, Graptolithengraben, etc.) are here located. Main types of exposed rocks include shallow water bioclastic limestones, nautiloid-bearing limestones, limestones interbedded with shales, and black graptolitic shales and cherts ("lydites"). The overall thickness of Silurian strata does not exceed 60 m. The Silurian transgression in the region started at the beginning of the Llandovery. The duration of the gap separating the Ordovician and Silurian successions is highly variable, and embracing several conodont zones of Llandovery up to early Wenlock age. Depositional features suggest an overall transgressional regime acting from Llandovery to Ludlow times. Uniform calcareous deposits in the Prídoli indicate the establishment of a more stable condition in the Carnic region at the end of the Silurian. In terms of lithostratigraphy, three formations follow each other in the succession in the proximal (calcareous) parts of the basin: the Kok Fm. (Telychian-lower Ludfordian), the Cardiola Fm. (Ludfordian) and the Alticola Fm. (upper Ludfordian-lowermost Lochkovian). The last unit corresponds to the former Alticola Limestone and Megaerella Limestone. All the three units are mainly represented by bioclastic cephalopod-rich limestones, whose colour turns gradually from dark red and black in the lower Silurian to light grey-ochre in the Prídoli. Nautiloid cephalopds are very abundant; trilobites, bivalves and conodonts are common; crinoids, gastropods and rarer ostracods, brachiopods, and chitinozoans are present as well. Starting from the middle of Prídoli, in the shallower parts of the basin the Seekopf Fm. (Prídoli-Pragian) deposed; it consists of a mostly grayish lithoclastic limestone with abundant fossil debris. In the deeper part of the basin, the Silurian corresponds to the up to 80 m thick Bischofalm Fm. It consists of black siliceous shales with interbeds of chert and clayish alum slate, mainly deposited in an euxinic environment. Graptolites are generally abundant in these rocks. Alternating black graptolitic shales, marls and limestones of the Nölbling Fm. were deposited in intermediate conditions between calcareous and shaley facies. Both the Bischofalm Fm. and the Nölbling Fm. range from the Rhuddanian to the Lochkovian. A precise biostratigraphy of these units has been mainly obtained thanks to rich conodont and graptolite faunas.

First complete record of the early Sheinwoodian carbon isotope anomaly from Australia

Frýda J.*[1-2], Simpson A.J.[3] & Frýdová B.[1]

[1] Faculty of Environmental Sciences, Czech University of Life Sciences Prague, Czech Republic. [2] Czech Geological Survey, Czech Republic. [3] Macquarie University, Australia.

Corresponding author email: bellerophon@seznam.cz

Keywords: Early Silurian, early Sheinwoodian carbon isotope anomaly, Ireviken Event, Australia.

The early Silurian Ireviken Event is one of the most profound intervals of species turnover during the Paleozoic that has been identified to date. This event is associated with a prominent carbonate carbon isotope anomaly, an early Sheinwoodian carbon isotope anomaly that reaches up to 5‰ δ13C (Cramer et al., 2013). This perturbation of carbon cycle has been reported from different areas of Baltica, Lauretia, Avalonia and Perunica, but data on the early Sheinwoodian carbon isotope anomaly from eastern Gondwana is sparse. The only available measurements are 5 elevated δ13Ccarb values reported by Talent et al. (1993) from the Boree Creek formation, a unit of limestones and volcaniclastic sediments from the middle Paleozoic Waugoola Group, in the Lachlan Fold Belt of central western New South Wales, Australia. Conodont faunas from the Boree Creek Formation give insights into extinctions during the event (Molloy & Simpson 2012). Here we report for the first time a complete and high-resolution record of the early Sheinwoodian carbon isotope anomaly from Australia and discus the relationship between biogeochemical cycling, extinction, and sedimentology.

Cramer B.D., Brett C.E., Melchin M.J., Männik P., Kleffner M.A., McLaughlin PI., Lloydell D.K., Munnecke A., Jeppsson L., Corradini C., Brunton F.R. & Saltzman M.R. (2011) - Revised correlation of Silurian provincial series of North America with global and regional chronostratigraphic and δ13Ccarb chemostratigraphy. Lethaia, 44, 185–202.

Molloy P. & Simpson A. (2012) - The Ireviken Event in the Boree Creek Formation, New South Wales, Australia. In: Talent, JA (ed.), Earth and Life, Extinction Intervals and Biogeographic Perturbations through Time. Springer Science and Media, Dordrecht, 615-630.

Talent J.A., Mawson R., Andrew A.S., Hamilton P.J. & Whitford D.J. (1993) - Middle Palaeozoic extinction events; faunal and isotopic data. Palaeogeography, Palaeoclimatology, Palaeoecology, 104, 139–152.

Mid-Ludfordian (late Silurian) carbon isotope anomaly: a tale of paired carbonate and organic carbon isotope record

Frýda J.[1-2] & Frýdová B.*[1]

[1] Faculty of Environmental Sciences, Czech University of Life Sciences Prague, Czech Republic.
[2] Czech Geological Survey, Czech Republic.

Corresponding author email: frydovab@seznam.cz

Keywords: Late Silurian, mid-Ludfordian δ^{13}C anomaly, paired carbonate and organic carbon isotope record, Czech Republic.

Processes responsible for the formation of global positive carbon isotope excursions (CIE) recorded in Paleozoic marine carbonates have attracted much controversy and discussion (e.g. Kozłowski 2015, Farkaš et al., 2016). One of the largest positive carbonate δ^{13}C excursions of the entire Phanerozoic (Cramer et al., 2013), the mid-Ludfordian δ^{13}C anomaly (MLCIE), is documented globally from late Silurian marine carbonates, including our study area (Frýda & Manda 2013), the Prague Basin (Czech Republic). To better constrain the carbon cycle we analyzed carbon isotope variation in high resolution and for the first time report the identification of a paired carbonate and organic carbon isotope record across the mid-Ludfordian anomaly. The observed carbonate and organic carbon isotope values closely covary during most of the CIE and therefore indicate a photosynthetic origin for the organic δ^{13}C excursion. The only exception is a short interval at the onset of the carbonate CIE, where a distinct decoupling of the both isotope records was observed. This stratigraphic level coincides with a globally recognized sea-level drop and cooling. The significance of the observed decoupling of both carbon isotope records for understanding of origin of the MLCIE is discused.

Cramer B.D., Brett C.E., Melchin M.J., Männik P., Kleffner M.A., McLaughlin PI., Lloydell D.K., Munnecke A., Jeppsson L., Corradini C., Brunton F.R. & Saltzman M.R. (2011) - Revised correlation of Silurian provincial series of North America with global and regional chronostratigraphic and δ13Ccarb chemostratigraphy. Lethaia, 44, 185–202.

Farkaš J., Frýda J. & Holmden C. (2016) - Calcium isotope constraints on the marine carbon cycle and CaCO3 deposition during the late Silurian positive δ13C excursion. Earth and Planetary Science Letters, 451, 31–40.

Frýda J. & Manda Š. (2013) - A long-lasting steady period of isotopically heavy carbon in the late Silurian ocean: evolution of the δ13C record and its significance for an integrated δ13C, graptolite and conodont stratigraphy. Bulletin of Geosciences, 88, 2, 463–482.

Kozłowski W. (2015) - Eolian dust influx and massive whitings during the kozlowski/Lau Event: carbonate hypersaturation as a possible driver of the mid-Ludfordian Carbon Isotope Excursion. Bulletin of Geosciences, 90, 4, 807–840.

High-resolution paired organic and carbonate carbon isotope chemostratigraphy of the Ireviken and Mulde events (Silurian) from the Altajme Drillcore, Gotland, Sweden

Heath M.*[1], Biebesheimer E.[1], Hartke E.[1], Calner M.[2], Oborny S.[1], Bancroft A.[3] & Cramer B.[1]

[1] University of Iowa, USA. [2] Lund University, Sweden.
[3] Indiana Geological and Water Survey - Indiana University, USA.

Corresponding author email: megan-heath@uiowa.edu

Keywords: Silurian, carbon isotope, Ireviken, Mulde, Gotland.

The Ireviken and Mulde Events are two Silurian extinction events and large perturbations in the global carbon cycle that occur within the Sheinwoodian and Homerian stages, respectively. A variety of hypotheses have attempted to explain the occurrence of these perturbations and extinctions, some of which include, glaciation, deglaciation, global oceanic anoxia, and increased weathering of carbonates. At present, there is still no consensus about the nature of global change during either of these Silurian global biogeochemical events. One of the most widely used proxies for global temperature is $\delta^{18}O$, and both events are correlative with intervals of elevated $\delta^{18}O$ values. Therefore, the $\delta^{18}O$ temperature proxy suggests global cooling is associated with these two events. For this project, we aimed to explore a widely used paleo-CO_2proxy, $\delta^{13}C$, which is the difference between $\delta^{13}C_{carb}$and $\delta^{13}C_{org}$, to determine if the paleo-temperature and paleo-CO_2proxies were behaving in a similar manner. Here, we present new extremely high-resolution paired carbonate and organic carbon isotope data from the recently drilled Altajme Drillcore from the Swedish island of Gotland to generate the first high-resolution $\delta^{13}C$ datasets through the Ireviken and Mulde Events in a single succession. The results of the $\delta^{13}C$ data are then compared to available $\delta^{18}O$ data from the literature and an extremely complex picture of Silurian biogeochemical events is beginning to come into focus.

Biostratigraphy and correlation of nautiloid cephalopods from the Llandovery (Telychian) of the Cellon Section (Carnic Alps, Austria)

Histon K.*

Independent researcher

Corresponding author email: hiscat@interfree.it

Keywords: Silurian, biostratigraphy, nautiloid cephalopods.

The Cellon Section located near the Austrian/Italian border is renowned for the almost continuous fossiliferous sequence of Paleozoic age (Ordovician - Permian) preserved there and as the stratotype for the Silurian of the Eastern and Southern Alps is critical for biostratigraphic studies for global correlation (Corradini et al., 2015). Differing from other areas along the North Gondwana Margin nautiloid faunas are found throughout the shallower Silurian successions there and not only within the Cephalopod Limestone Biofacies. An ongoing study at this section includes systematic bed by bed collection for nautiloids within 11 stratigraphic divisions ranging from the Llandovery to the Pridoli using the established standard Silurian conodont/graptolite/chitinozoan biozones for constraint. A summary of the various findings is given in Histon (2012). The results of a newly collected fauna representing the first early Silurian incursion of nautiloid faunas preserved within the Llandovery sequences at this section are presented in this paper. Correlation at both regional and global scales using multidisciplinary approaches of the variety of geodynamic events and paleogeographic settings during the Late Ordovician and early Silurian intervals has become a key goal in Lower Paleozoic research over the last decade. For example, evidence from Ordovician/Silurian boundary graptolite assemblages in the Carnic Alps has highlighted affinities with chinese faunas rather than those commonly found along the North Gondwana sector (Štorch & Schönlaub, 2012). Therefore, comparison of the findings from this detailed study of the Telychian nautiloids at the Cellon Section with Llandovery faunas from the British Isles, Baltica, Siberia and S.China and in particular from Iran may also have critical relevance within the context of identification of bioevents and migrational pathways within the Peri-Gonwanide area. Furthermore the nautiloid dataset representing a pelagic macrofauna may provide an additional biostratigraphical contribution within multidisplinary investigations towards the deciphering, timing and elaboration of the Lower Paleozoic geodynamic events in this region (Von Raumer et al., 2013).

Corradin C., Corriga M.G., Männik P. & Schönlaub H.P. (2015) - Revised conodont stratigraphy of the Cellon section (Silurian, Carnic Alps). Lethaia, 48 (1), 56–71.

Histon, K. 2012. The Silurian nautiloid-bearing strata of the Cellon Section (Carnic Alps, Austria): colour variation related to events. Palaeogeography, Palaeoclimatology, Palaeoecology, 367-368, 231-255.

Štorch P. & Schönlaub H.P. (2012) - Ordovician-Silurian boundary graptolites of the Southern Alps, Austria. Bulletin of Geosciences, 87 (3), 755–766.

Von Raumer J., Bussy F., Schaltegger U., Schulz B. & Stampli G.M. (2013) - Pre-Mesozoic Alpine basements—their place in the European Paleozoic framework. GSA Bulletin, 125, 89–108.

Geomagnetic polarity during the mid Ordovician to early Silurian

Hounslow M.W.*[1], Harris S.[1], Woodcock N.H.[2], Wójcik K.[3], Nawrocki J.[3], Channell J.E.T.[4], Lucas V.[1], Ratcliffe K.[5] & Montgomery P.[6]

[1] Lancaster Environment Centre, Lancaster University, Lancaster, UK. [2] Earth Sciences, Cambridge University, Cambridge, UK. [3] Panstwowy Instytut Geologiczny - Panstwowy Instytut Badawcz, Warszawa, Poland. [4] Department of Geological Sciences, Gainesville, USA. [5] Chemostrat Ltd, Welshpool, UK. [6] Chevron Upstream, UK.

Corresponding author email: mark.w.hounslow@gmail.com

Keywords: Magnetostratigraphy, Llandovery, Katian, Hirnantian.

Recovery of geomagnetic polarity information from early Paleozoic sediment successions has proved to be challenging because of weak magnetisations and later burial and tectonic related overprints. We provide new magnetostratigraphic data from the Dapingian through to the earliest Wenlock, covering for the first time, the late Ordovician and Llandovery. The new Ordovician datasets come from Mójcza (Poland), Backside Beck and Cheny Longville (UK) and cores from the Lublin Basin (Poland) and the Livonian Tongue (Lithuania). The new Silurian datasets come from Bardo Stawy (Poland) and Backside Beck and Buttington Quarry (UK) and the cores from Lithuania and Poland. The chronology is provided by existing biostratigraphy, principally based on chinitozoans and conodonts for the Ordovician and graptolites for the early Silurian. This is supported by new and existing carbon isotope stratigraphy and lithologic and local magnetic susceptibility correlations in the Llandovery and late Ordovician. The paleomagnetic signal is carried by both haematite and magnetite, with haematite dominating in red-coloured mudstones and marls and limestones and magnetite in non-red lithologies. Reversal tests and fold tests in some sections provide additional validation of the isolation of a primary palaeomagnetic signal. Palaeomagnetic directions from cores were re-oriented using Kiaman and Brunhes overprints. Our new data provides the first robust geomagnetic polarity data through the Katian- Hirnantian and Llandovery. Combining biochronology and magnetostratigraphic datasets with existing magnetostratigraphic data from Siberian, European and North American sections from the Dapingian, Darriwillian and Sandbian indicate significant normal polarity magnetozones start near the base of the Darriwillian, well into the top of what has previously been considered the Moyero reverse superchron (which began in the late Tremadocian). The Hirnantian-Rhuddanian boundary is very close to the top of a reverse magnetozone which characterises the mid and late Hirnantian. Our magnetostratigraphic data allows the construction of the first geomagnetic polarity timescale for the about 10 Ma of the Llandovery, ranging into the earliest Sheinwoodian. Age intervals which may prove to have a more complex pattern of polarity reversals are around the Katian-Hirnantian boundary and in the Aeronian, due to the likely insufficient sampling density in these intervals. Reversal frequencies for the mid and late Ordovician are 1.7 and 1.5 respectively and 3.0 per Ma in the Llandovery. Within the next decade the Ordovician and Silurian geomagnetic polarity timescale may be as well established as that in the Mesozoic, aiding high resolution correlation between different environmental systems.

The retiolitine *Gothograptus* (Graptolithina): a significant indicator of the *lundgreni* environmental crisis, upper Homerian, Silurian

Kozłowska A.*[1], Bates D.E.B.[2] & Zalasiewicz J.[3]

[1] Institute of Paleobiology PAS, Poland. [2] Aberystwyth University, UK. [3] University of Leicester, UK.

Corresponding author email: akd@twarda.pan.pl

Keywords: Silurian, graptolites, retiolitines, Gothograptus, stratigraphic tool.

New *Gothograptus* species have recently been described from the *lundgreni* and post-*lundgreni* biozones of Baltica (Kozłowska et al., 2019). They have become an additional stratigraphic tool as well as indicators of the environmental changes related to the *lundgreni* event. *Gothograptus* belongs to the retiolitids, a group of graptolites having a complex tubarium with very thin fusellar walls, lists built of bandages, and an additional outer layer, the ancora sleeve, being an extension of the ancora umbrella growing upwards from the virgella (Bates et al., 2005). Evolution of the *Gothograptus* lineage began in the *lundgreni* Biozone, with four species, and two in the succeeding *parvus/nassa, dubius/nassa* and one species in the *praedeubeli-deubeli* Biozone (Kozłowska et al., 2019). The elongated narrow tubarium of *Gothograptus*, terminated by a tubular appendix, was built of strong lists and a dense meshwork of thinner lists. The tubarium was strengthened by the nema's connection to the lateral wall (Kozłowska-Dawidziuk, 1990). *Gothograptus* species from the *lundgreni* Biozone are very different from the post-*lundgreni* species. They are short, usually having eight pairs of thecae, whereas species from the post-*lundgreni* interval may reach more than 20 thecal pairs. The thecal orifices are typically hidden by genicular structures. Reticulated genicular structures are common in the *lundgreni* Biozone forms. They are developed as reticulated hoods as in *G. kozlowskii* and well-developed veils which can also cover the ventral walls in *G. obtectus* and *G. velo* (Kozłowska-Dawidziuk, 1990; Kozłowska et al., 2019). Only one species of *Gothograptus* from the *lundgreni* Biozone, *Gothograptus domeyki*, has no genicular structures on most of the thecae. The post-*lundgreni* species *Gothograptus nassa* and *Gothograptus diminutus* have only genicular *nassa* type hoods (Kozłowska, 2015). The *nassa* type of hoods were strong and solid, built not by the reticulum, but by densely packed parallel bandages, additionally covered by different, pustule-bearing bandages running irregularly across the hoods' surfaces, this relationship giving insights into the constructional behavior of the *Gothograptus* zooids. The hidden orifices may have secured the zooids against hostile environmental factors (Kozłowska et al., 2019). Most of the *lundgreni* Biozone retiolitids such as *Sokolovograptus, Paraplectograptus* or *Cometograptus* did not have genicular structures and their tubaria were not massive, usually with no dense reticulum (Lenz & Kozłowska-Dawidziuk, 2001). Significantly, only *Gothograptus*, with its massive and compact tubarium and possessing covers over the thecal orifices, survived the *lundgreni* crisis and in consequence was able to evolve to continue the retiolitid lineage.

Bates D.E.B. Kozłowska A. & Lenz A.C. (2005) - Silurian retiolitid graptolites: morphology and evolution. Acta Palaeontologica Polonica, 50, 705-720.

Kozłowska A. (2015) - Evolutionary history of the *Gothograptus* lineage of the Retiolitidae (Graptolithina). Estonian Journal of Earth Sciences, 64, 56-61.

Kozłowska A., Bates D.E.B., Zalasiewicz J. & Radzevičius S. (2019) - Evolutionary significance of the retiolitine *Gothograptus* (Graptolithina) with four new species from the Silurian of the East European Platform (Baltica), Poland and Lithuania. Zootaxa 4568(3), 435-469. https://doi.org/10.11646/zootaxa.4568.3.2

Kozłowska-Dawidziuk A. (1990) - The genus Gothograptus (Graptolithina) from the Wenlock of Poland. Acta Palaeontologica Polonica, 35, 191-209.

Lenz A.C. & Kozłowska-Dawidziuk A. (2001) - Upper Wenlock (Silurian) graptolites of Arctic Canada: pre-extinction, *lundgreni* Biozone fauna. Palaeontographica Canadiana, 20, 1-61.

A (not so) brief history of the Llandovery/Wenlock boundary

Loydell D.K.*

University of Portsmouth, UK

Corresponding author email: david.loydell@port.ac.uk

Keywords: Silurian, stratigraphy, GSSP, Llandovery, Wenlock.

The base of the Wenlock Series is now widely portrayed as being coincident with the base of the *Cyrtograptus murchisoni* graptolite Biozone. This is based upon correlation (using chitinozoans) between the highly unsatisfactory GSSP at Hughley Brook in Shropshire, England and the graptolitc Banwy River section in Wales. In this presentation a review will be presented of work undertaken on some of the few extant sections that had been considered likely to expose fossiliferous latest Telychian and earlest Sheinwoodian strata and an update will be provided on ongoing studies which have the aim of identifying a more suitable, replacement GSSP for the base of the Wenlock Series. The hope is that this will inform discussions at the ISSS business meeting.

Conodonts from the GSSP for the base of the Ludfordian Stage of the Ludlow Series, Silurian at Sunnyhill Quarry, Ludlow, UK

Miller C.G.[1]*

[1]Natural History Museum, London.

Corresponding author email: g.miller@nhm.ac.uk

Keywords: Ludfordian, Gorstian, Silurian, conodonts, GSSP.

The boundary between the Upper Bringewood Formation and the Lower Leintwardine Formation is placed at the lower of two very thin shale bands within the top of a nodular limestone unit at Sunnyhill Quarry, Mortimer Forest in the Ludlow area of the Welsh Borderland of the UK. This is the internationally accepted GSSP for the base of the Ludfordian Stage. The boundary is placed within the top of a nodular limestone facies that is often termed the Aymestry Limestone and is replaced about 2.5m above the boundary by a more finely bedded siltstone facies. There is no significant change in the macrofauna across this boundary but the biostratigraphically significant graptolite *Saetograptus leintwardinesis* is recorded from the basal part of the Lower Leintwardine Formation (Cherns, 1988) and the boundary has been interpreted as representing the local base of the *leintwardinensis* biozone. $\delta^{13}C_{carb}$ values don't show a major trend across the boundary but are slightly higher in the Lower Leintwardine Formation than for the underlying Upper Bringewood Formation (Cramer in Cherns, 2011). The basal part of the Lower Leintwardine Formation has been interpreted as a limited transgression across the shelf area (Cherns, 1988). Conodonts have been recovered from 19 relatively calcareous horizons spanning the uppermost 4.5m of the Bringewood Formation and the lowermost 3.5m of the Lower Leintwardine Formation at Sunnyhill Quarry. Over 80Kg of dissolved limestone has yielded about 10,000 conodont elements mainly of the genera *Coryssognathus*, *Kockelella*, *Ozarkodina*, *Panderodus* and *Wurmiella*. Initial studies suggest little change in the conodont fauna across the base of the Ludfordian Stage but that rare occurrences *Kockelella* and subspecies of *Wurmiella excavata* could offer possibilities for correlation with sections in the Baltic region and beyond. Slight variations in dominant genera within the conodont fauna potentially mirror lithofacies changes and documented changes in fish, chitinozoan and acritarch floras and faunas just above the base of the Lower Leintwardine Formation.

Cherns L. (1988) - Faunal and facies dynamics in the Upper Silurian of the Anglo-Welsh basin. Palaeontology, 31, 451-502.

Cherns L. (2011) - The GSSP for the base of the Ludfordian Stage, Sunnyhill Quarry. In: Ray D. C. Ed., Siluria Revisited: A Field Guide. International Subcommission on Silurian Stratigraphy, Field Meeting 2011, 75-81. International Subcomission on Silurian Stratigraphy.

Augmenting gamma ray log correlation with biostratigraphic data using cross-recurrence approach – a case of Wenlock – Ludlow boundary in Baubliai – 2 well (Lithuania)

Radzevičius S.*[1], Stankevič R.[1] & Spiridonov A.[1-2]

[1] Vilnius University, Lithuania. [2] Nature Research Centre, Lithuania.

Corresponding author email: sigitas.radzevicius@gf.vu.lt

Keywords: cross-recurrence, gamma log, Silurian, Lithuania.

The Wenlock – Ludlow boundary marks the base of *nilssoni* Biozone and occurs above the second peak of the upper Homerian positive $\delta^{13}C$ excursion. It is clear and well defined, but sometimes doesn't work on practice particularly when there is limited graptolite or other biostratigraphic data. Baubliai – 2 well at and lower than the Wenlock-Ludlow boundary is lacking core material. Therefore integrated approach in which geophysical logs are tied to the biostratigraphic and $\delta^{13}C_{carb}$ data is needed. Baubliai – 2 well was drilled in the West Lithuania in the deep sea clayey facies zone. The well core from the Wenlock (?) – Ludlow interval was taken from 1556.1 to 1644.7 m depth interval. In it following graptolites assemblages are defined: *nilssoni* – *tenuis* biozones but just *Colonograptus gerhardi* (Kühne) and *Pristiograptus frequens* Jaekel are found in the lower part of investigated interval (1642.6 – 1644.7 m). The first appear of *C. gerhardi* is in the *ludensis* Biozone (uppermost Wenlock) and the last appear in the middle part of *nilssoni* Bizone (lowermost Ludlow). *P. frequens* is long ranging species which appears in the *nassa* Biozone and probably disappears in the *tenuis* Biozone. Therefore, question is where exactly Wenlock – Ludlow boundary in *C. gerhardi, P. frequens* interval is? We have used gamma ray log data and statistical cross-recurrence methods for tackling this problem. There is gamma log minimum peak at the depth 1657.6 m. This minimum excursion of gamma log is known as S4 geophysical horizon or marker level and it marks the Ančia Member as well the lower boundary of Gėluva Regional Stage of the middle Wenlock in the west Lithuania. For the fine scale correlation Baubliai – 2 well log was compared with biostratigraphically constrained Viduklė – 61 well and core data from the Homerian. Cross-recurrence plot synchronization was used for compering gamma logs from both wells. According to the analysis three intervals can be distinguished. First one revealed in the lower part pre Mulde interval, second in Mulde or the Gėluva Regional Stage and third in the Lower part of Ludlow. According to this pattern, the interval with *C. gerchardi* and *P. frequens* belongs to the uppermost Wenlock.

This study is supported by 09.3.3-LMT-K-712-02-0036.

The stratigraphy and correlation of the Wenlock Series of Radnorshire (Wales): preliminary results

Ray D.C.[1]*, Hughes H.E.[2], Jarochowska E.[3] & Claussen A.L.[3]

[1] School of Geography, Earth and Environmental Sciences (GEES), University of Birmingham. [2] School of Geography, Earth and Environmental Sciences, Plymouth University. [3] GeoZentrum Nordbayern, University of Erlangen-Nuremberg.

Corresponding author email: David.Ray@halliburton.com

Keywords: Silurian, Wenlock, Wales, Dolyhir Limestone, new stratigraphic data, correlation.

The Wenlock Series (Sheinwoodian) of Radnorshire (Powys, Wales) contains a highly localised and unusual development of algal limestones termed the Dolyhir Limestone, and its lateral equivalent the Nash Scar Limestone. These straddle the Church Stretton Fault Zone; an active structure between the Welsh Basin and Midland Platform of England, and deposition is considered to have taken place upon a tectonically active and uplifted area of the basin margin. Accordingly, their stratigraphic architecture may owe much to syn-sedimentary tectonism and have little in common with the age equivalent limestones of the passively subsiding Midland Platform (Woolhope-Buildwas-Barr limestones). This view may be further strengthened by the presence of an angular discordance between the Nash Scar limestone and the underlying upper Llandovery sandstones (Folly Sandstone) and the presence of a coral-bearing basal rudite to the Dolyhir Limestone that infills relief upon a Precambrian basement. In addition, features such as trilobitic-shale bands and scoured starvation surfaces between the limestones and the overlying shales of the Coalbrookdale Formation further distinguish the Radnorshire succession. The most comprehensive stratigraphic description of the Dolyhir and Nash Scar limestones took place 100 years ago (Garwood & Goodyear, 1919) and has formed the basis of most subsequent accounts. New sedimentology, palaeontology (bryozoans, conodonts and trilobites), carbon isotopic and sequence stratigraphic determinations can now allow comparison of the Dolyhir and Nash Scar limestones with the successions of the broader Midland Platform, including those of the type Wenlock area. Preliminary results identify the early Sheinwoodian carbon isotope excursion and confirm an apparent synchronicity of limestone deposition across the Midland Platform. Furthermore, sequence stratigraphic considerations indicate that the Dolyhir-Nash Scar limestones are the most proximal part of a more extensive carbonate shelf linked to the Woolhope Limestone, rather than a local carbonate build-up on a submarine topographic high. Finally, the abundant trilobite faunas of the shale flooding surfaces both within and immediately above the Dolyhir Limestone are unique in the British Wenlock, comprising distinctive trilobite associations numerically dominated by illaenids.

Garwood E.J. & Goodyear E. (1919) - On the geology of the Old Radnor district with special reference to an algal development in the Woodhope Limestone. Q. J. Geol. Soc. London, 74, 1-30.

Přídolí Series – prospects of chronostratigraphic subdivision based on data from the Prague Synform

Slavík L.*[1], Manda Š.[2], Štorch P.[1], Tasáryová Z.[2] & Čáp P.[2]

[1] Institute of Geology of the Czech Academy of Sciences. [2] Czech Geological Survey.

Corresponding author email: slavik@gli.cas.cz

Keywords: Chronostratigraphy, Přídolí Series, Subdivision, Prague Synform, Global Correlation.

In last decades the progress in stratigraphy of the Palaeozoic was enormous due to refined biozonations integrated with application of various chemostratigraphic and petrophysical methods. The current issue of the International Chronostratigraphic Chart (stratigraphy.org) shows, however, a prominent blank spot located in the Silurian System – the Přídolí Series. The Silurian System consists of four series, three of them further subdivided into stages. The definition of the Přídolí Series as the fourth division has been the only major addition to the Silurian System in over the past 100 years (Kříž et al., 1986). Since then the Přídolí remains almost unique in the Phanerozoic (except for incomparably shorter Holocene) as it is the only series recognized by the IUGS that has not been formally divided into stages. The GSSP for the base of the Přídolí Series has been defined in the Prague Synform. The duration of the Series is estimated at 3.8 myr, and thus, being only slightly shorter than the underlying Ludlow (Melchin et al., 2012). As all stratigraphic units of the same rank and of comparable durations have already been subdivided, there is a persistent international demand to fill in this gap. Recently, new biostratigraphic and geochemical data have been obtained from several sections of the stratotype area of the Přídolí. Detailed evaluation of all data suggests three possibilities for the prospective two-fold subdivision of the Series based on graptolite and/or conodont biozonations:

1. The base of the *bouceki* graptolite Biozone as a marker horizon for the base of the future upper stage. This has been already proposed by Kříž et al. (1994). Although the base of this graptolite biozone slightly coincides with the base of the conodont *ivochlupaci* Biozone, they do not match precisely. The major disadvantage is that the proportions in the duration of the lower and the upper stage would not have been well balanced.
2. The base of the *detorta* conodont Biozone, that is widespread and marks approximately the middle part of the Přídolí. The drawback is that it does not coincide with any base of graptolite biozone, because there is a lack of good graptolite biostratigraphic markers above the *bouceki* Biozone.
3. The base of the *klonkensis* conodont Biozone, that is close to the base of the *perneri* graptolite Biozone. The global distribution and the range of the *klonkensis* Biozone, however, still has to be tested.

Kříž J., Jaeger H., Dufka P. & Schönlaub H.P. (1994) - Jarovian Stage and Bítovian Stage – a Proposal for Prídolí Series Subdivisions (Silurian, Prague Basin, Bohemia). Bibl. Geol. B.-A. 30, 140.

Kříž J., Jaeger H., Paris F. & Schönlaub H.P. (1986) - Přídolí – the fourth subdivision of the Silurian. Jb. Geol. Bundesanst. 129, 291-360.

Melchin M.J., Sadler P.M. & Cramer B.D. (2012) - The Silurian period. In: Gradstein F.M., Ogg, J.G., Schmitz M.D. & Ogg G.M. (eds.), The Geologic Time Scale. Elsevier, Oxford, 525-558.

ST3.4

The Devonian: life, environments and time

Conveners and Chairpersons
John Marshall (University of Southampton)
Ladislav Slavik (Academy of Sciences of the Czech Republic)
Carlton Brett (University of Cincinnati)

Drowning the Shallow Water Model for Middle and Upper Devonian Black Shales of New York State

Brett C.E.*[1], Ver Straeten C.A.[2], Baird G.C.[3], Beard A.[4], Boyer D.L.[5], Ivany L.C.[6], Junium C.[6], Over D.J.[7] & Uveges B.[6]

[1] University of Cincinnati, Ohio USA. [2] New York State Museum, Albany NY USA. [3] SUNY-Fredonia NY USA.[4] University of Connecticut, Storrs CT USA. [5] Winthrop University, Rock Hill, SC USA. [6] Syracuse University, NY USA. [7] SUNY-Geneseo, NY USA.

Corresponding author email: carlton.brett@uc.edu

Keywords: bathymetry, black shale, Devonian, paleoenvironment, foreland basin, New York.

Over the last century, debates have intermittently surfaced about deeper versus shallower origins of widespread black shales, followed by the general acceptance of deep water interpretations. The issue has arisen again relative to Devonian black shales in New York State (NY; Smith et al., 2019). We recognize that epicontinental black shales can form in a range of settings from basinal to lagoonal/paludal. However, diverse lines of evidence from stratigraphy, sedimentology, paleobiology and geochemistry within and outside of the Appalachian Foreland Basin argues that a very shallow-water (<10 m) origin is difficult to apply to Devonian black/dark shales of NY, and many analogous deposits. Some key points of concern include: 1) a complete absence evidence for subaerial exposure (paleokarst, vadose cements) of limestones underlying black shales, in the classic NY succession; e.g., Devonian Marcellus Sh. over Onondaga Ls. and Geneseo Sh. over Tully Limestone. 2) Sedimentologic and geochemical data are inconsistent with pervasive whole-water-column mixing and sediment surface disturbance in shallow settings due to tides, long-fetch waves, and storms on short time scales, and more pronounced manifestations of Milankovitch band- to 10^6 year-scale sea level variations. 3) Middle Devonian black shales in the Appalachian Basin are concentrically bounded by gradations into gray mudstone and siltstone with gradients of increasingly diverse faunas, indicative of shallow water settings. If deposited in shallow lagoons, black shales would be geographically localized, laterally shift to terrestrial litho-and bio-facies and/or have consistently high % of fine terrestrial plant material rather than observed isolated logs. 4) Organic carbon $\delta^{13}C$ data suggest increasing terrestrially-derived carbon to the east, and more marine values to the west. In addition, characteristic organic-walled microfossils in the dark/black shales indicate deeper water assemblages to the west and shallow-water assemblages to the east (Kelly et al., 2019). 5) microendolithic borings in some brachiopod shells indicate presence of photosynthetic cyanobacteria in some black shales. These assemblages are adapted to low light levels and are quite different from known shallow water assemblages. 6) The presence of isorenierataneconfirms presence of green sulfur bacteria, obligate anaerobes, requiring at least intermittent development of a chemocline and anoxic conditions. While possible in shallow stagnant settings, such conditions are difficult to infer for widespread NY Devonian shales. 7) Finally, features of shallow water cratonic basins and intervening arches/domes are an inadequate analog for the foredeep of an active retro arc foreland basin system. Load-induced subsidence in this setting is orogenic-, not sediment-driven. Based on these and many additional points, we find a shallow water origin of Devonian black shales in New York untenable.

The quest for a trustworthy paleoclimatic proxy in a Lower Devonian hemipelagic succession from the Czech Republic

Da Silva A.C.*[1], Hladil J.[2], Chadimova L.[2], Slavík L.[2], Hilgen F.J.[3] & Dekkers M.J.[3]

[1] Liege University. [2] Czech Academy of Sciences. [3] Utrecht University.

Corresponding author email: ac.dasilva@uliege.be

Keywords: Devonian, climate proxy, cyclostratigraphy, geochemistry, magnetic susceptibility.

Understanding past climatic changes is essential for interpreting current climatic trends. Past climatic changes can also be used to build high-resolution time scales through cyclostratigraphy. A better-calibrated time scale would offer more insight into the mechanisms and causes of major biological evolutionary steps, adaptive radiations, mass extinctions and recoveries, as well as patterns of climate change occurring throughout the Paleozoic. Finding good proxies for climatic cycles is essential, but diagenesis can have a strong impact on most of these proxies. In various cyclostratigraphic studies, the fit of spectral peak ratios with those of the orbital cycles, is classically used as an argument for a preserved climatic signal. Magnetic Susceptibility (MS) is often used in sedimentary rocks for correlations, paleo-sea level or paleo-climatic reconstructions and cyclostratigraphy, based on the link between MS and detrital input which is influenced by sea level and climate variations. However, the interpretation of MS records in terms of depositional environment can be less straightforward because MS is a convolved signal potentially mixing the desired climatic information with undesired contributions representing other geologic phenomena (that may have occurred during or after deposition). Geochemical proxies can also bring insight into climate and diagenesis. The Pod Barrandovem section, from the Czech Republic, exposes a complete Pragian and Emsian (Lower Devonian) succession in hemipelagic sediments. A complete set of high-resolution MS and portable XRF records was generated and clearcut but different cyclicities are identified through spectral analysis of these records. Here, we will assess the preservation potential of the different proxy records and thus their quality as climatic proxy. This study demonstrates the essential need of comparing proxies and of assessing the quality of proxies prior to any cyclostratigraphic or paleoenvironmental work.

Environmental implications by Famennian and Tournaisian Ostracodes from the Moravian Karst (Czech Republic)

Dojen C.*[1], Lukosz R.[2], Cígler V.[2] & Kumpan T.[2]

[1] State Museum of Carinthia in Klagenfurt, Austria. [2] Masaryk University Brno, Czech Republic.

Corresponding author email: claudia.dojen@landesmuseum.ktn.gv.at

Keywords: Ostracodes, Moravian Karst, Famennian, Tournaisian.

Although the limestones of the Moravian Karst have been studied for more than 100 years, ostracodes are rarely described. Known taxa from the Lower Tournaisian of the Lesní lom quarry have been interpreted as faunas of open marine shelf environments for the lower half of the sequence, and as "basinal Thuringian paleofacies" for the upper sequence, suggesting a transgressive event during the Lower Tournaisian. However, a more detailed study has never been published. As the concepts of palaeoenvironments of ostracode groups have changed in some points, we started new studies in 2017. New material from the Lower Tournaisian calciturbidites from the Lesní lom quarry have been taken. They yielded ostracodes, trilobites, bivalves, crinoids, holothuroids and ophiuroids, which are well preserved due to silicification, especially in the limestones of the *Siphonodella jii – Siphonodella quadruplicata* conodont zones. The limestones of the Lesní lom quarry are mostly mudstones and wackestones that represent sedimentary background intercalated by layers of packstones as a result of turbidite events. Some ostracodes such as *Rectonaria muelleri, Orthonaria symmetrica* or *Triplacera trapezoidalis* have been described in former studies, but several others species of *Healdia, Praepilatina* or *Aparchites* seems to be new to the area. Bairdiids are surprisingly rare. So far, no Famennian samples have been investigated and thus, the transgressive event has not been reproductible yet.

Further research took place in the Křtiny Marble quarry. The material comes from pelagic nodular micritic limestones of Late Famennian to Early Tournaisian age. The Upper Famennian samples yielded ostracodes of the genera *Orthonaria*, *Rectonaria, Acratia* and *Bairdia*. The samples from the Lower Tournaisian also showed the genera *Orthonaria, Rectonaria* and *Acratia* but additionally *Amphissites, Triplacera, Healdia* and *Rectoplacera*, whereas surprisingly no Bairdiaceans have been found. In general, these genera belong to the Thuringian Mega-Assemblage, indicating calm environments. However, only *Orthonaria, Rectonaria, Rectoplacera* and *Triplacera* are restricted to the Thuringian Mega Assemblage whereas *Acratia*, *Bairdia, Healdia*, and *Amphissites* also have occurrences in Eifelian Assemblages. The presence of bairdiids in the Upper Famennian indicates open marine environments. Some authors favor also deeper and especially colder waters for the highly spinose ("palaeopsychrospheric") ostracodes, but due to the occurrence of both restricted and not restricted taxa, as well as the absence of deep pelagic faunas we cannot confirm this hypothesis. Strikingly no characteristic genera of Tournaisian age have been found so far and no distinct change in the ostracode assemblage between the Famennian and the Tournaisian is recognized.

This work was supported by the Czech Science Foundation (GAČR) research project 19-17435S (TK).

The Pragian/Emsian key section in the Novaya Zemlya Archipelago (Arctic Russia) - new ostracod data

Evdokimova I.O.[1]* & Sobolev N.N.[1]

[1]Russian Geological Research Institute (VSEGEI), Russia.

Corresponding author email: Irina_Evdokimova@vsegei.ru

Keywords: Early Devonian, Pragian, Emsian, conodonts, ostracods, Novaya Zemlya.

This study presents the first data relating to the distribution of the ostracod faunas in the late Pragian and early Emsian conodont-bearing strata in the Novaya Zemlya Archipelago and demonstrates their biostratigraphical value. The examined material comes from the key section of the Pragian-Emsian boundary beds situated in the Kabany peninsula, northwest of Novaya Zemlya. The section is composed of three lithostratigraphic units: Val'nev, Sinel'nikov, and Kabany formations. In this section the stratotype of the Sinel'nikov Regional Stage was established. The base of the Sinel'nikov Regional Stage is considered to coincide with the Pragian/Emsian Stage boundary in the region (Antsygin et al., 1993). This time interval is poorly represented in fossiliferous marine facies in Russia. The section studied is characterized by a continuous sequence of marine carbonate deposits yielded rich faunas of various fossil groups, such as conodonts, brachiopods, dacryoconarids, tabulate corals, and ostracods. Polygnathids occur in the Val'nev - Kabany fms and are represented by Polygnathus kitabicus, Po. perbonus, Po. dehiscens late morphotype, Po. inversus, Po. serotinus (Sobolev, 1984). The ostracod assemblages have relatively high species diversity. In the time interval studied, the ostracod fauna is dominated by podocopids (e.g., Microcheilinella, Bairdiocypris, Bairdia), often accompanied by platycopids (e.g., Uchtovia, Cavellina) and rare palaeocopins (e.g., Aparchitellina, Pribylites, Clavofabellina). The associations recovered are indicative of shallow open marine environments. Many of the taxa identified show a close affinity with ostracod species known from the Urals, Taimyr, and Kotel'ny Island, as well as in the Salair and Kuznetsk basins (southern West Siberia) (Polenova, 1960, 1974). Co-occurrence of ostracods with conodonts allows more precise ostracod biostratigraphic correlations.

Polenova E. N. (1960) - Devonian ostracods of the Kuznetsk Basin and the Munusa trough. Trudy Vsesoyuznogo Neftyanogo Nauchno-issledovatelskogo Geologorazvedochnogo Instituta (VNIGRI), Novaya Seriya, 152, 1–139 (in Russian).

Polenova E.N. (1974) - Early Devonian ostracods of the arctic regions of the USSR. Nauka, Moscow (in Russian).

Sobolev N.N. (1984) - Conodonts from the Early and Middle Devonian deposits of Novaya Zemlya. In: Bondarev V.I. Ed., Novaya Zemlya in the early stages of geological development. Collected scientific papers., 58-85. Leningrad. [In Russian].

Antsygin N.Y., Popov B.A., & Chuvashov B.I. (1993) - Stratigraphic schemes of the Urals (Precambrian, Paleozoic). Proceedings and resolutions of the Fourth Uralian Interdepartmental Stratigraphic Meeting (Sverdlovsk, 1990). Ekaterinburg.

Magnetic susceptibility records challenge Late Devonian paleogeographic relations between Avalonian and Gondwanan margins

Girard C.*[1], Cornée J.-J.[2], Camps P.[2], Corradini C.[3], Mossoni A.[3] & Feist R.[1]

[1] University Montpellier, France. [2] University Montpellier-Université des Antilles, France. [3] University Cagliari Italy

Corresponding author email: catherine.girard@umontpellier.fr

Keywords: magnetic susceptibility, Famennian, Gondwana, Avalonia, paleogeography.

Large-scale magnetic susceptibility (MS) variations in ancient sediments are usually interpreted as related to sea-level and climate changes affecting the erosional regime and the amount of detrital input. To constrain such environmental changes during the Late Devonian, we compared MS records in representative sections of outer shelf carbonates of (1) the Avalonian margin of Laurussia (Sessacker and Beringhauser Tunnel sections, Rhenish Slate Mountains, Germany) and (2) in Gondwana related terranes (Erfoud section, Tafilalt, Morocco; Col des Tribes section, Montagne Noire, France; Buschteich section, Thuringia, Germany; Corona Mizziu section, Sardinia and Pizzul West and Pramosio Bassa sections in the Carnic Alps, Italy). The latest Frasnian and the entire Famennian were sampled in the Montagne Noire, most of the Famennian was sampled in all other sections. MS values were obtained by means of a Bartington MS2E-1 High Resolution Surface Sensor. As a result, MS trends differ significantly between the considered paleogeographic entities. Very low MS values throughout the record characterize the Avalonian samples. In contrast, these are markedly and congruently varying on outer shelves of the Gondwanan margin (Montagne Noire, Sardinia and Carnic Alps) where initially high MS values shift to low ones within the *Palmatolepis marginifera marginifera* Zone (lower Famennian), and remain constantly low thereafter. This pattern though attenuated, also occurs both in the Saxo-thuringian terrane and on the stable cratonic margin of Gondwana where only a moderate increase in MS values preceding the *Palmatolepis marginifera marginifera* Zone was observed. These patterns are not consistent with eustatic trends. Indeed, early through middle Famennian times underwent long-term transgressive conditions with reduced detrital input which should have favored homogenously low MS values throughout. This is definitely not the case between Laurussian and Gondwanan margins. Climatic and eustatic trends cannot explain clear-cut MS decrease and pronounced differences between Gondwanan and Avalonian margins. Possible explanations of the differences in MS trends between both entities may rely on the paleogeographic context. The observed difference in behavior of MS values challenge dynamic paleogeographic models and favor the existence of considerable, remnant oceanic interspace, latitudinally separating the two margins in early Famennian times.

Some genera of Brachiopods D/ C boundary in Hoz- e- Dorah Section Tabas area (SE Tabas), Iran

Hassanzadeh A.[1], Bahrammanesh M.*[2], Madjidifard Mr.[3] & Khaksar K.[4]

[1] Research Earth Science Center, Iran. [2] Geological Survey of Iran. [3] Research Earth Science Center, Iran. [4] Islamic Azad University Qom Branch, Iran

Corresponding author email: bahrammanesh69@gmail.com

Keywords: Shishtu, Hoz-E-Dorah, Sardar Formation, Tabas, Brachiopods.

The type section of the Shishtu Formation (I, II) in Hoz-e-Dorah section, is one of the best section in the late Paleozoic of Central Iran, Tabas area. The thickness of the section is 362 meters that include 152 meters of Shishtu I Formation with lithologies dominated by pure limestone, and sandy shaly limestone that is overlain unconfably by the Shishtu II consisting of limestone and shale. The thickness of Shishtu II is 210 meters. The base of the section lies within the Shishtu I and the upper part of the section shows an unconformity with the Sardar Formation. This research yelded 122 Brachiopods that included 34 Species and 25 genera from the Orders Strophomenida, Orthotetida, Productida, Rhynchonellida, Spiriferinida, Athyridida Spiriferida, Atripida. The age of Brachiopods is Frasnian to Visean. Five genera are reported for the first time in the Tabas area. These are *Crinisarina, Verkhotomia, Sedenticellula, Latispirifer and Warsawia*. The *Spinatrypa* with two species indicate an age of middle to late Frasnian age for the Shishtu II Formation. The occurrence of *Warsawia* have shown a Middle Visean age at the Shishtu I.

Discussion on phylogeny of biostratigraphic markers among spathognathodontidae (Conodonta) around the Silurian/Devonian boundary

Hušková A.*[1-2] & Slavík L.[2]

[1] Institute of Geology and Palaeontology, Charles University, Czech Republic. [2] Institute of Geology of the Czech Academy of Sciences, Czech Republic.

Corresponding author email: huskovaa@natur.cuni.cz

Keywords: Silurian/Devonian boundary, conodont biostratigraphy, Spathognathodontidae.

The biostratigraphic study of two key sections across the Silurian/Devonian boundary in the Prague Synform provided relatively rich conodont material. The sections (Na Požárech and Praha-Radotín) represent different depositional environments above the Silurian/Devonian boundary which is similarly developed in both sections as the so-called *Scyphocrinites* horizon – light coarse-grained crinoidal limestones. The Devonian part of the Na Požárech section is developed in light gray, coarse-grained carbonates and the limestones in the Praha-Radotín section are typically dark gray, micritic with shale intercalcalations. The contrasting depositional environments in the two localities resulted in expected differences in composition of conodont faunas. The diversity among the conodonts around the Silurian/Devonian boundary is relatively high. Most common and are the representatives of the families Icriodontidae and Spathognathodontidae. Especially, the latter family, which is the most abundant and diverse. In the conodont material, some spathognathodontids with distinct morphologhical changes in P1 elements have been identified. These morphotypes are useful for biostratigraphic correlation. A reconstruction of phylogeny of the most promissing biostratigraphic markers bearing the same distinct morphology in P1 elements (e.g. *Zieglerodina paucidentata*, *Zieglerodina petrea*) will be discussed in the presentation.

This work has been supported by the grant GAUK no. 1698119, by the Czech Science Foundation (GA17-06700S) and by the Center for Geosphere Dynamics (UNCE/SCI/006).

Famennian conodont biostratigraphy and biofacies of the Minervois Nappe (Ravin de la Fontaine de Santé, Montagne Noire, Southern France) – a reinvestigation

Lüddecke F.*[1] & Hartenfels S.[2]

[1] Institut für Geologie und Paläontologie, Westfälische Wilhelms-Universität Münster, Germany. [2] Institut für Geologie und Mineralogie, Universität zu Köln, Germany.

Corresponding author email: felix.lueddecke@uni-muenster.de

Keywords: Conodonts, Upper Devonian, stratigraphy, facies, Montagne Noire, Europe.

The Montagne Noire represents one of the classical regions for the study of Upper Devonian strata in Europe. At the south-eastern margin of the Massif Central, its sedimentary successions belong to nappes, which were delivered from the north (Engel et al., 1981). Different non-metamorphic (par)autochthonous units can be distinguished: Faugères Nappe, Mont Peyroux Nappe (including the detached Pic de Bissous Block), and the olistolithic "Cabrières Klippen" in the east, as well as the Pardailhan and Minervois nappes in the west. In contrast to the well-studied eastern units, successions of the Minervois Nappe are poorly investigated, so far, although they offer tremendous research potential.

The section "Ravin de la Fontaine de Santé" crops out approximately 500 m to the north-east of Caunes Minervois, within a small, episodically water-bearing valley south of the road to the Rocamat marble quarry. Boyer et al. (1968) first described the succession, Tucker (1974) and Bourrouilh (1981) studied the sedimentology, Crilat (1983) and Bourrouilh et al. (1998) published sparse conodont data.

Due to the current outcrop conditions, two sections (A, B) have been logged bed by bed and sampled systematically for conodont stratigraphy, conodont biofacies, and carbonate microfacies. The ca. 15 m thick Section B, presented herein, contains the griotte (reddish flaserkalk with orange clay), vrai-griotte (red, nodular limestone) to supra-griotte (reddish to grey flaserkalk) succession. It ranges from the *Pa. termini* Zone to the *Pa. marginifera utahensis* Zone. Based on the carbonate microfacies (mudstone, mud-wackestone, wackestone, float-rudstone), it was deposited in a hemipelagic outer shelf region below the storm wave base. No specific facies trend can be recognized. In contrast, the conodont biofacies is very diverse. A refined conodont biofacies analysis, based on the separation of species groups within genera with potentially different palaeoecology, led to the distinction of 39 conodont biofacies variants/subfacies, which partly reflect the replacements of species groups by extinctions and evolutionary innovations.

The vertical conodont biofacies fluctuation indicates two possible regressive trends in the *Pa. glabra pectinata* and *Pa. marginifera utahensis* zones, each marked by abundance peaks of the genus *Icriodus*. However, only deeper-water icriodids occur. The hypothesis by Lüddecke et al. (2017) is confirmed, that distribution patterns of pelagic conodonts are a much finer detector of palaeoecological variations and changes than macroscopic lithology and carbonate microfacies.

Bourrouilh R. (1981) - 'Orthoceratitico-Rosso' et 'GoniatiticoRosso': Facies marqueurs de la naissance et de l'evolution de paleomarges au Paleozoıque. In: Farinacci A. & Elmi S. (eds.), Rosso Amonitico Symposium Proceedings. Tecnoscienza, Rome, 39–59.

Bourrouilh R., Bourque P.A., Dansereau P. Bourrouilh-Le Jan F. & Weyant P. (1998) - Synsedimentary tectonics, mud-mounds and sea-level changes on a Palaeozoic carbonate platform margin: a Devonian Montagne Noire example (France). Sedimentary geology, 118(1-4), 95-118.

Boyer F., Krylatov S., Le Fevre J. & Stoppel D. (1968) - Le Devonien superieur et la limite devono-carbonifere en Montagne Noire (France): lithostratigraphie–biostratigraphie. Bull. Cent. Rech. Pau, 2(1), 5–33. Engel W., Feist R. &

Crilat S. (1983) - Le Devonien supérieur et le Carbonifère inférieur des Pyrénées et de la Montagne Noire (Frasnien, Famennien, Tournaisien). IGCP nº 5, Newsletter, 5, 231-254.

Franke W. (1981) - La Carbonifère anté-Stephanien de la Montagne Noire: Rapports entre la mise en place des nappes et sédimentation. Bulletin du Bureau de Recherches Géologique et Minière, 1, 341–389.

Lüddecke F., Hartenfels S. & Becker R.T. (2017). Conodont biofacies of a monotonous middle Famennian pelagic carbonate succession (Upper Ballberg Quarry, northern Rhenish Massif). Palaeobiodiversity and Palaeoenvironments, 97(3), 591-613.

Tucker M. (1974) - Sedimentology of Palaeozoic pelagic limestones: the Devonian Griotte (Southern France) and Cephalopodenkalk (Germany). In: Hsu K.J. & Jenkyns H.C. (eds.), Pelagic Sediments: on Land and under the Sea. Spec. Publ. Int. Assoc. Sedimentol., 1, 71–92.

New conodont data from the Middle-Upper Devonian boundary stratotype section at Col du Puech de la Suque (Montagne Noire, France)

Liao J.-C.*[1], Girard C.[2], Valenzuela-Ríos J.I.[1] & Feist R.[2]

[1] University of Valencia, Spain. [2] ISEM, University of Montpellier, CNRS, EPHE, IRD, Montpellier, France.

Corresponding author email: jau.liao@uv.es

Keywords: Conodont, Col du Puech de la Suque, Montagne Noire, Givetian, Frasnian, Middle-Upper Devonian.

The GSSP for the base of the Frasnian (= base of the Upper Devonian) is defined by a stratotype at Col du Puech de la Suque E (CPS-E) section in the southeastern Montagne Noire (France). The exact position was chosen by the Subcommission on Devonian Stratigraphy (1982) to coincide with the base of Lower *asymmetricus* Zone and is defined by the first entry of *Ancyrodella rotundiloba* "early" form (= *A. rotundiloba pristina*) in the base of Bed 42a'. It is located near 1.1 km SE of St. Nazaire-de-Ladarez and is characterized by condensed red and grey bedded calcilutites of the offshore realm. The sequence is overturned, dipping about 60º to the west. It was described in detail in several publications (eg. Feist & Klapper, 1985; Klapper, 1985). After IUGS ratification, Klapper et al. (1987) published the formal statement of the decision. Recently, we took up Klapper & Feist works from the 80's and we re-sampled in detail the CPS-E section from the Middle Givetian to the Early Frasnian interval, where 54 samples were taken. We revised conodonts from un-published data at the University of Montpellier (Rodríguez, 2006) and compiled them with the new results for revision of this reference section. Our new results in the CPS-E section are: 1) Six conodont zones are identified: *latifossatus/semialternans*, Upper *hermanni*, Lower *disparilis*, Upper *disparilis*, *norrisi* and F1 zones; 2) new beds (2 to 34) are sampled; 3) the *norrisi* Zone starts in Bed 35; consequently the *disparilis* Zone ends earlier than previously recorded; 4) the start of the F1 Zone is currently placed in Bed 39'^{18} where the presence of *A. r. pristina* is recognized. These results imply that the current G/F GSSP boundary lies approximately 30 cm above from Bed 39'^{18}. Before any stratigraphical change regarding the position of current GSSP can be taken, we shall evaluate the possibility of selecting a different taxon, as has already been proposed (Klapper, 2000). After a taxonomic discussion, he considered that a better level to place the G/F boundary would be the base of Bed 46 with the lowest occurrence of *A. rotundiloba* "late" form (= *A. rotundiloba rotundiloba* s.s.), the index of F2 Zone. However, this is out of the scope of this report, which aims to present new conodont ranges and to revise the corresponding zonation.

Feist F. & Klapper G. (1985) - Stratigraphy and conodonts in pelagic sequences across the Middle-Upper Devonian boundary, Montagne Noire, France. Palaeontographica. Abt. A, 188, 1-18.

Klapper G. (1985) - Sequence in conodont genus *Ancyrodella* in Lower *asymmetricus* Zone (earliest Frasnian, Upper Devonian) of the Montagne Noire, France. Palaeontographica. Abt. A, 188, 19-34.

Klapper G. (2000) - Species of Spathognathodontidae and Polygnathidae (Conodonta) in the recognition of Upper Devonian stage boundaries. Courier Forschungsinstitut Senckenberg, 220, 153-159.

Klapper G., Feist R. & House M.R. (1987) - Decision on the Boundary Stratotype for the Middle/Upper Devonian Series Boundary. Episodes, 10, 97-101.

Conodont Biostratigraphy of the Yukiang Formation in the Liujing area of Guangxi, South China

Lu J.F.*[1], Valenzuela-Ríos J.I.[2] & Liao J.-C.[2]

[1] Nanjing Institute of Geology and Palaeontology and Center for Excellence in Life and Paleoenvironment, Chinese Academy of Sciences. [2] Department of Botany and Geology, University of Valencia.

Corresponding author email: jflu@nigpas.ac.cn

Keywords: Conodont biostratigraphy, Pragian, Emsian, Yukiang Formation, South China.

The Yukiang (Yujiang) Formation in the Liujing area of Guangxi, South China, consists of the Xiayiling, Shizhou, Daliancun, and Liujing members in ascending order. This formation is characterized by remarkably abundant and well-preserved benthic and pelagic fossils, which have been extensively studied by several generations of Chinese geologists. However, during the past 80 years, the age of the Yukiang Formation in the Liujing area has been debated. Wang and Ziegler (1983), Wang (1989), and Bai et al. (1994) correlated this formation with the then *dehiscens* Zone mainly on the basis of conodont evidence. New investigations at the Shizhou, Liujing, and Dacun-1 sections in the Liujing area have revealed a conodont fauna ranging from the uppermost Pragian to lower Emsian. The lowermost part of the Shizhou Member at the Liujing and Dacun-1 sections witnesses not only the co-occurrence of *P. pireneae* and *P. sokolovi*, but also that of sokoloviformis and kitabiformis morphs of *P. pireneae*. *P. kitabicus* is also demonstrated to have its lowest occurrence in the lowermost part of the Shizhou Member at the Dacun-1 section. Therefore, the lowermost part of the Shizhou Member at the Liujing and Dacun-1 sections can be assigned to the uppermost *pireneae* Zone and lowermost *kitabicus* Zone in ascending order. The Pragian/Emsian boundary defined by the lowest occurrence of *P. kitabicus* is recognized for the first time in the highest thick-bedded limestone bed that can be observed in the lowermost part of the Shizhou Member at the Dacun-1 section. Moreover, conodont fauna including *P. excavatus excavatus*, *P. excavatus* ssp. 114, *P. perbonus*, and *P. nothoperbonus* marks the interval from the uppermost part of the Shizhou Member to Liujing Member at the Shizhou and Liujing sections, indicating that the uppermost part of the Shizhou Member belongs to the Middle and Late *excavatus* subzones, and that the Daliancun and Liujing members are assignable to the *nothperbonus* Zone. Accordingly, the uppermost *pireneae* Zone, the lowermost *kitabicus* Zone, the Middle and Late *excavatus* subzones, and the *nothoperbonus* Zone have been successfully recognized from the Yukiang Formation in the Liujing area. However, the scarcity of suitable limestone samples for conodont analysis from the middle and upper parts of the Shizhou Member precludes decisive identification of the upper boundary of the *kitabicus* Zone and the lower boundary of the Middle *excavatus* Subzone in the Liujing area.

Bai S.L., Bai Z.Q., Ma X.P., Wang D.R. & Sun Y.L. (1994) - Devonian events and biostratigraphy of South China. Peking University Press, Beijing.

Wang C.Y. (1989) - Devonian conodont of Guangxi. Memoirs of Nanjing Institute of Geology and Palaeontology, Academia Sinica, 25, 1–231.

Wang C.Y. & Ziegler W. (1983) - Devonian conodont biostratigraphy of Guangxi, South China, and the correlation with Europe. Geologica et Palaeontologica, 17, 75–107.

There was a mass extinction in plants at the Devonian-Carboniferous Boundary

Marshall J.E.A.*

University of Southampton

Corresponding author email: jeam@soton.ac.uk

Keywords: Devonian/Carboniferous boundary, spores, mass extinction.

There has been much confusion about the role of terrestrial plant extinctions at the Devonian-Carboniferous Boundary. This confusion has led to many hypotheses that imply plant evolution drove the Earth System to a state that caused a mass extinction. To further complicate the issue, analysis of palynological and palaeobotanical databases imply there is no plant extinction at all across the boundary. However, these analyses sum the diversity present in the entirety of the Famennian and compare it with the Tournaisian. Both of these are long stages in which there is considerable internal change. To test whether there is an extinction within the combined interval an analysis was made by comparing spore and pollen disparity at the level of palynological zones. This shows a catastrophic reduction of palynological disparity in the earliest Carboniferous. Palynologists working on D-C boundary zonation have always known this. A number of major palynomorph groups become extinct including representatives from many ecological levels within the flora. Apart from these extinctions the terrestrial vegetation undergoes significant disruption. Changes in spores and pollen across the D-C boundary react to the pattern of climate change with the short sharp glaciation in the latest Famennian followed by equally rapid warming in the earliest Carboniferous. This pattern is now better understood following reinterpretation of the Kellwasser Black Shale as representing readjustment of the low latitude sedimentary system to the glaciation. This is different from its interpretation as a deposit that formed during the rising sea level that resulted from the deglaciation. This reinterpretation means that the pattern of cool aridity and warm humidity in the terrestrial sediments in East Greenland can be directly correlated with sections from Germany. This evidence demonstrates a clear separation of the marine and terrestrial mass extinctions with those in the marine realm resulting from glacial cooling with the terrestrial extinctions resulting from the post glacial warming.

Brachiopod faunas of the Type Devonian, SW England: Contrasting patterns of extinction in the Late Devonian across a terrane boundary

Page K.N.* & Gibson T.

[1] Geodiversity & Heritage. [2] Camborne School of Mines, University of Exeter.

Corresponding author email: kevinnpage@gmail.com

Keywords: Devonian, Devon, brachiopods, Variscan, extinction.

The Late Devonian Mass Extinction phase is one of the 'Big 5' of the Phanerozoic, and has been extensively studied globally except, remarkably, in the historical type region of the System in Devon and Cornwall, SW England. Many mechanisms for the extinctions, which occur in several discrete phases through the Upper Devonian and into the basal Carboniferous, have been proposed, including a meteorite impact, a major volcanic episode and oceanic anoxia, each attracting its own proponents. Not surprisingly, studies have concentrated on the most stratigraphically coherent successions globally (Germany, Morocco, etc). Nevertheless, despite the effects of the Variscan Orogeny, the stratigraphy of the type area of the System is now relatively well understood and sufficient biostratigraphical information, including data on conodonts, is now available to reconstruct faunal successions. Crucially, with the recent recognition of a terrane boundary across the region, with Armorican affinities in the south and Avalonian in the North, new insights and interpretations are now possible. In particular, although recent (and preliminary) assessments of ammonoid and trilobite faunas from Devon and Cornwall, tend to confirm well established patterns of extinction through the interval, brachiopods do not. In particular, those from Avalonian North and Armorican South Devon show different facies and faunal associations and successions, with the South showing a collapse of brachiopod diversity as elsewhere, whereas those in the North show little change and even an increase in diversity. Although broader patterns in the latter area do still match those seen elsewhere, with the extinction of the orders Atrypida and Pentamerida and the superfamilies Anoplothecoidea, Unitoidea, and Unicinuloidea, only in the south are net changes in diversity observed and, as in the north, diversity actually increases at one level. The explanation of such changes in SW England is not complicated, however, with the Armorican south showing a classical passage from shallow marine facies with reefal ecosystems to deep water pelagic facies, whereas in the north, shallow marine facies are retained throughout. In such scenarios, the loss of diverse, shallow-marine reef communities as sea level rose provides the well-known pattern for the Late Devonian, whereas the persistence of shallow water facies in the north meant that there was no significant loss of shallow marine habitats. Hence, as no significant change in diversity is observed in Avalonian North Devon, the contribution to the initial extinction phase, if any, from meteorite impact, volcanic activity, etc, must have been limited. In reality, plate tectonic driven deepening was a major factor in observed changes globally, as demonstrated by Armorican successions in South Devon.

Lower Famennian ammonoid stratigraphy in the Canning Basin (Western Australia)

Söte T.* & Becker R.T.

University of Münster, Germany

Corresponding author email: t_soet01@uni-muenster.de

Keywords: Ammonoids, Devonian, Canning Basin, Kellwasser Crisis, biostratigraphy.

The global Kellwasser Crisis at the Frasnian-Famennian boundary had a severe impact on ammonoids resulting in the complete extinction of the dominant Gephuroceratina. Ammonoids recovered in the western Prototethys realm after a long delay with the sudden appearance of cheiloceratids and of new tornoceratids groups. In Australia, there is no proof of any ammonoids from right after the extinction event until higher in the lower Famennian (Upper Devonian = UD II-C, *glabra prima* Zone, see Becker & House, 2009). The first Australian ammonoids represent remarkably new and endemic forms, followed slightly later (UD II-D) by the arrival of globally widespread taxa. In combination with the high-resolution conodont stratigraphy, we can perfectly correlate the regional succession with the global ammonoid zonation. The Canning Basin post-Kellwasser radiation starts in the UD II-C with a new genus comprising "falcitornoceratids" without the characteristic juvenile falcate ribbing. The regionally oldest Cheiloceratidae, a new species of *Compactoceras (Puncticeras)*, enters at the same level. *Oxytornoceras* n. sp., the oxyconic regional index fossil for the UD II-D, differs from German relatives in the lack of varices, the shape of the E-lobe, and size. A diversity maximum is reached by the influx of species of *Ch. (Cheiloceras)*, *Ch. (Staffites)*, *Com. (Puncticeras)*, *Torleyoceras*, *Armatites*, and by a few new, endemic "falcitornoceratids" and cheiloceratids. In the UD II-E, the onset of praemeroceratids marks the recovery after the global Lower Condroz Event. We could prove an involute early ontogeny for the index fossil *Praemeroceras petterae*, resulting in the establishment of a new subgenus for evolute species, which includes three new taxa. The UD II-F is characterized by a complex phylogeny of oxyconic paratornoceratids, which reflects the ontogenetical patterns of their praemeroceratid ancestors. Overall, our study confirms that the analysis of ontogenetic morphometry is essential to refine ammonoid taxonomy and in order to retrieve a reliable database for ammonoid biostratigraphy and palaeobiogeography. The eustatically driven deepening interval of UD II-D led to the lowest level of endemism in the Canning Basin.

Becker R.T. & House M.R. (2009) - Devonian ammonoid biostratigraphy of the Canning Basin. In: Playford P.E., Hocking R. & Cockbain A.E. Eds., Devonian reef complexes of the Canning Basin, Western Australia., Bulletin, 145, 415-439. Geological Survey of Western Australia.

Early Devonian conodonts and bioevents in the Prague Synform

Slavík L.* & Hladil J.

Institute of Geology of the Czech Academy of Sciences

Corresponding author email: slavik@gli.cas.cz

Keywords: Devonian Stratigraphy, Bioevents, Global Correlation, Conodont Biostratigraphy.

The Devonian carbonate succession of the Prague Synform includes several prominent sea-level fluctuations. Some of them can be traced globally, e.g., the Basal Pragian and Kačák events. In recent years, conodont biostratigraphy of the Early Devonian (Lochkovian, Pragian and early Emsian) of the Prague Synform has been refined. The regional subdivision of the Lower Devonian in its type area has been greatly improved by the integration of new biostratigraphic, chemostratigraphic, sedimentological, and petrophysical data that has, in turn, strengthened global correlations for this interval in Earth's history. A conodont biozonation has been established for the complete Early Devonian interval (basal Lochkovian to earliest Emsian) in the Prague Synform. It includes 17 units, which can be applied to sections reflecting different depositional environments. The proposed biozonation includes zones that are applicable across peri-Gondwana and can even be utilized globally. It, however, largely differs from the so-called "global" or "standard" scales that have proved to be problematic and are not, in fact, globally applicable. This new conodont zonation enables precise biostratigraphic delimitation of the major Early Devonian biotic events. Also, significant conodont events have been documented in the Prague Synform. They represent major changes and restructuring of the conodont faunas, which in turn had direct impacts on conodont biostratigraphy, at a global scale.

Vertebrate assemblages in the tidally influenced siliciclastic deposits of the epeiric Baltic Devonian basin

Stinkulis G. & Lukševičs E*.

Department of Geology, University of Latvia.

Corresponding author email: ervins.luksevics@lu.lv

Keywords: Middle and Upper Devonian, fossil fishes, ranges, tidal signatures.

The aim of this report is to summarize the preliminary results of complex sedimentological and paleontological studies of spatial and temporal distribution of vertebrate assemblages in relation to the influence of tidal processes in the Baltic Devonian basin (BDB). The BDB was a restricted shallow epeiric basin developed during the Devonian, which extended over the territory of the Baltic States, Kaliningrad, partly Leningrad and Pskov regions (Russia), Belarus, NE Poland, and a large part of the modern Baltic Sea (Kurshs 1992). Sedimentary structures of siliciclastics, facies and their associations indicate that tidal processes played a significant role in the BDB in estuarine and deltaic settings from the Eifelian to Famennian (e.g. Pontén & Plink-Björklund 2009; Tovmasjana 2013), with the exception of some regressive events, e.g. in the late Givetian, when the influence of tides decreased and fluvial sedimentation dominated. The role of tidal processes has been evaluated as yet only in a part of the Upper Devonian succession of BDB. Several detailed case-studies demonstrate that the most diverse vertebrate assemblages usually have been found in connection with tidally influenced deltaic settings, e.g. in the Frasnian Ogre Formation (Fm) (Lukševičs et al., 2011), Middle Famennian Tērvete Fm (Vasiļkova et al., 2012) and the Late Famennian Ketleri Fm (Lebedev & Lukševičs 2017).

Kurshs V. (1992) - Devonian terrigenous sedimentation in the Main Devonian Field. RigaZinatne. 208 pp.

Lebedev O. & Lukševičs E. (2017) - *Glyptopomus bystrowi* (Gross, 1941), an "osteolepidid" tetrapodomorph from the Upper Famennian (Upper Devonian) of Latvia and Central Russia. Palaeobiodiversity and Palaeoenvironments, 97, 615-632.

Lukševičs E., Ahlberg P. E., Stinkulis Ģ., Vasiļkova J. & Zupiņš I. (2011) - Frasnian vertebrate taphonomy and sedimentology of macrofossil concentrations from the Langsēde Cliff, Latvia. Lethaia, 45, 356-370.

Pontén A. & Plink-Björklund P. (2009) - Regressive to transgressive transits reflected in tidal bars, Middle Devonian Baltic Basin. Sedimentary Geology, 218, 48–60.

Tovmasjana K. (2013) - Depositional environment of the tidally-dominated transgressive succession: Rēzekne and Pärnu Regional Stages, Baltic Devonian basin. Summary of the doctoral thesis.

Vasiļkova J., Lukševičs E., Stinkulis Ģ. & Zupiņš I. (2012) - Taphonomy of the vertebrate bone beds from the Klūnas fossil site, Upper Devonian Tērvete Formation of Latvia. Estonian Journal of Earth Sciences, 61(2), 105-119.

Some thoughts regarding the position of the base of the middle Lochkovian (Lower Devonian)

Valenzuela-Ríos J.I.*

University of Valencia

Corresponding author email: jose.i.valenzuela@uv.es

Keywords: Lower-Middle Lochkovian, Spanish Pyrenees, Conodonts.

When the proposal of subdividing the Lochkovian into three parts was launched, the taxon chosen for tracing the base of the middle Lochkovian was *Lanea omoalpha*. Subsequently, the taxon was recorded in levels close to the base of the Devonian and, thus, the recognition of the middle Lochkovian based on the lowest record of this taxon became problematic. For these reason, different opinions have suggested placing the boundary with the entry of *Ancyrodelloides carlsi*. The purpose of this report is to analyse the conodont sequence around the entries of these two taxa in the Spanish Pyrenees. The initial intention of the Lochkovian subdivision placed the base of the middle Lochkovian at the base of Bed 12 in the Gerri 1.1 section (Spanish Pyrenees), which coincides with a marked facies shift from dominantly black shales with subordinate black limestone to well bedded dominant limestone with thin interbeded marl and shale. The recorded conodont sequence in the section Gerri 1.1 starts with *Icriodus woschmidti* in Bed 1. Its successor *I. transiens* enters in Bed 10a. This occurrence is followed by *I. bidentatus* in Bed 11, which also records the lowest entry of *A. carlsi*. Bed 12 yielded the entry of *L. omoalpha* in this section. This sequence of entries is also recorded in other three Pyrenean sections (Segre 5, Baen and Compte-I). In the latter, a few beds separate the lowest records of *A. carlsi* and *L. omoalpha*. Therefore, the position of the middle Lochkovian can be precisely traced with the entry of *L. omoalpha* and shows a consistent stratigraphical position above the lowest record of *A. carlsi* in the Spanish Pyrenees. However, the relative positions of these two taxa is not the same in other relevant sections from the Carnic Alps and Bohemia, and this might suggest to abandon the former idea of tracing the base of the middle Lochkovian with the entry of *L. omoalpha* and align this level with the entry of *A. carlsi* instead. Nevertheless, it is not yet certain that the *Lanea* morphologies that occur stratigraphically above *A. carlsi* in the Pyrenean sections are the same than those recorded in other places below it. Consequently, it will be desirable to make a thorough taxonomic study of the Spathognathodontidae from the key regions around the records of *A. carlsi* and *L. omoalpha* before a final decision on the selection of a stable criterion and boundary can be achieved.

Integrated Stratigraphy of the Middle Devonian Lake Church and Thiensville Formations, Western Michigan Basin, U.S.A.

Zambito J.*[1], Day J.[2] & McLaughlin P.[3]

[1] Beloit College. [2] Illinois State University. [3] Indiana University - Bloomington.

Corresponding author email: zambitoj@beloit.edu

Keywords: Devonian, Taghanic, Kacak, pumilio.

Placement of the Lake Church and overlying Thiensville Formation of the western Michigan Basin, Wisconsin, U.S.A. into a regional and global chronostratigraphic framework has been a challenge since these units were named (Raasch, 1935). Following initial description, the type and reference sections have become overgrown and/or partially covered and the few additional smaller outcrops mostly lost to urbanization. Conodont and brachiopod biostratigraphy constrains the age of the Lake Church Formation. Conodonts (including *Polygnathus angustipennatus*) recovered from the type Lake Church Formation were assigned by Schumacher (1971) to the Eifelian and/or lowermost Givetian. Subsequent correlations of the Lake Church and Spillville Formation (NE Iowa) faunas with the *Tortodus kockelianus* and *Polygnathus ensensis* zones were outlined by Klapper & Barrick (1983), Koch & Day (1996), and Day et al. (1996). Recent study of Middle Devonian icriodids (Narkiewicz & Bultynck, 2016) supports an Eifelian age for the Lake Church. No conodonts are known from the Thiensville, but conodonts from the overlying Milwaukee Formation indicate an age of late Givetian and assignment to the *Schmidtognathus hermanni* Chronozone (Schumacher, 1971). Following this biostratigraphic work, acquisition of numerous drill cores led to lithostratigraphic revisions and facies determinations for the Lake Church (fossiliferous dolostone) and Thiensville (stromatolitic sandy dolostone) Formations. Kluessendorf et al. (1988) suggested that the Lake Church and Thiensville may be age equivalent, but Rovey (1997), using additional cores, considered them in their traditional stratigraphic order. We use carbonate carbon isotopic data to better constrain the age of the type and reference sections of these units. Although none of the Lake Church carbon isotopic profiles reconstructed contain excursions, absolute isotopic values observed are different at the type area and ~25 km away at the reference section (baseline of +0.25 and -3.0, respectively). The disagreement in carbon isotopic composition suggests that the type and reference sections of the Lake Church Formation are not the same age; to date, no samples have yielded conodonts for the Lake Church reference section, making the age somewhat ambiguous. Notably, there is ~12 meters of relief over 0.6 km on the unconformable contact with Silurian strata in the Lake Church type region, suggesting that these strata were deposited during transgressive onlapping of a high-relief landscape. Although no conodonts have been recovered from the Thiensville Formation, stratigraphic position and positive excursions in the carbon isotopic profile suggest that these rocks record the Givetian Taghanic Crisis. Limited brachiopod data from a thin interval of normal marine strata deposited during the excursion supports this interpretation. This combination of biostratigraphic and carbon isotope data provides a higher resolution stratigraphic framework for the Wisconsin Devonian succession.

Day J., Uyeno T.C., Norris A.W., Witzke B.J., & Bunker B.J., (1996) - Middle-Upper Devonian relative sea-level histories of North American cratonic interior basins. In: Witzke, B.J., Ludvigson, G.A. & Day, J., Eds., Paleozoic Sequence Stratigraphy, views from the North American Craton. GSA Special Paper, 306, 259-276.

Klapper G. & Barrick J.E. (1983) - Middle Devonian (Eifelian) conodonts from the Spillville Formation in northern Iowa and southern Minnesota. Journal of Paleontology, 57, 1212-1243.

Koch W.F. & Day J. (1996) - Middle Devonian (late Eifelian-early Givetian) brachiopod paleobiogeography of central and eastern North America. In: Copper P. & Jin J. (eds.), Brachiopods, Proceedings of the Third International Brachiopod Congress. A.A. Balkema Press, Rotterdam, Netherlands, 135-144.

Kluessendorf J.J., Miukulic D.G. & Carman M.R. (1988) - Distribution and depositional environments of the westernmost Devonian rocks in the Michigan Basin. In: McMillan N.J., Embry A.F., & Glass D.J. (eds.), Devonian of the World, Volume 1: Regional Synthesis, Canadian Society of Petroleum Geologists Memoir 14, 251-263.

Narkiewicz K. & Bultynck P. (2016) - Taxonomy and biostratigraphic significance of Icriodus orri Klapper and Barrick and related Middle Devonian conodont species. Journal of Paleontology, 90(6), 1181-1196.

Raasch G.O. (1935) - Devonian of Wisconsin. Kansas Geological Society Guidebook for the 9th Annual Field Conference, 261-267.
Rovey C.W. (1997) - Proposed reference sections and correlation of Upper Silurian and Devonian strata, eastern, Wisconsin. Geoscience Wisconsin, 16, 37-46.
Schumacher D. (1971) - Devonian biostratigraphy. In: Clark D.L. (ed.), Conodonts and biostratigraphy of the Wisconsin Paleozoic. Wisconsin Geological and Natural History Survey Information Circular 19.

ST3.5

Carboniferous-Permian GSSPs and correlations: state of the art

Conveners and Chairpersons

Lucia Angiolini (Università di Milano)

Xiangdong Wang (China University of Geosciences)

Shuzhong Shen (Nanjing University)

The redefinition of the Devonian/Carboniferous Boundary: state of the art

Aretz M.*[1] & Corradini C.[2]

[1] University Paul Sabatier Toulouse, France
[2] Università di Cagliari, Italy

Corresponding author email: markus.aretz@get.omp.eu

Keywords: Devonian/Carboniferous Boundary, GSSP, Boundary definition.

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/ISCS 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 met several times at various international meetings, and a dedicated workshop with two days of discussions and a field trip to the classical sections in Montagne Noire, where the present GSSP is located, was organized in Montpellier in September 2016. On that occasion it was decided to test a possible position of the Devonian/Carboniferous Boundary based on a timeline defined by "the base of the *Pr. kockeli* conodont Zone, the end of the Devonian mass extinction and beginning of the Carboniferous radiation, and the top of a major regression (top of Hangenberg Sandstone)". This timeline is based on different criteria, which should increase the potential of placing the boundary in different facies realms and provinces, and increase the practicability of global correlations. Another advantage of this timeline is its position near the timeline defined by the current GSSP level, which would help to maintain stratigraphic stability. The proposed timeline is in accordance to the approach of the task group to reduce the dependence of the boundary definition based on the presence of absence of a single marker. This is not only done by characterising the boundary timeline by different criteria, but also be the development of a robust framework of well-defined timelines below and above. Task group members and other scientists are currently checking the suitability of that boundary position in sections all over the world, and the new boundary definition will be voted most likely in Cologne/Germany at the 19th International Congress on the Carboniferous and Permian in early August 2019. Only after acceptance of a new criterion, the search for the new GSSP will start.

No more in the Mesozoic. The Permian world as cradle for the origin of key vertebrate groups

Bernardi M.*[1-2], Petti F.M.[1] & Simões T.R.[3]

[1] MUSE - Museo delle Scienze di Trento, Italy. [2] School of Earth Sciences, University of Bristol, UK. [3] Museum of Comparative Zoology, Harvard University, Cambridge, UK.

Corresponding author email: massimo.bernardi@muse.it

Keywords: Dating, calibration, fossil vertebrate, molecular clock.

The precise dating for the origin of taxa is of key importance for both stratigraphers and evolutionary biologists. Thanks to exceptional fossil discoveries and the development of new computational methods, in the last years huge progress has been made in dating the divergence time for major groups of tetrapods such as archosauromorphs, lepidosaurs (and squamates in particular) and marine reptiles (e.g. sauropterygians and ichthyosaurs). As a result, new hypotheses have been proposed to describe their early evolution. Here we present and discuss the most recent estimates for the origin and early diversification of these three main groups of reptiles based on fossil occurrences and calibrated relaxed clock divergence time estimates using molecular and combined evidence approaches. We focus in particular on the impact that these new data have on the composition of Permian vs. Triassic tetrapod faunas, and discuss the consequences of such results to both geologists and evolutionary biologists.

The present state of the Capitanian-Upper Permian bivalve biostratigraphic scale of Northeast Russia in the light of the latest new fauna finds, dating of zircons, and chemostratigraphy of d13Corg

Biakov A.*[1-2]

[1] N.A. Shilo North-East Interdisciplinary Scientific Research Institute, Russian Academy of Sciences (Far Eastern Branch), Magadan, Russia. [2] Kazan (Volga) Federal University, Kazan, Russia.

Corresponding author email: abiakov@mail.ru

Keywords: Northeast Russia, bivalve stratigraphic scale, Permian.

The bivalve biostratigraphic scale is an important component of the Permian Regional Stratigraphic Scale (RSS) of Northeast Russia. The RSS is the single complete stratigraphic sequence of Permian marine sediments in Russia and allows to correlate the sections not only in Northeast Russia, but also in all regions of the eastern part of the Boreal Superrealm – the North of the Siberian Platform, Taimyr, Novaya Zemlya and Transbaikalia. Most part of the bivalve scale is based on the phylogenetic sequence of *Inoceramus*-like bivalves. These bivalves dominated in the benthic communities and are very common in all types of sediments. However, a significant endemism of the fauna makes extremely difficult to directly correlate the RSS with the International Stratigraphic Scale (ISS). Especially it concerns the Capitanian and Upper Permian. The U-Pb TIMS and SHRIMP dating of zircons from tuff interlayers carried out in recent years made it possible to obtain several important reference levels in the Middle and Upper Permian of the RSS (Davydov et al., 2016; 2018; Biakov et al., 2017a,b). Another important element for the correlation of the sequences is the chemostratigraphy of d13Corg., the study of which for the first time made it possible to trace the P-T and Wuchiapingian-Changhsingian boundary (Biakov et al., 2017b,c). The recent discovery of late Changhsingian bivalve complex made it possible to get the information on the youngest Permian bivalves of the Boreal regions and more reliably substantiate the Changhsingian stage in Northeast Asia (Biakov et al., 2018).

This research was funded by the grants RFBR N 17-05-00109.

Biakov A.S., Shpikerman V.I., Vedernikov I.L. & Tolmacheva E.V. (2017a) - The first U-Pb SIMS age datings of zircons from Upper Permian deposits of the Northeastern Russia: Significance for interregional correlations. Stratigr. Geol. Correl., 25(3), 256–264.

Biakov A.S., Goryachev N.A., Vedernikov, I.L., Brynko I. V. & Tolmacheva E. V. (2017b) - New results of U–Pb SHRIMP dating of zircons from Upper Wuchiapingian (Upper Permian) deposits in Northeastern Russia. Dokl. Earth Sci., 477(1), 1348–1352.

Biakov A.S., Horacek M., Goryachev N.A., Vedernikov, I. L. & Zakharov Y. D. (2017c) - The first detailed δ13Corg record in Permo-Triassic boundary deposits in the Kolyma-Omolon region (Northeast Asia). Dokl. Earth Sci., 474(1), 591–594.

Biakov A.S., Kutygin R.V., Goryachev N.A., Burnatny S.S., Naumov A.N., Yadrenkin A.V., Vedernikov I.L., Tretyakov M.F. & Brynko I.V. (2018) - Discovery of the late Changhsingian bivalve complex and two fauna extinction episodes in Northeastern Asia at the end of the Permian. Dokl. Biol. Sci., 480, 78–81.

Davydov V.I., Biakov A.S., Crowley J.L., Schmitz M. D., & Vedernikov I. L. (2016) - Middle Permian U-Pb zircon ages of the "glacial" deposits of the Atkan Formation, Ayan-Yuryakh anticlinorium, Magadan province, NE Russia: Their significance for global climatic interpretations. Gondwana Res., 38, 74–85.

Davydov V.I., Biakov A.S., Schmitz M.D. & Silantiev V.V. (2018) - Radioisotopic calibration of the Guadalupian Series: review and updates. Earth Sci. Rev., 176, 222–240.

A stratigraphic approach to the study of the growth history of a mud mound in the Viséan (Mississippian, Carboniferous) of Derbyshire, UK

Carniti A.[1], Angiolini L.*[1], Banks V.[2], Della Porta G.[1] & Stephenson M.[2]

[1] Dipartimento di Scienze della Terra "A. Desio", Università degli Studi di Milano, Italy. [2] British Geological Survey, Keyworth, Nottingham, UK.

Corresponding author email: lucia.angiolini@unimi.it

Keywords: Carbonate mud mounds, Mississippian, brachiopods.

Mississippian carbonate platforms were predominantly ramps characterized by a widespread development of shallow to deep water mud mound bioconstructions (e.g. Lees & Miller, 1995). The Viséan carbonate platform of Derbyshire hosts several of these mud mounds, such as the Ricklow Dale mound, near Monyash, which offer a window to unravel mud mounds' growth history and stratigraphic relationships. The investigated mud mound overlies bioturbated bioclastic wackestone and packstone beds grading upward into bioclastic grainstone representing middle ramp deposits of the Monsal Dale Limestone Formation. The mud mound is a composite and complex structure which reflects the juxtaposition of several smaller mounds comprising a complex set of core-, flank- and intermound facies. The mound cores consist predominantly of clotted peloidal and leiolitic micrite with bryozoans, rare fistuliporid bryozoans, brachiopods, crinoids and abundant early marine radiaxial fibrous calcite cement filling primary growth cavities. Brachiopods are very diversified and abundant in the core facies, and occur also in neighbourhood assemblages in the well bedded flank-facies, which are otherwise dominated by large crinoids. Brachiopods from the core and flank facies are similar and comprise free-living seminfaunal productids, pedicle-attached terebratulids and rhynchonellids and free-living spiriferids. Seminfaunal productids are dominant and reach a larger size than the other taxa, suggesting sparse food resources. The stratigraphic ranges of the most important brachiopod genera in the mound span the middle-upper Viséan. The mud mound shows evidence of subaerial exposure prior to the deposition of the overlying beds of the Eyam Limestone Formation (Gutteridge, 1991; Nolan et al., 2017), which led Gutteridge (1991) to propose a revision of the boundary between the Monsal Dale Limestone and the Eyam Limestone formations. The revised boundary has, however, not been formally adopted. The outcrops of the Eyam Limestone Formation at Ricklow are mostly inner to middle ramp facies, characterized by the occurrence of massive shell beds dominated by large and thick-shelled seminfaunal species of *Gigantoproductus* (Nolan et al., 2017 and references therein), molluscan wackestone and crinoidal high energy grainstone. These deposits onlap the flanks of the mound and its top. The few tens of metres thick succession at Ricklow Dale records the growth of a bryozoan-crinoid-brachiopod dominated mud mound in an open middle ramp setting. Its growth was interrupted by subaerial exposure and it was replaced by a restricted lagoon dominated by molluscs and then an inner ramp setting dominated by a low diversity *Gigantoproductus* facies that onlapped and overlapped the mound surface.

Gutteridge P. (1991) - Revision of the Monsal Dale/Eyam Limestones boundary (Dinantian) in Derbyshire. Mercian Geologist, 12, 71-78.

Lees A. & Miller J. (1995) - Waulsortian banks. Carbonate mud-mounds, 191-271.

Nolan L.S.P., Angiolini L., Jadoul F., Della Porta G., Davies S.J., Banks V.J. & Leng M.J. (2017) - Sedimentary context and palaeoecology of Gigantoproductus shell beds in the Mississippian Eyam Limestone Formation, Derbyshire carbonate platform, central England. Proceedings of the Yorkshire Geological Society, 61(4), 239-257.

Conodonts from the Carboniferous and Permian Cache Creek Complex, British Columbia, Canada, and their significance for Panthalassan biostratigraphy

Golding M.L.* & Orchard M.J.

Geological Survey of Canada

Corresponding author email: martyn.golding@canada.ca

Keywords: Carboniferous, Permian, Canada, terranes, Panthalassa, Conodont.

The Cache Creek terrane in British Columbia, Canada, is a fault bounded crustal block that has been interpreted as preserving part of the remains of the Panthalassa Ocean (Gabrielse & Yorath, 1991). Late Paleozoic and Mesozoic carbonate in the central region of this terrane belong to the Cache Creek Complex (Struik et al., 2001). Conodonts from this complex range in age from Bashkirian (early Pennsylvanian) to Rhaetian (Late Triassic), and were described briefly by Orchard et al. (2001). The Carboniferous and Permian conodonts from the central region of the Cache Creek Complex have been re-examined as part of a wider study on the conodont faunas of the Cache Creek terrane (Golding, 2018). More than 2000 specimens have been identified as belonging to more than 70 species, including three new species: *Declinognathodus benedictus* from the Bashkirian, *Neognathodus brulensis* from the Bashkirian-Moscovian, and *Pseudosweetognathus accensus* from the Artinskian. Additionally, a new genus, *Carbogondolella* is proposed to encompass segminiplanate gondolellids from the Pennsylvanian that lack platform ornamentation, such as *Gondolella clarki*. Some of the conodonts recovered from the central Cache Creek terrane are rare in North America, including *Idiognathodus bashkiricus* from the Carboniferous, and *Pseudohindeodus oertlii* from the Permian. Others have a wider geographic range, and allow the correlation of the Cache Creek Complex with units in the North American Midcontinent and Tethys. Many of the conodont biozones recognized in the Midcontinent during the Pennsylvanian (Barrick et al., 2013) and globally during the Permian (Henderson, 2016) can also be identified in the Cache Creek Complex. These Late Paleozoic conodonts provide an important perspective on the nature of Panthalassan faunas, which are less well characterized than contemporaneous faunas from the Tethys Ocean. Other Panthalassan conodonts of Carboniferous and Permian age can be found in Japan, New Zealand, and northeastern Asia. These areas contain many of the same species as found in the Cache Creek terrane, and show strong similarities during the late Pennsylvanian and Cisuralian. There are, however, some differences between the Panthalassan faunas, including the dominance of *Clarkina* in the Lopingian of Japan (e.g. Xia et al., 2004), which is rare in the Cache Creek terrane at this time, and the presence of several genera in Japan that are absent from the Cache Creek terrane, such as the Pennsylvanian *Neolochriea* (e.g. Mizuno, 1997).

Barrick J.E., Lambert L.L., Heckel P.H., Rosscoe S.J. & Boardman D.R. (2013) - Midcontinent Pennsylvanian conodont zonation. Stratigraphy, 10, 55-72.

Gabrielse H. & Yorath C.J. (1991) - Tectonic synthesis. In, Gabrielse, H. & Yorath, C.J., Eds., Geology of the Cordilleran Orogen in Canada. Geological Survey of Canada, Geology of Canada, 4, 677-705.

Golding M.L. (2018) - Heterogeneity of conodont faunas in the Cache Creek Terrane, Canada; significance for tectonic reconstructions of the North American Cordillera. Palaeogeogr. Palaeoclimatol. Palaeoecol., 506, 208-216.

Henderson, C.M. (2016) - Permian conodont biostratigraphy. In, Lucas, S.G. & Shen, S.Z., Eds., The Permian Timescale. Geological Society of London Special Publications, 450, 119-142.

Mizuno, Y. (1997) - Conodont faunas across the Mid-Carboniferous boundary in the Hina Limestone, Southwest Japan. Paleontol. Res., 1, 237-259.

Orchard M.J., Cordey F., Rui L., Bamber E.W., Mamet B., Struik L.C., Sano H. & Taylor H.J. (2001) - Biostratigraphic and biogeographic constraints on the Carboniferous to Jurassic Cache Creek Terrane in central British Columbia. Can. J. Earth Sci., 38, 551-578.

Struik L.C., Schiarizza P., Orchard M.J., Cordey F., Sano H., MacIntyre D.G., Lapierre H. & Tardy M. (2001) - Imbricate architecture of the upper Paleozoic to Jurassic oceanic Cache Creek Terrane, central British Columbia. Can. J. Earth Sci., 38, 495-514.

Xia, W., Zhang, N., Wang, G. & Kakuwa, Y. (2004) - Pelagic radiolarian and conodont biozonation in the Permo-Triassic boundary interval and correlation to the Meishan GSSP. Micropaleontology, 50, 27-44.

Completing the Permian with refined *Sweetognathus* lineages

Henderson C.M.[1]*

Department of Geoscience, University of Calgary, Canada.

Corresponding author email: cmhender@ucalgary.ca

Keywords: Conodonts, Sweetognathus, lineages, Lower Permian, Biostratigraphy, GSSP.

Issues of morphologic plasticity and homeomorphy within the *Sweetognathus* lineage have for years cast doubt on the value of these conodonts to define Lower Permian GSSPs. Now with the recognition of two distinct lineages of species within this genus-group, as well as interpreted migration pathways, it is possible to reliably correlate the base-Sakmarian, base-Artinskian and base-Kungurian in shallow-water facies. In this presentation, I refer to these lineages as the blue lineage and the red lineage. The base-Sakmarian has recently been ratified at a level defined by the first appearance datum (FAD) of *Mesogondolella monstra* in the Usolka section, south Urals and is dated at 293.52 Ma +/- 0.17 Myr. This level closely corresponds to the local first occurrence (FO) of *Sweetognathus binodosus* within the red lineage that also includes *Sw. anceps*, *Sw. asymmetrica*, *Sw. behnkeni*, *Sw. clarki* as well as *Neostreptognathodus pequopensis* and *N. pnevi*. This lineage is recognized in stratigraphic successions that post-date the P1 glaciation of the late Paleozoic ice age (LPIA) and as such these successions lack high frequency cyclicity interpreted to be associated with long eccentricity Milankovitch origin (405 Kyr cyclothems). These post-P1 stratigraphic successions instead represent primarily longer duration (3 to7 million years) shallowing upward depositional sequences. The proposed GSSP for the base-Artinskian is at the FAD of *Sweetognathus* aff. *whitei* in the Dalny-Tulkas section of the southern Urals; this form is a homeomorph for *Sweetognathus whitei*, which is a member of the blue lineage. *Sweetognathus* aff. *whitei* has recently been named at the Tieqiao section (Sun et al., 2017) within the Chihsia Formation of south China as *Sw. asymmetrica*. This species exhibits considerable morphologic plasticity, but *Sw. asymmetrica sensu lato* has a near global distribution including in the Canadian Arctic, and is therefore a good taxon for GSSP definition. The base-Kungurian is proposed at the FAD of *N. pnevi* at the Mechetlino section; this taxon is well recognized widely in the USA, Canadian Arctic and south Urals. In contrast, the blue lineage appears within a cyclothemic succession in the mid-west USA and includes Asselian age *Sw. expansus*, *Sw. merrilli*, and *Sw. whitei* and Sakmarian age *Sw. obliquidentatus*. The latter species seems to migrate to the south Urals during the mid-Sakmarian and dominates assemblages with *Sw. anceps* and *Sw. asymmetrica*. This migration event occurs during a major transgressive event associated with the end of LPIA P1 glaciation. These new interpretations indicate that we can proceed to complete the definitions of remaining Permian stages and thereby complete the Permian System – a process begun by Sir Roderick Murchison in 1841.

Sun Y.D. Liuc X.T., Yana J.X., Li B., Chen B., Bond D.P.G., Joachimski M.M., Wignall P.B., Wanga X. & Laia X.L. (2017) - Permian (Artinskian to Wuchapingian) conodont biostratigraphy in the Tieqiao section, Laibin area, South China. Palaeogeography, Palaeoclimatology, Palaeoecology, 465, 42-63.

Permian stratigraphy, facies patterns and palaeogeography of southeastern Turkey

Hoşgör I.* & Kara B.

Çalık Petrol (Oil and Gas Exploration and Production Company), Ankara, Turkey

Corresponding author email: izzet.hosgor@calikpetrol.com

Keywords: Permian, Tanin Group, surface to subsurface stratigraphy, SE Turkey.

Permian shallow-marine carbonates and clastics are widely exposed in southeastern Turkey, and they were connected to a carbonate platform succession that extended to northern Syria and Iraq (Fortuny et al., 2015). Revision of the lithostratigraphy of Permian deposits in southeastern Turkey led to a re-evaluation of the age assignments of formations identified in the subsurface and at outcrop. Southeastern Turkey (Hazro area, Diyarbakır Basin and Çukurca area, Hakkari) was located in the northern Arabian Platform during the Permian time. This platform hosts many sections representing delta plain, fluviatile to tidal, paralic and shallow-marine depositional environments under low-energy conditions on its margins. The Gomaniibrik Formation (Capitanian-Changhsingian) is the upper formation in the Tanin Group and conformably overlies the Kaş Formation (Wordian) (Stolle, 2010). Kaş Formation is represented by shallow marine-near shore shales and sandstones in the western part, by lagoonal shales, carbonates and fluvial-deltaic sandstone in the eastern part of Diyarbakır Basin and in the Hakkari area. In the Hazro area, the conformably overlying Gomaniibrik Formation comprises three informal members; A, B and C. Members A and C are composed of carbonates, whereas member B is made up of siltstones and sandstones with a few coal layers and is similar to the underlying Kas Formation (Fortuny et al., 2015). Although the outcrops of the Tanin Group formations are well exposed in middle and eastern SE Turkey, its subsurface distribution is quite variable across Diyarbakır Basin. Review of measured outcrop sections and subsurface data (wireline logs) illustrates similar litho-facies patterns. Along the northern margin of Gondwana, namely along the southern margin of the Neo-Tethys, there existed several scattered Middle-Upper Permian localities, from which Guadalupian and Lopingian invertebrate fossils and trace fossils have been recorded. Also the present work is concerned with myalinid bivalve from the Kaş Formation in the Hakkari and ichnofossils recovered from the Guadalupian from the middle part of the Gomaniibrik Formation in the Hazro area.

Fortuny J., Steyer J.S. & Hoşgör I. (2015) - First occurrence of temnospondyls from the Permian and Triassic of Turkey: Paleoenvironmental and paleobiogeographic implications. Comptes. Rendus. Palevol., 14, 281-289.

Stolle E. (2010) - Recognition of southern Gondwanan palynomorphs at Gondwana's northern margin and biostratigraphic correlation of Permian strata from SE Turkey and Australia. Geol. J., 45, 336–349.

Tournaisian-Viséan magnetostratigraphy: new data from British and Polish limestones

Kamenikova T.[1], Hounslow M.W.*[1], van der Boon A.[2], Sprain C.[2], Wójcik K.[3], Nawocki J.[4] & Biggin A.[2]

[1] Lancaster Environment Centre, Lancaster University, UK. [2] Earth and Ocean Sciences Department, Liverpool University, Liverpool, UK. [3] Państwowy Instytut Geologiczny - Państwowy Instytut Badawczy, Warszawa, Poland. [4] Earth Sciences and Spatial Management, Maria Curie-Skłodowska University, Lublin, Poland.

Corresponding author email: mark.w.hounslow@gmail.com

Keywords: Magnetostratigraphy, Visean.

Our knowledge of the polarity of the earth's magnetic field in the Paleozoic is still only fragmentary. The Tournaisian-Viséan is one such interval, in which the geomagnetic polarity pattern is barely known. Russian work from the 1960's and 1970s attempted to fill this interval, but it is not clear how reliable these are data are, since remagnetisations were not realised at that time, and data differ from modern studies. Late Carboniferous and early Permian (Kiaman) remagnetisations have proven to dominate many well-dated Carboniferous carbonate units in Europe and North America. We outline promising data from a) Chadian and Asbian (early and late Viséan) limestones in Northern England, and b) latest Famennian-earliest Tournaisian limestones from the Krakow area (S. Poland). In Britain, we sampled limestones in south Cumbria which have lower thermal maturation (CAI ~2) than previously studied sections from the Craven Basin, and are less impacted by Triassic mineralisation and karstification which dominates the same formations further west. The units are easily-divided, into the British and Irish regional stages, by foraminifera, coral, brachiopods, and a regional base-level stratigraphy. The units may also yield a cyclostratigraphy. The limestone formations in the Chadian are partially dolomitized, and in the Asbian have intermittent paleosol development. In Poland, samples across the Famennian-Tournaisian from the Krakow area (Czatkowice Quarry; Raclawka Fm) are well dated by foraminifera, conodonts and corals. This area has low thermal maturation (CAI ~1). British results indicate magnetite-carried components, with the Kiaman component dominant, but with a higher stability Carboniferous-like dual polarity magnetisations, once the Kiaman component is demagnetised. In some specimens the Kiaman component is the only one present, and is often difficult to totally remove. Demagnetisation protocols use combined thermal and AF demagnetisation, which differ from previously used thermal protocols, to avoid thermal alteration, which impacted previous studies on the British and Irish Carboniferous. Polish results are rather similar (but thermal demagnetisation alone appears to work best for these) with a difficult to remove Kiaman component- like in the British sections. Our greater success than previous studies likely relates to greater sensitivity of modern magnetometers and targeting lower thermal maturation sections. Both datasets show a fairly complex pattern of polarity reversals, hinting at high reversal rates during these two intervals. Data from further sampling in these two areas may yield a magnetostratigraphy through the entire Tournaisian and Viséan.

Early Permian environmental crisis and its aftermath: biotic and abiotic study

Kossovaya O.L.*[1-2], Wang X.[3], Filimonova T.V.[4] & Ponomareva G.Yu.[5]

[1] Russian Geological Reseach Institute, Russia. [2] Kazan Federal University, Russia. [3] Nanjing University, China. [4] Perm Federal University, Russia.

Corresponding author email: olga_kossovaya@vsegei.ru

Keywords: Early Permian, rugosa corals, ecological crisis.

Coral communities, being typical of the Photozoan biota, depend on paleogeographical and paleoclimatic habitat. Decrease in diversity of Kleopatrinidae, Durhaminidae, Petalaxidae rugose families in the Cordillera-Arctic-Urals Realm (CAUR) was gradual and lasted for 7 Ma up to the early Kungurian (Fedorowski et al., 2007). The assemblage was replaced by Heterozoan biota, which mostly included cosmopolitan genera. The temporal span between final episodes of massive colonial corals extinction was fixed in separate parts of the Realm. Taxonomic composition is also variable. Heritschioides species are absent in the eastern part of the Realm and Protolonsdaleiastraea – in the Cordilleran part. In the Urals and N. Timan, the last massive colonies were recorded in the E. Artinskian, and in the northern part, they disappeared in the L. Sakmarian (Chwieduk, 2013). The main decrease in the coral diversity in the CAUR (from 85 to 8 species) coincides with the early Artinskain. Similar to that, the maximal diversity in South China was identified in the Asselian and Sakmarian (Wang et al., 2018). Petalaxidae, Bothrophyllidae and Cyathopsidae families occurred in both regions. The interregional taxonomic differentiation increased in the Kungurian. Peri-Gondwanan Artinskian coral assemblage was limited to only 'cyathaxonian' genera. Fusulinid diversity shows similar strategy with species decrease in the L. Sakmarian to the E. Kungurian. It followed by species diversification from the L. Kungurian in the Tethys. The similar trend in rugose evolution showed the replacement of the peri-Gondwanan assemblage with the Cathasyan one in the second half of the Kungurian. Thus, the subsequent evolution in the Northern and Southern hemispheres had the inverse tendency. The warming in the South Hemisphere triggered sea level rising. Transgression began in the early Artinskian in the Urals, in the Middle Artinskian in the Northern Timan, and in the Kungurian in Spitsbergen. The general northward drift of Pangea could cause additional temperature decrease. This study is supported by RFBR-SFNS China 18-55-53055.

Chwieduk, E. (2013) - Palaeogeographical and palaeoecological significance of the Uppermost Carboniferous and Permian rugose corals of Spitsbergen Poznań 2013. Adam Mickiewicz University Press. Seria Geologia nr 23. Pp. 270.

Fedorowski, J., Bamber, E.W. & Stevens, C.H. (2007) - Lower Permian colonial rugose corals, Western and Northwestern Pangea: Taxonomy and distribution. XII + 231 pp. National Research Council of Canada. Monograph Publishing Program, Ottawa.

Wang X., Yao L. & Lin W. (2018) - Permian rugose corals of the world. In: Lucas S.G. & Shen S.Z. (eds.), The Permian Timescale. Geological Society, London, Special Publications, 450, 165–184.

Stevens C.H. & Stone P. (2009) - New Permian Durhaminid cerioid corals from East-Central California. J. Paleont., 83(6), 946-953.

Visean to Gzhelian integrated biochronostratigraphy of Sardar Formation, Central Iran

Mandrioli R.*[1], Balini M.[1], Nicora A.[1], Angiolini L.[1], Borlenghi M.[1], Marchesi R.[1], Sohrabi Z.[2] & Soleimani S.[2]

[1] University of Milan, Italy. [2] Geological Survey of Iran.

Corresponding author email: riccardo.mandrioli@gmail.com

Keywords: Pennsylvanian, Cimmerian blocks, Ammonoids, Brachiopods, Conodonts.

Understanding the Carboniferous sedimentary evolution of Central Iran is crucial in the comprehension of the geological history of Cimmerian blocks during the opening of Neothetys. In Central Iran one the most important carboniferous unit is the Sardar Formation. This formation is widespread, with limited changes in thickness and facies, mostly consisting of green shales and siltstones with quartzarenitic intercalations and rare limestone and sandy limestone beds. In literature, Sardar Formation, in particular in its upper part, is characterized by a poor and discontinuous fossil record. The lack of consistent paleontological data makes difficult the age assignement of this unit. In this work it is described the Sardar Formation outcropping in the Bagh-e-Vang area (South of Shirgesht), where a thick Devonian to Permian succession is widely exposed. In this area, only a Bashkirian ammonoid fauna (Ruttner et al., 1968 and Hairapetian et al., 2006) was reported from the lower Sardar Formation. Instead the only fossils reported from the upper part of this unit are Early Permian brachiopods (Ruttner et al., 1968), that were classified by Stepanov (in Ruttner et al., 1968) but never described. Two stratigraphic sections were selected at Kuh-e-Shesh Angosht and at Kuh-e-Bagh-e-Vang. The studied sections were sampled for brachiopods, conodonts and ammonoids for an integrated biostratigraphic study. Brachiopod and conodont faunas come from the lower part of the the Shesh Angosht section. On the contrary, ammonoids come from the uppermost Sardar Formation in both Kuh-e-Shesh Angosht and Kuh-e-Bagh-e-Vang sections. Brachiopod fauna, collected from the levels yielding the "Early Permian" brachiopod fauna reported by Ruttner et al. (1968), includes the genera *Marginovatia*, *Brochocarina*, *Coledium* and *Frechella*. The composition of this assemblage is totally different from the one reported by Ruttner et al. and suggests a Visean age. Conodont fauna, collected few meters above the brachiopod-bearing levels, consists of *Neolochriea*, *Idiognathoides*, *Streptognathodus*, *Neognathodus* and *Idiognathodus*. This fauna documents a late Bashkirian age. The uppermost fauna consists of the ammonoids genera *Agathiceras*, *Somoholites*, *Marathonites* and *Pseudopronorites*. This association suggests a Gzhelian (end of Pennsylvanian) age for the uppermost Sardar Formation. The Visean-Bashkirian age for the middle part of the Sardar Formation is consistent with the literature, but the assignment of the uppermost part of the formation to the Gzhelian is new. The continuous sedimentation of the Sardar Formation to the Gzhelian, validate the hypothesis of this unit as documenting the pre-Neotethys rift history.

Hairapetian V., Korn D. & Bahrami A. (2006) - Viséan and Bashkirian ammonoids from Central Iran. Acta Geologica Polonica, 56(3), 229-240.

Ruttner A., Nabavi M.H. & Hajian J. (1968) - Geology of the Shirgesht area (Tabas area, East Iran). Geological Survey of Iran, Report 4, 1-133.

The Pennsylvanian flora of the Italian Carnic Alps

Opluštil S.[1], Pšenička J.[2], Šimůnek Z.[3], Simonetto L.[4], Kustatscher E.*[5-7] & Votočková Frojdová J.[8]

[1] Charles University, Czech Republic. [2] West Bohemian Museum in Pilsen, Czech Republic. [3] Czech Geological Survey, Czech Republic. [4] Museo Friulano di Storia Naturale, Italy. [5] Museum of Nature South Tyrol, Italy. [6] Ludwig-Maximilians-Universität München, Germany. [7] SNSB-Bayerische Staatssammlung für Paläontologie und Geologie, Germany. [8] Academy of Sciences of the Czech Republic, Czech Republic.

Corresponding author email: evelyn.kustatscher@naturmuseum.it

Keywords: Carboniferous, plant fossils, Pramollo Basin.

The Carnic Alps, located along the Italian–Austrian border, provide excellent outcrops of Pennsylvanian deposits often very rich in fossils. Be+sides the diverse fauna preserved in marine carbonates and siliciclastics, the successions yielded exceptional macrofossil plant assemblages. It is therefore not surprising that these well-exposed fossiliferous successions have attracted attention of earlier geologists and palaeontologists since the middle of the 19th century. After WWI and the division of the Carnic Alps between Austria and Italy, continued the studies of the Carboniferous plant fossils of the Carnic Alps almost only on the Austrian side. Today are distinguished more than 30 fossiliferous sites and more than 90 taxa. On the other hand, the plant assemblages collected from the Italian side, today mostly stored at the Museo Friulano di Storia Naturale (about 2,500 specimens), have so far never studied in detail. A revision of the plant assemblages permitted to distinguishes 14 different fossiliferous sites on the Italian side of the Carnic Alps. All major plant groups are preserved. The lycophytes are represented by vegetative organs (*Sigillaria, Syringodendron*) and reproductive organs (*Lepidostrobophyllum*, *Sigillariostrobus*). Sphenophytes are represented by the genera *Calamites, Annularia, Asterophyllites, Calamostachys* and *Sphenophyllum*. Zygopteridales are quite rare and restricted to the two genera *Nemejcopteris* and *Schizostachys*. Ferns are very abundant and diverse and include, among others the genera *Cyathocarpus, Lobatopteris, Acitheca, Pecopteris*, *Diplazites, Scolecopteris, Senftenbergia* and *Oligocarpia*. Quite common are also the Callistophytales (*Dicksoniites, Eusphenopteris*), Medullosales (e.g., *Alethopteris*, *Neuropteris, Odontopteris, Callipteridium*) whereas taeniopterids (*Taeniopteris*) and Cordaitanthales (*Artisia, Cordaites*) are subordinate. Plant assemblages from all the 14 localities are of Late Pennsylvanian age.

First volumetric body mass estimate of the dinocephalian *Tapinocaninus pamelae* (Synapsida: Therapsida) from the lowermost Beaufort Group of South Africa

Romano M.* & Rubidge B.

Evolutionary Studies Institute (ESI) and School of Geosciences, University of the Witwatersrand.

Corresponding author email: marco.romano@uniroma1.it

Keywords: Body mass estimate, 3D modeling, photogrammetry, dinocephalians, Therapsida, Guadalupian.

In this contribution we provide the first body mass estimate and *in-vivo* reconstruction of the basal tapinocephalid *Tapinocaninus pamelae*, based on a remarkably complete and well preserved skeleton from the lowermost Beaufort Group of South Africa. Despite the significance of the huge size reached by dinocephalians, to date no detailed body mass estimations are available for the group, which are the earliest large terrestrial tetrapods from Gondwana. To accomplish this we produced a 3D photogrammetric model of *Tapinocaninus* based on the holotype skeleton, and utilised mounted skeletons of the dinocephalians *Ulemosaurs* and *Moschops* to reconstruct the missing autopods. The photogrammetric model was modelled in ZBrush, software for digital sculpting and painting, which also enabled separation of individual bones and body portions and digital modification and arrangement of the the posture of the skeleton to perfectly fit the skeletal reconstruction of Rubidge et al. (2019). Using the software we modelled and sculptured the soft parts around the 3D photogrammetric model of the skeleton, while the surface area and the volume were calculated using the software 3D Studio Max. By applying a living tissue density range of between 0.9 and 1.15 Kg/ 1000 cm^3 to the model, we reconstructed an average body mass of 894 Kg for *Tapinocaninus*. Application of traditional regression formulae, based on long bone circumference, provides higher values of 1694.5 Kg and 2015.8 Kg. The study has demonstrated that volumetric body mass estimates are the most precise, and are recommended if mounted or relatively complete skeletons are available. The 'intermediate' posture inferred for *Tapinocaninus*, more upright than the sprawling condition characterizing sphenacodontid 'pelycosaurs' (Rubidge et al., 2019), could represent a structural response to a large body mass, which, for the first time in synapsids, reaches weights close to a ton.

Rubidge B., Govender R. & Romano M. (2019) - The postcranial skeleton of the basal tapinocephalid dinocephalian Tapinocaninus pamelae (Synapsida: Therapsida) from the South African Karoo Supergroup. J. Syst. Palaeontol. https://doi.org/10.1080/14772019.2018.1559244

The Permian of the Nurra region (NW Sardinia, Italy): a unique window for the Late Palaeozoic tetrapod communities of Europe

Romano M.*[1], Ronchi A.[2], Citton P.[3], Maganuco S.[4], Caratelli M.[3], Sacchi E.[5] & Nicosia U.[5]

[1] Evolutionary Studies Institute (ESI), School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa. [2] Dipartimento di Scienze della Terra e dell'Ambiente, Università di Pavia, Pavia, Italy. [3] Instituto de Investigación en Paleobiología y Geología, Universidad Nacional de Río Negro, General Roca, Río Negro Province, Argentina. [4] Museo di Storia Naturale di Milano, Milan, Italy. [5] Dipartimento di Scienze della Terra, "Sapienza" Università di Roma.

Corresponding author email: marco.romano@uniroma1.it

Keywords: non-therapsid synapsids, Southern Europe, Sphenacodontidae, Permian, Sardinia, tetrapod footprints.

Since 2008 more than fifteen fieldworks have been conducted in the Nurra area in NW Sardinia, were a well-known thick succession of more than 600 m of post-Variscan continental deposits crops out. The fieldworks, headed by a team of the Department of Earth Sciences of Sapienza of Rome in collaboration with the University of Pavia, led to the collection of truly unique osteological material for both Italian and European Permian panorama. The first vertebrate find in 2008 was represented by both articulated and isolated postcranial material referred to a new genus and species of Caseidae *Alierasaurus ronchii* from the red Permian sediments of the Cala del Vino Formation, outcropping in the Torre del Porticciolo promontory (Romano & Nicosia, 2014). In 2015 a second productive site was discovered, about hundred metres from the original *Alierasaurus* site. Fieldworks in this locality in 2016 and 2017 led to the recovery of several isolated and fragmentary bones found both embedded in the original red bed deposit, and as loose material deriving from the erosion of the productive sedimentary body. A detailed taphonomic analysis allows us to refer all the collected material to a single individual, characterized by peculiar features typical of the non-therapsid synapsids family Sphenacodontidae (Romano et al., 2018). Thus, in addition to a big herbivorous represented by the huge caseid *Alierasaurus*, the new finding testifies the presence of a medium size carnivorous "pelycosaur" in the study region, the first in Italy and one of the few described for the whole European continent, throwing new light on the occurrence and dispersal of the clade. In 2017 a third site was discovered at Cala Viola locality, which led to the discovery of both isolated and in situ tetrapod tracks (Citton et la., 2018). The new material represents the first Permian tetrapod footprints from Sardinia, adding a new crucial piece of evidence to the overall picture. Considering these elements together, the Torre del Porticciolo area results one of the very few sites in Europe where both body fossils and ichnofossils are jointly preserved. The Nurra Region in Sardinia thus shows a real great potential to throw new light on the Permian faunal diversity and ecosystem structure in this area of Pangea.

Citton P., Ronchi A., Maganuco S., Caratelli M., Nicosia U., Sacchi E., & Romano M. (2018) - First tetrapod footprints from the Permian of Sardinia. Geol. J. https://doi.org/10.1002/gj.3285

Romano M. & Nicosia U. (2014) - *Alierasaurus ronchii* gen. et sp. nov., a caseid from the Permian of Sardinia, Italy. J. Vert. Paleontol., 34, 900–913.

Romano M., Citton P., Maganuco S., Sacchi E., Caratelli M., Ronchi A. & Nicosia U. (2018) - New tetrapod discovery at the Permian outcrop of Torre del Porticciolo (Alghero, Italy). Geol. J. https://doi.org/10.1002/gj.3250.

The Permian timescale of China: A key reference to understand the major global events during Permian-Triassic transition

Shen S.Z.*

School of Earth Sciences and Engineering, Nanjing University.

Corresponding author email: szshen@nju.edu.cn

Keywords: Permian, timescale, China, GSSP, event.

A series of global major geological, climatic and biological events occurred across the Permian-Triassic transition. These include the Late Paleozoic Ice Age from Late Carboniferous to Cisuralian followed by the transition from icehouse to greenhouse, the turnover from the reverse polarity Kiaman Superchron to the mixed-polarity Illawarra Superchron marked by the Illewarra Reversal, the Emeishan volcanism and the end-Guadalupian biotic crisis, and the largest mass extinction at the end-Changhsingian. Establishing a high-resolution stratigraphic and temporal framework is essential to understand their cause-effect relationship. Integrative studies from China during the last two decades suggest that the timescale of China has become a more and more important reference for international correlation based on multidisciplinary data. Thirty-five conodont, 23 fusulinid and 20 ammonoid zones are established for the Permian in China, of which the Guadalupian and Lopingian conodont zones have been served as the standard for international correlation. The early Cisuralian conodont succession established in the southern Urals, Russia have been mostly found in China as well. In addition, continuous carbonate sequences of the whole Permian are very well developed in South China, which have been served as the best sequences for chemostratigraphical studies. The Permian $\delta^{13}C_{carb}$ trend established in China indicates that the $\delta^{13}C_{carb}$ records from the Cisuralian and Guadalupian may have more or less suffered subsequent diagenetic alteration or represented regional or local signatures, but the rapid negative shift of 3–5‰ at the end of the Changhsingian can be used for global correlation of the end-Permian mass extinction interval. Permian $\delta^{18}O_{apatite}$ studies suggest that an icehouse stage dominated the time interval from the late Carboniferous to Kungurian (late Cisuralian). However, paleoclimate began to ameriolate during the late Kungurian and gradually shifted into a greenhouse-dominated stage during the Guadalupian. The Changhsingian Stage was followed by a globally-recognizable rapid temperature rise of 8–10°C. The $^{87}Sr/^{86}Sr$ ratio trend shows that their values at the beginning of the Permian were between 0.70800, then gradually decreased to the late Capitanian minimum 0.70680–0.70690, followed by a persistent increase until the end of the Permian with the value 0.70708. The end-Permian mass extinction was a catastrophic event that is best constrained at the Meishan section, which occurred at 251.941±0.037 Ma. The top of the Permian defined by the FAD of the conodont *Hindeodus parvus* at Meishan, China has an interpolated age 251.902±0.024 Ma (Shen et al., 2019).

Shen S.Z., Zhang H., Zhang Y.C., Yuan D.X., Chen B., He W.H., Mu L., Lin W., Wang W.Q., Chen J., Wu Q., Cao C.Q., Wang Y. & Wang X.D. (2019) - Permian integrative stratigraphy and timescale of China. Sci. China Earth Sci., 62, 154-188.

Intriguing stratigraphic sequences in Indian Gondwana system

Srivastava A.K.*[1] & Rashmi S.[2]

Former Scientists Birbal Sahni Institute of Palaeobotany.

Corresponding author email: srivastava019@gmail.com

Keywords: Gondwana, Carboniferous, Permian, Triassic, stratigraphic units.

The term “Gondwana” was coined by H.B. Medlicott in 1872. Gondwana is commonly used for several associated groups or for associated groups and formations with significant lithological properties in common. The Gondwana is made up of 6 to 7 km thick succession of mainly fluviatile and lacustrine deposits. However, a glacial deposit occurs at the base and the intercalations of the fossiliferous marine beds occur both in the lower and upper parts of the succession. The chief rock types are sandstones ,shales, clays, conglomerates and coal seams. In addition to these rocks the upper Gondwana succession contain about 600 meter thick lavaflows of basalt. Presence of three types of floras helps to recognize the Gondwana into Lower, Middle and Upper part which are characterized by Glossopteris flora of ?Carboniferous-Permian succession, Middle Gondwana Dicroidium flora representing Lower Triassic and Upper Gondwana Ptilophyllum flora of Jurassic-Cretaceous in age. Gondwana rocks are distributed in different coal bearing basins of Penisular India viz., Koel-Damodar, Son-Mahanadi, Godavari-Pranhita and Satpura basin. In standard classification Lower Gondwana (Permian) is represented by Talchir, Karharbari, Barakar, Barren Measures and Raniganj formations , Middle Gondwana (Panchet) is known by Kamthi?, Maitur? And Hitrapur formations, Upper Gondwana consists of Mahadeva, Rajmahal and Jabalpur series which is further divided into Pachmarhi, Maleri, Parsora, Rajmahal, Kota, Chaugan, Jabalpur and Umia stages. The Lower Gondwana sequence of Talchir, Karharbar, Barakar, Barren Measures, Raniganj formations have found to contain characteristic assemblages of Glossopteris flora, however, gradational and conformable phase between the Upper Permian (Raniganj) and Panchet (Early Triassic) and presence of transitional flora (Glossopteris+Dicroidium) in transitional bed /units exposed in different basins i. e. Pachhwara in Rajmahal Basin, Maitur, Panchet in Damodar Basin, Pali/Tiki/Parsora in Rewa Basin, Kamthi in Wardha-Godavari Basin, Motur, Bijori in Satpura Basin suggest varying circumstances and surrounding at Carboniferous-Permian-Triassic boundary. Recent study point out that these stratgraphic units have their own litological characteristics and distinctly share out in specifically marked basin. In view of such inconsistency the correlation of such stratigraphic units are discussed with standard markers of ?Carboniferous-Permian-Triassic.

Permian palynostratigraphy: the state of the art

Stephenson M.H.*

British Geological Survey.

Corresponding author email: mhste@bgs.ac.uk

Keywords: Permian, review, palynostratigraphy.

Palynostratigraphy (the use of palynomorphs in biostratigraphy) aims to correlate sedimentary rocks, and to relate geological resources or events to each other and to other important geological or scientific phenomena. In the Permian, palynostratigraphy has been used primarily to correlate coal- and hydrocarbon-bearing rocks within basins and between basins, sometimes at high levels of biostratigraphic resolution. Though these palynostratigraphic schemes related to resource extraction have been very successful, their main shortcoming has been a lack of correlation with schemes outside the basins, coalfields and hydrocarbon fields that they serve, and chiefly a lack of correlation with the international Permian scale. The benefits of a better integrated general palynostratigraphy are very great scientifically because there are numerous events of global scientific interest in the Permian, for example the timing and order of deglaciation events and the detailed characteristics and timing of mass extinction events within the Permian and at the Permian-Triassic boundary. Permian palynostratigraphy is strongly affected by phytogeographic provinciality particularly from the Middle Permian onwards, as predicted by palaeobotanical studies. This makes correlation between regional palynostratigraphic schemes difficult. For these reasons it is unlikely that a single comprehensive palynostratigraphic scheme for the Permian globally will ever be developed. However local high resolution palynostratigraphic schemes for regions are being linked either by precise assemblage-level quantitative taxonomic comparison or by the use of single well-characterised palynological taxa that occur across Permian phytogeographical provinces. Such taxa include: *Scutasporites* spp., *Vittatina* spp., *Weylandites* spp., *Lueckisporites virkkiae*, *Otynisporites eotriassicus* and *Converrucosisporites confluens*. These palynological correlations can be facilitated and supplemented with radiometric, magnetostratigraphic, independent faunal, and strontium isotopic dating. None of the Permian GSSPs involve palynological definitions, which may be problematic given the importance of palynology in correlation in the commercial and academic worlds. However there appear to be taxa that occur at GSSPs or well dated boundary sections that could be used to correlate those boundaries. For example *Aratrisporites* and *Otynisporites eotriassicus* may be useful to correlate the Permian-Triassic boundary into non-marine sections or sections without radiometric dates. *Converrucosisporites confluens* may be useful in correlating the CarboniferousPermian boundary.

Paleoenvironmental changes across Permian–Triassic boundary sections in the Mino Belt, central Japan

Uemura S.*[1] & Onoue T.[2]

[1] Kumamoto University, Japan. [2] Kyushu University, Japan.

Corresponding author email: 181d8153@st.kumamoto-u.ac.jp

Keywords: Permian, Triassic, bedded chert, Japan, Panthalassa.

The ca. 251 Ma Permian–Triassic boundary (PTB) records the largest biotic catastrophe of the Phanerozoic. Many studies have examined the PTB event on Tethyan platforms and circum-Pangean shelves, and various hypotheses have been proposed to explain the extinction event: oceanic anoxia, meteorite impact, flood basalt volcanism, and global warming. Sano et al. (2010, 2012) documented stratigraphic variations in total organic carbon content, δ13Corgvalues, and the diversity of Permian radiolarian species in a PTB siliceous rock section in the Mino Belt, central Japan, and inferred that reducing conditions existed in the deep Panthalassic Ocean at the PTB. In this study, we examined the mineralogical and geochemical compositions of the same sections studied by Sano et al. (2010, 2012). The studied sections (NF1212F and NF195) consist of upper Permian chert (Changshingian) and Lower Triassic (Induan) black claystone containing occasional thin chert beds. A total of 81 claystone samples were obtained from the two sections. Powder X-ray diffraction analysis shows that the claystones below the PTB contain quartz, magnetite, illite, and chlorite, whereas those above the boundary contain only quartz and illite. Geochemical analysis revealed that the concentrations of redox-sensitive trace elements (V, Cr, Mo, and U) increase in the uppermost Permian chert beds. The increasing Mo/U ratios in the interval from 150 to 25 cm below the PTB indicate a shift from anoxic to euxinic conditions. This suggests that strong reducing conditions developed just before the end-Permian mass extinction.

Sano H., Kuwahara K., Yao A. & Agematsu S. (2010) - Panthalassan Seamount-Associated Permian-Triassic Boundary Siliceous Rocks, Mino Terrane, Central Japan. Paleont. Res., 14, 293-314.

Sano H., Wada T. & Naraoka H. (2012) - Late Permian to Early Triassic environmental changes in the Panthalassic Ocean: Record from the seamount-associated deep-marine siliceous rocks, central Japan. Palaeogeogr. Palaeoclimatol. Palaeoecol., 2012, 363, 1-10.

The Cisuralian to Guadalupian Qarari Unit (Oman): new data from brachiopods and implications for correlation

Viaretti M.[1], Angiolini L.*[1] & Heward A.[2]

[1] Dipartimento di Scienze della Terra "A. Desio", Università degli Studi di Milano, Milan, Italy
[2] 23 Croftdown Court, Malvern, WR14 3HZ, UK

Corresponding author email: lucia.angiolini@unimi.it

Keywords: Permian, brachiopods, Batain Basin, Qarari Unit, Oman.

The Qarari Unit in NE Oman is the oldest unit of the Batain Group. It was deposited in the Batain Basin, a failed southern arm of Neotethys. The age of the Qarari Unit is controversial; different ages have been interpreted from different faunal elements and highlight the problems of correlation between the Tethyan and the International chronostratigraphic scale. The Qarari unit was first assigned to the Permian based on brachiopods and corals from Jebel Qarari by Shackleton et al. (1990). Later, it was constrained to the Wordian (ISC scale) by Immenhauser et al. (1998) based on ammonoids and to the Murgabian (Tethyan scale) by Peters et al. (2001) from conodonts and ammonoids. Subsequent studies on foraminiferans gave a Yakhtashian to Midian age (Tethyan scale). Leven & Heward (2013) provided new fusulinid identifications suggesting a Kubergandian age (Tethyan scale). According to the correlation of the Tethyan stages with the ISC stages by Angiolini et al. (2015), the Murgabian roughly corresponds to the Wordian (Guadalupian) while the Kubergandian correlates to the Kungurian-Roadian (late Cisuralian-early Guadalupian). Recent data from conodonts suggest that Wadi Khawr al Jaramah outcrops are Kungurian, while those at Jebel Qarari are Wordian. The brachiopod assemblages of the Qarari Unit cropping out at Wadi Khawr al Jaramah, Jebel Qarari and Shiya comprise 244 specimens belonging to 68 species of the following genera: *Neochonetes*, *Costispinifera*, *Echinauris*, *Neoplicatifera*, *Nudauris*, *Retimarginifera*, *Transennatia*, *Kozlowskia*, *Callytharrella*, *Calliprotonia*, *Juresania*, *Bilotina*, *Waagenoconcha*, *Magniplicatina*, *Edriosteges*, *Derbyia*, *Perigeyerella*, *Goniarina*, *Rhipidomella*, *Parenteletes*, *Acosarina*, *Orthotichia*, *Stenoscisma*, *Goleomixa*, *Ancorhynchia*, *Uncinunellina, Cleiothyridina*, *Posicomta*, *Hustedia*, *Martinia*, *Purdonella*, *Spiriferella*, *Arcullina*, *Tipispirifer*, *Squamularia*, *Permophricodothyris*, *Paraspiriferina*, *Callispirina*, *Spiriferellina*, *Hunzina*. Based on these brachiopod taxa, the age of the Qarari Unit straddles the Cisuralian-Guadalupian boundary, with slight variations between localities and stratigraphic levels. The co-occurrence of brachiopod taxa which are typical of the Cisuralian with others characteristic of the Guadalupian and those that originate in the late Cisuralian suggests an age close to the Cisuralian-Guadalupian boundary. This is older than the faunas in the basal Khuff Formation of the Arabian Plate.

Angiolini L., Zanchi A., Zanchetta S., Nicora A., Vuolo I., Berra F., Henderson C., Malaspina N., Rettori R., Vachard D. & Vezzoli G. (2015) - From rift to drift in South Pamir (Tajikistan): Permian evolution of a Cimmerian terrane. Journal of Asian Earth Sciences, 102, 146-169.

Immenhauser A., Schreurs G., Gnos E., Oterdoom H. & Hartmann B. (2000) - Late Paleozoic to Neogene geodynamic evolution of the northeastern Oman margin. Geol. Mag., 137, 1-18.

Leven E. & Heward A. (2013) - Fusulinids from isolated Qarari limestone outcrops (Permian), occurring among Jurassic-Cretaceous Batain Group (Batain Plain, eastern Oman). Riv. It. Paleontol. Strat., 119(2), 153-162.

Peters T., Al-Battashy M., Bläsi H., Hauser M., Immenhauser A., Moser L. & Al-Rajhi A. (2001) - Geological map of Sur and Al Ashkharah, Sheet NF 40-8F and Sheet NF 40-12C, scale 1:100,000, explanatory notes. Sultanate of Oman Ministry of Commerce and Industry, Directorate General of Minerals.

Shackleton R.M., Ries A.C., Bird P. R., Filbrandt J. B., Lee C.W. & Cunningham G.C. (1990) - The Batain Melange of NE Oman. Geol. Soc. London, Spec. Publ., 49, 673-696.

Progress on the Gzhelian GSSP in South China

Wang X.D.*[1-2], Qi Y.P.[1], Wang Y.[1] & Chen J.T.[1]

[1] CAS Key Laboratory of Economic Stratigraphy and Palaeogeography, Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, China. [2] Center for Research and Education on Biological Evolution and Environment, Nanjing University, China

Corresponding author email: xdwang@nju.edu.cn

Keywords: Gzhelian, Pennsylvanian, GSSP, Conodont, South China.

The base of the Gzhelian Stage has been defined by the FAD of the conodont *Idiognathodus simulator*, but the GSSP has not been selected yet. The reason why it is difficult might be due to a global event at this time interval. The Naqing and Narao sections in the southern Guizhou, South China preserve continuously deposited successions of deep water, slope to basinal carbonates and yield abundant conodonts which contain continuous lineages evolving to *I. simulator*. Just below the level where *I. simulator* appears, $\delta^{13}C$ falls to 2‰. Just above the $\delta^{13}C$ excursion, many Kasimovian species disappear and several conodont species first appear with *I. simulator*, including two new species of *Streptognathodus*, and three species of *Idiognathodus*. The negative $\delta^{13}C$ excursion in combination with the abrupt faunal turnover in South China suggests an oceanic event at the K-G boundary, which can be recognized on a global scale. The fusulinids also occur around the boundary interval, although they are not rich in these two sections. Detailed sedimentological study and other paleontological works were also carried out. One of the two sections may be the best location for the GSSP for the base of the Gzhelian Stage.

ST3.6
Late Triassic biotic, climatic and environmental events and timescales

Conveners and Chairpersons

Mark W. Hounslow (Lancaster UNiversity)

Sylvain Richoz (Graz University)

Christopher A. McRoberts (State University of New York)

The Carnian/Norian boundary interval at Pizzo Lupo (Sicani Mountain) and its correlation with the GSSP candidate section Pizzo Mondello

Balini M.*[1], Tripodo A.[2], Di Stefano P.[2], Levera M.[1], Mazza M.[3], Nicora A.[1] & Rigo M.[4]

[1] University of Milano, Italy. [2] University of Palermo, Italy. [3] University of Modena, Italy. [4] University of Padova, Italy.

Corresponding author email: marco.balini@unimi.it

Keywords: Carnian/Norian boudary, GSSP, Sicano Basin, Ammonoids, Conodonts, Halobia.

Pizzo Mondello is one of the two GSSP candidate sections for the definition of the Norian stage. In the past 20 years the Scillato Formation exposed at this site has been studied for sedimentology, magnetostratigraphy and stable isotope variations, all calibrated on the basis of integrated ammonoid, bivalve (i.e. *Halobia*) and condont bio-chronostratigraphy. Both the candidate markers, the FO of bivalve *Halobia austriaca* and FO of the conodont *Metapolygnathus parvus* have been identified in this section. In the last 8 years, we have studied a second section in the Sicano Basin, Pizzo Lupo, selected to test the reliability of the fossil record of Pizzo Mondello section. This new section is located about 16 km ENE from Pizzo Mondello, and is exposed in an active quarry. The studied succession is about 50 m thick. The distribution of ammonoid faunas is very similar to that described at Pizzo Mondello. A fauna with *Microtropites* and *Gonionotites,* documenting the Upper Carnian *Anatropites spinosus* zone, is found from levels CPL19 to CPL31. Bed CPL 78 yielded *Gonionotites*, *Thisbites* and Juvavitinae. *Dimorphites selectus*, marker of the second subzone of the Lower Norian *Guembelites jandianus* zone, has been identified in bed CPL 87. The halobiids are represented by *H. radiata* (CPL25-CPL91b), *H. austriaca* (CPL78-CPL95) and *H. styriaca* (CPL98). The rich conodont faunas at Pizzo Lupo can be easily compared with those of Pizzo Mondello. In particular, the two faunal turnovers (T2 and T3) that characterize the C/N boundary (CNB) interval have been recognized also at Pizzo Lupo. The position of T1, which corresponds to the LO of the largest part of the carnepigondolellids and the occurrence of the first epigondolellids cannot be well defined because the lower resolution of conodont biostratigraphy in this interval at Pizzo Lupo. Instead, T2 is well represented at Pizzo Lupo and placed at sample CPL57, and it corresponds to the sudden proliferation of the genus *Metapolygnathus* (*M. communisti, M. parvus, M. echinatus, M. linguiformis*). This event is particularly important for the definition of the CNB interval because it is well recognized in the entire Tethys and also in North America. Remarkable is the FO of *M. parvus* at sample CPL63. Turnover 3 (T3) is placed in correspondence of sample CPL77, which corresponds to the FO of ?*Carnepigondolella gulloae* and it marks the disappearance of the genus *Metapolygnathus* replaced by a ?*C. gulloae* population and advanced epigondolellids. The new data from Pizzo Lupo show that the fossil record of this section is mostly equivalent to that of Pizzo Mondello, that is not controlled by local factors. Therefore Pizzo Lupo supports Pizzo Mondello as candidate section for the Norian GSSP.

From Cave del Predil (ex Raibl) to the Dogna Valley: stratigraphy and impact of the Carnian Pluvial Episode in the Julian Alps

Caggiati M.[1], Gianolla P.*[1], Franceschi M.[2], Roghi G.[3], Mazaheri-Johari M.[1], Jin X.[2-4], Rigo M.[2] & Preto N.[2]

[1] University of Ferrara. [2] University of Padova. [3] IGG-CNR. [4] Chengdu University of Technology.

Corresponding author email: glr@unife.it

Keywords: Triassic, Carnian, CPE, Southern Alps, paleoclimate.

The Dogna Valley is a key-area for the Upper Triassic stratigraphy of the Southern Alps, between the Dolomites and Cave del Predil village, previously named Raibl, that gave the name to the *Raibler Schichten* and to the Raibl Group *auctorum*. Dal Corso et al. (2018) reviewed the age of carbonate-terrigenous units at Cave del Predil, making problematic the existing correlations with the Dogna Valley. In this area, a carbonate-siliciclastic inner to middle ramp succession (Rio di Terrarossa Dolomite and Rio del Lago Fm. in Jadoul et al., 2002), overlying an unconformity marked by a bauxite-bearing horizon and sitting on inner carbonate platform facies, was attributed to the Early Carnian based on a monospecific conodont fauna consisting of *Pseudofurnishus m. murcianus* (Jadoul et al., 2002) and passes upward to carbonate-terrigenous units (Dogna and Tor fms in Preto et al., 2005). However, a detailed mapping of the upper Dogna Valley and of the region close to Raibl area, enhanced by 3D-analysis techniques based on new high-resolution LIDAR data allowed to establish new physical correlations. The former Rio del Lago Fm. of the Dogna Valley has been reviewed as the lower part of Tor Fm., whereas the Rio di Terrarossa dolomite correlates to the Conzen Fm. In the Upper Dogna valley, well-stratified limestones of Conzen Fm. lay in places above the well-developed bauxite horizon or unconformably above the Ladinian-Carnian inner platform facies. In this new stratigraphic framework, sedimentary patterns of the Upper Triassic succession of the western Julian Alps fit well with the sequence stratigraphic architecture of the region. According to this revised stratigraphy, the carbonate-clastic ramps of Dogna Valley have been deposited during the Carnian Pluvial Episode, and not before. This fits perfectly with the notion that microbial carbonates were substituted by ooids and skeletal carbonates during the CPE. However, it implies that the stratigraphic distribution of the conodont *Pseudofurnishus m. murcianus* has to be extended up to the end of the early Carnian. New biostratigraphic, chemostratigraphic and magnetostratigraphic investigations are needed to support this new correlation.

Preto N., Roghi G. & Gianolla P. (2005) - Carnian stratigraphy of the Dogna area (Julian Alps, northern Italy): tessera of a complex palaeogeography: Bollettino della Società Geologica Italiana, 124, 269-279.

Dal Corso J., Gianolla P., Rigo M., Franceschi M., Roghi G., Mietto P., Manfrin S., Raucsik B., Budai T., Jenkyns H.C., Reymond C.E., Caggiati M., Gattolin G., Breda A., Merico A. & Preto N. (2018) - Multiple negative carbon-isotope excursions during the Carnian Pluvial Episode (Late Triassic): Earth-Science Reviews, 185, 732-750.

Jadoul F., Nicora A., Ortenzi A. & Pohar C. (2002) - Ladinian Stratigraphy and Paleogeography of the Southern Val Canale (Pontebbano-Tarvisiano, Julian Alps, Italy): Memorie della Società Geologica Italiana, 57, 29-43.

Unravelling the paleoecology of Upper Triassic Halobiid Bivalves

Del Piero N.*[1], Rigaud S.[2] & Martini R.[1]

[1] Department of Earth Sciences, University of Geneva, Switzerland. [2] Asian School of the Environment, Singapore

Corresponding author email: Nicolo.DelPiero@unige.ch

Keywords: Halobiids, carbonate platform, anoxic environments, Upper Triassic, Vancouver Island, paleoecology

Typically recovered in abundance from deep water, anoxic to suboxic, open marine depositional settings, halobiids bivalves constitute an important biostratigraphic tool for the Upper Triassic. Their paleoecology has been the subject of a long-lasting debate: a broad range of different mode of life have been proposed in the literature, often accompanied by misleading facies interpretations. To better constrain the mode of occurrence of halobiids we took as case-study a Lower Norian deep-water sequence in Vancouver Island, there Hallstatt-like pelagic/hemipelagic sediments consist of alternations of radiolarian-rich packstones and *Halobia*-bearing organic-rich wackestones. An integrated geochemical, palaeoecological, sedimentological and pyrite petrographic study has been undertaken to track possible changes in the physico-chemical conditions of the basin. These reveal a range of facies from dysoxic strata, moderately bioturbated and with different form of pyrite, to anoxic/euxinic strata characterized by fine lamination and pyrite framboids of small size and narrow size range. Through the analysis of halobiids occurrences this study gives new insight regarding the habitat and ecology of this widely used group of organism, allowing us to contrast the different theories of their mode of life.

Development of early calcareous nannoplankton in the Northern Calcareous Alps (Austria) in the Late Triassic

Demangel I.*[1-2], Kovács Z.[1-2], Richoz S.[1-2], Gardin S.[3], Krystyn L.[4], Baldermann A.[5] & Piller W.E.[1]

[1] Institute of Earth Sciences, University of Graz, NAWI Graz Geocenter, Graz, Austria. [2] Department of Geology, University of Lund, Lund, Sweden. [3] Centre de Recherche sur la Paléobiodiversité et les Paléoenvironnements, Sorbonne Université, Paris, France. [4] Department of Paleontology, University of Vienna, Vienna, Austria. [5] Institute of Applied Geosciences, University of Technology, NAWI Graz Geocenter, Graz, Austria.

Corresponding author email: isaline.demangel@geol.lu.se

Keywords: Coccolithophorids, Calcareous nannofossils, Prinsiosphaera triassica, Evolution, Triassic.

Coccolithophorids are among the most productive calcifying organisms on Earth and therefore play an important role in the modern and ancient marine carbon cycle, as a biological pump and as a regulator of surface ocean alkalinity. Though the significance of coccolithophorids in the modern ocean is well constrained, fundamental knowledge gaps still persist regarding the emergence and the early evolution of the calcareous nannofossils in the ancient marine ecosystem, which shifted the major carbonate production from the shallow seas to the open marine realm during the Late Triassic period. The Northern Calcareous Alps (Austria) represent a key study site to tackle the evolution of calcifying plankton throughout the Late Triassic. In this study, the Steinbergkogel section, a candidate for the Global Stratotype Section and Point (GSSP) for the Norian–Rhaetian boundary, and the Zlambach section were investigated for their calcareous nannofossils content using both Scanning Electron Microscopy and Optical Microscopy. These sedimentary successions were deposited either on a topographic (hemipelagic) high or in a toe-of-slope paleo-environment,and are only slightly affected by post-depositional (e.g. diagenetic) overprinting. The studied sections record the dominance of the nannolith, *Prinsiosphaera triassica,* which is known from different other locations worldwide since the early Norian. This species increases slightly in abundance toward the early Rhaetian, reaching rock-forming abundance in the late Rhaetian. The evolution of *P. triassica* is seemingly affected by the occurrence of a second nannolith, from the *Eoconusphaeraceae* family, in the early Rhaetian, which is traceable slightly before the onset of the Zlambach Formation. The latter nannolith is appearing in the upper*Paracochloceras suessi* (early Rhaetian) Zone. The coccolithophorids are present in low abundance throughout in the studied sections, increasing slightly in the middle Rhaetian. Coccoliths were recorded for the first time from the middle Norian (Alaunian). The oldest *Crucirhabdus minutus* and *Archaeozygodiscus koessenensis* were observed in the late Norian (Sevatian) and the First Occurrence Datum (FOD) of *Crucirhabdus primulus* was ascertained in the early Rhaetian. These observations suggest a rather slow temporal diversification of the first coccolithophorids, with millions of years from the ancestor *C. minutus* to *A. koessenensis* and then *C. primulus*.

Calcareous nannofossils from the Triassic/Jurassic boundary in the Northern Calcareous Alps (Austria)

Fraguas A.*[1], Hillebrandt A.v.[2] & Urlichs M.[3]

[1] Departamento de Geodinámica, Estratigrafía y Paleontología, Facultad de Ciencias Geológicas, Universidad Complutense de Madrid, Spain. [2] Institut für Angewandte Geowissenschaften, Technische Universität, Berlin, Germany.

[3] Staatliches Museum für Naturkunde, Stuttgart, Germany.

Corresponding author email: arfragua@geo.ucm.es

Keywords: Triassic/Jurassic boundary, mass extinction, calcareous nannofossils, biostratigraphy, calcification crisis, Northern Calcareous Alps.

We have studied the latest Rhaetian-earliest Hettangian transition in a composite section, belonging to the Dürrnberg Formation and well-dated with ammonites, of the Hallstatt-Zlambach Basin (Northern Calcareous Alps, Austria), located in the Euroboreal outer shelf transitional to the Tethys Ocean. The first occurrence of the ammonite *Psiloceras spelae tirolicum* supports the position of the Triassic/Jurassic (T/J) boundary (Hillebrandt et al., 2013). Below this subspecies was found *P. spelae* n. ssp., a new subspecies of *P. spelae,* which can be considered as a Triassic forerunner of *P. spelae tirolicum.* Foraminifera (Hillebrandt), ostracods (Urlichs) and calcareous nannofossils (Fraguas) have also been investigated, and these micro- and nannofaunas are more diverse and abundant in the studied area than in the Eiberg Basin (Hillebrandt et al., 2013), situated further northwest. In terms of calcareous nannofossils, the NJT1 Schizosphaerella punctulata Zone of Bown & Cooper (1998) has been identified. The marker species, *S. punctulata,* which defines the base of this zone, is present from the lowermost sample studied to the top of the composite section. Considering the precise calibration to ammonite zones, probably its first occurrence took place below the T/J boundary in the studied area. Two nannofossil events, the last occurrences of *Prinsiosphaera triassica* and *Eoconusphaera zlambachensis* could help to constrain the T/J boundary. Some relevant changes in nannofossil assemblages have also been observed around this boundary: the switch in dominance from *P. triassica t*o calcispheres *and S. punctulata*, as Hillebrandt et al. (2013) detected in the Eiberg Basin, or the size reduction of the calcispheres and *P. triassica,* and the disappearance of other scarce Triassic nannofossils, such as *Tetralithus cassianus* and *Hayococcus floralis*, as Bottini et al. (2016) described in the Italian Alps. Probably, calcareous nannofossils were affected by the calcification crisis linked to the paleoenvironment perturbations recorded during this time interval, marked by a major mass extinction recorded in different fossil groups all around the world

This work was supported by the Spanish research projects CGL2015-66604-R and UCM-910431.

Bottini C., Jadoul F., Rigo M., Zaffani M., Artoni C. & Erba E. (2016) - Calcareous nannofossils at the Triassic/Jurassic boundary: stratigraphic and paleoceanographic characterization. Riv. Ital. Paleontol. S., 122, 141-164.

Bown P.R. & Cooper M.K.E. (1998) - Jurassic. In: Bown, P.R. Ed., Calcareous Nannofossil Biostratigraphy, 86-131. Kluwer Academic Publishers, London.

Hillebrandt A.V., Krystyn L., Kürschner W.M., Bonis N.R., Ruhl M., Richoz S., Schobben M. A. N., Urlichs M., Bown P.R., Kment K., McRoberts C.A., Simms M. & Tomãsových A. (2013) - The Global Stratotype Sections and Point (GSSP) for the base of the Jurassic System at Kuhjoch (Karwendel Mountains, Northern Calcareous Alps, Tyrol, Austria). Episodes, 36, 142-198.

The interplay of climate forcing, sea level fluctuations and carbonate factory changes during the Carnian Pluvial Episode as recorded in the Southern Alps of Italy

Gianolla P.*[1], Caggiati M.[1], Dal Corso J.[2], Franceschi M.[3], Jin X.[3-4], Mazaheri-Johari M.[1], Roghi G.[5] & Preto N.[3]

[1] University of Ferrara. [2] University of Leeds. [3] University of Padova. [4] Chengdu University of Technology
[5] IGG-CNR, Padova.

Corresponding author email: glr@unife.it

Keywords: Triassic, CPE, Southern Alps, Sequence Stratigraphy.

The Carnian Pluvial Episode (CPE) is an interval of global climate change that profoundly modified the Upper Triassic depositional systems. The CPE influenced both shallow and deep water environments and investigations are revealing the complex expression of its effects in different geological settings. The Southern Alps of Italy host an articulated sedimentary succession deposited during the CPE. The available high-resolution ammonoid, conodont and sporomorph biostratigraphy offer the unique opportunity to disentangle the temporal and cause-and-effect relationships between the sedimentological, geochemical and biological changes that characterize the CPE in the Western Tethys. Furthermore, it makes it possible to link them to the 3rdorder sea-level fluctuations and provides means for global scale correlations. The onset of the CPE in the Southern Alps is marked by a first negative carbon-isotope ($\delta^{13}C$) shift (base of the *A. austriacum* Zone) that is associated with a drastic change in shallow water carbonate factories from microbial- to skeletal grain-dominated, anoxia in some marginal basins and a first pulse of immature siliciclastics. A sudden sea level drop follows, and the subaerial unconformity forming on top of carbonate platforms is testifies for more humid conditions (karst, spodic paleosols, etc.). Forced regression units (terrigenous, mixed or skeletal carbonates) were deposited in the surrounding basins. The following lowstand units (skeletal grainstones and hybrid sandstones in the shallow seas, mud-dominated low-density turbidites in deeper areas) testify for the infilling of residual basins. A second negative $\delta^{13}C$ shift is documented in different areas at the top of the regressive units and is associated with a new pulse of siliciclastic sediment, probably related to increased runoff. Afterward, depositional systems quickly evolve from inner to outer ramps following a marked transgression (late *A. austriacum* Zone). A third negative $\delta^{13}C$ shift has been recorded at the Julian/Tuvalian boundary, about at the end of the transgressive systems tract. It is followed again by a distinct terrigenous pulse. During this regressive interval, shallow mixed terrigenous-carbonate ramp deposits developed at a regional scale, and were only locally interrupted by siliciclastic tidal inlets, connected landward with alluvial plains (*T. dilleri* Zone). Another marked sea level fall is then recognized, which made the shoreline move basinward for tens of kilometers. Alluvial to marginal marine environments were established in the whole Southern Alps with a a carbonate platform-to-basin transition to the northeast. This regressive interval is probably associated with a fourth negative $\delta^{13}C$ shift (*T. subbullatus* Zone) at the end of the CPE. The following transgression is associated with the return of the microbial carbonate platforms and arid conditions in the whole region.

A review of Late Triassic and Early Jurassic palynology

Kürschner W.M.[1]*

University of Oslo, Norway.

Corresponding author email: w.m.kurschner@geo.uio.no

Keywords: Carnian, Triassic – Jurassic interval, palynology, biotic turnover, Europe, Scandinavia.

The Late Triassic is characterized by enhanced rates of biotic turnover in the marine and terrestrial realms culminating in the End-Triassic extinction. Several negative C-isotope anomalies have been reported that indicate coeval pertubations in the carbon cycle. An integrated approach using physical, bio - and chemostratigraphic tools is pivotal to improve correlations between regions across different latitudes and constrain rates of biotic and environmental changes. In this contribution I review palynological data with emphasis on the Carnian and Triassic – Jurassic intervals from different sections in Europe and Scandinavia and discuss their stratigraphic correlation and environmental significance.

Late Triassic $^{87}Sr/^{86}Sr$ isotope trends reveal distinct fluctuations with high-level correlation potential

Kovács Z.[1-2], Demangel I.[1-2], Richoz S.*[1-2], Hippler D.[3], Baldermann A.[3] & Krystyn L.[4]

[1] Institute of Earth Sciences and Graz Geocenter, University of Graz, Austria. [2] Department of Geology, University of Lund, Sweden. [3] Institute of Applied Geosciences and Graz Geocenter, Graz University of Technology, Austria. [4] Institute for Paleontology, University of Vienna, Austria

Corresponding author email: sylvain.richoz@uni-graz.at

Keywords: Late Triassic, strontium, Austria, Rhétien, Norian.

The latest Triassic records one of the most important mass-extinctions in Earth`s History, which is linked to the emplacement of the Central Atlantic magmatic province (CAMP). Preceding these events, the Late Triassic time interval witnessed several important biological turnovers and extinctions for example among conodonts, radiolarians, ammonoids and pectinoid bivalves (*Monotis*), as well as important originations and remplacements: The scleratinian corals became the dominant reef builders and dinoflagellates and coccolithophores also radiated around this time. However, the tectonic and climatic evolution of the Late Triassic, framing these events, is still not well constrained. It is thus difficult to decipher between intrinsic and extrinsic factors that have influenced these biological changes.

The radiogenic strontium isotopic composition (i.e. $^{87}Sr/^{86}Sr$ ratio) of the seawater reflects, due to the long residence time of Sr, global changes. It is mainly governed by continental riverine flux and by the hydrothermal flux at mid-oceanic ridges, both contributing to the overall seawater chemistry. Authigenic or biogenic marine carbonates subsequently incorporate the seawater $^{87}Sr/^{86}Sr$ signal, thus providing an archive of the global oceanic Sr signature. In this study, we present a Late Triassic $^{87}Sr/^{86}Sr$ dataset across the Norian-Hettangian interval from the Northern Calcareous Alps (Austria) and from the central Taurids (Turkey). The high sampling resolution and the well-established biostratigraphy allows to evaluate changes in the $^{87}Sr/^{86}Sr$ record with a better time constraint than previously.

One of the main characteristics of the obtained $^{87}Sr/^{86}Sr$ record is a sharp decline from the Norian/Rhaetian boundary toward the middle early Rhaetian. The $^{87}Sr/^{86}Sr$ ratio then further decreases, however less rapidly, almost until the top of the Rhaetian. Simple mass balance calculations show that tectonic reorganization, which led to the catchment of river fluxes in newly formed rifted basins is a plausible mechanism of the $^{87}Sr/^{86}Sr$ decrease. This process together with the probable recycling of large Anisian – Carnian platform carbonates is favored over hydrothermal flux changes at mid-oceanic ridges or basalt weathering, which were probably only minor contributors. Another important feature of the record is the small increase in $^{87}Sr/^{86}Sr$ just before the mass-extinction level in the late Rhaetian. This is likely related to strong continental weathering linked to the increase in atmospheric pCO_2 as a result of CAMP activity. The effect of weathering of the newly-formed basaltic rocks on the Sr isotope ratio was likely suppressed by the increased weathering of old, more radiogenic crustal material. The observed characteristic $^{87}Sr/^{86}Sr$ decline across the Norian/Rhaetian boundary can thus act as an indicator for the stage boundary, which could overcome the biostratigraphic correlation difficulties in the Tethyan realm and the Panthalassa.

A new zonation for the Lower Carnian Desatoyense Zone (Upper Triassic, Nevada), an example of a revised Oppel Zone

Marchesi R.*[1], Balini M.[1] & Jenks J.F.[2]

[1] Dipartimento di Scienze della Terra "A. Desio", Università degli Studi di Milano, Italy. [2] Independent researcher

Corresponding author email: ruben.marchesi@unimi.it

Keywords: Upper Triassic, Carnian Stage, Desatyense Zone, ammonoids, Nevada.

A revised zonation is proposed for the sedimentary succession within the middle member of the Augusta Mountain Formation at South Canyon (New Pass Range, Nevada), type locality of the Desatoyense Zone of the North American chronostratigraphic scale. Bed by bed collection efforts from 103 fossiliferous beds in six stratigraphic sections have yielded ~3900 specimens, which allow the construction of range charts and recognition of the bioevents on which this revision is based. Silberling & Tozer, 1968 introduced the Desatoyense Zone to replace the "*Joannites* zone" of Johnston, 1941, with *Trachyceras desatoyense* Johnston, 1941, as the index species. The fauna described by Johnston was collected without accounting for the stratigraphic position of the specimens, and consequently, a range chart could not be provided for the 24 taxa attributed to this zone. Thus, the Desatoyense Zone serves as an ideal example of an Oppel Zone. An intensive sampling program utilizing the bed-by-bed method was begun in 2002 by Marco Balini and James Jenks and continued intermittently with other occasional collaborators over a period of several years. Then, Balini et al., 2012 subdivided and replaced the Desatoyense Zone with two biostratigraphic units: the lower, an informal biozone termed the *Daxatina* beds and the upper, the formal *Trachyceras silberlingi* range zone. Subsequent comprehensive studies of the collection has provided new information regarding faunal variability, which is useful for zonation. Extensive suture line analyses of the numerous trachyceratid specimens has proven to be crucial for the differentiation between *Daxatina* and *Trachyceras*, the most important taxa for Lower Carnian zonation. The lower part of the succession (section A and B) is characterized by faunal elements typical of the Sutherlandi Zone, e.g., *Frankites sutherlandi* and *Daxatina*. The middle-upper part of the succession (section D2, E and lower part of section F) exhibits a different faunal composition and *Trachyceras* co-occurs with at least one new species of *Daxatina*. The upper part of section F is characterized by another major faunal change, the onset of *Trachyceras* with highly indented suture lines that co-occur with *Coroceras*. Based on our present data, it is possible to subdivide the Desatoyense Zone into three parts: a lower zone characterized by *Daxatina* and *Frankites*, a middle-upper zone characterized by *Trachyceras* and *Daxatina* and an upper zone characterized by *Trachyceras* and *Coroceras*.

Balini M., Jenks J. & Martin R. (2012) - Taxonomy and stratigraphic significance of Trachyceras silberlingi n. sp., from the lower Carnian of South Canyon (New Pass Range, Central Nevada, USA). B. Soc. Paleontol. Ital., 51(2), 127-136.

Johnston F.N. (1941) - Trias at New Pass, Nevada (new Lower Karnic ammonoids). J. Paleontol., 15(5), 447-491.

Silberling N.J. & Tozer E.T. (1968) - Biostratigraphic Classification of the Marine Triassic in North America. Geol. Soc. Am. Spec. Pap., 110, 1-63.

Environmental conditions for the bivalve *Halobia austriaca* at the Carnian/Norian boundary

Onoue T.*[1], Tripodo A.[2] & Rigo M.[3]

[1] Kyushu University, Japan. [2] University of Palermo, Italy. [3] University of Padova, Italy.

Corresponding author email: t_onoue@kumamoto-u.ac.jp

Keywords: Carnian, Norian, GSSP, Halobia, Black Bear Ridge, Pizzo Lupo.

The Pizzo Lupo section is located in the eastward portion of the Sicani Mountains (Sicily, Italy), ca. 20 km ENE from Pizzo Mondello, which is a candidate section for the Norian GSSP (Nicora et al., 2007). As Pizzo Mondello, Pizzo Lupo section is also very rich in macrofossils such as bivalves (halobids) and ammonoids and also in microfossils like conodonts. Fossils were collected along the section, but more attention was paid around the Carnian/Norian boundary interval. The bivalve fauna of Pizzo Lupo is pretty similar in both species and distributions to that collected in Pizzo Mondello section, providing a useful biostratigraphical tool at least for regional correlation. Similarly, conodonts provided a great correlation with Pizzo Mondello, and they have been primarily used to correlate Black Bear Ridge, which is the other candidate section for the Norian GSSP, cropping out in British Columbia (Canada), and located on the western side of the Pangea during the Late Triassic. Comparing the two candidate sections by using conodont biostratigraphy and conodont turnovers (Mazza et al., 2018), the occurrence of bivalve *Halobia austriaca*appears being asynchronous between the two sections. Onoue et al. (2015) have recognized a change in redox-sensitive elements towards anoxic condition in Black Bear Ridge section at the occurrence level of *Halobia austriaca*. Similar conditions have been identified in Pizzo Lupo section very close to the first occurrence of *H. austriaca*, suggesting that this bivalve might have prospered in oxygen depleted environments. Preliminary data seem thus to show that *H. austraica*apparently occurred in both Black Bear Ridge and Pizzo Lupo when the basins went under dysoxic/anoxic conditions that can justify the asynchronous occurrence of this bivalve in the two sections/basins.

Mazza M., Nicora A. & Rigo M. (2018) - *Metapolygnatus parvus* Kozur, 1972 (Conodonta) as primary marker for the Norian GSSP (Upper Triassic). Boll. Soc. Paleont. It., 57, 81-101.

Nicora A., Balini M., Bellanca A., Bertinelli A., Bowring S.A., Di Stefano P., Dumitrica P., Guaiumi C., Gullo M., Hungerbuehler A., Levera M., Mazza M., Mcroberts C.A., Muttoni G., Preto N. & Rigo M. (2007) - The Carnian/Norian boundary interval at Pizzo Mondello (Sicani Mountains, Sicily) and its bearing for the definition of the GSSP of the Norian Stage. Albertiana, 36, 102-129.

Onoue T., Zonneveld J-P., Orchard M.J., Yamashita M., Yamashita K., Sato H. & Kusaka S. (2015) - Paleoenvironmental changes across the Carnian/Norian boundary in the Black Bear Ridge section, British Columbia, Canada. Palaeogeogr. Palaeoclimatol. Palaeoecol., 441, 721-733.

Birth and death of Upper Triassic seamounts in the Panthalassa Ocean: Ladinian?-Carnian to Rhaetian sedimentary records at Mount Sambosan, Shikoku, Southwest Japan

Peybernes C.*[1], Peyrotty G.[1], Chablais J.[2], Onoue T.[3], Yamashita D.[3] & Martini R.[1]

[1] University of Geneva, Switzerland. [2] Hydro-geo environnement, Switzerland. [3] Kumamoto University, Japan.

Corresponding author email: camille.peybernes@unige.ch

Keywords: Triassic, Panthalassa, Carbonate platform, Microfacies.

Mid-oceanic shallow water carbonate platforms are usually characterized by long-term deposition due to the continuous subsidence of the underlying volcanic edifices and thus provide good records of biotic evolution and environmental changes. However, since most of the pre-Jurassic oceanic crust has been subducted, very few remains of Triassic atoll-like platforms are preserved in the Circum-Pacific region. Therefore, it is crucial to precisely document these Triassic carbonate occurrences to better understand the evolution of climates and ecosystems during the Early Mesozoic in the huge Panthalassa Ocean. In the Sambosan Accretionary Complex (Southwest Japan), several Upper Triassic shallow water limestone blocks are especially well exposed at Mount Sambosan. Microfacies analyses associated with biostratigraphic data (reef assemblages, foraminifer associations and conodonts) allow us to reconstruct the geological history of these seamount fragments from the first settlement of reef biota in the Ladinian?-Early Carnian to platform growth during the Late Carnian to Rhaetian and finally platform collapse and accretion to the East Asia margin in the Late Jurassic-Early Cretaceous. Furthermore, cathodoluminescence microscopy reveals that the Sambosan limestone experienced several diagenetic episodes including early cementation, dissolution and dolomitisation. At the global scale, the comprehensive sedimentary record at Mount Sambosan shows that evolution of shallow water ecosystems in the Panthalassa Ocean is consistent with biotic and environmental changes documented in coeval carbonate platforms from the Tethys Ocean.

Instabilities in the Carbon Cycle during the Carnian as recorded in the Northern Calcareous Alps

Richoz S.*[1-2] & Krystyn L.[3]

[1] Institute of Earth Sciences, University of Graz. [2] Department of Geology, Lund University. [3] Department of Palaeontology, Vienna University.

Corresponding author email: sylvain.richoz@uni.graz.at

Keywords: Carnian, Calcareous Alps, Carbon cycle, carbon isotopes.

The Carnian Pluvial Episode is a major phase of global climatic and biotic changes during the Triassic. A drastic increase in siliciclastics, profound changes of the type of carbonate factory on the platform and drastic biotic turnover marked this period. Multiple shifts in the carbon isotope curves record perturbations in the carbon cycle. However, until now there are discrepancies between the $\delta^{13}C_{carb}$ and the $\delta^{13}C_{org}$ curves. Carbonate carbon isotope curves in the classical sections of the Dolomites and the Northern Calcareous Alps of Austria are not reflecting the multiple negative shifts as seen in the $\delta^{13}C_{org}$ of these areas or in the $\delta^{13}C_{carb}$ in South China and Oman. Here we present $\delta^{13}C_{carb}$ curves from two sections in the Juvavicum nappes system of the Northern Calcareous Alps of Austria: Leckkogel (Gosaukamm), a 320m long section and the 770m long Aflenz-Bürgeralmsection (Hochschwab). Both successions start with 350m of the Julian (early Carnian) Leckkogel Formation, a detritus-rich carbonate slope facies interrupted by three terrigeneous intervals; the latter is followed in Aflenz by 400m of platy limestone of Tuvalian age (late Carnian). These two expanded sections show three negative shifts of 1 to 4 per mill in the Julian1 to Tuvalian 1 and a strong positive peak of up to 4.8‰ at the base of Tuvalian 2. The new results demonstrate that the multiple shifts in the carbon isotope curves on carbonates are also present in the western Tethys, where the carbonate successions are expanded enough. Within our well-dated chronostratigraphic framework, they show the high complexity of the perturbations of the carbon cycle around the Carnian Pluvial Episode.

On the onset of camp volcanism, Ocean Anoxia, and the magnitude of carbon-cycle change at the Triassic–Jurassic transition (Neuquén Basin, Argentina)

Ruhl M.*[1-2], Hesselbo S.P.[3], Mancenido M.[4], Al-Suwaidi A.[5], Jenkyns H.C.[2], Damborenea S.[4], Storm M.[6] & Riccardi A.[4]

[1] Department of Geology, Trinity College Dublin, The University of Dublin, Ireland. [2] Department of Earth Sciences, University of Oxford, UK. [3] Camborne School of Mines, University of Exeter, UK. [4] Museo de Ciencias Naturales La Plata, Universidad Nacional de La Plata, Argentina. [5] Petroleum Institute, Khalifa University, UAE. [6] Stellenbosch University, South Africa.

Corresponding author email: micha.ruhl@tcd.ie

Keywords: Triassic Jurassic, mass extinctions, oceanic anoxic event, carbon-cycle perturbation, Neuquen basin, Argentina, end-Triassic mass extinction.

The Triassic–Jurassic transition is marked by the end-Triassic mass extinction approximately synchronous with the onset of emplacement of the Central Atlantic Magmatic Province (CAMP), and associated with a major negative carbon-isotope excursion (CIE) in the ocean–atmosphere system. New ammonite collections allow us to present a bio- and chemostratigraphically constrained and expanded Triassic–Jurassic boundary succession from the Arroyo Alumbre section in the Rio Attuel Region of the Neuquén Basin, Argentina. We show that the end-Triassic mass extinction is marked here by a limited (2–3‰) negative CIE in bulk organic matter, similar in magnitude to that observed in other eastern Panthalassic marine basins, and to $\delta^{13}C_{CARB}$ records from the Tethyan realm. However, this value of 2–3‰ in the Argentinian section is significantly smaller than that recorded in contemporaneous Tethyan 5–6‰ negative excursions in $\delta^{13}C_{TOC}$. We present a model that suggests that extreme aridity, extending between latitudes of 60º north and south across the western Pangaean landmass, may have resulted in very limited terrestrial organic-matter flux to the sedimentary realm in eastern Panthalassic marine basins, and that mixing and changing marine/terrestrial organic-matter sources explain the observed larger amplitude negative CIE in $\delta^{13}C_{TOC}$ records from the Tethyan realm. We further show that increased accumulation rates of sedimentary Hg (and Hg/TOC) in the marine Neuquén Basin began significantly before the end-Triassic mass extinction and associated negative CIE, and before the commencement, in North America and Africa, of CAMP-related basalt emplacement. The onset of sedimentary Hg enrichment in the Neuquén Basin directly coincided with the early emplacement of CAMP-associated dykes and sills, suggesting thermal alteration of intruded country rocks as a potential major source of elevated Hg fluxes to the atmosphere at this time. We also show that the Neuquén Basin was marked locally by the development of oxygen-depleted marine conditions across the Triassic–Jurassic transition as a result of increased primary productivity and/or watermass stratification, enabling increased preservation of organic matter. Combined with similar observations across the Panthlassic margin and the north-west Tethyan seaway, burial rates of organic matter must have been relatively elevated in a global context. Using simple mass-balance calculations, we show that enhanced carbon burial rates, either during or directly succeeding the end-Triassic mass extinction, and in line with the major phase of CAMP basalt emplacement, can explain the observed evolution of the global exogenic carbon cycle across the Triassic–Jurassic transition.

Re-Os isotope and PGE signatures of the deep-sea deposits from Japanese accretionary complex: implications for the Late Triassic impact event

Sato H.*[1], Nozaki T.[2], Ishikawa A.[3], Onoue T.[4], Kimura J.-I.[2], Chang Q.[2] & Suzuki K.[2]

[1] Chiba Institute of Technology, Japan. [2] Japan Agency for Marine-Earth Science and Technology, Japan
[3] Tokyo Institute of Technology, Japan. [4] Kyushu University, Japan.

Corresponding author email: honami.sato@p.chibakoudai.jp

Keywords: Upper Triassic, bedded chert, Re-Os isotope, platinum group elements, impact event.

The 34-million-year interval during the Late Triassic is marked by the formation of the several impact craters on the Earth (Spray et al., 1998). Late Triassic impact events have been considered as one of factors in biotic extinction events in the Late Triassic (e.g., end-Norian extinction event), but this scenario remains controversial because of a lack of stratigraphic records of ejecta deposits. In order to reconstruct the stratigraphic record of impact events in the Late Triassic, we examined a stratigraphic profile of the marine osmium isotope compositions (187Os/188Os) and highly siderophile elements (HSE: Os, Ir, Ru, Pt, Pd and Re) concentrations from Upper Triassic bedded chert successions from Japan. 187Os/188Os ratios of the bedded cherts demonstrate two negative excursions between the Middle and Upper Norian. The onset of the first negative Os isotope excursion (~0.477 to ~0.126) is almost equivalent to the base of the *E. bidentata* conodont zone. This Os isotope excursion interval exhibits the elevated Os concentrations (3.1 ppb) and low Re/Os ratios (~0.03; Sato et al., 2013). HSE concentrations in this layer are three orders of magnitude higher than the average terrestrial crustal abundances (Onoue et al., 2012; Sato et al., 2016), indicating a significant input of an extraterrestrial materials. Based on calculations using the Os isotope ratios, we estimated the size of the chondritic impactor to be between 3.3–7.8 km in diameter. The timing of the second negative Os isotope excursion is in the early Late Norian and its isotopic composition shifted to unradiogenic 187Os/188Os ratios. However, HSE concentrations obtained from this layer are almost equivalent to average terrestrial crustal abundances. CI chondrite-normalized HSE pattern shows a pronounced step pattern (low Ir, and high Pt and Pd) similar to those of the upper continental crust. Detailed studies are needed to specify the cause of this second negative Os isotope excursion.

Onoue T., Sato H., Nakamura T., Noguchi T., Hidaka Y., Shirai N., Ebihara M., Osawa T., Hatsukawa Y., Toh Y., Koizumi M., Harada H., Orchard M.J. & Nedachi M. (2012) - Deep-sea record of impact apparently unrelated to mass extinction in the Late Triassic. P. Natl. Acad. Sci. Usa, 109, 19134–19139.

Sato H., Onoue T., Nozaki T. & Suzuki K. (2013) - Osmium isotope evidence for a large Late Triassic impact event. Nat. Commun., 4, 2455.

Sato H., Shirai N., Ebihara M., Onoue T. & Kiyokawa S. (2016) - Sedimentary PGE signatures in the Late Triassic ejecta deposits from Japan: Implications for the identification of impactor. Palaeogeogr. Palaeoclimatol. Palaeoecol., 442, 36–47.

Spray J.G., Kelley S.P. & Rowley D.B. (1998) - Evidence for a late Triassic multiple impact event on Earth. Science, 392, 171–173.

Terrestrial Triassic-Jurassic boundary of the Junggar Basin, NE China

Sha J.*[1] & Fang Y.[2]

[1] State Key Laboratory of Palaeobiology and Stratigraphy, Nanjing Institute of Geology, Chinese Academy of Sciences, China. [2] CAS Key Laboratory of Economic Stratigraphy and Palaeogeography, Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, China.

Corresponding author email: jgsha@nigpas.ac.cn

Keywords: Terrestrial Triassic–Jurassic boundary, non-marine and marine correlation, Junggar Basin of northwestern China.

The global (marine) Triassic-Jurassic boundary has been established at the Kuhjoch of Karwaendel Mountains, Austria (e.g., Bonis et al., 2009; Hillebrandt et al., 2013) for about ten years, but the terrestrial Triassic-Jurassic boundary has not yet been recognized, because the non-marine strata must be correlated within the framework of international marine chronostratigraphy, mainly by means of the linking of fossils and/or radiometric dating (e.g., Sha, 2007), but it is extremely difficult. There exists a successive and completely exposed section covering the Triassic-Jurassic boundary interval, yielding macro- and microfossils, along the Haojiagou (gou = valley) on the southern margin of the Junggar Basin of the northwest corner of China (e.g., Sha et al., 2011). In this section, the latest Rhaetian taeniate gymnosperm pollen *Lunatisporites rhaeticusis* within the Rhaetian sporopollen assemblage of *Dictiophyllidites*-*Aratrisporites*-*Cycdolites* and disappeared with *Limbosporites* spp. in bed 52. Bed 53 yields the Hettangian sporopollen assemblage of *Alisporites*–*Osmundocites*–*Cyathidites*, including the abundant Hettangian *Retritriletes semimuris* and *Retritriletes austroclavatidites*. Therefore, the Triassic-Jurassic boundary in Haojiagou section is placed between bed 52 and 53 (e.g., Sha et al., 2015). The widely distributed continental palynomorph *Cerebropollenites thiergartii* is recorded in bed 44 below the Triassic-Jurassic boundary, resembling the first occurrence of the species in the international GSSP section of the base Jurassic System of Austria, where *Cerebropollenites thiergartii* first appears in the horizon 3.2 m lower of the base Hettangian (e.g., Bonis et al., 2009; Hillebrandt et al., 2013). Furthermore, in mollusks, bed 52 below the Triassic-Jurassic boundary, only yields non-marine bivalve *Ferganoconcha*, but since bed 77 above the Triassic-Jurassic boundary, non-marine bivalves including *Unio*, *Yannoconcha* and *Ferganoconcha*, and particularly the marine-brackish-water bivalve *Waagenoperna* appear abundantly (e.g. Sha et al., 2011, 2015, 2016). The occurrence of all these fossils not only support the placement of Triassic-Jurassic boundary between bed 52 and bed 53, which is confirmed by the cyclostratigraphic result (e.g., Sha et al., 2015), but also implies that the terrestrial end-Triassic extinction event happened near the Triassic-Jurassic boundary in the Junggar Basin (e.g., Sha et al., 2015) .

Bonis N.R., Kürschner W.M. & Krystyn L. (2009) - A detailed palynological study of the Triassic-Jurassic transition in key sections of the Eiberg Basin (Northern Calcareous Alps, Austria): Review of Palaeobotany and Palynology, 156, 376-400.

Hillebrandt A.V., Krystyn L., Küschner W.M., Bonis, N.R., Ruhl M., Richoz, S., Schobben M.A.N., Urlichs M., Bown P.R., Kment K., McRoberts C.A., Simms M. & Tomãsový A. (2013) - The global stratotype sections and point (GSSP) for the base of the Jurassic System at Kuhjoch (Karwendel Mountains, Northern Calcareous Alps, Tyrol, Austria). Episodes, 36 (3), 162-198.

Sha J.G. (2007) - Cretaceous stratigraphy of northeast China: non-marine and marine correlation. Cretaceous Research, 28 (2), 146-170.

Sha J.G., Vajda V., Pan Y.H., Larsson L., Yao X.G., Zhang X.L., Wang Y.Q., Cheng X.S., Jiang B.Y., Deng S.H., Chen S.W. & Peng B. (2011) - Stratigraphy of the Triassic–Jurassic boundary successions of the southern margin of the Junggar Basin, northwestern China. Acta Geologica Sinica, 85 (2), 421–436.

Sha J.G., Olsen P.E., Pan Y.H., Xu D.Y., Wang Y.Q., Zhang X.L., Yao X.G. & Vajda V. (2015) - Triassic-Jurassic climate in continental high-latitude Asia was dominated by obliquity-paced variations (Junggar Basin, Ürümuqi, China). PNAS, 112 (12), 3624–3629.

Sha J.G, Wang Y.Q., Pan Y. H., Yao X.G., Rao X., Cai H.W. & Zhang X.L. (2016) - Temporal and spatial distribution patterns of the marine–brackish-water bivalve Waagenoperna in China and its implications for climate and palaeogeography through the Triassic–Jurassic transition. Palaeogeography, Palaeoclimatology, Palaeoecology, 464, 43–50.

Timing and global manifestations of the Carnian Crisis, Late Triassic

Sun Y.*[1], Joachimski M.M.J.[1], Richoz S.[2] & Krystyn L.[3]

[1] University of Erlangen-Nuremberg, Germany. [2] Lund University, Sweden. [3] University of Vienna, Austria

Corresponding author email: yadong.sun@fau.de

Keywords: Carnian Humid Episode, anoxia, carbonate production crisis, carbon isotope.

The mid-Carnian (~233 Ma) is a time of major climatic changes in the Late Triassic. We investigated sections in the Northern Calcareous Alps (NCA), Indian Himalaya, Oman and South China to reveal the nature of environmental perturbations in a global context. In the Scheiblingsgraben section of the NCA, the Carnian Humid Episode (CHE) is marked by the disappearance of reef-derived debris in the Reifling Limestone (and Raming L. of coeval sections) and a transition to thin lime laminites of the Göstling Member in the latest Julian 1, accompanied by a prominent negative shift in $\delta^{13}C_{carb}$ from 2.6 to 0.4 ‰. This transition is followed by the onset of intense anoxia and a carbonate production crisis above the Julian 1-Julian 2 boundary, evidenced by the development of fine laminated black paper shales (Reingraben Shales) on top of the Göstling silty carbonates. In contrast to the intra-platform Reifling Basin setting of Scheiblingsgraben, anoxic facies and carbonate production crisis were not recorded in the condensed, open-marine Hallstatt facies at Feuerkogel, NCA. Instead, the distinct reddish Hallstatt limestones with diverse faunas suggest a fully oxygenated environment from the late Ladinian to the early Norian. In the Spiti Valley of the Indian Himalaya, carbonate deposition of Chomule Fm also ceased below the Julian 1-Julian 2 boundary and was followed by dark grey shales and phosphate-bearing black paper shales of the Rama Fm, indicating a transition from oxic-dysoxic to dysoxic-anoxic conditions. The CHE in the Nanpanjiang Basin of South China coincides with the transition from the hemipelagic nodular limestones of the Zhuganpo Fm to the Wayao black shales. The onset of basin-wide anoxia-euxinia in South China was coeval with that seen in the Scheiblingsgraben section, NCA but was long-lasting, persisting to at least the Tuvalian 2. In the Wadi Mayhah section of northern Oman, the carbonate production was weakened, but not fully suspended during the CHE, evidenced by a transition from the cherty carbonates in Julian 1 to a carbonate and shale combination in the Julian 2. Clearly evidence for anoxia is absent at Wadi Mayhah. Thus both carbonate production crisis and oceanic anoxia were geographically widespread in the mid-Carnian, but with large regional variations in duration and intensity, and are not recorded in all sections. Large negative $\delta^{13}C_{carb}$ perturbations are documented in all studied sections, suggesting that large amount of light carbon input might be one of the important triggers of the Carnian crisis. Differences in timing and manifestations of the CHE were probably controlled, at least partially, by regional oceanographic settings.

Formation of stratiform manganese deposits during the Carnian (Late Triassic) "pluvial event" in the pelagic Panthalassa

Yuki T.*[1], Tetsuji O.[1], Daisuke Y.[2], Tatsuo N.[3-4-5], Yutaro T.[6-3-4] & Manuel R.[7]

[1] University of Kumamoto. [2] Satsumasendai city office. [3] University of Tokyo. [4] JAMSTEC • IFREE. [5] University of Kobe. [6] University of Waseda. [7] University of Padova.

Corresponding author email: nic0tmy.om@gmail.com

Keywords: Stratiform manganese deposit, Triassic, Carnian Pluvial Event, Jurassic accretionary complex, microfossil, geochemistry.

Stratiform manganese deposits have been reported from the Triassic bedded chert sequences in the Japanese accretionary complexes, which are considered to have accumulated in a mid–oceanic basin of the Panthalassa Ocean. However, their precise mineralization age and depositional environment remain poorly understood. In the present study, we investigated lithostratigraphy, conodont and radiolarian ages, and geochemistry of bedded cherts and chert-hosted manganese deposits from the Jurassic accretionary complexes (Chichibu, Mino–Tamba, and Northern Kitakami Belts) in Japan. The studied sequences are classified into three to four lithostratigraphical units; lower bedded chert, massive chert, manganese ore (30-150 cm thick), and upper bedded chert units in ascending order. Radiolarian fossils from the lower bedded chert unit indicate the Early Carnian age, based on the occurrence of *Capnuchosphaera deweveri* and *C. triassica*, whereas the upper bedded chert unit contains Late Carnian radioralian species, including *Poulpus carcharus* and *Trialatus megacornutus*. Conodonts extracted from the upper bedded chert unit also include Late Carnian species, such as *Paragondolella praelindae* and *Metapolygnathus praecommunisti*. These occurrences of microfossils suggest that the sedimentary age of the manganese ores can be constrained from the late Early Carnian to early Late Carnian. Chemical compositions of the manganese ore are characterized by the enrichments in Mn and low concentrations of Co, Ni, and Zn. These geochemical features are similar to those in modern submarine hydrothermal manganese deposits. On the other hand, highly enrichments in V, Ni, Zn, U, and high U/Th ratio were recognized in the massive chert unit below the manganese ores, which indicate deposition under a reducing depositional environment. Our biostratigraphic and geochemical analyses indicate that a redox state change from anoxic to oxic environments occurred in a pelagic deep seafloor in the late Early to early Late Carnian. This interval is known as a period of increased rainfall, named the Carnian Pluvial Event (CPE) in the western Tethys. CPE is characterized by the increased continental weathering which led to the increased nutrient flux and triggered the development of anoxia. It is likely that the Upper Triassic manganese deposits may have been formed during recovery from the reducing environment associated with the CPE.

ST3.7

Towards an Integrated Stratigraphy for the Jurassic

Conveners and Chairpersons

Stephen Hesselbo (University of Exeter)

Grzegorz Pieńkowski (Państwowy Instytut Geologiczny)

Emanuela Mattioli (Claude Bernard University Lyon 1)

Clemens Ullmann (University of Exeter)

Temporal analysis of Karoo-Ferrar large igneous province activity and its relationship to Early Jurassic environmental perturbations

Al Suwaidi A.*[1], Ruhl M.[2] & Mercer C.[3]

[1] Khalifa University of Science and Technology, UAE. [2] Trinity College Dublin, Ireland.
[3] Arizona State University, USA.

Corresponding author email: aisha.alsuwaidi@ku.ac.ae

Keywords: Karoo-Ferrar, Geochronology, T-OAE, Large Igneous Province.

Volcanism in Karoo-Ferrar Large Igneous Province (LIP) is considered to be the trigger for major environmental changes in the Early Jurassic associated with the Toarcian Oceanic Anoxic Event(T-OAE) and carbon isotope excursion (CIE), as well as the Pliensbachian-Toarcian Event and CIE. This environmental change is characterized by carbon cycle perturbations that affected the whole ocean-atmosphere system, as well as mass extinction in the marine realm. Significant work has been undertaken to understand the impact, absolute age and duration of these events in relation to LIP activity. Despite the plethora of vintage and recent geochronological datasets that have been generated for the large igneous provinces of the Early Jurassic, no rigorous statistical analyses of all of the published data have been undertaken to assess the temporal relationship between igneous province activity and environmental changes. Here we provide a compilation of over 200 ages for the entire large igneous province and statistical analyses of these ages. Examination the of the age range and distribution of flood basalts compared to dyke and sill intrusions highlights the complexity of the province and provides insights in to the nature and timing of the T-OAE.

Calcareous nannofossils biostratigraphy and chemostratigraphy of the Pliensbachian-Toarcian interval from the NW Gondwana

Baghli H.*[1-2], Mattioli E.[1-3], Spangenberg J.[4], Bensalah M.[2], Arnaud-Godet F.[1], Pittet B.[1] & Suan G.[1]

[1] Université de Lyon, UCBL, ENSL, CNRS, LGL-TPE, 69622 Villeurbanne, France. [2] Laboratoire de Recherche N° 25, Université de Tlemcen, Algeria. [3] Institut Universitaire de France, Paris, France. [4] Institute of Earth Surface Dynamics (IDYST), University of Lausanne, Building Géopolis, CH-1015 Lausanne, Switzerland.

Corresponding author email: hicham.baghli@univ-lyon1.fr

Keywords: Calcareous nannofossils, Carbon and Oxygen stable isotopes, Early Jurassic, NW Algeria.

Upper Pliensbachian-Lower Toarcian strata across the Jurassic Tethys Ocean record some of the most dramatic environmental changes of Earth's history. A series of ecological events, including crises of marine ecosystems and a widespread anoxia in the Lower Toarcian, are associated with major global carbon cycle perturbations likely linked to the Karoo-Ferrar volcanism. We present here a high-resolution study of the calcareous nannofossil responses to these events. We focused on nannofossils bioevents and assemblages of sections from two regions of NW Algeria, the Ksour Mountains in the Saharian Atlas and the Traras Mountains in the Tell region. Our samples cover the interval from Emaciatum (Late Pliensbachian) to Bifrons Ammonite Zones (Middle Toarcian). We compare nannofossil data of the two Algerian sites to other southern and northern Tethyan sites and to the Toarcian stratotype. The calcareous nannofossil biostratigraphy is compared to chemostratigraphy, namely to $\partial^{13}C$and $\partial^{18}O$ data measured on brachiopod calcite. Despite a moderate-to-poor nannofossil preservation, we have identified the main stratigraphic markers for the considered interval. The nannofossils zones that have been recognized in Raknet El Kahla and Djebel Chemarikh (Ksour Mountains) sections range from NJT4b to NJT8b. The Melalla section documents the NJT5a to NJT7 zones. A higher richness in nannofossils in the Mellala section compared to the Ksour mountains, and a great thickness of the sedimentary succession, allowed us to clearly document all the events across the Pl-Toa transition. Numerous first occurrences of coccolith taxa are recorded in the Pl-Toa interval, further confirming the record of NW Tethys. A peculiar pattern of N-Gondwana sections is that the species *Mithrolitus jansae* is recorded in high abundances in both regions, even in the interval corresponding to the T-OAE. The comparisons between stable isotopes and calcareous nannofossil data provide valuable information on the climatic and environmental evolution in the Pliensbachian-Toarcian interval in the northern margin of Gondwana. The new NW Algerian records reveal a systematic positive offset of ~0.5 ‰ for δ13C values and negative offset of ~1.5 ‰ for δ18O values compared to European sections. We interpret these offsets as mainly reflecting higher seawater temperatures along the southern margin of Tethys. The high proportions of *M. jansae*, which is considered as a deep-dweller taxon, having an ecological affinity for South-Tethyan regions, suggest that the nutricline was deep in the photic zone of NW Algeria paleo-environments. This was probably due to an intense thermic stratification of the water column along the southern margins of Tethys. The consistent presence of *M. jansae* during the T-OAE interval suggests that the spread of anoxic conditions towards surface waters, which is in some cases observed in NW Tethyan regions, was not an effective mechanism in southern Tethys.

Biostratigraphy in the light of C isotope investigations: the Toarcian (Lower Jurassic) in the eastern part of the Central European Basin System

Barth G.*[1], Obst K.[1], Pieńkowski G.[2], Hesselbo S.P.[3] & Leng M.J.[4]

[1] Geological Survey of Mecklenburg-Western Pomerania, Germany. [2] Polish Geological Institute - National Research Institute, Poland. [3] Camborne School of Mines, and Environment and Sustainability Institute, University of Exeter, United Kingdom. [4] British Geological Survey, United Kingdom.

Corresponding author email: gregor.barth@lung.mv-regierung.de

Keywords: chemostratigraphy, biostratigraphy, CEB, Toarcian.

The Toarcian (upper part of the Lower Jurassic) starts in the eastern part of the Central European Basin (CEBS, including the North German Basin – NGB, and the Polish Basin - PB) with a widespread marine transgression from the west (Zimmermann et al., 2018). Thus, the facies changes from W to E from marine mudstones (named Posidonia and Dörnten shales) to brackish-marine silty and sandy deposits (so-called Green Series and Ciechocinek Fm). This is also visible in the biostratigraphic record. More than 300 ammonite occurrences are known from the marine western part of the NGB (Barth et al., 2018). The biostratigraphy of the more brackish eastern part and the PB is largely based on microfossils such as palynomorphs (megaspores), ostracods and foraminifera. Therefore, correlations of different Toarcian sections on regional scales can be difficult. Studies of the fully cored Kb KSS 5/1966 borehole (one of key Lower Jurassic sections in Germany, drilled in the central part of the NGB), allowed detailed facies analysis. Biostratigraphical subdivision based on ammonite finds are best in the lower and uppermost part of the cored Toarcian interval containing index forms. Foraminifers useful for stratigraphic subdivision are restricted to the top of the Toarcian but do not fit with ammonite zonation. In such circumstances, other methods may help to solve the problem. Chemostratigraphy based on newly obtained, high-resolution δ13C data obtained from the separated, homogenous macrophyte fraction from the KSS 5 borehole, reveals a very expanded interval with a negative carbon isotope excursion (CIE) in the Lower Toarcian, correlatable with regional and global standards (e.g. correlation in PB - Hesselbo & Pieńkowski, 2011). The new data allow for a significant correction of to the existing Toarcian stratigraphic subdivision, with profound significance for regional sequence stratigraphic and paleogeographical interpretations.

This paper is a part of the project financed from resources of the Polish National Science Centre, granted on the basis of decision no. DEC-2012/06/M/ST10/00478 and the Polish National Science Centre, granted on the basis of decision no. 2017/25/B/ST10/02235. This is a contribution to the ICDP and NERC project JET (grant number NE/N018508/1) and IGCP project 632 "Continental Crises of the Jurassic".

Barth G., Pieńkowski G., Zimmermann J., Franz M., & Kuhlmann G. (2018) - Palaeogeographical evolution of the Lower Jurassic: high-resolution biostratigraphy and sequence stratigraphy in the Central European Basin. Geological Society, London, Special Publications, 469(1), 341-369.

Hesselbo S.P. & Pieńkowski G. (2011) - Stepwise atmospheric carbon-isotope excursion during the Toarcian Oceanic Anoxic Event (Early Jurassic, Polish Basin). Earth Planet. Sci. Lett., 301, 365–372.

Zimmermann J., Franz M., Schaller A. & Wolfgramm M. (2018) - The Toarcian–Bajocian deltaic system in the North German Basin: Subsurface mapping of ancient deltas-morphology, evolution and controls. Sedimentology, 65(3), 897-930.

The biostratigraphic framework of the Lower and Middle Jurassic in the North German Basin

Barth G.*[1], Zimmermann J.[2], Franz M.[3] & Obst K.[1]

[1] Geological Survey of Mecklenburg-Western Pomerania, Germany. [2] Institut für Angewandte Bauforschung Weimar gGmbH, Germany. [3] University of Göttingen, Germany.

Corresponding author email: gregor.barth@lung.mv-regierung.de

Keywords: CEB, Liassic, Dogger, ammonite zones, Germany.

Basin-scale stratigraphic correlations are the basis for reconstructions of palaeogeographic settings, sea-level records and environmental changes, but also for exploring resources in the deep subsurface. In the Central European Basin System, correlations between fully marine Lower Jurassic successions of the UK, which are well constrained to NW European ammonite zones, and the subsurface of the North German Basin (NGB) rely on a biostratigraphic framework of ammonites, ostracods, foraminifera and palynomorphs (including dinocysts and miospores).

This biostratigraphic framework was established upon vast numbers of macro- and microfossil records from cored wells and outcrops. The fully marine Lower and Middle Jurassic of NW Germany is well calibrated to NW European ammonite zones, subzones and biohorizons due to numerous records of index ammonites (Hoffmann, 1960). The zonations based on ostracods, foraminifera and palynomorphs are well calibrated to ammonite biostratigraphy (overview in Zimmermann et al., 2015). The fully marine to brackish Lower and Middle Jurassic of NE Germany is biostratigraphically constrained by the records of index ammonites, ostracods, foraminifera and palynomorphs. Recently, the records of index fossils from the NGB were merged into a comprehensive data base (Barth et al., 2018).

The biostratigraphic framework of the NGB enabled the reconstruction of the sea-level record and correlation of epicontinental sequences with Boreal and Tethyan cycles (Zimmermann et al., 2015) and the analyses of depositional environments (Zimmermann et al., 2018) and palaeogeographic settings (Barth et al., 2018). Employing stable isotopes ($\delta^{13}C$ and $\delta^{18}O$) and organic geochemistry, ongoing work is focused on environmental perturbations, such as the Late Pliensbachian event and Toarcian OAE.

Barth G., Pieńkowski G., Zimmermann J., Franz M. & Kuhlmann G. (2018) - Palaeogeographical evolution of the Lower Jurassic: high-resolution biostratigraphy and sequence stratigraphy in the Central European Basin. GSL Spec. Pub,. 469, 341–369.

Hoffmann K. (1960) - Jura. In: Boigk H. et al., Eds., Zur Geologie des Emslandes. Geologisches Jahrbuch, Beiheft 37, 46–86.

Zimmermann J., Franz M., Heunisch C., Luppold F. W., Mönnig E. & Wolfgramm M. (2015) - Sequence stratigraphic framework of the Lower and Middle Jurassic in the North German Basin: Epicontinental sequences controlled by Boreal cycles. Palaeogeogr., Palaeoecolo., Palaeoclimatol., 440, 395–416.

Zimmermann J., Franz M., Schaller A. & Wolfgramm M. (2018) - The Toarcian-Bajocian deltaic system in the North German Basin: Subsurface mapping of ancient deltas – morphology, evolution and controls. Sedimentology, 65, 897–930.

Recurrent high-amplitude relative sea-level fluctuations in the Bajocian of Morocco

Bodin S.*[1], Mau M.[1], Danisch J.[1], Sadki D.[2] & Nutz A.[1]

[1] Department of Geoscience, Aarhus University, Denmark. [2] Department of Geology, Faculty of Science, Moulay Ismaïl University, Meknes, Morocco.

Corresponding author email: stephane.bodin@geo.au.dk

Keywords: Central High Atlas, sea-level fluctuations, sedimentary record, medium-term sequences.

Mesozoic sea-level fluctuations have been a matter of debate for several decades, especially the veracity and origin of sea-level cycles that have a periodicity of about 1 Myr or less. The debate lies in the main driving mechanism for sequence development (global sea-level or sediment flux variations) as well as the reason behind water exchanges between the continents and the oceans (glacio- or aquifer-eustatism). In this study, we focus on the carbonate-dominated Bajocian (Middle Jurassic) sedimentary record of the Central High Atlas Basin of Morocco. Several aspects make this basin an appropriate location for discussing Middle Jurassic sea-level changes. Firstly, the outstanding exposures of the High Atlas Mountains, with continuous exposures for 10s of kilometres, allow to describe and track sedimentary packages and their bounding surfaces from proximal to distal settings. Moreover, a combination of ammonite biostratigraphy and carbon-isotopes chemostratigraphy allows to temporarily constrain their development, which permits to correlate and compare the Central High Atlas sedimentary record to other basins. Finally, due to high-subsidence rates, thick Bajocian sedimentary sequences have accumulated, minimizing condensation and hiatus that might prevail in other basins due to a lack of accommodation space creation. Two Bajocian long-term transgressive-regressive (T-R) packages are observed throughout the basin. They are modulated by several medium-term T-R packages, that have each an approximate duration of 1 Myr. These sequences can also be correlated on a basinwide scale. Short-term, decametric T-R sequences are the building blocks of packages. They are not correlatable over long distances. In fact, exceptional exposures clearly highlight their localised extension, showing textbook stacking patterns that can be used to better constrain medium-term sequences. Hence, combined with sedimentological and facies analyses, architectural evidence illustrates that several of the medium-term sequences are characterized by the presence of a falling stage and lowstand systems tracts, demonstrating that medium-term T-R stacking patterns are not solely linked to fluctuation in sediment supply, but also to episodes of relative sea-level fall. This is confirmed by backstripping analysis performed in the center of the Basin. Comparison with Bajocian deposits from Scotland, where good biostratigraphic dating is also available, shows that similar sea-level fall can be observed, highlighting their potential global character. The two long-term Bajocian sequences are more difficult to correlate on a global scale, suggesting that they are rather primarily linked to fluctuation in regional sediment supply or dynamic topography. The cause of the medium-term sea-level fall is currently unknown, but it is here interesting to note that a relatively cool globate climate has been postulated for the Middle Jurassic, leaving the glacio-eustasy hypothesis open.

A « short » duration (300-500 kyr) of the early Toarcian T-OAE and evidence for carbon-reservoir change from the High Atlas (Morocco)

Boulila S.*[1-2], Galbrun B.[2], Sadki D.[3], Gardin S.[4] & Bartolini A.[4]

[1] Sorbonne Université, CNRS, Institut des Sciences de la Terre Paris, ISTeP, Paris, France. [2] ASD/IMCCE, CNRS, Observatoire de Paris, PSL University, Sorbonne Université, Paris, France. [3] Moulay Ismaïl University, Faculty of Science, Department of Geology, Meknes, Morocco. [4] Sorbonne Université, MNHN, CNRS, Centre de Recherche sur la Paléobiodiversité et les Paléoenvironnements, CR2P, Paris, France.

Corresponding author email: slah.boulila@sorbonne-universite.fr

Keywords: T-OAE, Pliensbachian-Toarcian transition, High Atlas, Morocco, Astronomical timescale.

The early Toarcian oceanic anoxic event (T-OAE, ~183 Ma) marks a geologically brief and severe global warming, associated with a profound perturbation in the global carbon cycle. The carbon cycle perturbation has been documented worldwide in marine and continental sedimentary records with a pronounced negative carbon isotope excursion (CIE) in the long-term $\delta^{13}C$ profile. However, the cyclostratigraphically inferred duration of the CIE, which was mainly derived from the Paris (France) and Lusitanian (Portugal) basins, remains controversial, resulting in two notably different estimates of 300–500 and 900 kyr. Here we provide a new early Toarcian cyclostratigraphic record from the High Atlas in Morocco (Talghemt section) to attempt to resolve these controversies. This record is based on high-resolution $\delta^{13}C$ and %CaCO3 data, which capture the Pliensbachian-Toarcian (Pl-To) transition and the T-OAE, and strongly correlate to previous $\delta^{13}C$ key records. Orbital tuning based on the short and long, stable 405 kyr (g2–g5) eccentricity cycles, provides a duration of ~400 to ~500 kyr for the T-OAE. This duration is very close to that previously inferred from the Sancerre Core in the Paris Basin (300 to 500 kyr), and similar to that recently revised from the Peniche section (Lusitanian Basin, Portugal) (~472 kyr). In addition, the 405 kyr %$CaCO_3$ timescale at Talghemt calibrates high-frequency $\delta^{13}C$ variations at the Pl-To transition and the initiation part of the T-OAE to the obliquity cycle band, thus concurring with previous studies for obliquity forcing during these time intervals. The 405 kyr calibrated O1 obliquity period (~30 kyr) is shorter than the astronomically predicted one (~35 kyr), hence supporting the hypothesis of shortened obliquity periods during the Early Jurassic, and providing constraints on Earth's tidal dissipation factor during this geologic epoch. Finally, a remarkable phase change between %$CaCO_3$ and $\delta^{13}C$ orbitally paced cycles is observed for the first time at the T-OAE, suggesting a change in the carbon reservoir in relation with volcanically released greenhouse gases and major carbonate crisis. However, this phase shift is not observed at the Pl-To event implying different causal mechanisms on the carbon cycle perturbation between the Pl-To and T-OAE events (Boulila et al., 2019).

Boulila S., Galbrun B., Sadki D., Gardin S. & Bartolini A. (2019) - Constraints on the duration of the early Toarcian T-OAE and evidence for carbon-reservoir change from the High Atlas (Morocco). Global and Planetary Change, 175, 113–128.

High-resolution integrated stratigraphy and geochemistry of the Late Pliensbachian and Early Toarcian sediments of the Lower Saxony Basin

Celestino R.[1], Ruhl M.[2], Dickson A.[3], Jenkyns H.C.[4], Idiz E.[4], Mattioli E.[5], Weijers J.[6] & Hesselbo S.P.*[1]

[1] University of Exeter, UK. [2] Trinity College Dublin, Ireland. [3] Royal Holloway University of London, UK. [4] University of Oxford, UK. [5] Université Lyon 1, France. [6] Shell, Netherlands.

Corresponding author email: s.p.hesselbo@exeter.ac.uk

Keywords: Jurassic, multi-proxy, Toarcian, OAE, Germany.

The Early Jurassic epoch was marked by widespread marine anoxia and euxinia, in response to climatic and environmental change associated with perturbations to the global carbon cycle. New data have been obtained through a multi-proxy approach to reconstruct the depositional environment and geochemical evolution of the Lower Saxony Basin (LSB), Germany, during the formation of the organic-rich Posidonienschiefer Formation, commonly associated with the Toarcian Oceanic Anoxic Event (T-OAE). High-resolution carbon isotope stratigraphy from cores drilled in the LSB in combination with calcareous nannofossil biostratigraphy allows the identification of the T-OAE, shows that the event is recorded at the base of the Posidonienschiefer formation, and indicates that the onset of organic-rich sedimentation coincided with the carbon cycle perturbation and climatic changes. The carbon isotope dataset from the LSB is calibrated with new calcareous nannofossil biostratigraphic data, which allows the assignment of nannofossil zones from the Late Pliensbachian to the Middle/Late Toarcian. Geochemical data further show that the black shale unit was deposited under persistent euxinic conditions that reached the photic zone, resulting in an efficient burial of organic carbon and a negative feedback mechanism to counter the high $p\mathrm{CO}_2$ conditions of the Toarcian.

The Upper Jurassic foraminiferal *Pseudolamarckina pseudorjasanensis* Zone: a marker level for interregional correlations between Subboreal and Arctic regions of Northern Eurasia

Colpaert C.*[1-2] & Nikitenko B.L.[1-2]

[1] Trofimuk Institute of Petroleum Geology and Geophysics, Siberian Branch of the Russian Academy of Sciences, Novosibirsk, Russia. [2] Novosibirsk State University, Novosibirsk, Russia.

Corresponding author email: clementinecolpaert@gmail.com

Keywords: Foraminifera, Kimmeridgian, Biostratigraphy, Palaeoecology, Palaeobiogeography, Eurasia.

The study of the Kimmeridgian strata of Europe and Western Siberia dates back to the end of the 19th century. However, first biostratigraphical analyses were performed near the second half of the 20th century only. At that time, most of the micropalaeontological investigations across the different regions of Europe and Western Siberia were performed separately. Various interpretations on the observed taxa and evolving different authors, resulted in problematic interregional correlations. In that way, recent studies had proved many of the previously described Kimmeridgian index-species of the genus *Pseudolamarckina* must be attributed to a single species defined by high intraspecific variability (Levchuk and Nikitenko, 2010; Colpaert and Nikitenko, 2019). Furthermore, the taxonomical revision of some important marker-species has shown they were defined during the Late Jurassic by a wide spread palaeobiogeographic distribution. Therefore, the geographical distribution of the foraminifera P. pseudorjasanensis Zone is identified through northern regions of western Europe (Kuznetsova, 1979), eastern Europe (Bielecka and Kuznetsova, 1969), european part of Russia (Mitta et al., 2012; Colpaert et al., 2017), Western and Eastern Siberia, northern Alaska and Arctic Canada (Nikitenko, 2009). The P. pseudorjasanensis Zone ranges from the uppermost Lower to Upper Kimmeridgian and is defined by high lateral and vertical variations across various palaeobasins.

Analyses of the composition of the foraminiferal associations shows the P. pseudorjasanensis Chron was defined by a warm climate extended across all territories currently situated in the Boreal-Atlantic Realm, as well as southern Arctic Realm. Subsequently, cool climate was restricted to the territories currently associated to the regions on the northern part of the Arctic Realm (Boucot et al., 2013), whereas arid and tropical climates prevailed in regions of the Peri-Tethys. From the end of the Late Oxfordian to the Kimmeridgian, the overall teritory of Submediterranean to Arctic regions was characterized by a general transgressive event, associated with a continuous rise of the temperature (Zakharov et al., 2005; Nunn et al., 2009). The wide deposition of fine-grained substrate associated with normal salinity and high oxygenation have favored the development of rather similar foraminiferal associations dominated by the genus *Pseudolamarckina*. Finally, the development of palaeogeographically well-connected palaeobasins probably resulted in the formation of massive microfossils migrations (Oxford, 2004; Colpaert et al., 2017). In that way, the analysis of the palaeobiogeographic distribution of some important benthic taxa underlines they were initially restricted to western and central Europe from the Callovian to the Oxfordian, and spread toward the North during the Kimmeridgian only. Finally, only a few species spread toward the East-South East on the direction of the Tethys Ocean: i.e. Syria (Kuznetsova et al., 1996). Indeed, the occurrence of the Carbonate Helvetic Shelf as an indicator of warm tropical environment may had act like a climatic barrier for the distribution of Subboreal to Arctic microorganisms.

We are grateful for the financial support of the Russian Science Foundation: project no. 18-17-00038.

Bielecka W. & Kuznetsova K.I. (1969) - Foraminifery i paleogeografiya kimeridzhskogo veka Vostochnoy Yevropy (Pol'sha i Yevropeyskaya chast' SSSR). Voprosy mikropaleontologii, 12, 58-80.

Boucot A.J., Chen Xu & Scotese C.R. (2013) - Phanerozoic Paleoclimate: An Atlas of Lithologic Indicators of Climate, SEPM Concepts in Sedimentology and Paleontology. Society for Sedimentary Geology, Tulsa.

Colpaert C., Pestchevitskaya E.B. & Nikitenko B.L. (2017) - Upper Jurassic foraminifera, dinoflagellates and terrestrial sporomorphs from the Gorodishche Section (Ul'yanovsk Region, East European Platform, Russia): biostratigraphic, palaeoenvironmental and palaeobiogeographical implications. Revue de micropaléontologie, 60(4), 549-572.

Colpaert C.P.A.M. & Nikitenko B.L. (2019) - Pseudolamarckina pseudorjasanensis Dain, 1967 (Foraminifera) as a Kimmeridgian marker species and its significance to biostratigraphy, palaeoecology, and palaeobiogeography: Polar Research, in press.

Kuznetsova K.I. (1979) - Stratigrafiya i paleobiogeografiya pozdney yury Boreal'nogo poyasa po foraminiferam. Moscow: Nauka.

Kuznetsova K.I., Grigelis A.A., Adjamian J., Jarmakani E. & Hallaq L. (1996) - Zonal Stratigraphy and Foraminifera of the Tethyan Jurassic (Eastern Mediterranean): Gordon and Breach Publishers.

Levchuk L.K. & Nikitenko B.L. 2010. Kelloveyskiye i pozdneyurskiye foraminifery zapadnoy i tsentral'noy chastey zapadno-Sibirskoy nizmennosti. Novosti paleontologii i stratigrafii: Prilozheniye k zhurnalu "Geologiya i geofizika" (Palaeontological and stratigraphical news: Supplement to the review of Geology and Geophysics), 51 (14), 85-110.

Mitta V.V., Alekseev A.C. & Shik C.M. (eds.) (2012) - Unifitsirovannaya regional'naya stratigraficheskaya skhema yurskikh otlozheniy Vostochno-Yevropeyskoy platformy. Ob'yasnitel'naya zapiska. Moscow: PIN RAN –VNIGRI.

Nikitenko B.L. (2009) - Stratigrafiya, paleobiogeografiya i biofatsii yury Sibiri po mikrofaune (foraminifery i ostrakody). Novosibirsk: Parallel.

Nunn E.V., Price G.D., Hart M.B., Page K.N., & Leng M.J. (2009) - Isotopic signals from Callovian—Kimmeridgian (Middle—Upper Jurassic) belemnites and bulk organic carbon, Staffin Bay, Isle of Skye, Scotland. J. Geol. Soc. London, 166, 633—641.

Oxford M.J. (2004) - Foraminiferal distribution and sequence stratigraphy of Oxfordian successions in the Wessex/Anglo-Paris Basin [Unpublished PhD thesis]: University of Plymouth.

Zakharov V.A., Baudin F., Dzyuba O.S., Daux V., Zverev K.V. & Renard M. (2005) - Isotopic and faunal record of high paleotemperatures in the Kimmeridgian of the Subpolar Urals). Russian Geology and Geophysics, 1, 3-20.

Pliensbachian calcareous nannofossil paleoecology in the E Rodiles section (Asturias, N Spain): a key location connecting the Boreal and Tethyan Realms

Fraguas A.[1]*, Comas-Rengifo M.J.[1], Gómez J.J. & Goy A.[1]

[1]Departamento de Geodinámica, Estratigrafía y Paleontología, Facultad de Ciencias Geológicas, Universidad Complutense de Madrid.

Corresponding author email: arfragua@geo.ucm.es

Keywords: Pliensbachian, Lower Jurassic, Northern Spain, Calcareous nannofossils, paleotemperatures, productivity.

Quantitative analysis performed on 51 Pliensbachian calcareous nannofossil assemblages from the E Rodiles section (N Spain) have allowed us to determine the palaeoenvironmental changes occurred during this time interval in a key location connecting the Boreal and Tethyan Realms (Fraguas et al., 2018). The results were compared to already published stable isotope data and TOC (Gómez et al., 2016). During the lowermost Pliensbachian, when seawater temperatures were around 16ºC, nannofossil assemblages were dominated by *Schizosphaerella punctulata* and *Parhabdolithus* spp., suggesting their affinity for rather cold waters, as it was hypothesized by Fraguas et al. (2012) for *Schizosphaerella*. The Ibex Ammonite Zone (AZ) was characterized by the dominance of *Similiscutum* spp., interpreted as meso-eutrophic taxa (Reggiani et al., 2010), and *M. elegans*. Hence, we can infer eutrophic conditions during the Ibex AZ in the studied section, with nutrient-rich and warm seawaters, as the stable isotope and TOC curves support. *Crepidolithus* spp. show an opportunistic behavior, with fluctuations in their relative abundances all along the studied interval, including peaks within the Jamesoni, Davoei and Margaritatus AZs, characterized by different paleoenvironmental conditions. The first occurrence of *Calcivascularis jansae* took place in the Margaritatus AZ, when warm Tethyan currents were blowing northwards. This taxon became especially abundant during the Spinatum AZ, when there was a cooling event based on oxygen isotope data, dominating the nannofossil assemblages together with *Tubirhabdus patulus* and *Lotharingius hauffii*, interpreted as taxa with cold water affinities (Fraguas et al., 2012). These variations in relative abundances, which perfectly match with the stable isotope and TOC curves, could be related to paleotemperatures, primary productivity and changes in water current circulation in this connection area.

This work was supported by the Spanish research projects CGL2015-66604-R and UCM-910431.

Fraguas A., Comas-Rengifo M.J., Gómez J.J. & Goy A. (2012) - The calcareous nannofossil crisis in Northern Spain (Asturias province) linked to the Early Toarcian warming- driven mass extinction. Mar. Micropaleontol., 94-95, 58-71.

Fraguas A., Comas-Rengifo M.J., Goy A. & Gómez J.J. (2018) - Upper Sinemurian–Pliensbachian calcareous nannofossil biostratigraphy of the E Rodiles section (Asturias, N Spain): a reference section for the connection between the Boreal and Tethyan Realms. Newsl. Stratigr., 51, 227-244.

Gómez J.J., Comas-Rengifo M.J. & Goy A. (2016) - Palaeoclimatic oscillations in the Pliensbachian (Lower Jurassic) of the Asturian Basin (Northern Spain). Clim. Past, 12, 1199-1214.

Reggiani L., Mattioli E., Pittet B., Duarte L.V., Veiga de Oliveira L.C. & Comas-Rengifo M.J. (2010) - Pliensbachian (Early Jurassic) calcareous nannofossils from the Peniche section (Lusitanian Basin, Portugal): A clue for palaeoenvironmental reconstructions. Mar. Micropaleontol., 75, 1-16.

Integrated bio-, magneto- and chemostratigraphy and clay mineral data from the Kimmeridgian – Tithonian pelagic Fatric succession in the Western Tatra (Dolina Lejowa section; Central West Carpathians, Poland)

Grabowski J.*[1], Jach R.[2], Iwańczuk J.[1], Reháková D.[3] & Derkowski A.[4]

[1] Polish Geological Institute - National Research Institute, Warsaw, Poland. [2] Jagiellonian University, Cracow, Poland
[3] Comenius University, Bratislava, Slovakia. [4] Polish academy of Sciences, Cracow, Poland.

Corresponding author email: jacek.grabowski@pgi.gov.pl

Keywords: Kimmeridgian, Tithonian, Carpathians, pelagic sediments, integrated stratigraphy.

Kimmeridgian – Tithonian pelagic succession of the Lejowa Valley section, ca. 47 m in thick, originated in the Fatricum basin which was one of paleogeographical domains of Western Tethys. This section comprises uppermost part of calcareous radiolarites (Czajakowa Radiolarite Formation), red platy and nodular limestones of Ammonitico rosso type (Czorsztyn Limestone Formation) and grey platy limestones of the Jasenina Formation. Integration of biostratigraphy (calcareous dinocysts and calpionellids) with magneto- and chemostratigraphy allowed to create a high resolution chronostratigraphic framework. The interval studied spreads from the Upper Kimmeridgian (Moluccana Zone) to Upper Tithonian (Crassicollaria Zone). According to preliminary magnetostratigraphic interpretation it corresponds to polarity zones from M24r to lower part of M19n. The Kimmeridgian/Tithonian boundary (Borzai/Pulla zonal boundary) falls in the lower part of red platy and nodular limestones of Ammonitico rosso type (Czorsztyn Limestone Formation). The sedimentation of red nodular limestone terminates in the Malmica or Semiradiata Zone of Lower Tithonian. Calcareous radiolarites of Czajakowa Formation contain Bositra, radiolarian-Bositra and Bositra-radiolarian-spiculite microfacies. Red platy and nodular limestones of Ammonitico rosso type (Czorsztyn Limestone Formation) consist microfacies with Saccocoma (Saccocoma-radiolarian, Saccocoma-Globochaete, radiolarian-Saccocoma-Globochaete and Saccocoma wackeston/packstone). Saccocoma microfacies continue higher up into the lower part of Jasenina Formation. In the upper part of this formation the calpionellids start to occur and they stepwise dominate over the the saccocomids. The Saccocoma microfacies finally disappear in the polarity chron M19r and combinations of calpionellid – Globochaete – radiolarian microfacies is the most common. The carbon isotopic ratio (δ13C) reveals a long term decrease from ca. 2.5 ‰ in the Upper Kimmeridgian to ca. 1 ‰ in the Upper Tithonian. The major decrease between 2.5 ‰ and 1.5 ‰ occurs just in the Kimmeridgian/Tithonian boundary interval. Magnetic susceptibility (MS) in the grey coloured Jasenina Formation correlates very well with lithogenic elements and might be regarded as reliable proxy of terrigenous input. The correlation is not as evident in reddish Czajakowa and Czorsztyn formations due to more complex rock magnetic properties and mineralogical source of MS (co-occurrence of magnetite and hematite) The amount of terrigenous elements is apparently lower in the Upper Kimmeridgian/Lower Tithonian than in the Upper Tithonian. Large increase of terrigenous input is observed in the polarity zone M20n. Burial diagenesis, however, imposed significant alteration of the primary mineral composition. Radiolaria's opal changed to quartz that is indistinguishable from the detrital quartz component using X-ray diffractometry. Kaolinite and potassium feldspar are absent, implying high burial temperatures, whereas the clay minerals composition is dominated by illite (illitic member of mixed-layered illite-smectite mineral) with minor chlorite.

Carbon and oxygen isotope records from the southern Eurasian Seaway following the Triassic-Jurassic boundary: parallel long-term enhanced carbon burial and seawater warming

Hesselbo S.P.*[1], Korte C.[2], Ullmann C.V.[1] & Ebbesen A.L.[2]

[1] University of Exeter. [2] University of Copenhagen.

Corresponding author email: s.p.hesselbo@exeter.ac.uk

Keywords: Jurassic, carbon oxygen isotopes, Eurasian Seaway.

Carbon and oxygen isotope analyses of benthic and necktobenthic invertebrates have been shown to be faithful recorders of seawater isotope geochemistry and/or temperature. In this study we present an extensive dataset from Lower Jurassic (Hettangian and lower Sinemurian) molluscs and brachiopods collected from biostratigraphically well-calibrated UK coastal outcrops (Bristol Channel and Hebrides basins), which lay palaeogeographically in the southern part of the Laurasian Seaway that connected the Tethys and Boreal oceans. All samples have been subject to screening for diagenesis on the basis of elemental composition, light microscopy, and SEM observations. In the case of some localities within the Hebrides Basin, alteration by hydrothermal systems around Paleogene intrusions has led to re-setting of carbonate oxygen isotopes, but original carbon isotope values from the shells are largely preserved. After the prominent and short-lived, ~3 per mil $\delta^{13}C_{carb}$ amplitude positive carbon-isotope excursion (CIE) that immediately follows the T-J boundary (in the *tilmanni* ammonite biozone), a pronounced negative CIE (the so-called Main Negative CIE) lasts the entire Hettangian stage, after which carbon-isotope values of the skeletal carbonate again trend towards progressively more positive values over several million years. The heaviest $\delta^{13}C_{carb}$ values of about ~ +4.3 per mil are evident in the mid Sinemurian and are comparable with values observed from the *tilmanni* Zone, and from immediately before the later Toarcian Oceanic Anoxic Event. This long-term positive hump, which confirms trends derived from bulk organic matter carbon-isotope records, is supporting evidence of prolonged enhanced organic carbon burial that is inferred to have occurred in the extensive system of lacustrine and marine rifts that traversed a fragmenting Pangaea after emplacement of the Central Atlantic Magmatic Province. In parallel, oxygen-isotope values of the skeletal carbonate show a continuous downward trend from the T-J boundary (~ 0 per mil $\delta^{18}O_{carb}$ in the *tilmanni* Zone) to the mid Sinemurian (~ –3 per mil $\delta^{18}O_{carb}$ in the *turneri* Zone). Oxygen-isotope values may be interpreted as due to increasing palaeotemperature, and/or a component derived from meteoric or cryospheric water; in the case of the Laurasian Seaway, palaeoceanographic considerations point towards a dominant palaeotemperature signal. Consequently, any atmospheric carbon-dioxide drawdown effect on global palaeotemperatures, as suggested by progressively increasing$\delta^{13}C_{carb}$ values, was more than counterbalanced in the seaway by regional processes that led to significantly warmer bottom water temperatures.

The dinoflagellate cysts of Jurassic-Cretaceous Moroccan formations: stratigraphy and paleoenvironment

Hssaida T.*[1], Benbouziane A.[1], Essamoud R.[1], Hamoumi N.[2], Bouwafoud A.[1], Chakir S.[1], Jaydawi S.[1], Khafou H.[1], Maatouf W.[1] & Rachid J.[1]

[1] Faculty of sciences Ben M'sik, University of Hassan II, Casablanca, Morocco. [2] Facuty of sciences Rabat, University of Mohammed V, Morocco.

Corresponding author email: touria.hssaida@gmail.com

Keywords: dinoflagellate cysts, palynostratigraphy, Mesozoic, Morocco, palaeoenvironment, Jurassic, Cretaceous.

This study is a palynostratigraphic synthesis work, based on dinoflagellate cysts, carried out on several polls and Moroccan Mesozoic land cuts (Jurassic - Cretaceous). Currently, thanks to dinoflagellates, it has been possible to establish stratigraphic scales, unequalled finesse, especially for the field Boreal and sub-Boreal. For the Tethysian domain (eastern North Morocco: Guercif basin, the Atlantic margin: the Essaouira - Agadir basin, the Rifain domain (external Rif, internal Rif, Mesorif) and the South Rifian wrinkles, the Atlas domain: Middle Atlas and the moroccan Sahara), and precision dating done in several polls and land cuts. In addition to their stratigraphic role by fossilized cysts in sediments, dinoflagellates have a distribution according to the nature of the sediments, the physico-chemical parameters and a latitudinal distribution: from the coast to the open sea, this gives them the title of excellent ecological marker. Thus the variations in the composition of their assemblages in sediments, allowed us to reconstruct the palaeoenvironments (deposit environment, bathymetry ..) in all studied regions.

High-Resolution Early Jurassic Palaeoclimate Record: Geochemistry of the Burton Row Borehole, Bristol Channel Basin, UK

Hudson A.J.L.*[1], Riding J.B.[2], Al-Suwaidi A.[3], Ullmann C.V.[1], Szűcs D.[1] & Hesselbo S.P.[1]

[1] Camborne School of Mines, University of Exeter. [2] British Geological Survey.
[3] Department of Geosciences, Khalifa University

Corresponding author email: alex.hudson@exeter.ac.uk

Keywords: stratigraphy, Sinemurian, Jurassic, climate, geochemistry, isotopes.

Palaeoclimate research in the Jurassic has historically focussed on geologically short, large-scale events such as the Triassic-Jurassic boundary mass extinction and the Toarcian Oceanic Anoxic Event (T-OAE). However, the climate of the remaining 17 Myr of the Early Jurassic is significantly understudied, this despite the identification of several smaller magnitude and, crucially, less well understood carbon-cycle perturbations such as the 'Liasidium Event' (*obtusum-oxynotum* zones, Sinemurian; Riding et al, 2013) and the Sinemurian-Pliensbachian boundary event (SPBE; Korte and Hesselbo, 2011). The Liasidium Event is a –ve carbon isotopic excursion (CIE) associated with thermophilic palynological taxa and has been compared with larger hyperthermals such as the T-OAE (Riding et al., 2013). Other high-resolution studies have not fully resolved this event due to poor biostratigraphic dating (Massetti et al., 2017) or significant hiatus (Jenkyns and Weedon, 2013), limiting the scope of interpretation. Here we provide a new, high resolution, multiple proxy dataset on the Sinemurian and Early Pliensbachian stages from the Burton Row Borehole, Somerset, UK, which is biostratigraphically complete at the ammonite zonal level. Carbon isotope stratigraphy ($\partial^{13}C_{org}$) is complemented with elemental analysis (XRF) and Rock Eval datasets to understand the long-term carbon cycle and palaeoenvironmental evolution. Results show a fluctuating carbon isotope profile at the base of the Sinemurian (*bucklandi – Semicostatum*) with generally low isotopic values (-29 ‰ $\partial^{13}C_{org}$). This interval is a period of significant burial of organic matter with high total organic carbon (TOC). A broad long-term positive trend is present beginning in the *semicostatum* Zone and reaching an optimum in the *turneri* Zone (-24 ‰ ∂13Corg). Two large negative CIE's are identified, first a sharp excursion in the mid-Sinemurian, *obtusum* Zone (4‰ –ve CIE) and second the broader CIE in the *jamesoni*Zone, early Pliensbachian (3‰ –ve CIE). Both CIE's are associated with significant organic matter enrichment. In the *obtusum*CIE organic-rich shales, elevated pyrite and redox-sensitive elements suggest locally developed bottom water anoxia. The strata of *jamesoni* ZoneCIE, although enriched in organic matter does not show enrichment in redox-sensitive elements. These new stratigraphic data through the Early Jurassic support the presence of regionally significant palaeoclimatic events in the mid-Sinemurian and at the Sinemurian-Pliensbachian boundary. The data highlight several similarities between the Liasidium Event and the T-OAE, albeit on a smaller scale but raises questions as to the exact position of this stratigraphic feature when compared to previous studies. This new study goes some way to addressing the notable scarcity of long continuous high-resolution stratigraphic records through the Sinemurian and helps to contextualise previous focused studies.

Jenkyns H.C. & Weedon G.P. (2013) - Chemostratigraphy (CaCO3, TOC, δ13Corg) of Sinemurian (Lower Jurassic) black shales from the Wessex Basin, Dorset and palaeoenvironmental implications. Newsl. Stratigr., 46, 1–21.

Korte C. & Hesselbo S.P. (2011) - Shallow marine carbon and oxygen isotope and elemental records indicate icehouse-greenhouse cycles during the Early Jurassic. Paleoceanography, 26(4).

Masett D., Figus B., Jenkyns H.C., Barattolo F., Mattioli E. & Posenato R. (2017) - Carbon-isotope anomalies and demise of carbonate platforms in the Sinemurian (Early Jurassic) of the Tethyan region: evidence from the Southern Alps (Northern Italy). Geol. Mag., 154, 625–650.

Riding J.B., Leng M.J., Kender S., Hesselbo S.P. & Feist-Burkhardt S. (2013) - Isotopic and palynological evidence for a new Early Jurassic environmental perturbation. Palaeogeogr. Palaeoclimatol. Palaeoecol., 374, 16–27.

Csővár revisited: new geochemical data to the integrated stratigraphy of a Triassic-Jurassic boundary section in the western Tethys

Kovács E.B.*[1], Demény A.[2], Ruhl M.[3] & Pálfy J.[1]

[1] Eötvös Loránd University, Hungary. [2] Institute for Geochemical Research, Hungarian Academy of Sciences, Hungary. [3] Trinity College Dublin, Ireland.

Corresponding author email: kovacsemmablanka@gmail.com

Keywords: carbon isotope, mercury, CAMP volcanism.

One of the canonical Big Five mass extinctions and major environmental changes occurred at the end of the Triassic. Despite vigorous research in recent years, many questions remain open regarding the details of timing, driving forces and mechanism of this event. Here we combine integrated stratigraphic analyses with the application of geochemical proxies at improved resolution to gain new insights. The Vár-hegy section at Csővár (Hungary) presents one of the few continuous and reasonably fossiliferous marine sedimentary records across the Triassic-Jurassic boundary. Previous studies were among the first to recognize a major negative carbon isotope anomaly near the system boundary (Pálfy et al., 2001), confirmed by subsequent work (Pálfy et al., 2007). The Upper Triassic to lowermost Jurassic Csővár Limestone Formation was deposited in an intraplatform sedimentary basin. The system boundary is defined by micropaleontological analysis of conodonts, radiolarians and foraminifera, as well as ammonoid biostratigraphy (Pálfy et al., 2007). Carbon isotope chemostratigraphy offers the best potential for global correlation (Korte et al., 2019), but ambiguity remains as not all of the anomalies reported from other sections appear at Csővár. To resolve this problem, we have started to develop an improved carbon isotope curve from the section, on the basis of higher resolution sampling over an extended stratigraphic interval and measuring both carbonate and organic carbon. In addition to new total organic content measurements, we also investigated changes in Hg as this emerging geochemical proxy has been demonstrated to be useful to track coeval volcanism. The Central Atlantic Magmatic Province (CAMP) is generally assumed to have a role in the end-Triassic global change and mass extinction, and observed peaks in Hg abundance provide some of the most powerful evidence for this link (Percival et al., 2017). Our new carbon isotope curve from Csővár, along with new data that document stratigraphic changes in Hg concentration and the Hg/TOC ratio across the Triassic-Jurassic boundary reveal further details to the link between CAMP volcanism, carbon cycle perturbation and biotic turnover across the Triassic-Jurassic boundary.

Korte C., Ruhl M., Pálfy J., Ullmann C.V. & Hesselbo S.P. (2018) - Chemostratigraphy across the Triassic–Jurassic boundary. AGU Geophys. Monogr. Ser., 240, 185-210.

Pálfy J., Demény A., Haas J., Hetényi M., Orchard M. & Vető I. (2001) - Carbon isotope anomaly and other geochemical changes at the Triassic-Jurassic boundary from a marine section in Hungary. Geology, 29, 1047-1050.

Pálfy J., Demény A., Haas J., Carter E.S., Görög Á., Halász D., Oravecz-Scheffer A., Hetényi M., Márton E., Orchard M.J., Ozsvárt P., Vető I., & Zajzon N. (2007) - Triassic-Jurassic boundary events inferred from integrated stratigraphy of the Csővár section, Hungary: Palaeogeography, Palaeoclimatology, Palaeoecology, 244(1-4), 11-33.

Pálfy, J., Demény, A., Haas, J., Hetényi, M., Orchard, M., & Vető, I., 2001. Carbon isotope anomaly and other geochemical changes at the Triassic-Jurassic boundary from a marine section in Hungary: Geology, 29(11), 1047-1050.

Percival, L. M. E., Ruhl, M., Hesselbo, S. P., Jenkyns, H. C., Mather, T. A., Whiteside, J. H. 2017. Mercury evidence for pulsed volcanism during the end-Triassic mass extinction. Proceedings of the National Academy of Sciences, 114(30), 7929-7934.

Effect of the Toarcian Oceanic Anoxic Event on a hemipelagic carbonate system: new results from the Western Carpathians

Müller T.[1], Pálfy J.*[2-3], Karancz Sz.[2-4], Mattioli E.[5], Schlögl J.[6], Šimo V.[1] & Tomašových A.[1]

[1] Earth Science Institute, Slovak Academy of Sciences, Slovakia. [2] Department of Geology, Eötvös Loránd University, Hungary. [3] MTA-MTM-ELTE Research Group for Paleontology, Hungary. [4] Alfred-Wegener-Institute for Polar and Marine Research, Germany. [5] Université de Lyon, UCBL, ENSL, CNRS, LGL-TPE, France. [6] Department of Geology and Paleontology, Comenius University, Slovakia.

Corresponding author email: palfy@elte.hu

Keywords: anoxia, black shale, carbon isotope excursion, nannoplankton, trace fossils, ammonites.

The Toarcian Oceanic Anoxic Event (T-OAE or Jenkyns event) was one of the most severe environmental perturbations of the Mesozoic Era coupled with second order mass extinction, anoxia, carbon cycle perturbation and marine calcification crisis. However, the impact of these phenomena, especially the calcification crisis is still poorly understood. Here we report new geochemical and paleontological data from Skladana Skala, a section in the Western Carpathians in central Slovakia, composed of thick, rhythmic series of carbonate rich marls ($CaCO_3$ from 40 to 80%) spanning the Upper Pliensbachian–Lower Toarcian, with a 60 cm thick pyritic black shale intercalation representing the T-OAE. Carbon isotope records ($\delta^{13}C_{carb}$ and $\delta^{13}C_{TOC}$) show a broad positive excursion in the Lower Toarcian interrupted by a sharp negative excursion recorded only in the $\delta^{13}C_{TOC}$ with very low values (~31‰), restricted to the black shale unit where TOC reaches 2–3% (compared to a background of ~0.3%) and $CaCO_3$ drops to 3–7%. Ammonites above the black shale unit indicate the presence of the Falciferum Zone. Calcareous nannofossils are completely absent in the Upper Pliensbachian and lowermost Toarcian at Skladana Skala, but they occur with relatively high diversity above the T-OAE interval, allowing to identify the boundary between NJT6 and NJT7 nannozones. The last occurrence of *Mitrolithus jansae* matches with the end of the negative carbon isotope excursion corresponding to the T-OAE, as observed in other Tethyan sections. In the interval above the black shale, nannofossil assemblages document the amelioration of environmental conditions and appear to be primary carbonate producers as suggested by the matching pattern of $CaCO_3$ content and the number of individuals. Trace fossil assemblages indicate significant changes in oxygen availability on the seafloor, suggesting a trend towards oxygen depletion in the Lower Toarcian with a total absence of bioturbation in the black shale unit, and fluctuating trace fossils diversity, still indicating low oxygen levels above the T-OAE. These results suggest that carbonate systems collapsed during the T-OAE in the Western Carpathians, which might reflect a more widespread crisis that affected the hemipelagic-pelagic carbonate systems in the NW Tethyan realm. Although direct evidence is still lacking, we speculate that a combination of effects of global warming, oceanic anoxia and acidification explain the observed phenomena.

Updated radiolarian zonation for the Jurassic in Japan and the western Pacific: a framework for the oceanic plate stratigraphy of the Panthalassa

Matsuoka A.*[1] & Ito T.[2]

[1] Department of Geology, Faculty of Science, Niigata University, Japan. [2] Research Institute of Geology and Geoinformation, Geological Survey of Japan, AIST, Japan.

Corresponding author email: amatsuoka@geo.sc.niigata-u.ac.jp

Keywords: Jurassic, radiolaria, biostratigraphy, Panthalassa, accretionary complex.

Radiolarian zonation for the Jurassic and Lower Cretaceous using data from land sections in Japan and deep sea cores in the western Pacific was proposed in Matsuoka (1995). Since then, taxonomic and biostratigraphic studies on Jurassic radiolarians have been actively carried out in Europe, North America, Asia and Antarctica. The accumulation of new data in the last two decades requires a revision of the zonation and age assignments. Although revision of the zonation was briefly reported elswhere, detailed explanations have not been demonstrated yet. An updated version of the zonal scheme of Matsuoka (1995) for the entire Jurassic in Japan and the western Pacific is presented. The major modifications are as follows: The *Bipedis horiae* Zone (JR0) is added below the *Parahsuum simplum* Zone (JR1). The base of the *Bipedis horiae* Zone (JR0) is defined by the first occurrence of *Bipedis horiae* Sugiyama and is located a little higher than the Triassic (Rhaetian)/ Jurassic (Hettangian) boundary. The base of the *Parahsuum simplum* Zone is dated within the Sinemurian. The *Tricolocapsa plicarum* Zone (JR4), *Tricolocapsa conexa* Zone (JR5), and *Stylocapsa*(?) *spiralis* Zone (JR6), and *Pseudodictyomitra primitiva* Zone (JR8) are replaced by the *Striatojaponicapsa plicarum* Zone (JR4), *Striatojaponicapsa conexa* Zone (JR5), *Kilinora spiralis* Zone (JR6), and *Loopus primitivus* Zone (JR8), respectively, in accordance to the change of generic assignment of zone-nominal species. In the framework of the updated version of Jurassic zonation, the oceanic plate stratigraphy of the Panthalassa obtained from accretionary complex geology in and around Japan is presented.

Matsuoka A. (1995) - Jurassic and Lower Cretaceous radiolarian zonation in Japan and in the western Pacific. Island Arc, 4, 140–153.

Towards a High Resolution ammonite-based Biochronology for the Lower Toarcian Oceanic Anoxic Event (TOAE)

Page K.N.*

Geodiversity & Heritage.

Corresponding author email: kevinnpage@gmail.com

Keywords: TOAE, Ammonites, Toarcian, Stratigraphy, Jurassic.

Nevertheless, correlations between northern (i.e. Subboreal in a bioprovincial sense) and Sub-Mediterranean and Mediterranean areas in Europe using ammonites remain poor due to a frequent lack of understanding of 'southern' faunas by authors in northern areas and *vice versa* for authors in southern areas. This issue is particularly problematical for the Subboreal 'type' region of the TOAE (North Yorkshire, England), where the presence of many species of correlative importance in southern areas has been overlooked. Similarly, many works from more southern areas of Europe, such as Spain, Portugal and Italy tend to emphasise differences rather than similarities, in particular through the common use of different zonal nomenclatures – despite many species being common to all provinces. A new section in the pelagic facies of the Beacon Limestone Formation in Somerset, SW England, however, is yielding faunas with Submediteranean bioprovincial affinities rich in varied Hildoceratidae associated with typical Subboreal Dactylioceratidae. A number of rare genera, such as *Polyplectites, Osperleioceras* and *Frechiella* are also present and provide tantalising possibilities for more correlations with Mediterranean and even Ethiopean areas. Crucially, the site is also being sampled for nanno- and microfossils and geochemistry, and the results will be integrated into the multidisciplinary studies of the famous Mochras borehole in Wales which forms part of the JET (Jurassic Earth Systems and Timescales) Project, where cyclostratigraphical calibrations is also available. With such a chronology in place, it will finally be possible to make statements about the relative, even the absolute, chronology of Early Toarcian events. Crucially this chronology, being independent of any oceanic chemistry or ecological changes, will, for the first time, provide a reliable test of synchronicity, duration and even rates of change through this remarkable time interval.

A relationship between carbon-isotopes and soil carbon - a tool for temperature estimates in the Rhaetian and Early Jurassic

Pieńkowski G.*[1], Hesselbo S.P.[2], Barbacka M.[3-4] & Leng M.J.[5]

[1] Polish Geological Institute – National Research Institute, Warszawa, Poland. [2] Camborne School of Mines, and Environment and Sustainability Institute, University of Exeter, Penryn, UK. [3] W. Szafer Institute of Botany, PAN, Kraków, Poland. [4] Department of Botany, Hungarian Natural History Museum, Budapest, Hungary. [5] British Geological Survey, Keyworth, Nottingham, UK

Corresponding author email: grzegorz.pienkowski@pgi.gov.pl

Keywords: Carbon isotopes, terrestrial organic matter, temperature.

Decreasing carbon isotope ratios ($\delta^{13}C$) in the Earth's surface carbon reservoirs testify to a radical reduction of the terrestrial carbon pool as a response to climate warming, in contrast to enhanced carbon storage caused by nutrient supply and eutrophication in coeval open marine environments. Temperature estimates in deep geological past are often controversial, and they are almost entirely based on $\delta^{18}O$ data from calcium carbonate (mostly) fossils. Here we show $\delta^{13}C$ and organic matter concentrations (Total Organic Carbon – TOC) response to climatic changes and inferred paleotemperature estimates from the fully cored Kaszewy 1 borehole located in central Poland. The core was 980 m of continuous length, of which 112 m belongs to the Rhaetian and 782 m to the Lower Jurassic. New $\delta^{13}C$ data obtained from homogenous organic material (separated wood - $\delta^{13}C_{wood}$) allowed chemostratigraphical correlation with the biostratigraphically constrained Mochras profile (UK), supported by sequence stratigraphic correlation and biostratigraphical proxies. Continental TOC (TOC_{cont}) concentrations in the Polish succession are strongly positively correlated with $\delta^{13}C_{wood}$ values (r = 0.6 – exponential correlation in statistically significant number of 225 samples). In contrast, 23 samples containing significant amounts of marine kerogen show a weak negative correlation (r = -0.2) and were not taken into further consideration. Changes to the terrestrial carbon reservoir and TOC_{cont} content during the Rhaetian-Early Jurassic times are hypothetically related to temperature changes and enhanced decomposition of terrestrial carbon pool during hotter periods, caused by microorganisms (mainly fungi). Given the $\delta^{13}C_{wood}$ / TOC_{cont} function and assuming that higher content of the (light) ^{12}C isotope reflected additional CO_2 in the latest Triassic/Early Jurassic atmosphere and higher temperature, an approximate estimation of the annual mean air temperature changes for c. 40°N paleolatitude, spanning over 25 Mya of the latest Triassic – Early Jurassic time, is attempted. The approximate absolute temperature scale of the $\delta^{13}C$ values/continental TOC content plot of the Kaszewy profile was calibrated based on the stratigraphically well constrained $\delta^{18}O$ paleotemperature proxy from benthic invertebrate fossils in marine deposits in UK and Portugal (corrected for air temperature by adding 5 degrees). Accuracy of these estimations depend on the position of a given sample against the trend line. A weaker correlation in Rhaetian deposits is explained by local environmental factors (TOC concentration dependent on a more localized fluvial plain settings), while mostly deltaic – coastal deposits contain more representative, averaged material delivered from a large catchment area. We calculate that approximate average air temperature through the Rhaetian and Early Jurassic ranged from some 19°C to 30°C. The observed trend in temperature is generally in concordance with pCO_2 trends calculated from stomatal index.

This paper is a part of the project financed from resources of the Polish National Science Centre, granted on the basis of decision no. DEC-2012/06/M/ST10/00478 and the Polish National Science Centre, granted on the basis of decision no. 2017/25/B/ST10/02235. This is a contribution to the ICDP and NERC project JET (grant number NE/N018508/1) and IGCP project 632 "Continental Crises of the Jurassic".

Global correlation potential of the Lower Sinemurian ammonite genus *Arnioceras*: new studies from England and Wales using a statistical approach

Szűcs D.[1]*, Page K.N.[1], Ullmann C.V.[1] & Hesselbo S.P.[1]

Camborne School of Mines, University of Exeter

Corresponding author email: ds537@exeter.ac.uk

Keywords: Jurassic, Sinemurian, ammonoids, Arnioceras, principal component analysis, United Kingdom.

Arnioceras is a cosmopolitan, long-ranged ammonite genus, widely known from the Lower Sinemurian, upper Bucklandi to the Upper Sinemurian, upper Obtusum chronozones and abundant across Sub-Boreal to Mediterranean regions of Europe. Crucially, the genus is also well-known from northern Africa, Tunisia, Caucasus, NE Russia, China, Vietnam, Japan, Indonesia, New Zealand, New Caledonia, Canada, United States, Mexico, Ecuador, Colombia, Argentina, Chile and Peru. Despite the relatively straightforward recognition of the genus, it has proven challenging to distinguish individual species of *Arnioceras,* due to the apparent lack of significant morphological evolution throughout much of both the stratigraphic and geographic range of the genus, and the confusing use of many stratigraphically poorly constrained names. These problems have significantly decreased the biostratigraphical value of the genus, despite its great potential for tracking ammonite migration pathways globally and addressing palaeobiogeographical questions through the Sinemurian. To be able to track and reconstruct the phylogenetic evolution of the genus, a well constrained stratigraphic framework is necessary, and this is being constructed through the integration of sampling from both outcrop, including the classic sections of Dorset, Somerset and North Yorkshire in England, and from borehole cores, including from Burton Row in Somerset and from the famous Llanbedr (Mochras Farm) borehole in West Wales, as a contribution to the JET project. Principal component analysis (PCA) of quantitative morphological data can be an efficient statistical approach to describe and differentiate distinctive patterns of morphological groups in ammonites, including the genus *Arnioceras*. Importantly, PCA models give objective results assuming that the input parameters are valid and meaningful, which can make it a powerful tool to solve taxonomical issues where subjectivity is often a concern. Based on a rigorously defined stratigraphical sucession, it is proposed to capture the variability of each successive sampled *Arnioceras* fauna (i.e. potentially representing interbreeding populations) and define the succession of morphological characters and their variation using PCA. Preliminary results relating to these questions, as well as to the species-level taxonomy, will be presented. These results will be integrated with available micropalaeontological, astrolochronological, chemostratigraphical and sequence stratigraphical schemes, to provide not only a framework for a ‘correlatable’ absolute chronology for the Sinemurian Stage but also to reveal complex palaeobiogeographical changes driven by factors such as oceanic circulation and palaeogeography.

Palaeoenvironment and diagenesis decoded from bulk rock, veins and fossils in the Early Jurassic carbonate of the Llanbedr (Mochras Farm) drill core, Cardigan Bay Basin, UK

Ullmann C.V.*, Hesselbo S.P., Szűcs D. & Jiang M.

University of Exeter, Camborne School of Mines.

Corresponding author email: c.ullmann@exeter.ac.uk

Keywords: Jurassic, diagenesis, macrofossil, calcite, chemostratigraphy, palaeoenvironment.

The Early Jurassic was a critical interval of time for the development of the modern plate tectonic setting, recovery of biota from the end-Triassic mass extinction, and saw major palaeoenvironmental upheavals, including the well-known Early Toarcian Oceanic Anoxic Event. The Early Jurassic strata recovered by the Mochras drill core contain a highly detailed record of these environmental conditions due to its expanded nature, with 1,300 m of core representing the entire Early Jurassic. Here, results are presented from a systematic study of bulk carbonate C and O isotope ratios, carbonate content and carbonate mineralogy, as well as C and O isotope and element/Ca ratios of vein calcite and fossil shell materials. Bulk carbonate C isotope chemostratigraphy at Mochras tracks known perturbations of the exogenic carbon cycle at high fidelity, but amplitudes are exaggerated by partial oxidation of organic matter and subsequent precipitation as carbonate, particularly in carbonate-lean intervals. Siderite nodules are concentrated in the lower Toarcian and upper Sinemurian part of the core and are distinctly depleted in ^{13}C and enriched in ^{18}O with respect to calcite in the core. The depletion in ^{13}C potentially points to an early diagenetic origin, involving microbial activity. Calcite of sparitic veins and slickensides is most abundant in the middle Toarcian and upper Pliensbachian part of the Mochras core. The calcite is isotopically similar to bulk carbonate, suggesting that carbon was not sourced from large-scale pervasive features of fluid flow, despite the sometimes impressive size of veins in the drill core. Geochemically, the vein calcite carries a remnant signature of earlier celestine, in some cases leading to strongly increased Sr/Ca ratios. Macrofossils in the Mochras core are abundant and allow for a relatively highly resolved fossil chemostratigraphy based on belemnite, bivalve and brachiopod calcite, as well as aragonite from ammonites. Carbon and oxygen isotopic signature derived mostly from belemnites and bivalves appear to conform to patterns observed elsewhere in Tethyan successions. Distinct long-term trends in Mg/Ca and Sr/Ca ratios of shell carbonate in the macrofauna are also observed which partially align with and partially contrast to previously published datasets. Fossil carbonate, bulk rock carbonate, vein and contain unique information relating mostly to palaeoenvironmental information in the former and diagenetic processes in the latter. Combined multi-proxy analysis of these different phases allows for assessing environmental and post-depositional processes in detail.

Evidence for placement of the base Kimmeridgian GSSP at Flodigarry, Isle of Skye, Scotland, UK

Wierzbowski A.[1], Coe A.L.*[2], Barski M.[1], Hounslow M.W.[3], Matyja B.A.[1], Mattioli E.[4], Price G.[5], Ustinova M.[6], Wierzbowski H.[7], Wright J.K.[8] & members of the Kimmeridgian Working Group

[1] University of Warsaw, Poland. [2] The Open University, UK. [3] Lancaster University, UK. [4] Lyon University, France. [5] University of Plymouth, UK. [6] Russian Academy of Sciences, Russia. [7] Polish Geological Institute - National Research Institute, Poland. [8] Royal Holloway College, UK.

Corresponding author email: Angela.Coe@open.ac.uk

Keywords: Kimmeridgian, GSSP, Oxfordian, Isle of Skye.

The proposed Global Stratotype Section and Point (GSSP) for the base of the Kimmeridgian Stage is in the upper part of Bed 35 of the Staffin Shale Formation, 1.25 ± 0.01 m below the base of Bed 36 in block F6 (sections F6N and F6S) of the foreshore at Flodigarry, Staffin Bay, Isle of Skye, Scotland (N 57° 39’ 40”, W 6° 14’ 44”; NG 4687 7140). This proposed stratigraphic point coincides with the appearance over a short stratigraphic interval of several new ammonite taxa that delineate the base of the Subboreal ammonite Baylei Zone and the base of the Densicostata Subzone marked by the base of the *flodigarriensis* horizon, and, independently, the base of the Boreal ammonite Bauhini Zone. The main advantages of this locality are: the presence of a dual ammonite zonation marked by two extensively studied, well-preserved and very abundant groups of ammonites and, their preservation within a continuous section of *c.*120 m of open marine, fossiliferous, thermally immature mudrocks with no evidence of condensation or gaps. Furthermore, dinoflagellate cysts, magnetostratigraphy and carbon isotope data from the same section provide auxilliary markers. The stratigraphic point is located near, but possibly somewhat below, the boundary between the dinoflagellate cyst zones DSJ 26 and DSJ 27 (equivalent to boundary between subzones c and d of the Scriniodinium crystallinum (=Scr) Zone) which is placed 0.60 to 1.08 m below the base of Bed 36. The point is located about 0.15 m above the base of the reversed-polarity magnetozone F3r (the magnetozone base is between 1.32 and 1.45 m below the base of Bed 36) that most likely correlates with marine magnetic anomaly M25A.2r. The proposed point coincides with a well-marked broad minimum in $\delta^{13}C$ values and a calculated low Sr-isotope value of 0.70687. Preliminary work shows that the section is suitable for nannofossil studies and that the last occurrence of *Octopodorhabdus decussatus* might lie just below the proposed boundary. The thermal immaturity and unweathered nature of the strata in the Flodigarry section has permitted a direct Re-Os radiometric age of 154.1 ± 2.2 Ma to be obtained from the mudrocks at the boundary. The corresponding level in the Submediterranean-Mediterranean successions is close to the boundary between the Hypselum and Bimammatum zones. The changes in ammonite groups noted at this level provides global correlation potential. At the time of writing this proposal for the base Kimmeridgian Global Stratotype and Point is being put forward for consideration for ratification with the International Subcommission on Jurassic Geology and the International Commission on Stratigraphy.

ST3.8

Cretaceous integrated stratigraphy, greenhouse climate change and events

Conveners and Chairpersons

Maria Rose Petrizzo (Università di Milano)

Michael Wagreich (Universität Wien)

Jim Haggart (Natural Resources Canada)

Francesca Falzoni (Università di Milano)

Timing and Paleoenvironmental implications of Deccan volcanism relative to the K/Pg

Adatte T.*[1], Keller G.[2], Font E.[3], Mateo P.[4], Punekar J.[5], Schoene B.[2], Eddy M.[2], Samperton K.M.[6], Spangenberg J.[7], Bitchong A.M.[8], Sharma N.[1], Lorenzo V.[1] & Cujean S.[1]

[1] ISTE, University of Lausanne, Switzerland. [2] Department of Geosciences, Princeton University, USA. [3] Departamento de Ciências da Terra, Universidade de Coimbra Portugal. [4] Division of Geological and Planetary Sciences, California Institute of Technology, USA. [5] Indian Institute of Technology, Mumbai, India. [6] Nuclear and Chemical Science Division, Lawrence Livermore National Laboratory, USA. [7] IDYST, University of Lausanne, Switzerland. [8] Department of Earth Sciences, University of Yaounde 1, Cameroon and Institute of Mines and Petroleum Industries, University of Maroua, Cameroon

Corresponding author email: Thierry.adatte@unil.ch

Keywords: Mass Extinction, Cretaceous-Paleogene, Deccan Volcanism.

Mercury (Hg) as indicator of large-scale volcanism in marine sediments provides new insights into relative timing between biological and environmental changes, mass extinctions and delayed recovery. Several studies evaluated the relationship between Hg anomalies in sediments and LIP activity across mass extinction horizons. The bulk (80%) of Deccan Trap eruptions occurred over a relatively short time interval in magnetic polarity C29r. U-Pb zircon geochronology reveals the onset of this main eruption phase 250 ky before the Cretaceous-Tertiary (KT) mass extinction and continued into the early Danian suggesting a cause-and-effect relationship. Maximum eruption rates occurred before and after the K-Pg extinction, with one of the three main pulses initiating tens of thousands of years prior to both the bolide impact and extinction. These findings support extinction models that incorporate both catastrophic events as drivers of environmental deterioration associated with the K-Pg extinction and its aftermath. We present the first comprehensive high-resolution analysis of Deccan Traps Hg loading, climate change and end-Cretaceous mass extinction from a transect, which includes 25 sections deposited in both shallow and deep environments. We investigate the Hg contents of around sections located in France (Bidart), Spain (Zumaya, Caravaca, Agost), Denmark (Nye Klov, Stevn Klint), Austria (Gams), Italy (Gubbio), Tunisia (Elles, El Kef), Turkey (Goniuk, Okcular), Egypt (Wadi Nukhul, Sinai, Duwi), Israel (Negev), Oman (Abat), India (Megalaya, Anjar, Podgavan, Cauvery Basin), Demarara Rise, Texas USA (Brazos River) and NE Mexico (El Penon, La Parida). In all sections, results show that Hg concentrations are more than 2 orders of magnitude greater during the last 100ky of the Maastrichtian up to the early Danian P1a zone (first 380 Ky of the Paleocene). These Hg anomalies are correlative with the main Deccan eruption phases. Hg anomalies generally show no correlation with clay or total organic carbon contents, suggesting that the mercury enrichments resulted from higher input of atmospheric Hg species into the marine realm, rather than organic matter scavenging and/or increased run-off. Significant and coeval Hg enrichments are observed in multiples basins characterized by proximal and distal, as well as shallow and deep-water settings, supporting a direct direct fallout from volcanic aerosols. At Gams, Bidart, Elles and Demerara, the highest Hg anomalies correlate with high shell fragmentation and dissolution effects in planktic foraminifera indicating that paleoenvironmental and paleoclimate changes drastically affected marine biodiversity especially during the last 25 ky preceding the K/Pg. These observations provide further support that Deccan volcanism played a key role in increasing atmospheric CO_2 and SO_2 levels that resulted in global warming and acidified oceans, increasing biotic stress that predisposed faunas to eventual extinction at the K/Pg.

Neodymium isotopic evidence for large-scale oceanographic change during the collapse of the Cretaceous hothouse

Batenburg S.J.*[1-2], Drage E.[1], Gao E.Y.[1], O'Connor L.K.[1], Jenkyns H.C.[1], Gale A.S.[3] & Robinson S.A.[1]

[1] Department of Earth Sciences, University of Oxford, Oxford, United Kingdom. [2] Géosciences Rennes, Université de Rennes 1, Rennes, France. [3] School of Earth and Environmental Sciences, University of Portsmouth, Portsmouth, United Kingdom.

Corresponding author email: sbatenburg@gmail.com

Keywords: Late Cretaceous, neodymium-isotope ratios, Trunch borehole of Norfolk, England.

After the peak hothouse conditions of the Late Cretaceous, ending at ~ 91 Ma, climate was characterised by a gradual decrease in temperatures and CO_2 levels, an absence of major carbon cycle perturbations, and a reorganisation of deep-water circulation patterns. Throughout this time, the Atlantic Ocean was gradually opening and sea level was higher than at present, with large parts of north-western Europe covered by shallow epicontinental chalk seas. The role of surface-water oceanography in the long-term Late Cretaceous cooling is poorly understood, as reconstructed upper-ocean circulation patterns are based on relatively low-resolution records that have often been assembled from multiple localities. Here we present a ~28 Myr continuous record of neodymium-isotope ratios (ε_{Nd}) of fish debris from the Trunch borehole of Norfolk, England, to reconstruct the evolution of upper-ocean waters of the Boreal-Tethyan epicontinental shelf during the Late Cretaceous. During the Cenomanian–Turonian, background ε_{Nd} values are in the range of -9 to -10, comparable to previously published high-resolution datasets from elsewhere in southern England that span Oceanic Anoxic Event 2 (OAE 2). Unfortunately, OAE 2 is marked y a disconformity in the Trunch core. Surprisingly, our record shows a ~5 unit positive excursion during the mid-late Turonian, a much larger shift than those recorded in southern England during OAE 2. The ε_{Nd} excursion lasts ~ 1.5 Myr, and coincides with cooling observed in oxygen-isotope and faunal records across the Chalk Sea, a global positive $\delta^{13}C$ excursion, and a major change in sea-level, suggesting a potentially global driver of climate- and circulation change. The high ε_{Nd} values (peaking at -5.9 units) indicate basalt-seawater interactions, probably in the Boreal Sa, suggesting that volcanic activity and/or basalt weathering accompanied the cooling. After the late Turonian, Nd-isotope values return to relatively stable background levels of -11 to -12 in the Coniacian–Campanian; this long-term stability of circulation in the Chalk Sea suggests that circulation in this region was neither driving nor responding to the long-term global cooling trend. Further, the strongly unradiogenic signature of the Trunch record suggests a decline in influence from other water masses–Boreal or Tethyan–consistent with a reduction of low-latitude Pacific–Tethyan gateways. Our ε_{Nd} data, particularly the unexpected Nd-isotope variability in the Turonian, highlight the necessity to look beyond abrupt climate perturbations and to generate long-term continuous proxy records to gain a thorough understanding of climate processes in a greenhouse world.

Dinoturbation structures from the Aptian of Araripe Basin, Brazil, as tools for stratigraphic correlation

Carvalho I.S.*[1], Rios-Netto A.M.[1], Borghi L.[1] & Leonardi G.[2]

[1] Universidade Federal do Rio de Janeiro, Brazil. [2] Istituto Cavanis, Italy.

Corresponding author email: ismar@geologia.ufrj.br

Keywords: Dinoturbation, Araripe Basin, Aptian, omission surface.

Terrestrial environments of the Brazilian Cretaceous basins sometimes are characterized by high-energy and oxidizing conditions, that tend to prevent the fossil preservation and organic matter accumulations, limiting their biostratigraphic and paleoenvironmental interpretations. The use of trace fossils in this context become important for understanding these ecosystems, and also, intra-basinal stratigraphical correlation by identification of key-beds. During the Aptian (local Alagoas Stage), in the Araripe Basin, a terrigenous clastic to evaporitic succession not only bear local economic resources, but above all consist in a key-area for understanding the final stages of the tectono-stratigraphic evolution in the adjacent Brazilian continental margin basins. The analysis of the dinoturbation recently found in the Araripe Basin presents a special importance to the correlation of subaerial (omission) surfaces throughout the basin. Dinoturbation affects deeply the underlying layers as sub-cylindrical structures ranging in length from 35-100 cm and in depth from 30-50 cm. They are found in fine grained sandstones interbedded with mudstones of the Rio da Batateira Fm, interpreted as clastic lake shores, and in calcimudstones of the Crato Fm, in flooding areas of alkaline lakes. Temporary subaerial exposure of these scenarios allowed them to suffer dinoturbation. The pressure during the contact of a dinosaur autopodia and the substrate, led to the origin of load structures with successive laminae deformation. Preservation of tracks with anatomical details are controlled by the grain-size, consistency and plasticity of the substrate and by its burial rate (Avanzini, 1998), and the absence of such details in the casts found in the Araripe Basin, suggest high water content enhancing plasticity and modifying consistency of the substrates (Carvalho et al., 2018). Dinoturbation structures observed as cross section casts are generally scarcely documented, and it allows the understanding of environmental changes from terrigenous to carbonate lake scenarios that are so peculiar in this sedimentary succession. Their regional distribution also allows the identification of basinal correlation surfaces by the analysis of the spatial and temporal distribution of the biota in association to its paleoenvironments.

The authors gratefully acknowledge support from Shell Brasil Petróleo Ltda and the strategic importance of the support given by ANP (Brazil's National Oil, Natural Gas and Biofuels Agency) through the R&D levy regulation. Financial support also from CNPq (303596/2016-3) and Faperj (E-26/202.910/2017).

Avanzini M. (1998) - Anatomy of a footprint: bioturbation as a key to understanding dinosaur walk dynamics. Ichnos 6, 129-139.

Carvalho I.S., Melo, B.G.V., Borghi L., Rios-Netto A.M., Andrade J.A.F.G. & Freitas F.I. (2018) - Dinosaur Tracks From The Aptian (Early Cretaceous) of Araripe Basin, Brazil. In: Simp. Lat.-Am. Icnología, 4, Colombia, Res., p. 69.

Reliability and time variability of calcareous nannofossil events through the Tithonian-Early Berriasian interval: a critical review of published and new biostratigraphies

Casellato E.C.[1]* & Erba E.[1]

[1]University of Milan, Dipartimento di Scienze della Terra "A.Desio", Milano, Italy.

Corresponding author email: elisabetta.erba@unimi.it

Keywords: Jurassic/Cretaceous boundary, calcareous nannofossils, reliability, reproducibility, Integrated bio-mgneto-straigraphy.

The latest Jurassic was a crucial time interval for calcareous nannoplankton as a major speciation episode took place with the appearance and rapid evolution of several new genera and species. Particularly, highly calcified taxa (mainly nannoliths) appeared and progressively dominated the nannofossil assemblages at low latitudes. This dramatic change in calcareous nannofloras provides the opportunity to achieve high-resolution biostratigraphic data and amplify the possibility of dating and correlating. A thorough revision of published and newly updated nannofossil biostratigraphies for the Tithonian-earliest Berriasian time intervalare presented, aimed at evaluating the reliability and time variability of nannofossil biohorizons. Our database originally comprises ca. 80 sites (land sections and DSDP-OPD Sites) from different paleogeographic settings and latitudes. We excluded from the evaluation sections with hiatuses or characterized by uncertain calcareous nannofossil biostratigraphy due to scarcity of data and/or poor preservation. We critically evaluated sampling rates, nannofossil preservation and abundance, and taxonomy applied by individual specialists: events based on single samples, or quoted with a question mark, or based on taxonomic concept inconsistent with the original description were excluded. As a first step, we privileged calibrations against magnetostratigraphy to highlight reproducibility of single nannofossil events and their time variability in the CM22-CM17 interval. The time uncertainty of individual nannofossil event is also calculated, accounting sampling and sedimentation rates derived from magnetostratigraphy of each section. As a second step, we evaluated reproducibility of nannofossil against other biostratigraphies, with a special consideration of calpionellids, as they are the primary tool selected by the Berriasian Working Group (ICS) for the definition of the Cretaceous base. The main result of our critical revision points out a sequence of several first occurrences calibrated against magntostratigraphy, calpionellid and ammonite biozones. The reproducibility estimates demonstrate that some nannofossil events are more reproducible and reliable than others and, consequently, we discriminated among highly, medium and poorly reliable events. Results allow the revision of the available calcareous nannofossil zonation and confirm the nannofossil potential as a powerful tool for high-resolution dating and long-distance correlations, overcoming paleoprovincialism often shown by other biostratigraphic tools.

Stratigraphy around the Jurassic-Cretaceous boundary in the Bosso Valley section, Central Italy

Chiari M.[1], Bertinelli A.[2], Li X.[3] & Matsuoka A.*[4]

[1] C.N.R., Institute of Geosciences and Earth Resources, Florence, Italy. [2] Department of Physics and Geology, University of Perugia, Italy. [3] Nanjing Institute of Geology and Palaeontology and Center for Excellence in Life and Paleoenvironment, Chinese Academy of Sciences, Nanjing, China. [4] Department of Geology, Faculty of Science, Niigata University, Japan

Corresponding author email: marco.chiari@unifi.it

Keywords: Jurassic, Cretaceous, Radiolaria, Bosso section, Umbria-Marche, Italy.

The Bosso Valley section is located in the Umbria-Marche area of the Northern Apennines (Central Italy). The stratigraphic succession which outcrops in this area is made of several lithological units, spanning from Late Triassic to Miocene. Since the Jurassic, the Umbria-Marche area was characterized mainly by calcareous sediments, with scarce terrigenous influx, deposited in a basin with topographic differences of the sea floor, due to tectonic activity. Different Jurassic stratigraphic sequences were deposited, and from the Late Jurassic (Tithonian) the basinal deposits remain uniform throughout the Northern Apennines. The Maiolica Formation (Tithonian to Barremian-early Aptian) is the first pelagic and quite uniform unit, consisting of white to light gray well bedded limestones, with gray to black thin shale interbeds. Light gray to black nodules and layers of diagenetic chert are abundant. The bioclastic content is composed mainly of calpionellids, calcareous nannofossils, radiolarians, siliceous sponge spicules and rare ammonites. The stratigraphic transition of the Maiolica Formation with the underlying Calcari a Saccocoma ed Aptici (if present) or Calcari Diasprigni formations coincides with a major change in sedimentation in the pelagic environment during the Late Tithonian. The Jurassic-Cretaceous boundary (JKB) is recorded in the lower part of the Maiolica Formation and the Bosso Valley section is a potential candidate for the definition of the GGSP for the base of the Berriasian Stage (JKB). It was previously studied for calpionellid biostratigraphy and magnetostratigraphy by Housa et al. (2004). Furthermore, radiolarians are good candidates for defining the JKB because they are widespread and can be found both shallow and deep sedimentary facies. Evolutionary lineages of several radiolarian taxa across the JKB are reviewed and discussed by Matsuoka et al. (2018). In the Bosso Valley section the first paper describing radiolarians was published by Kocher (1981) and the data were re-examined by Baumgartner (1984, 1990). Successively, Jud (1994) sampled the Tithonian-Barremian interval in the Bosso valley. These data were included in the database utilized for the radiolarian zonation proposed by Baumgartner et al. (1995). Recently a detailed biostratigraphic study was carried out by Li et al. (2018).

Baumgartner P.O. (1984) - A Middle Jurassic-Early Cretaceous low latitude radiolarian zonation based on the unitary associations and age of Tethyan radiolarites. Eclogae Geologicae Helvetiae, 77 (3), 729-837.

Baumgartner P.O. (1990) - Genesis of Jurassic Tethyan radiolarites - The example of Monte Nerone (Umbria Marche Apennines). In Pallini, G. et al., Eds. Atti del II convegno internazionale Fossili Evoluzione Ambiente. Pergola 1987, 19-32.

Baumgartner P.O., Bartolini A., Carter E.S., Conti M., Cortese G., Danelian T., De Wever P., Dumitrica P., Dumitrica-Jud R., Goričan Š., Guex J., Hull D.M., Kito N., Marcucci M., Matsuoka A., Murchey B., O'Dogherty L., Savary J., Vishnevskaya V., Widz D. & Yao A. (1995) - Middle Jurassic to Early Cretaceous radiolarian biochronology of Tethys based on Unitary Associations. In: Baumgartner P.O., O'Dogherty L., Goričan Š., Urquhart E., Pillevuit A. & De Wever P. Eds., Middle Jurassic to Lower Cretaceous Radiolaria of Tethys: Occurrences, Systematics, Biochronology. Mémoires de Géologie (Lausanne), 23, 1013-1048.

Housa V., Krs M., Man O., Pruner P., Venhodova D., Cecca F., Nardi G. & Piscitello M. (2004) - Combined magnetostratigraphic, paleomagnetic and calpionellid investigations across Jurassic/Cretaceous boundary strata in the Bosso Valley, Umbria, central Italy. Cretaceous Research, 25, 771–785.

Jud, R. (1994). Biochronology and systematics of Early Cretaceous Radiolarian of the Western Tethys. Mémoires de Géologie (Lausanne), 19, p. 1-147.

Kocher R.N. (1981) - Biochronostratigraphiche Unterschungen Ober jurassicher radiolarienführender Gesteine insbesondere der Südalpen. Mittelungen Geologisch Instut ETH und Zurich (N.F.), 234, 1-184.

Li X., Matsuoka A., Bertinelli A. & Chiari M. (2018). Well preserved radiolarians across the Jurassic-Cretaceous (J/K) boundary in the Bosso Valley section, Central Italy. International Meeting around the Jurassic-Cretaceous Boundary, Geneve 5-7 December, abstract volume, 48-49.

Matsuoka A., O'Dogherty L., Gorican S., Baumgartner P.O., Li X., Chiari M. & Bertinelli A. (2018) - Radiolarian phylogeny around the Jurassic-Cretaceous boundary and radiolarian occurrences in the Bosso Valley section, central Italy. International Meeting around the Jurassic-Cretaceous Boundary, Geneve 5-7 December, abstract volume, 58-59.

Age and synchronicity of planktonic foraminiferal bioevents across the Cenomanian–Turonian boundary interval (Late Cretaceous)

Falzoni F.*[1], Petrizzo M.R.[1], Caron M.[2], Leckie R.M.[3] & Elderbak K.[3-4]

[1] Dipartimento di Scienze della Terra "A. Desio", Università degli Studi di Milano, Italy. [2] Départment de Geosciences, Institut de Géologie, Université de Fribourg, Switzerland. [3] Department of Geosciences, University of Massachusetts-Amherst, USA. [4] ALS Oil & Gas, Houston, USA

Corresponding author email: francesca.falzoni1@gmail.com

Keywords: Cenomanian-Turonian, stratigraphy, mid-low latitude correlations, planktonic foraminifera, Eastbourne, Pueblo.

The upper Cenomanian–lower Turonian is a key-stratigraphic interval, as it encompasses the Late Cretaceous supergreenhouse and a major perturbation of the global carbon cycle (i.e., Oceanic Anoxic Event 2). A turnover in planktonic foraminiferal assemblages and in other marine organisms is documented across this stratigraphic interval, but reconstruction of the timing and identification of the cause and effect relationships between environmental perturbations and organism response require a highly-resolved stratigraphic framework. The appearances and extinctions of planktonic foraminiferal species generally allow accurate intra- and supra-basinal correlations. However, bioevents cannot be assumed to be globally synchronous, because the stratigraphic and geographic distribution of species is modulated by ecological preferences exhibited by each taxon and controlled by oceanic circulation, often resulting in earlier or delayed events in certain geographic areas (i.e., diachronous datums). The aim of this study is to test the synchronicity of the planktonic foraminiferal bioevents recognized across the C/T boundary and to provide the most reliable sequence of events for correlation of low to mid-latitude localities. We have compiled a highly-resolved biostratigraphic analysis of the European reference section for the C/T boundary at Eastbourne, Gun Gardens (UK), and core S57 (Tarfaya, Morocco), and correlated the sequence of bioevents identified with those recorded in other coeval sections available in the literature, including the GSSP section for the base of the Turonian Stage at Rock Canyon, Pueblo (Colorado), where we calculated reliable estimates of planktonic foraminiferal events that are well-constrained by radioisotopically and astrochronologically dated bentonite layers. Results indicate that the extinctions of *Thalmanninella deeckei*, *Thalmanninella greenhornensis*, *Rotalipora cushmani* and "*Globigerinelloides*" *bentonensis* in the latest Cenomanian are reliable bioevents for correlation. In addition, our analysis highlights other promising lowest occurrences (LOs) that need to be better constrained by bio- and chemostratigraphy, including the LO of *Marginotruncana schneegansi* falling close to the C/T boundary. By contrast, the appearance of *Helvetoglobotruncana helvetica* and of some *Dicarinella* species, the extinction of anaticinellids and the onset of the "*Heterohelix*" shift are likely diachronous across low to mid-latitude localities. Finally, our study suggests that different species concepts among authors, different sample size and sampling resolution, as well as species paleoecology are important factors that control the stratigraphic position at which bioevents are identified (Falzoni et al., 2018).

Falzoni F., Petrizzo M.R., Caron M., Leckie R.M. & Elderbak K. (2018) - Age and synchronicity of planktonic foraminiferal bioevents across the Cenomanian–Turonian boundary interval (Late Cretaceous). News. Stratig., 51, 343-380.

Organic matter accumulation and paleoenvironmental conditions for the Upper Cretaceous organic-rich sediments on the southern Tethys, Egypt: evidence from stable carbon isotopes and organic geochemistry

Fathy D.*[1-4], Wagreich M.[1], El Nady M.E.[2], Sachsenhofer R.F.[3], Bechtel A.[3] & Sami M.[4]

[1] Department for Geodynamics and Sedimentology, University of Vienna, Austria. [2] Exploration Department, Egyptian Petroleum Research Institute, Cairo, Egypt. [3] Department of Applied Geosciences and Geophysics, Montanuniversitaet Leoben, Austria. [4] Department of Geology, Faculty of Science, Minia University, Egypt.

Corresponding author email: douaafathy@mu.edu.eg

Keywords: oil shales, greenhouse climate, reducing condition, organic matter, Egypt.

Upper Cretaceous organic-rich sediments provide a unique sedimentary archive for better understanding the marine realm during greenhouse climate. This study used stable carbon isotopic data along with biological, paleontological and geochemical signatures to evaluate the paleo-environmental conditions and the potentiality as a source rock for hydrocarbon. The Upper Cretaceous organic-rich sediments of Egypt were deposited within intracratonic sedimentary basins in an epeiric sea. They mainly consist of oil shales, limestone and phosphorite. Dakhla and Duwi formations are the main host for the studied organic rich-sediments in the Eastern Desert. The studied sediments cover a time interval of ca. 2- 2.9 Myr based on nannofossil biostratigraphy. These sediments were mostly formed under warm greenhouse conditions, evidenced by several geochemical proxies, clay mineralogy and warm-water nannofossils taxa. The studied samples have TOC values up to 22 wt %. The pyrolysis data indicate that those sediments are considered as a good to excellent source rock for hydrocarbon as well as oil prone with kerogen type I and II. The organic matter is mainly derived from algal-bacterial microorganisms based on the petrographic observation and biomarker proxies. In addition, the stable carbon isotopic and molecular fossils data for the analyzed samples illustrate that the organic-rich source rocks were formed in marine environments, varying from dysoxic to euxinic conditions. The organic matter varies vertically and laterally during deposition and associated with water-level changes. These differences could be a controlling factor during accumulation of the organic matter.

The Albian, Cenomanian and Turonian Stages: stratigraphy, sea level and palaeoclimate change

Gale A.S.*

SEES University of Portsmouth

Corresponding author email: andy.gale@port.ac.uk

Keywords: climatic change, palaeoenvironmental change, isotopic analysis, Cretaceous.

Our improved understanding of the mid-Cretaceous period (c. 113-90Ma) has been underpinned by exceptional advances in stratigraphical precision, brought about by integration of different biostratigraphic schemes, the advent of carbon isotope stratigraphy, cyclostratigraphy, and the ratification of GSSPs for the three stages. Additionally, the recognition of globally correlatable eustatic sea level changes provides a framework with which to understand changing patterns of sedimentation. New proxies for climatic change, including improved oxygen isotopic analysis, TEX86 and an array of newly studied stable isotopes provide evidence for the patterns of and controls on paleoenvironmental change. Of the above, carbon isotope stratigraphy perhaps provides the greatest benefits, because it provides an independent means of high-resolution correlation, applicable across biotic realms and facies boundaries. When integrated with biostratigraphy and cyclostratigraphy, it provides an accurately calibrated, high-resolution timescale on which to plot paleoclimatic and paleoceanographic change. This is illustrated with reference to the Cenomanian-Turonian OAE2 interval, for which a large range of geochemical proxy data is now available, and has lead to a detailed understanding of the interaction of Earth System processes through this interval.

Palaeoproductivity and palaeoclimatic changes in the Late Berriasian: geochemical trends, stable isotope stratigraphy and clay mineralogy in the Barlya section (western Balkan, Bulgaria)

Grabowski J.*[1], Wójcik-Tabol P.[2] & Wierzbowski H.[1]

[1] Polish Geological Institute – National Research Institute, Warsaw. Poland. [2] Institute of Geological Sciences, Jagiellonian University, Cracow, Poland.

Corresponding author email: jacek.grabowski@pgi.gov.pl

Keywords: Berriasian, magnetic stratigraphy, carbon isotope stratigraphy, palaeoproductivity, clay minerals, Western Balkan.

The Barlya section, situated in the Western Balkan (Bulgaria), contains a complete sedimentary succession from the Callovian to the Hauterivian (Lakova et al., 2007). Around the Lower/Upper Berriasian boundary, calpionellid limestones of the Glozhene Fm pass into hemipelagic marls and marly limestones of the Salash Fm. The studied interval, 39 m thick, is calibrated with biostratigraphy and magnetic stratigraphy, ranging from the upper part of polarity chron M17r (upper part of the Lower Berriasian) to the polarity chron M14r (lowermost Valanginian) (Grabowski et al., 2016). Carbon isotope curve correlates very well with reference Upper Berriasian $\delta^{13}C$ data from the Vocontian Basin (Emmanuel & Renard, 1993) indicating similar second order variations, with decrease of $\delta^{13}C$ from 1.4 to 0.9 ‰ in the polarity chron M16n (Grabowski et al., 2016). The carbon isotopic r atio is inversely correlated with organic palaeoproductivity proxies expressed by calculated P_{org}, Zn_{org} and Cd_{org} deposition rates. A profound minimum of $\delta^{13}C$ in polarity chron M16n correlates with regressive interval in the Late Berriasian (Oblonga Subzone). A long term increase of lithogenic input is observed. The siliciclastics are represented by phyllosilicates (mica, chlorite and kaolinite), quartz and feldspars. The amount of K-feldspar and quartz/phyllosilicate ratio decrease throughout the Upper Berriasian. Climate might have turned into more humid with higher chemical weathering rate and more effective runoff. However, the relative amount of kaolinite decreases, this indicates that the terrigenous flux was not solely related to humidity changes but rather controlled by sea-level variations as well as an uplift and erosion of the NeoTethyan Collisional Belt, south of the West Balkan basin.

Acknowledgements. Investigations and integration of the data were financially supported by projects of the National Science Centre, Poland: DEC-2011/03B/ST10/05256 and 2016/21/B/ST10/02941 .

Emmanuel L. & Renard M. (1993) - Carbonate geochemistry (Mn, $\delta^{13}C$, $\delta^{18}O$) of the Late Tithonian – Berriasian pelagic limestones of the Vocontian Trough (SE France). Bulletin des Centres de Recherches Exploration-Production Elf Aquitaine, 17, 205–221.

Grabowski J., Lakova I., Petrova S., Stoykova K., Ivanova D., Wójcik-Tabol P., Sobień K. & Schnabl P. (2016) - Paleomagnetism and integrated stratigraphy of the Upper Berriasian hemipelagic succession in the Barlya section, Western Balkan, Bulgaria: implications for lithogenic input and paleoredox variations. Palaeogeography, Palaeoclimatology, Palaeoecology, 461, 156-177.

Lakova I., Tchoumatchenco P., Ivanova D. & Koleva-Rekalova E. (2007) - Callovian to Lower Cretaceous pelagic carbonates in the West Balkan Mountains (Komshtitsa and Barlya sections): integrated biostratigraphy and microfacies. Geologica Balcanica, 36, 81–89.

OAE 2 black shales and other Cretaceous critical intervals recovered at high paleolatitudes in the SE Indian Ocean during IODP Expedition 369

Huber B.T.*[1], Hobbs R.W.[2], Bogus K.A.[3] & Expedition 369 Scientists

[1] Smithsonian Institution, USA. [2] University of Durham, UK. [3] University of Exeter, UK

Corresponding author email: huberb@si.edu

Keywords: Oceanic Anoxic Event 2, Cretaceous climate.

IODP Expedition 369 recovered an extensive succession of Cretaceous sediments in the southeast Indian Ocean (Mentelle Basin) and Great Australian Bight (GAB) that will provide new insights to high latitude paleoclimatic and paleoceanographic changes during the last phase of breakup of the Gondwana continents. Four sites offshore southern and southeast Australia cored Cretaceous sediments with a nearly continuous composite recovery from the late Albian through early Campanian. On the continental slope of the GAB (3000 m depth), Site U1512 recovered 690 m of lower Turonian–Santonian black claystone that was deposited in a prodelta setting at 60°S paleolatitude during the mid-Cretaceous. Dysoxia at depth, influence of freshwater runoff, and high sedimentation rates in the semi-enclosed basin account for the depauperate and sporadic occurrence of microfossil assemblages at this site. Observation of high amplitude cyclic fluctuations in detrital content during several intervals in the Late Cretaceous will be investigated to determine if their cyclicity can be tuned to climatic forcing at Milankovitch cyclicity. Three sites located at 60°–62°S paleolatitude during the mid-Cretaceous were drilled offshore SW Australia in a N-S transect of the Mentelle Basin. Site U1513 (2900 m depth) recovered a nearly continuous ~150 m succession of upper Cenomanian–lower Campanian nannofossil chalk. Calcareous microfossils were mostly well preserved in the Coniacian–Campanian and preservation quality is more variable in the Cenomanian–Turonian. Nearly strata across the Cenomanian-Turonian boundary Oceanic Anoxic Event 2 (OAE 2) contains a laminated black shale bed with up to 10.5% total organic carbon (TOC) was also recovered. A ~200 m thick Albian–Cenomanian black claystone underlies the upper Cenomanian and yields low diversity calcareous microfossil assemblages that are moderately to well preserved. Site U1514 is located on the northern Mentelle Basin at 3900 m depth. The top of the Cretaceous succession is marked by a complete Cretaceous/Paleogene boundary and is underlain by ~40 m of Cenomanian-Maastrichtian nannofossil claystone with variably preserved calcareous microfossils. A highly disturbed interval is present at the expected level of the Cenomanian-Turonian boundary and is interpreted as evidence of decollement between the over- and underlying strata. The underlying 60 m of Albian-Cenomanian black claystone contains low diversity calcareous microfossil assemblages showing moderate to good preservation. Site U1516 (2700 m depth) is missing the Coniacian-Maastrichtian sediment record because of a major hiatus, but the ~100 m thick late Albian-Turonian chalk and black claystone below is stratigraphically continuous. Importantly, two boreholes at this site recovered the Mid-Cenomanian Event and a complete OAE 2 interval that includes a black shale bed containing up to 12% TOC. Shore-based studies of the Cretaceous cores and their publication are in progress.

The stratigraphic record of the Tepeyac section, Coahuila, north-eastern Mexico, Santonian-Campanian boundary

Ifrim C.*[1], Gale A.S.[2], Adatte T.[3], Wagreich M.[4], Wolfgring E.[4], Moreno-Bedmar J.A.[5], González González A.H.[6] & Stinnesbeck W.[1]

[1] Institut für Geowissenschaften, Ruprecht-Karls-Universität Heidelberg, Germany. [2] School of Earth and Environmental Sciences, University of Portsmouth, UK. [3] Institut de Géologie et Paléontologie, Université de Lausanne, Switzerland. [4] University of Vienna, Department of Geodynamics and Sedimentology, Vienna, Austria. [5] Instituto de Geología, Universidad Nacional Autónoma de México, Ciudad de México, México- [6] Museo del Desierto, Saltillo, Coahuila, Mexico

Corresponding author email: christina.ifrim@geow.uni-heidelberg.de

Keywords: biostratigraphy, chemostratigraphy, magnetostratigraphy, sedimentology, Santonian-Campanian boundary, long-distance correlation.

The Arroyo Blanco and Arroyo Tecolote riverbeds were known for their occurrence of giant ammonites for 101 years. A restudy of these outcrops in the dry riverbeds near the village of Tepeyac showed that a 25 m thick succession of carbonates crops out there. It comprises a complete sedimentary record across the Santonian-Campanian boundary. Bedding surfaces are widely exposed and allow for the collection of abundant macrofossils and thus a detailed ammonoid and inoceramid biozonation, for which we here present new biostratigraphic data suitable for long-distance correlation. A high-resolution stable carbon isotope curve and sedimentological data are now also available, together with biozonation by microcrinoids and magnetostratigraphy. This approach of intergrated stratigraphy allows for long-distance correlation with other Santonian-Campanian boundary sections in Europe and North America, despite the fact that micro- and nannofossil assemblages are not diversified and/or well-enough preserved for precise age correlation. Graphic correlation is used to compare the Tepeyac with various Santonian-Campanian sections in North America and Europe to show if it has potential as a reference section across the Santonian-Campanian boundary.

The El Rosario section, Coahuila, north-eastern Mexico, and its potential as a reference section (GSSP) for the Turonian-Coniacian boundary

Ifrim C.*[1], Peryt D.[2], Linnert C.[3], Adatte T.[4], González González A.H.[5] & Stinnesbeck W.[1]

[1] Institut für Geowissenschaften, Ruprecht-Karls-Universität Heidelberg, Germany. [2] Instytut Paleobiologii, Polska Akademia Nauk, Warszawa, Poland. [3] Ruhr-Universität Bochum, Germany. [4] Institut de Géologie et Paléontologie, Université de Lausanne, Switzerland. [5] Museo del Desierto, Saltillo, Coahuila, México

Corresponding author email: christina.ifrim@geow.uni-heidelberg.de

Keywords: biostratigraphy, chemostratigraphy, sedimentology, Turonian-Coniacian boundary, graphic correlation, reference section.

The El Rosario quarry section in north-eastern Mexico comprises the Turonian-Coniacian boundary. It was resampled for high-resolution bio-, chemostratigraphic, mineralogic and sedimentological analyses. Biozonation was refined and supported by a detailed stable carbon isotope stratigraphy. 50 bio- and chemostratigraphical events can now be correlated between El Rosario and other Turonian-Coniacian boundary sections. Graphical correlation between these sections indicates that some bioevents formerly regarded as reliable produce repeated outliers. Other events, on the other hand, prove to be useful for interbasinal correlation. The El Rosario section is at least equal in stratigraphic quality as the Salzgitter-Salder section in Germany, and both are here regarded to be strong candidates for the GSSP of the Turonian-Coniacian boundary. Comparable sedimentation rates characterize the Turonian part of both sections, and similar variations in sedimentation rates are present in the lower Coniacian zone of both sections. The El Rosario section is one of the few sections in the world to yield an abundant ammonoid and vertebrate record. In addition, is can be correlated with a stable carbon isotope curve, the standard inoceramid biozonation, a micro- and nannofossil biozonation, and sedimentological data. The section is thus ideally suited for long-distance correlation between the Gulf of Mexico and European, Tethyan, South American and Western Interior sections.

Organic-walled dinoflagellate cyst records from prospective Turonian–Coniacian (Upper Cretaceous) GSSPs: Salzgitter-Salder, Germany and Słupia Nadbrzeżna, Poland; preliminary data

Jarvis I.*[1] & Pearce M.[1-2]

[1] Kingston University London, UK. [2] Evolution Applied Ltd, UK.

Corresponding author email: i.jarvis@kingston.ac.uk

Keywords: palynology, Turonian, Coniacian, GSSP, dinoflagellate cysts.

The Salzgitter-Salder quarry section of Lower Saxony, northern Germany, combined with a river section at Słupia Nadbrzeżna, central Poland, have been proposed as a candidate Turonian–Coniacian (Cretaceous) composite GSSP. Results of a high-resolution (50 cm) palynological study of the boundary interval at Salzgitter-Salder (34 samples) are presented and compared to published data from Słupia Nadbrzeżna (21 samples). Terrestrial palynomorphs are rare in both sections; marine organic-walled dinoflagellate cysts (dinocysts) dominate the palynological assemblages. The dinocyst assemblage at Słupia Nadbrzeżna has a low species richness (5–11 per sample; 18 species recorded) and diversity (Shannon index H 0.8–1.4), dominated by four taxa: *Circulodinium distinctum* subsp. *distinctum*; *Oligosphaeridium complex*; *Spiniferites ramosus* subsp. *ramosus*; *Surculosphaeridium longifurcatum*. Abundances are ~1500 dinocysts/gram (dpg). Declining proportions of *O. complex* and *S. r. ramosus* characterise the uppermost Turonian, with an increased dominance of *S. longifurcatum* in the Lower Coniacian. The Turonian–Coniacian boundary interval includes an acme of *C. distinctum* subsp. *distinctum* in the upper *Mytiloides scupini* Zone, a dinocyst abundance maximum in the *Cremnoceramus w. walterdorfensis* Zone, and the highest occurrence of *Senoniasphaera turonica* in the basal Coniacian lower *Cremnoceramus d. erectus* Zone. Most previously reported Turonian–Coniacian boundary dinoflagellate cyst marker species are absent; a shallow-water oligotrophic epicontinental depositional setting, remote from terrestrial influence, likely limited species diversity and excluded many taxa of biostratigraphic value. Three samples from Saltzgitter-Salder have been analysed to date from the: Upper Turonian, *M. scupini* Zone (Bed 42a), and Lower Coniacian *C. d. erectus* (Bed 48) and *C. w. hannovrensis* (Bed 57) zones. The lower two samples contained a relatively high species richness (43–59, H ~2.8) with 1400–2500 dpg. Bed 57 yielded lower values (29, H 1.9) and 367 dpg. The dinocyst assemblages indicate that Saltzgitter-Salder occupied a more fertile, deeper water setting than Słupia Nadbrzeżna, and no biostratigraphic similarities are observed. However, comparisons with other deeper water sites (Běchary-1 core, Czech Republic; Trunch core, UK), are apparent: (1) a highest occurrence of frequently occurring but questionable *Cauveridinium membraniphorum* is present in the Turonian sample (as seen in Běchary-1); (2) superabundant *Palaeohystrichophora infusorioides* is present in the highest Coniacian sample and appears to be correlatable with acmes at Běchary-1 and Trunch; (3) the absence of the traditional Turonian–Coniacian boundary marker *Stephodinium coronatum* is noted, supporting observations from Běchary-1 and Trunch that this should be regarded as an intra-Upper Turonian marker. These preliminary findings will be assessed further following completion of the sample preparation and analysis.

Microfossils of Turonian-Coniacian in the Kamenny Brod section (Russian Platform, Ulyanovsk-Saratov depression) − stratigraphic and palaeogeographic aspects

Kopaevich L.F.[1], Pervushov E.M.[2], Proshina P.A*.[3], Riabov I.P.[2] & Vishnevskaya V.S.[3]

[1] Geological Faculty, Lomonosov Moscow State University, Moscow, Russia. [2] Saratov State Unversity, Saratov, Russia. [3] Geological Institute, Russian Academy of Sciences, Moscow, Russia.

Corresponding author email: lfkopaevich@mail.ru

Keywords: Upper Cretaceous, Turonian-Santonian, Russian Platform, Foraminifera, Radiolaria.

Turonian-Coniacian Foraminifera and Radiolaria were analysed from Kamenny Brod (KB) section (Russian Platform, Ulyanovsk-Saratov depression). The stratigraphically most complete of the Turonian–Coniacian interval for this area was established. The benthic foraminifers (BF) Zones were established on the base of zonal scheme of Beniamovsky, 2008 with additions of new data for another area. BF assemblages are the most abundant, their distribution in the section have established 5 Zones. Middle—Upper Turonian, Lower-Middle Coniacian and Lower Santonian are present in KB section. Planktonic foraminifers (PF) are represented by two groups. The first group consists of trochospiral *whiteinellids*, *archaeoglobigerinellids,* rare *dicarinellids* and *marginotruncanids.* The second one is represented by biserial *heterohelicids.* Trochospiral PF have low taxonomic diversity, they are distributed very irregularly through section and do not allow to distinguish zonal divisions. At the same time, this section can be subdivided into 2 parts – first, corresponding to the Turonian, and second, corresponding to the Coniacian. Biserial *heterohelicids* are distributed through the section irregularly and demonstrate a low diversity of taxa (6 species). However, their joint distribution has allowed to establish 6 layers whose age is correlated with Cenomanian-Turonian, Turonian and Coniacian. Radiolarian assemblages are extremely poor, because the KB section is represented by carbonate rocks. However, in these assemblages, typical Santonian relatively boreal species, as well as relatively warm water Albian–Turonian species, are recorded. The PF/BF ratio within the foraminiferal assemblages indicates the predominance of shallow-water environments within the southern part of the Ulyanovsk-Saratov depression. According to this indicator, the incision can be clearly divided into two intervals. The content of PF reaches 50-60% in the Turonian and partially Lower Coniacian and generally fluctuates from 39 to 60%. In the upper part of the section, the content of PF is sharply reduced, not exceeding 10-20%, only in rare cases reaching 30%. The ratio of different morphological types of PF (trochospiral/biserial) is also variable. In the lower part of the section corresponding to the Turonian and Lower Coniacian the content of trochospiral PF is up from 40 to 100%. Biserial *heterochelicids* predominate above the section, their content stably stays within 60-70%. Such ratios indicate an increase in transgression from the south throughout Turonian and early Coniacian.

This research was supported by the IGCP-609 Project and the RFBR: 18-05-00494, 18-05-00495, 18-05-00-501, 18-05-00503 and was performed according to task 0135-2018-0036 (GIN RAS).

Beniamovski, V. (2008) - Infrazonal biostratigraphy of the Upper Cretaceous in the East European Province based on benthic foraminifers, Part 1: Cenomanian and Coniacian. - Stratigr. Geol. Correl., 16(3), 257 – 266. https://doi.org/10.1134/S0869593808030039.

Palaeosols in Lameta Formation (Jabalpur, Central India): their use in palaeoclimate reconstruction and stratigraphic correlations during Late Cretaceous.

Kumari A.*, Singh S. & Khosla A.

Centre for Advanced Study in Geology, Panjab University, Chandigarh, India

Corresponding author email: anjalidgr11@gmail.com

Keywords: Dinosaur bearing Creatceous sediemnts, paleoclimate, paleosols.

Researchers have well established that the Cretaceous time constitutes youngest prolonged greenhouse state along with varied intermittently extreme environments. This period is known for enormous reptilian evolution and a repository of some of the last dinosaur species on Earth. Therefore, Late Cretaceous sediments have been studied worldwide for various geological reconstructions. The Cretaceous sediments in Central India occur as isolated outcrops along the Narmada valley, known as Lameta beds. These sediments stratigraphically occur as infratrappean deposits, below Deccan Traps. Depositional environment of Lameta beds has reached no consensus among researchers. These beds comprise limestone, marl, sandstone and palaeosol as major sedimentary facies. These have been studied in detail but Lameta palaeosols have gone through limited investigations; primarily on the basis of broad field features and stable isotope studies (Tandon et al., 1995). On the contrary, similar Late Cretaceous sediments in other parts of world have been extensively investigated for palaeosols (Therrein et al., 2009; Basilici et al., 2017). Palaeosols, are significant in solving diverse geological problems including palaeoclimate and sequence stratigraphy. Therefore we have focused on detailed palaeosol studies in Late Cretaceous Mottled Nodular Bed of Lameta Formation in Chui Hill and Chota Simla Hill outcrops at Jabalpur city (Madhya Pradesh, Central India), and it will fill void in research in globally equivalent uppermost Cretaceous dinosaur-fossil bearing strata. Detailed morphological and micromorphological studies reveal textural, depletion, nodules, concretions, infillings and b-fabric pedofeatures suggesting pedogenesis of Pedotype III-V category (Singh et al., 2015). Such detailed studies are required all along Narmada valley to find out the degree, nature and variation of pedogenesis, thereby enhancing our understanding of extreme events that occurred at the end of the Cretaceous.

Tandon S. K., Sood A., Andrews J. E. & Dennis P. F. (1995) - Palaeoenvironments of the dinosaur-bearing Lameta beds (Maastrichtian), Narmada valley, central India. Palaeogeogr. Palaeoclimatol. Palaeoecol. 117(3-4), 153-184.

Therrien F., Zelenitsky D. K., Weishampel D. B. (2009) - Palaeoenvironmental reconstruction of the Late Cretaceous Sânpetru Formation (Haţeg Basin, Romania) using paleosols and implications for the “disappearance” of dinosaurs. Palaeogeogr. Palaeoclimatol. Palaeoecol. 272(1-2), 37-52.

Basilici G., Hechenleitner E.M., Fiorelli L.E., Dal Bó P.F. & Mountney, N.P. (2017) - Preservation of titanosaur egg clutches in Upper Cretaceous cumulative palaeosols (Los Llanos Formation, La Rioja, Argentina. Palaeogeogr. Palaeoclimatol. Palaeoecol. 482, 83-102.

Singh S., Parkash B., & Awasthi A. K. (2015) - Tectono-geomorphic and environmental set-up deduced during deposition of Mio-Pleistocene sediments in NW Himalaya, India. Catena, 126, 173-188.

Abundance and preservation of radiolarians across the Jurassic-Cretaceous (J/K) boundary in the Bosso Valley section, Central Italy

Li X.*[1], Matsuoka A.[2], Bertinelli A.[3] & Chiari M.[4]

[1] Nanjing Institute of Geology and Palaeontology and Center for Excellence in Life and Paleoenvironment, Chinese Academy of Sciences, China. [2] Niigata University, Japan. [3] Università degli Studi di Perugia, Italy. [4] Istituto di Geoscienze e Georisorse, Italy.

Corresponding author email: xinli@nigpas.ac.cn

Keywords: J/K boundary, radiolarian, lithology, preservation, abundance.

The Bosso Valley section is located near the Pianello-Cagli road and follows the Bosso River in the Umbria-Marche area of the Central Italy. The magnetostratigraphical record of the J/K boundary has been correlated with the Calpionella zone (Housa et al., 2004). The Maiolica Formation, which crosses the J/K boundary, is characterized by whitish, beige to gray colored, well-bedded limestones with abundant black to gray chert layers and chert nodules and marly intervals. In order to establish radiolarian biostratigraphy across the J/K boundary, detailed study was conducted to elucidate relationship between lithology and preservation of radiolarians in the Bosso Valley section. Totally, 35 samples near the J/K boundary were collected for analyzing the preservation. Samples were immersed in 10% hydrochloric acid for 30 to 60 minutes, then washed, dried and examined under a binocular microscope and a scanning electron microscope. The etched surfaces of five samples were observed. Thin sections of 29 samples were observed carefully. Radiolarians are abundant both in the chert bands or nodules and in the limestone. Preservation of radiolarians varies in different parts because of the diagenesis. Surfaces of etched limestone are observed and divided into different parts, based on the preservation of radiolarians. Radiolarians are generally calcified in the pure lime beds. Radiolarians are generally badly preserved in the chert bands or nodules. Well-preserved radiolarians are located inside the lime part near the chert bands or nodules. Primary results of radiolarian assemblages near the J/K boundary are proposed.

New data on the Jurassic–Cretaceous transition in the Transdanubian Range (Hungary): integrated stratigraphy and paleomagnetic study of the Hárskút and Lókút sections

Lodowski D.G.*[1], Főzy I.[2], Pszczółkowski A.[3], Szives O.[2] & Grabowski J.[4]

[1] University of Warsaw, Poland. [2] Hungarian Natural History Museum. [3] Polish Academy of Sciences. [4] Polish Geological Institute – National Research Institute.

Corresponding author email: damian.lodowski@student.uw.edu.pl

Keywords: magnetostratigraphy, biostratigraphy, Tithonian, Berriasian, Tethys.

An integrated stratigraphic study (magneto-, bio- and $\delta^{13}C$ stratigraphy) of the Tithonian and Berriasian pelagic limestones has been performed in the Hárskút and Lókút sections (Transdanubian Range, Hungary). Studied sections are located in different sedimentary zones of the Transdanubian Range unit and reveal clearly distinct lithologic record. Applied methodology allowed precise correlation of the sections with the Geological Time Scale. The Lókút section has been previously studied by Grabowski et al. (2010); this study is focused on the recently excavated, younger part of the succession. The section starts at the top of the Grabowski et al. section, at the *Calpionella alpina* Subzone (top of M19n magnetozone), and provides 8.2 m of monotonous Maiolica-type limestones with cherts. The rock record ends at the M17n**?** magnetozone, within the *Calpionella elliptica* Subzone, proving the Lower Berriasian age of the succession, which is in concordance with the nannofossil record. The Hárskút section is composed of two outcrops, located very close to each other, referred in the literature as the HK-12 and HK-12/a sections (Főzy et al., 2010). The succession starts with the Ammonitico Rosso-type limestone, most probably below the M22n magnetozone (Lower Tithonian); the succession becomes less nodular (to pelitic) upwards and continues through the Jurassic/Cretaceous boundary, up to the M14r magnetozone (Lower Valanginian). Upper Tithonian and upper Lower Berriasian–Lower Valanginian is well documented by ammonites. This study provides new data on the Lower Tithonian–Lower Valanginian succession of the Western Tethyan realm. Correlation between the magneto-, bio- and isotope stratigraphy, as well as palaeogeographic relations between the sections are established on sedimentological and rock magnetics basis. Magnetic susceptibility, related to lithogenic input, reveals few peaks within the Lower Tithonian, middle Upper Tithonian and Upper Berriasian. Variations of lithogenic input could be controlled by joint effects of climate, eustasy and/or tectonics.

Investigations were financially supported by the National Science Center, Poland (project no.: 2016/21/B/ST/10/02941 – project leader: J. Grabowski; PGI-NRI, Warsaw); and OTKA/NKFI project no: K123762 – project leader: I. Főzy.

Főzy I., Janssen N.M.M., Price G.D., Knauer J. & Pálfy J. (2010) - Integrated isotope and biostratigraphy of a Lower Cretaceous section from the Bakony Mountains (Transdanubian Range, Hungary): A new Tethyan record of the Weissert event. Cretaceous Res., 31, 525-545.

Grabowski J., Haas J., Márton E. & Pszczółkowski A. (2010) - Magneto- and biostratigraphy of the Jurassic/Cretaceous boundary in the Lókút section (Transdanubian Range, Hungary). Stud. Geophys. Geod., 54, 1-26.

Albian dinoflagellate cysts from the Agadir Basin: Palynology and Palynofacies

Maatouf W.[1]*, Hssaida T.[1] & Benbouziane A.[1]

[1]University of Hassan II, Faculty of Sciences Ben M'Sick, Morocco.

Corresponding author email: maatouf.wafaa@gmail.com

Keywords: Albian, Dinoflagellates, Palynology, Palynofacies, Morocco.

Palynological investigation of the Middle Cretaceous succession from the Taghrout section in the Agadir Basin (25 km north of Agadir) has revealed a well-preserved palynological material exceptionally rich in dinoflagellate cysts. The analysis of the Taghrout section samples enabled the identification of three palynozones. The base of the section (sample AA572) was assigned to the middle Albian age due to *Dinopterigium alatum*. Its middle part (samples AA573 to AA580) is dominated by marker taxa of the middle to upper Albian: *Florentinia mantellii, Coronifera oceanica, Exochosphaeridium phragmites, Dapsilidinium chems, Hapsocysta peridictya* and *Litosphaeridium arundum*. Dinoflagellate cysts characteristic of the upper Albian age were identified in the upper part of the section (samples AA580 to AA583), these taxa are represented by *Cyclonephelium chabaca, Montanarocysta mirabilis, Chichaouadinium vestitum, Cribroperidinium? intricatum* and *Florentinia laciniata.* Quantitative vertical distributions of palynomorphs and particulate organic matter exhibit three palynofacies intervals in this section. i) Interval of middle Albian age marked by a high dominance of littoral cysts and continental influences. ii) An interval from the middle to upper Albian age divided into two phases: the first marked by the dominance of the group of cysts from middle neritic group and the second dominated by the oceanic group of cysts. iii) Interval of the upper Albian age corresponds to a middle neritic depositional environment with a transgressive trend.

Calcareous nannofossils of Aptian - Albian strata from the Zagros Basin (Kazhdumi Formation), SW Iran

Mahanipour A.*[1], Mutterlose J.[2] & Hassani sadi M.[3]

[1] Department of Geology, Faculty of Science, Shahid Bahonar University of Kerman, Iran. [2] Institute for Geology, Mineralogy and Geophysics, Ruhr-Universität Bochum, Germany. [3] Department of Geology, Faculty of Science, Shahid Bahonar University of Kerman, Iran.

Corresponding author email: a_mahanipour@uk.ac.ir

Keywords: Calcareous nannofossils, Biostratigraphy, Aptian, Albian, Zagros Basin, Iran.

The pelagic interval of the Kazhdumi Formation of the Zagros Basin, SW Iran, consists of marls, marly shales and thin interbedded limestone layers. Lithologically the succession closely resembles pelagic - hemipelagic sequences of Aptian - Albian age well known from the Tethyan Realm. Based on calcareous nannofossil assemblages, the studied interval ranges from nannofossil zone NC7A (late early Aptian) to NC10 (Albian) of the Roth (1978) zonation. Eleven calcareous nannofossil bioevents were identified within the studied interval. *Eprolithus floralis* was observed in the lowermost sample, assigning this part of the Kazhdumi Formation a late early Aptian age. The next bioevent is the first occurrence (FO) of *Prediscosphaera columnata* which marks the top of nannofossil NC7 and the base of the Albian stage based on calcareous nannofossil data. The last occurrence (LO) of *Micrantholithus* spp. and the FO of *Rhagodiscus achlyostaurion* are also recorded, which subdivide NC7 biozone into NC7A, NC7B and NC7C subzones. The next bioevent is the FO of *Axopodorhabdus albianus* which marks the top of biozone NC8. The FOs of *Hayeites albiensis* and *Tranolithus orionatus* were used to define a NC8A, NC8B and NC8C subzone (from base to top). The FO of *Eiffellithus turriseiffelii* marks the top of NC9, which is further subdivided by the FO of *Eiffellithus monechiae* into a NC9A and NC9B subzone. The uppermost bioevent is the FO of *Corollithion kennedyi*, which marks the boundary between the NC10A and NC10B subzones. According to these data, the succession is defined of late early Aptian - late Albian age. Several black shale horizons were recorded within the studied interval which can be related to oceanic anoxic events.

Astronomical calibration of the Barremian Stage

Martinez M.*[1], Aguado R.[2], Company M.[3], O'Dogherty L.[4] & Sandoval J.[3]

[1] Université de Rennes, France. [2] Universidad de Jaén. [3] Universidad de Granada. [4] Universidad de Cádiz.

Corresponding author email: mathieu.martinez@univ-rennes1.fr

Keywords: astrochronology, Cretaceous organic-rich levels, Barremian, Geologic Time Scale.

The estimated duration of the Barremian Stage ranges from 3 to 7 myr, depending on the astronomical time scale used. Most of the uncertainty is due to the method employed to provide an orbital time scale for the Barremian. Studies were successively based on lithological counting on sections hardly showing the marl-limestone couplets and on spectral analyses performed on paleoclimatic series which were not densely sampled enough. Here, we show a total of 2,000 magnetic susceptibility and calcium carbonate content data measured every 7 cm on two basin sections of the Subbetic Domain (Southeastern Spain). Spectral analyses were performed using the multi-taper method and the evolutive Fast Fourier Transform weighted with a Slepian sequence. We find a duration of the Lower Barremian recorded in the Arroyo Gilico section of 1.5 myr and a duration of the Upper Barremian recorded in the Cavila section of 2.1 myr. By correlation with the Rio Argos and the Angles sections, it appears that the Arroyo Gilico section contains hiatuses probably because of its particular position in the paleo-high relief. Correlation to the Tethyan area suggest a duration of 1.7 myr of the Early Barremian. However, the duration of 2.1 myr of the Late Barremian appears more realistic than previous assessments based on lithological cycles hardly identifiable with visual inspection only. We thus suggest a minimum duration of the Barremian Stage of 3.8 myr. Interestingly, the three pre-Aptian organic-rich levels recorded in the Tethyan area (Faraoni Level, Mid-Barremian Event and Taxy Level) are separated by ~2 myr, which corresponds to the period of the long-eccentricity cycle. This suggests a strong orbital control on the occurrence of the organic-rich layers of the end of the Hauterivian to the Barremian Stage in the Tethyan area.

Detailed lithostratigraphy and radiolarian biostratigraphy around the Jurassic–Cretaceous boundary in the Bosso Valley section, Central Italy

Matsuoka A.*[1], Li X.[2], Chiari M.[3] & Bertinelli A.[4]

[1] Department of Geology, Faculty of Science, Niigata University, Japan. [2] State Key Laboratory of Palaeobiology and Stratigraphy, Nanjing Institute of Geology and Palaeontology and Center for Excellence in Life and Paleoenvironment, Chinese Academy of Sciences, China. [3] C.N.R., Istituto di Geoscienze e Georisorse, sede secondaria di Firenze, Italy. [4] Dipartimento di Fisica e Geologia, Università degli Studi di Perugia, Italy.

Corresponding author email: amatsuoka@geo.sc.niigata-u.ac.jp

Keywords: Jurassic, Cretaceous, Radiolaria, biostratigraphy, GSSP.

The Bosso Valley section in the Umbria–Marche area, central Italy, is one of potential candidates for GSSP of the JKB. The Maiolica Formation, which includes the JKB, is characterized by white to light gray colored, well-bedded micritic limestones with abundant light gray to black chert layers and nodules. Calpionellid stratigraphy and magnetostratigraphy have already been studied sufficiently in the section (Housa et al., 2004). The base of the Calpionella alpina Subzone, i.e. the JKB, is placed in the lower part of the Maiolica Formation (Housa et al., 2004). We carried out detailed field observations and careful sample collections in a 4-m interval across the JKB. Acid-etched examination of rock samples revealed that well-preserved radiolarians are recognized inside the lime part near the chert layers or nodules. We made a detailed sketch map at a scale of 1/200 for the Bosso Valley section. More than 20 samples were collected carefully from the section for examination of radiolarian biostratigraphy. Abundant and common genera include *Alievium, Archaeodictyomitra, Cinguloturris, Complexapora, Crococapsa, Doliocapsa, Emiluvia, Hemicryptocapsa, Hsuum, Loopus, Mirifusus, Neorelumbra, Pantanellium, Pseudodictyomitra, Ristola, Spinosicapsa, Tethysetta, Thanarla, Xitus*, and *Zhamoidellum*. As discussed by Goričan et al. (2018), the evolutionary first appearance datums (FADs) within firmly recognized lineages are extremely valuable. Potential candidate for defining the JKB can be found from the lineages of these genera.

Goričan Š., O'Dogherty L., Baumgartner P.O., Carter E.S. & Matsuoka A. (2018) - Mesozoic radiolarian biochronology – current status and future directions. Revue de micropaléontologie, 61, 165-189.

Housa V., Krs M., Man O., Pruner P., Venhodova D., Cecca F., Nardi G., Piscitello M. (2004) - Combined magnetostratigraphic, paleomagnetic and calpionellid investigations across Jurassic/Cretaceous boundary strata in the Bosso Valley, Umbria, central Italy. Cretaceous Research, 25, 771–785.

High resolution microfacies study of the Jurassic/Cretaceous pelagic limestone sequence of the northern Tethyan basins

Michalík J.*[1], Reháková D.[2] & Lintnerová O.[2]

[1] Earth Sci. Institute, Slovak Academy of Sciences, Bratislava.
[2] Faculty of Sci., Comenius University, Bratislava, Slovakia.

Corresponding author email: geolmich@savba.sk

Keywords: microfacies, biostratigraphy, chemostratigraphy, bioevents, J/K boundary, N Tethys.

Upper Jurassic hemipelagic carbonate sediments along northern margin of the Mediterranean Tethys have been typically represented by Rosso Ammonitico limestones: deeper basinal bottoms were occupied by less oxic shaly facies. During Late Tithonian (in the Praetintinnopsella Zone), nodular facies have been substituted by planktogenic biancône limestones (Michalík et al., 2009; 2016). Complex study of microfacies succession, quantitative analysis of calcareous micro- and nannoplankton, O and C isotope ratios and paleomagnetic record in West Carpathians provided a precise tool of stratigraphic and paleoenvironmental interpretation. Four cyst-, four calpionellid zones (with eight subzones) and two nannofossils zones (three subzones) were determined. Abundance increase of saccocomids in the Chitinoidella Zone seems to correlate with more positive δO^{18} isotope ratios (cooling?). Similar positive δO^{18} excursion accompanied the crassicollarian boom stimulated by reorganization of plankton associations due to Late Tithonian transformation of the global system of oceanic currents. However, distinct negative δO^{18} peak which could signalize short top-Jurassic warming in the latest Tithonian Colomi Subzone, heralded the J–K *Calpionella alpina* boundary event (loricae size change of this species indicated by Kowal-Kasprzyk & Reháková, 2019). It was accompanied by the FO´s of *Nannoconus wintereri* and *N. steinmannii minor*. The Alpina event occurs in the M19n Magnetozone nearby to the Brodno Subchron (M19n.1r; Michalík et al., 2009).

Research was supported by projects of both the Slovak Grant Agency APVV-14-0118, and the VEGA 2/0034/16.

Kowal-Kasprzyk J. & Reháková D. (2019) - A morphometric analysis of loricae of the genus *Calpionella* and its significance for the Jurassic/Cretaceous boundary interpretation. Newsletter on Stratigraphy, 52(1), 33-54.

Michalík J., Reháková D., Halásová E. & Lintnerová O. (2009) - A possible West Carpathian regional stratotype of the Jurassic/Cretaceous boundary (the Brodno section near Žilina). Geologica Carpathica, 60(3), 213-232.

Michalík J., Reháková D., Grabowski J., Lintnerová O., Svobodová A., Schlögl J., Sobień K. & Schnabl P. (2016) - Stratigraphy, plankton communities, and magnetic proxies at the Jurassic/Cretaceous boundary in the Pieniny Klippen Belt (Western Carpathians, Slovakia). Geologica Carpathica, 67(4), 303-328.

Provenance of quartz-rich sandstones from the northern Bohemian Cretaceous Basin (Germany, Czech Republic): detrital zircon ages, rutile thermometry and tourmaline geochemistry

Niebuhr B.[1], Hofmann M.[1], Pusch M.[2] & Wilmsen M.*[1]

[1] Senckenberg Natural History Collections Dresden, Museum of Mineralogy and Geology, Germany. [2] Institute of Geology, TU Bergakademie Freiberg, Germany.

Corresponding author email: markus.wilmsen@senckenberg.de

Keywords: petrography, heavy-mineral analysis, age-dating, source-rock characterization, inversion tectonics.

Upper Cretaceous quartz arenites that fill the Bohemian Cretaceous Basin show high compositional but low textural maturity. In the Kreibitz-Zittau area at the northern Czech-German boundary, a ca. 1.000 m thick Cenomanian to Mid-Coniacian succession is exposed and has been the subject of an integrated study. The majority of sandstones studied contain as much as 99% predominantly monocrystalline, but also polycrystalline quartz grains among the poorly sorted framework components, which are angular to sub-rounded. Light heavy minerals are constant through time and nearly exclusively composed of zircon (Z), tourmaline (T) and rutile (R) with a ZTR maturity index of 88–100 (mean 95). Detrital rutile and tourmaline studies show that they are sensitive indicators of granitic/metamorphic/sedimentary (multi-recycling) origin. In all samples Zr-in-rutile temperatures of the granulite facies appear with a peak between 850–950°C. These temperatures have not been reached in the presumed source area of the Upper Cretaceous quartz arenites which were derived from the inverting Lusatian Massif in the north. The successive tourmaline population points unambiguously to various metamorphic source rocks with a predominant group of Al-rich metapelites (Al-rich, Fe-poor dravite) which are present in the gneiss/migmatitic Góry Sowie Massif, ca. 100 km to the east of the depositional area. Likewise, based on the Cr-Nb discrimination, most of the rutile grains originate from metapelitic host rocks. The limited amount of ca. 540 Ma U/Pb-ages of detrital zircon and the predominance of Variscan ages in all samples confirm that the Cadomian basement units of the source area were still covered by Permian–Mesozoic sedimentary rocks. The textural immaturity of Upper Cretaceous sandstones is misleading in terms of their recycled origin, and is inherited from immature clastic source rocks. However, Triassic sandstones are not the predominant source of the Upper Cretaceous sandstones because of their much better maturity of quartz grains and the different heavy mineral composition. The Cenomanian to Mid-Coniacian of the Kreibitz-Zittau area was affected by inversion tectonics especially during Late Turonian times, expressed by strongly increasing sediment supply.

Re-evaluating the paleoecology of Late Cretaceous calcareous nannofossils – the record from shallow marine deposits

Püttmann T. & Mutterlose J.*

University of Bochum, Germany.

Corresponding author email: joerg.mutterlose@rub.de

Keywords: calcareous nannofossils, shallow water assemblages, Late Cretaceous.

Calcareous nannofossils are common components of Jurassic, Cretaceous and Cenozoic marine deposits. They are formed by unicellular algae in photic zone environments, their biogeography is controlled by temperature, nutrients, salinity and other physical or chemical variables. Our understanding of their spatial distribution is biased, because the majority of publications is based on assemblage compositions of pelagic and hemi-pelagic settings. Infrequent are studies of shallow-water, near-shore environments. This is partly because shallow-water deposits are often barren of nannofossils or only provide poorly-preserved and reworked assemblages. Glauconite rich near-shore deposits from several wells, which cored Late Cretaceous sediments in northern Germany, provided well-preserved and diverse calcareous nannofossils. The light-microscopic analysis of 330 sediment samples, studied for biostratigraphy, provided the following conclusions:

- To our knowledge it is for the first time that well preserved Upper Cretaceous calcareous nannofossils are reported from very shallow marine near shore settings, 0 – 10 km off the former coast.
- The diversities of calcareous nannofossils are higher than in contemporaneous pelagic off-shore settings i.e. the classic chalk sediments.
- We are questioning the paradigm, that calcareous nannofossils are necessarily open oceanic or at least hemi-pelagic primary producers in the Late Cretaceous.
- Given the species richness of our coastal assemblages, the palecological affinities of Cretaceous nannofossils need to be re-assessed.

Hothouse to coldhouse transition in the Late Cretaceous: evolution of the circum-Antarctic climate based on planktonic foraminifera biogeography

Petrizzo M.R.*[1], Huber B.T.[2] & Falzoni F.[1]

[1] University of Milan, Italy
[2] Smithsonian Institution, USA

Corresponding author email: mrose.petrizzo@unimi.it

Keywords: planktonic foraminifera, biogeography, Turonian-Maastrichtian, high latitudes.

Late Cretaceous paleotemperature estimates from low to high latitudes reveal a comparable trend, with a warming phase from the Albian to the Cenomanian followed by a hot greenhouse interval from the Turonian to Santonian, and by a progressive cooling phase during the Campanian through Maastrichtian. We present quantitative assemblage data of Turonian-Maastrichtian planktonic foraminifera from ODP Hole 690C (Maud Rise), Hole 700B (Northeast Georgia Rise), Hole 1138A (Kerguelen Plateau) and Hole 762C (Exmouth Plateau). Sites studied were located between paleolatitude 47° and 65°S in the southern South Atlantic and Indian Ocean where any change in vertical gradients and surface water temperatures of the circum-Antarctic region were registered. Planktonic foraminifera underwent major changes during the hothouse interval with species diversification among oligotrophic taxa in the Turonian-Coniacian and appearance of oligotrophic and meso-eutrophic taxa in the Coniacian-Santonian, while the hothouse to coldhouse transition in the Santonian–early Campanian is characterized by few extinctions. The assemblage changes are registered worldwide, from low to high latitudes, although the timing and magnitude of the planktonic foraminiferal evolution at high latitudes is less understood being the assemblages typically dominated by long-ranging, unkeeled and more eutrophic taxa and because of the limited recovery of stratigraphically complete Turonian–lower Campanian sediments by deep-sea exploration programs (DSDP, ODP, IODP). The analysis of the planktonic foraminifera biogeographic distribution patterns in the southern high latitudes is crucial to an accurate and deep understanding of the evolution of the circum-Antarctic climate and of the surface water circulation during the Late Cretaceous climatic transitions. The taxonomic composition of the deep-sea planktonic foraminiferal assemblages is compared among sites and paleolatitudinal position of the biogeographic boundaries are obtained by plotting eco- morphogroup diversity (e.g., shallow/deep dwellers and unkeeled/keeled) identified based on current knowledge of species paleoecology inferred from shell morphology in analogy with living taxa, latitudinal distributions and from stable-isotope studies. Biogeographic distribution patterns reveal that the highest paleotemperatures of the Turonian-Santonian coincide with the broadest expansion of the Tethyan tropical climatic belt. The progressive increase of the low to high latitude temperature gradient correlates to a faunal change in the Santonian, and marks the transition from a dominantly Tethyan influence to a more Transitional affinity throughout the Campanian with the onset of the Austral Province in the Maastrichtian. Poleward and equatorward migration of species are investigated to evaluate if diachronism across latitudes is climate-related or is an artifact because of species rarity.

New data about Santonian-Campanian boundary in the Alan-Kyr section (Central Crimea)

Proshina P.A.*[1], Kopaevich L.[2], Guzhikov A.[3], Aleksandrova G.[1], Ovechkina M.[4] & Ryabov I.[3]

[1] Geological Institute of Russian Academy of Sciences, Russia. [2] Lomonosov Moscow State University, Russia. [3] Saratov State University, Russia. [4] Geological Survey of Israel, Israel.

Corresponding author email: lina.not@mail.ru

Keywords: Santonian-Campanian, Crimea, Foraminifera, Nannoplankton, Palynomorph, Magnetostratigraphy.

One of the problematic boundaries of the Upper Cretaceous is the base of the Campanian, for which GSSP has not yet been established. In the Central Crimea, the Santonian-Campanian boundary interval is represented by a lithologically monotonous carbonate deposits. In the absence of macrofossils, the boundary can be established by microfossil and magnetostratigraphic techniques. The Coniacian-Campanian interval of the Alan-Cyr section (Central Crimea) was studied by Bragina et al. (2016). There was a discrepancy in stratigraphy by the benthic foraminifera on the one hand, and the planktic foraminifera and radiolarians on the other. Therefore, a comprehensive additional study of the Alan-Kyr section deposits was carried out by authors in order to clarify the issue of the boundary position for nannoplankton, palynomorphs and foraminifera using the magnetostratigraphy. At the lower part of the section, according to the results of magnetostratigraphic studies, the chron of reverse polarity was established, correlated with chron 33r, the base of which equals in the International stratigraphic scale to the base of the Campanian. Nannoplankton data confirm the conclusions about the correct interpretation of the interval of reverse polarity. At this level the transition Zone ??17 (Upper Santonian) is established. Above in the section Zone CC18 (Lower Campanian) is recognized. Palynomorphs are fixed in this interval, which is compared with the Newhaven Chalk Formation and part of the Margate Chalk (corresponds to Santonian too). In the lower part of section (Zone CC17) typical Santonian-Campanian bentic and plaktic foraminifera were established. At the terminal part of CC17 Pseudogavelinella clementiana clementiana (d'Orb.) was encountered, indicating a transitional level of the terminal Santonian–Lower Campanian. Zone CC18 is characterized by Lower Campanian planktic foraminifera Globotruncana elevata (Brotz.), above in the section G. ventricosa (White), Heterohelix sphaeralis (Georg.) (Middle Campanian) are established. As a result, the characteristics of the Alan-Kyr section have been supplemented in comparison with the published data. Campanian age of the upper part of the section is confirmed to the data from previous researchers (Bragina et al., 2016). Lower part of the section is determined as Coniacian by Bragina et al. (Bragina et al., 2016) vs. dated by our data Santonian-Lower Campanian.

This research was supported the RFBR: 18-05-00784-a, 18-05-00501 and was carried out of the frame work of State Task Theme 0135-2018-0036 (GIN RAS).

Bragina L., Beniamovsky V. & Kopaevich L. (2016) - Radiolarians, Foraminifers, and Biostratigraphy of the Coniacian–Campanian Deposits of the Alan-Kyr Section, Crimean Mountains. Stratigraphy and Geol. Corr. https://doi.org/10.1134/S0869593816010020.

Exploring the Magnitude, Cause, and Significance of Short-Term Eustatic Cretaceous Sea-Level Change

Ray D.C.*, van Buchem F.S.P., Baines G., Davies A., Gréselle B., Simmons M.D. & Robson C.

Halliburton.

Corresponding author email: David.Ray@halliburton.com

Keywords: Cretaceous, glacio-eustasy, prediction, sedimentary facies patterns, short-term sea-level change.

There is currently no consensus in terms of the magnitude of Cretaceous short-term (<3 Ma) eustatic sea-level change. These limits, for example, the ability to predict sedimentary facies and architecture and to assess potential drivers of eustasy during a period of Earth history considered to be significantly warmer than present day. An analysis of rigorously documented records of short-term relative sea-level change can be used to generate a robust estimate of Cretaceous magnitudes and therefore evaluate observed trends in the context of potential climatic drivers and their eustatic expression. Although Cretaceous sea-level change is addressed in many publications no synthesis of this data exists. Following an exhaustive review, a statistical analysis identifies four broad episodes of magnitude change: three trends of increasing magnitudes of sea-level change—from the Berriasian to Valanginian, Hauterivian to Aptian, and Santonian to Maastrichtian—and one decreasing magnitude trend—from the Albian to Coniacian. The typical maximum magnitude of sea-level change for each stage has been identified and categorised as slight (<10 m), modest (10–40 m), or significant (41–65 m). Significant magnitudes are inferred for the Valanginian, Aptian, Albian and Maastrichtian, while exclusively slight magnitudes are restricted to the Berriasian. Such an assessment casts doubt on the repeated and stratigraphically widespread episodes of extremely large magnitudes (>75 m) advocated by some and instead predicts distinct periods and magnitudes of eustatic sea-level change that should be globally reflected in sedimentary facies patterns. Particularly, intervals of significant magnitude change are commonly associated with increased delivery of shallow-marine sediments into basin settings alongside the enhanced development of karst and erosional features (viz. reservoir development). Because climatically driven eustasy is the likely cause of short-term sea-level change, an assessment of the characteristic upper magnitude limits of the principal climatic drivers (thermo-, aquifer- and glacio-eustasy) has been made. Such a comparison argues for glacio-eustasy as the driver of significant short-term sea-level change. In addition, climate proxy data demonstrate that the Valanginian, Aptian, Albian and Maastrichtian are intervals of cooling within the Cretaceous, thereby supporting the link between significant magnitudes and glacio-eustasy.

Bioevents across the Tithonian-Berriasian boundary, NW margin of Tethys

Reháková D.*[1], Svobodová A.[2], Švábenická L.[3], Svobodová M.[2], Skupien P.[4], Elbra T.[2] & Schnabl P.[2]

[1] Comenius University, Faculty of Natural Sciences, Bratislava. [2] Czech Academy of Sciences, Institute of Geology, Prague. [3] Czech Geological Survey, Prague 4 Technical University of Ostrava.

Corresponding author email: daniela.rehakova@uniba.sk

Keywords: microfossils, nannofossils, bioevents, integrated stratigraphy, J-K boundary, NW Tethys.

Calpionellids, dinoflagellate cysts, palynomorphs, calcareous nannofossils, and microfacies compared to magnetozones offered data for high resolution stratigraphy, paleoenvironmental interpretations and determination of bioevents of the Jurassic–Cretaceous (J–K) boundary at the Kurovice Quarry situated in the Magura Nappe, Outer Western Carpathians. Section is formed by allodapic and biomicritic limestones with thin marlstone intercalations deposited under the enhanced water dynamics in deep shelf margin passing into the distal basin and spans the Early Tithonian-Early Berriasian interval. The J–K boundary is marked by the dominance of small forms of *Calpionella alpina*. Following micro- and nannofossil events were found: the base of section, Malmica Zone is marked by the presence of *Polycostella beckmannii.* The first occurrence (FO) of *Helenea chiastia,* NJT16a is recorded in the dinocyst Semiradiata Zone followed by the Tenuis-Fortis Zone and crassicolarian Remanei Subzone. The FO of *Nannoconus globulus minor,* NJT17a and the last occurence of *P. beckmannii* fall into the lower part of Intermedia Subzone. The FO of *N. wintereri*, NJT17b was found in the upper part of Colomi Subzone. Onset of common *C. alpina* indicates Berriasian Stage. The FO of *N. steinmannii minor*, NKT belongs to the lower part of Calpionella Zone (Alpina Subzone). The FO of *N. kamptneri kamptneri*, NK-1 coincides approximately with the base of Ferasini Subzone. The top of section is marked by the Elliptica Subzone falling still into the NK-1 Zone. Depositional area was situated at the NW margin of Tethys. Low numbers of nannoconids and scarce predominatly tethyan taxa compared to nannofossils from other sites of Tethys highlight influence from high latitudes. Rare calpionellids, the absence of chitinoidellids, and the occurrence of neocomitid ammonites in the Silesian Unit (Vašíček et al., 2017) confirm the cold currents from the North.

The research was supported by the Czech Science Foundation, project No. 16-09979S, by Research plan of the Institute of Geology of the CAS, v.v.i., No. RVO67985831, by the Slovak Grant Agency APVV-14-0118, and by VEGA 2/0034/16.

Vašíček Z., Reháková D. & Skupien P. (2017) - Some perisphinctoid ammonites of the Štramberk Limestone and their dating with associated microfossils (Tithonian to Lower Berriasian, Outer Western Carpathians, Czech Republic). Geologica Carpathica, 68, 6, 583-605.

Paleo-environmental and Paleogeographic Evolution of the Alagoas Stage (~Aptian) in the NE Brazilian Interior Basins

Rios-Netto A.M.*, Carvalho I.S., Alves T.D., Borghi L. & Schmitt R.S.

Federal University of Rio de Janeiro, Brazil.

Corresponding author email: rios.netto@geologia.ufrj.br

Keywords: Araripe Basin, Parnaíba Basin, Aptian, Alagoas Stage, paleoenvironment, paleogeography

The local Alagoas Stage (Aptian–Albian?) represents a time interval of important environmental changes, related to the final phases of the Gondwana breakup. In the interior of the Northeastern Brazil, the Aptian only crops out in the Parnaíba (Codó and Itapecuru formations) and Araripe (Rio da Batateira and Santana formations) basins. This area is close to the continental margins that would be generated with the breakup, then occupying a key position in the understanding of the marine ingressions that drastically affected the regional paleogeography (Arai, 2014). Thus, the interior basins sedimentary record can also provide relevant information about how Aptian paleoceanography was influenced by the contemporary rift systems of both Central and South Atlantic. The current study proposes an interdisciplinary approach which includes Regional Geology (paleogeographic maps and tectonic models involving basement and sedimentary sequences), Sedimentary Geology (stratigraphic infilling *vs* physiographic evolution of the basins), Geophysics (seismic, well logs, airbone methods), Paleontology (macro- and microfossils) and Organic Facies, aiming: (1) to propose a biostratigraphic framework for correlation of the Aptian Stage between Parnaíba and Araripe basins; (2) to understand the paleoenvironmental evolution of that basins, through the characterization of the different sedimentation scenarios, with its paleobiota and associated paleoclimates; (3) to comprehend the paleogeographic evolution of this area, contextualized in the regional tectonostratigraphic evolution; and (4) to construct a regional geological model, which can be stratigraphically correlated and compared to geotectonic models of basins along both the Equatorial and the Eastern Brazilian margins for the Alagoas Age. Preliminary results indicate that: (1) despite the Aptian-Albian age widely mentioned in the paleontological literature, palynological analyzes confirmed that the Santana Formation is restricted to the Aptian (as previously pointed out by Rios-Netto et al., 2012); (2) the early tectonic structures of the Araripe basin are represented by a NE-SW, ENE-WSW oblique fault system that follows the basement fabric; (3) dinoturbation levels were recognized and indicates potential correlative surfaces; (4) wood growing patterns were identified, which enhance the comprehension of the climatic changes during this time interval.

The authors gratefully acknowledge support from Shell Brasil Petroleo Ltda. and the strategic importance of the support given by ANP (Brazil's National Oil, Natural Gas and Biofuels Agency) through the R&D levy regulation.

Arai M. (2014) - Aptian/Albian (Early Cretaceous) paleogeography of the South Atlantic: a paleontological perspective. Brazi. J. Geol., 44(2), 339-350.

Rios-Netto A.M.R., Regali M.S.P., Carvalho I.S. & Freitas F.I. (2012) - Palinoestratigrafia do intervalo Alagoas da Bacia do Araripe, Nordeste do Brasil. Brazi. J. Geol., 42, 331-342.

Biostratigraphy and bioevents during the Jurassic - Cretaceous transition of central Chile

Salazar C.*[1] & Stinnesbeck W.[2]

[1] Escuela de Geología, Facultad de Ingeniería, Universidad del Desarrollo, Santiago, Chile. [2] Institut für Geowissenschaften, Universität Heidelberg, Germany

Corresponding author email: christiansalazar@udd.cl

Keywords: Ammonites, Tithonian, Berriasian, Valanginian, Hauterivian.

The Lo Valdés Formation in the Andes of central Chile contains abundant and well preserved ammonites, indicating a Tithonian-Hauterivian age (Late Jurassic - Early Cretaceous) for this unit. In the type locality at Lo Valdés, also in Cajón del Morado and Cruz de Piedra sections, a total of 1206 ammonites were collected, grouped in 39 species were distinguished referred to 22 genera. This faunal assemblage is here described and discussed for the first time. *Aulacosphinctes proximus*, *Micracanthoceras spinulosum*, *Corongoceras* cf. *koellikeri*, *Substeueroceras koeneni*, *Argentiniceras fasciculatum*, *Pseudofavrella angulatiformis*, *Crioceratites andinum* and *Crioceratites diamantense* were informally recorded previously from the Lo Valdés Formation. *Frenguelliceras magister* is a new record for the unit and for central Chile. *Pterolytoceras exoticum*, *Aspidoceras rogoznicense*, *Micracanthoceras microcanthum*, *Micracanthoceras vetustum*, *Corongoceras lotenoense*, *Corongoceras mendozanum*, *Spiticeras acutum*, *Spiticeras pricei*, *Spiticeras spitiense*, *Groebericeras rocardi*, *Berriasella* (*Berriasella*) *jacobi*, *Malbosiceras malbosi*, *Chigaroceras bardensis*, *Tirnovella kayseri*, *Thurmaniceras thurmanni*, *Crioceratites perditum* and *Bochianites* sp. are first registers for Chile. *Lytohoplites paredesi*n. sp., *Lytohoplites zambranoi* n. sp., *Lytohoplites varelae* n. sp. and *Lytohoplites rauloi* n. sp. are new species. *Parodontoceras* is here considered a junior synonym of *Substeueroceras*. Other lectotypes were designated for *Micracanthoceras spinulosum*, *Micracanthoceras vetustum*, *Spiticeras acutum*, *Substeueroceras calistoide*, *Argentiniceras fasciculatum*, *Tirnovella kayseri*, *Crioceratites andinum*, *Crioceratites diamantense* and *Crioceratites perditum*. *Spiticeras acutum* is considered a morphologically variable taxon. *Berriasella* "*jacobi fraudans*" is considered a synonym of *B. jacobi*; nevertheless *B. jacobi* is a widely used index taxon for the base of the Berriasian and the name should be kept. The following upper Tithonian to upper Hauterivian index fossils are used to subdivide the Lo Valdés Formation: *Micracanthoceras microcanthum* (lower Upper Tithonian), *Corongoceras alternans*, *Berriasella jacobi*, *Groebericeras rocardi*, *Substeueroceras koeneni* (lower Lower Berriasian), *Thurmanniceras thurmanni*, *Argentiniceras fasciculatum* and *Crioceratites diamantense*. Ammonites of the Lo Valdés Formation were collected from sections at Lo Valdés, Cajón del Maipo and at Cruz de Piedra. A total of 1206 ammonites were collected in the Lo Valdés Formation (LV, CM and CP) and these specimens were assigned to 39 species. Here we propose the following zones, from base to top: Zone 1 *Micracanthoceras microcanthum* / *Corongoceras alternans*, Zone 2 *Substeueroceras koeneni* (*Berriasella fraudans* and *Groebericeras rocardi* sub-zone), Zone 3 *Thurmaniceras thurmanni* / *Argentiniceras fasciculatum*, Zone 4, Zone 5 and Zone 6 *Crioceratites diamantense*. Data of "relative abundance", "relative richness", "Evenness and Shannon diversity index" of Baños del Flaco and Lo Valdés formations are integrated and the data set was grouped in stratigraphic intervals, which correspond to the 9 biozones identified. The "abundance" increases gradually from the lower part of the middle Tithonian to the upper Tithonian, with the highest values reached during the upper Tithonian. From the upper Tithonian to the upper Valanginian the "relative abundance" decreases gradually. Ammonites are rare to absent in the upper Valanginian to lower Hauterivian interval and the "relative abundance" drops to low values or even zero but rises again to low "relative abundance" levels in the Upper Hauterivian. "Richness" is high during the middle and upper Tithonian and into the lower Berriasian. During this latter stage numbers decrease to the lower Valanginian. No ammonites were identified for the upper Valanginian and lower Hauterivian interval. "Richness" is low for the upper Hauterivian. Our species turn-over analysis of ammonites based on sections. Zero similarity between the lower and the middle Tithonian; from the upper Tithonian to the upper Berriasian, similarity values increase gradually, coincident with the gradual decline of the diversity. Values indicate highest similarity values during the upper Tithonian, coincident with a high diversity; similarity declines (20%) during the lower Berriasian as most taxa registered in the upper Tithonian are absent during the lower Berriasian. Ecological indices, such as "relative abundance", "relative richness", "evenness" and the "Shannon" diversity index, show that the highest

relative abundance and diversity were reached during the middle to upper Tithonian, with the main bioevent at the end of the upper Tithonian The ecological index is still high for the lower Berriasian, with the highest richness, but taxa differ between these stages, with the exception of *Substeueroceras callistoide*, and the Jaccard index is low. Relative richness and relative abundance of Baños del Flaco and Lo Valdés formations, during the Tithonian to Hauterivian, the ecological index shows similar values during the Tithonian and Berriasian; 41% and 41% richness and 43% and 42% abundance. During the Valanginian the richness and abundance decrease abruptly to values 12% and 13% respectively. During the Hauterivian the values are lower, due to low ammonites collected in the sections.

The Cretaceous of Tunisia – A new window on marine to non-marine strata and changing palaeoenvironments at the southern Tethys margin of North Gondwana

Sames B.*[1], Trabelsi K.[2-3], Wagreich M.[1], Nasri A.[4], Houla Y.[5], Soussi M.[3], Elferhi F.[6], Skanji A.[6], Martín-Closas C.[7], Wolfgring E.[1] & Piovesan K.[8]

[1] University of Vienna, Austria. [2] University of Sfax, Tunisia. [3] University of Tunis El Manar, Tunisia. [4] Mazarine Energy BV, Tunisia. [5] Office National des Mines (ONM), Tunisia. [6] Entreprise Tunisienne d'Activités Pétrolières (ETAP), Tunisia. [7] University of Barcelona, Spain. [8] Federal University of Pernambuco, Brazil.

Corresponding author email: benjamin.sames@univie.ac.at

Keywords: Aptian-Albian, biostratigraphy, North Africa, sea-level changes, continental.

Within the scope of new collaborations between Tunisian and Austrian researchers, we (re)study the Jurassic to Cretaceous of the Central Tunisian Atlas (CTA) and the Tunisian Saharan Platform (TSP). During this time interval, transgressions and regressions onto the essentially stable Saharan Platform and coeval tectonics produced a complex pattern of basins and islands. The respective marine to non-marine successions of the CTA and TSP document regional and major global sea-level fluctuations, changing palaeogeographic patterns, as well as shallow marine to non-marine palaeoenvironments and deposits of Peri-Tethyan islands of northern Gondwana. A first research focus is on the Aptian–Albian Orbata carbonate platform of the CTA (Orbata Formation). Previous litho- and biostratigraphic studies confined this formation to the Aptian suggesting an upper Aptian–lower Albian major gap between Orbata deposits and overlying Upper Albian transgressive carbonates and shales (Zebbag Fm.). Based on detailed sedimentological logging and reliable chronostratigraphic data (charophyte, ostracod and dinosaur track biostratigraphy; strontium isotopy) we reject this hypothesis by extending the upper parts of the Orbata Fm. into the Lower Albian, as recently stated for the northern Tunisian Atlas (Jebel Serdj-Bargou area, Ben Chaabane et al., 2019) as well. In central Tunisia, two major regional discontinuities (emersion surfaces) of eustatic order, KAp1 and KAp7 of Haq, have been identified and dated. The latter caused the total emersion of the central domain of the CTA (revised "Kairouan island" concept) and is followed by deposits of the non-marine Kebar Fm. in several localities of the southern CTA and dated uppermost Aptian?–Lower Albian with non-marine ostracod and charophytes. Current main focus is the mapping, documentation, correlation/dating, and micropalaeontology of Lower Cretaceous (cf. Trabelsi et al., 2015) and Middle–Upper Jurassic non-marine deposits. This includes characterization, refined stratigraphy, and evolution of mid-late Mesozoic lake-systems and their deposits in the CTA/TSP, and their regional to supra-regional correlation. Also, the relation of these ancient lake ecosystems to, and control by, tectonics, palaeoclimate, and sea-level changes will be evaluated. New discoveries of non-marine deposits and fossils in Tunisia lead to the conclusion that the CTA and TSP have been key areas for floral and faunal exchange between Gondwana and Eurasia during the mid-late Mesozoic, shedding new light on palaeobiogeographic dispersal schemes and patterns.

Trabelsi K., Sames B., Salmouna A., Piovesan E.K., Rouina S.B., Houla Y., Touir J. & Soussi M. (2015) - Ostracods from the marginal coastal Lower Cretaceous (Aptian) of the Central Tunisian Atlas (North Africa): Paleoenvironment, biostratigraphy and paleobiogeography. Rev. de Micropal., 58, 309–331.

Chaabane N. B., Khemiri F., Soussi M., Latil J. L., Robert E. & Belhajtaher I. (2019) - Aptian-Lower Albian Serdj carbonate platform of the Tunisian Atlas: Development, demise and petroleum implication. Marine and Petroleum Geology, 101, 566–591.

Cretaceous cold start: the Jurassic–Cretaceous transition in the Rollrock Section, Sverdrup Basin, Canadian Arctic Archipelago

Schneider S.*[1], Kelly S.R.A.[1], Herrle J.[2], Hülse P.[1], Ingrams S.[3], Jolley D.[3], Mutterlose J.[4], Schröder-Adams C.[5] & Lopez-Mír B.[1]

[1] CASP, Cambridge, United Kingdom. [2] Institute of Geosciences, Goethe-University Frankfurt, Germany. [3] School of Geosciences, Geology & Petroleum Geology, University of Aberdeen, United Kingdom. [4] Institute for Geology, Mineralogy and Geophysics, Ruhr-Universität Bochum, Germany. [5] Department of Earth Sciences, Carleton University, Ottawa, Canada

Corresponding author email: simon.schneider@casp.cam.ac.uk

Keywords: Arctic, biostratigraphy, palaeoclimate, glendonites, ammonites, J-C boundary.

The Rollrock Section on northern Ellesmere Island (Arctic Canada) is one of the most complete rock archives of the Jurassic-Cretaceous transition in the Arctic. It exposes an over 500 m thick, continuous succession of Upper Jurassic to Lower Cretaceous sediments, providing a unique opportunity to study the stratigraphy and palaeoclimate of this interval in detail. We use a multi-proxy approach to unlock this archive, analysing macro- and microfossils, palynomorphs and geochemistry. The lower half of the succession, assigned to the Ringnes Formation, is dominated by mudstones, with fine-grained sandstones and siltstones forming the top 20 m of the unit. A rapid transition to mudstone deposition and the sudden occurrence of abundant dropstones mark the onset of the Deer Bay Formation. These mudstones grade into the sand-dominated Isachsen Formation at the top. The succession likely was deposited in a moderately shallow, relatively proximal position on the shelf of the Sverdrup Basin. Dropstones occur throughout the Deer Bay Formation, but it is an open question whether the ice rafts transporting the pebbles formed during winter along the coast, or were proper icebergs. Glendonites, which are confined to ten horizons in the upper half of the unit, also document cold, Arctic conditions during the deposition of the Deer Bay Formation. In order to analyse the palaeoclimatic record of the Rollrock Section, the succession was sampled at 1.5 m intervals for microfossil, palynomorph and geochemical analysis. Additionally, macrofossils serving as biostratigraphic markers were collected from sideritic concretions, which occur in discrete horizons in the upper 350 m of the succession. These fossils collectively document early Tithonian to Valanginian ages. The early Tithonian Buchia rugosa Zone is recorded at 192 to 197 m, and the mid Tithonian Dorsoplanites maximus Zone at 307 m. A monospecific *Buchia terebratuloides* shell pavement at 333.5 m allocates this horizon as close to the Jurassic-Cretaceous transition. Furthermore, Ammonites and *Buchia* indicate an early Berriasian age for the interval from 355 to 363.5 m. Finally, belemnites evidence a Valanginian age for the 410.5 to 425 m interval. Both marine and terrestrial palynomorphs are being analysed to support biostratigraphy, and infer climatic conditions within the basin, as well as in its surroundings. Preliminary results suggest that the basal part of the section may be of Oxfordian age, while typical Jurassic-Cretaceous transition taxa are abundant at 320 m and above. These new data provide better constraints on the biostratigraphy of the Rollrock Section and of the Sverdrup Basin succession as a whole, and pave the way for establishing the presence of Arctic cold snaps and ice caps over the Jurassic-Cretaceous transition.

Middle Jurassic to Cretaceous shallow marine to non-marine micropalaeontology (Ostracoda, Charophyta) in Tunisia: insights from a biogeographic crossroad

Trabelsi K.[1-2], Sames B.*[3], Tiss L.[1], Piovesan K.[4], Martín-Closas C.[5], Soussi M.[2], Elferhi F.[6], Houla Y.[7], Nasri A.[8], Wagreich M.[3] & Wolfgring E.[3]

[1] University of Sfax, Tunisia. [2] University of Tunis El Manar, Tunisia. [3] University of Vienna, Austria.[4] Federal University of Pernambuco, Brazil. [5] University of Barcelona, Spain. [6] Entreprise Tunisienne d'Activités Pétrolières (ETAP), Tunisia. [7] Office National des Mines (ONM), Tunisia. [8] Mazarine Energy BV, Tunisia.

Corresponding author email: benjamin.sames@univie.ac.at

Keywords: biostratigraphy, palaeobiogeography, continental, marginal marine, north Gondwana, Peri-Tethyan islands.

Mesozoic non-marine to marine transitions and respective successions are known from the Central Tunisian Atlas (CTA) and the Tunisian Saharan Platform (TSP), north Gondwana, southern Tethys margin. During Middle Jurassic to mid-Cretaceous times transgressions and regressions onto the essentially stable Saharan Platform and coeval tectonics produced a complex pattern of basins and islands. Non-marine successions of the CTA and TSP both well document deposits of contemporaneous Peri-Tethyan islands offshore northern Gondwana. In the context of a successful collaboration project between Tunisian and Austrian researchers, including specialists from other countries, we focus on calcareous microfossils (Ostracoda and Charophyta) as well as the characterization, refined stratigraphy, and evolution of mid-late Mesozoic lake-systems and their deposits in the CTA and TSP, the controlling factors and their regional to supra-regional biostratigraphic context. Tunisian Mid-Jurassic to mid-Cretaceous marine to non-marine deposits reveal partially new, rich ostracod faunas and charophyte floras, many elements of which can be supra-regionally linked to Gondwana, i.e., West Africa and South America, and Eurasia plus partially North America (Trabelsi et al., 2015, 2016; Tiss et al., 2019). This is a result of the same dispersal strategies and mechanisms of certain non-marine ostracod groups and charophytes, i.e., they are passively transported by larger animals over short and long distances – crossing migration barriers, even oceans. Our new discoveries do not only improve the regional biostratigraphy but also facilitate supra-regional correlations in this time interval and support concrete considerations of non-marine faunal and floral exchanges between South America and Asia via North Africa and the Peri-Tethyan islands, for example. Considering varying dispersal vectors coming into question at different respective time intervals (e.g. evolution of birds) in the context of contemporaneous palaeogeograpic patterns and changes and palaeoclimate, the CTA and TSP are becoming key areas of interest for mid-late Mesozoic non-marine (micro?)palaeontological research and application. Our new data corroborate the fundamental utility of non-marine Ostracoda and Charophyta as chronostratigraphic tool.

Trabelsi K., Sames B., Salmouna A., Piovesan E.K., Rouina S.B., Houla Y., Touir J. & Soussi M. (2015) - Ostracods from the marginal coastal Lower Cretaceous (Aptian) of the Central Tunisian Atlas (North Africa): Paleoenvironment, biostratigraphy and paleobiogeography. Rev. de Micropal., 58, 309–331.

Trabelsi K., Soussi M., Touir J., Houla Y., Abbes C. & Martín-Closas C. (2016) - Charophyte biostratigraphy of the non-marine Lower Cretaceous in the Central Tunisian Atlas (North Africa): palaeobiogeographic implications. Cret. Res., 67, 66-83.

Tiss L., Trabelsi K., Kamoun F., Soussi M., Houla Y., Sames B., & Martín-Closas C. (2019) - Middle Jurassic charophytes from southern Tunisia: Implications on evolution and paleobiogeography. Review of Palaeobotany and Palynology, 263, 65–84.

Late Cretaceous Microfossils as indicators of warming episodes (Boreal and Peri-Tethyan Russia)

Vishnevskaya V.S.[1] & Kopaevich L.F.*[2]

[1] Geological Institute, Russian Academy of Sciences, Moscow, Russia. [2] Geological Faculty, Lomonosov Moscow State University, Moscow, Russia.

Corresponding author email: valentina.vishnaa@mail.ru

Keywords: Foraminifera, Radiolaria, nannoplankton, calcareous dinocysts.

The Late Cretaceous main palaeogeographic features of the Eastern European Platform (EEP) and its framework, as well as Western Siberia are summarized on the base of micropalaeontological data. An integrated foraminiferal-radiolarian Zonation for the Late Albian-Maastrichtian is presented for all this area and serves as a basis for palaeogeographic reconstructions. The study is mainly focused on the several time-slices: Late Albian–Cenomanian, Turonian–Coniacian, Santonian–Campanian and Maastrichtian intervals. The Late Albian time was characterized by tectonic rebuilding all this area, when a meridional sea–straight through the EEP disappeared, and connections with western part of Peri-Tethyan seas, and Tethys Ocean opened. The presence Tethyan species inside micropalaeontological assemblages confirms more warm climate compared the Late Albian. The Turonian-Coniacian interval is characterized by appearance of the planktonic foraminifers typical for Crimea-Caucasus area in sections of southern part of EEP. Upper Cenomanian−Lower Turonian foraminiferal Zone *Whiteinella archaeocretacea* is recognized not only in Crimea-Caucasus area, but in EEP and in the Western Siberia Basin. The rapid increase in the number of keeled specimens of *Dicarinella*, *Marginotruncana* among foraminifers and *Alievium* among radiolarians can be explained by Tethys transgression and rise of water temperature. As the result, during the Middle Turonian–Santonian time mainly carbonate sedimentation prevailed. However the cold Boreal water influence can be recognized not only on the northern margin of the EEP, but so far as Northern Caucasus during certain time interval and especially intensive during Campanian. The Western Siberia Boreal basin also influenced on climatic fluctuations through the Palaeo-Ural territory and Turgai strait. The formation of the siliceous wedge, which is composed of diatom and radiolarian skeletons, continued to the Campanian and Maastrichtian. The finding of plankton foraminifers and calcareous nannoplankton in Maastrichtian of the Westerm Siberia point to green house episode. The plankton foraminifers and calcareous nannoplankton and dinocysts *Pithonella globosa* Futterer, occurring in the Middle Maastrichtian also allows indicate a relatively warm episode during the sedimentation of the opoka like clay in the Saratov Volga Basin of EEP. This impulse is fixed in isotope data (Iakovishina et al., 2017).

This research was supported by the IGCP-609 Project and the RFBR: 18-05-00494, 18-05-00495, 18-05-00503.

Guzhikov A.Y., Baraboshkin E.Y., Benyamovskiy V.N., Vishnevskaya V.S., Kopaevich, L.F., Pervushov E.M. & Guzhikova A.A., (2017) - New bio-and magnetostratigraphic data on Campanian–Maastrichtian deposits of the classical Nizhnyaya Bannovka section (Volga river right bank, southern Saratov region). Stratigraphy and Geological Correlation, 25(1), 39-75.

Iakovishina E., Mashkina Y.A., Blinov I.V. & Bordunov S.I. (2017) - Maastrichtian paleotemperature changes in the Southern Russia. Berichte der Geologischen Bundesanstalt, Band 120, Wien, 122 pp.

Aquifer eustasy was the main driver of short-term sea-level fluctuations during Cretaceous hothouse climate phases

Wagreich M.*[1], Sames B.[1], Wolfgring E.[1] & Iqbal S.[1-2]

[1] University of Vienna, Austria. [2] Quaid-i-Azam University, Islamabad, Pakistan

Corresponding author email: michael.wagreich@univie.ac.at

Keywords: Cretaceous, sea level, aquifer eustasy.

Evaluation of short-time, 100 ka–2 Ma, sea-level fluctuations during the Mesozoic greenhouse interval indicates, similar to icehouse phases, that these 3rd and 4th order greenhouse and hothouse sea-level changes are linked to Milankovitch-type of climate cycles especially prevailing longer Milankovitch cycles such as 405 ka, 1.2 Ma and 2.4 Ma. In the lack of ice during Cretaceous hothouse times, there exists growing evidence for groundwater-related sea-level cycles: 1) the existence of Milankovitch-type of humid-arid climate oscillations, proven via intense humid weathering records during times of regression and sea-level lowstands; 2) Missing or inverse relationships of sea level to the marine $\delta^{18}O$ records, i.e., the lack of a pronounced positive excursion cooling signal during sea-level lowstands; 3) the anti-phase relationship of sea level and lake levels, attesting to high groundwater levels and charged continental water reservoirs during sea-level lowstands (the limno-eustatic process). These evidences substantiate the aquifer eustasy hypothesis, which assumes that during greenhouse/hothouse times, the filling of continental groundwater aquifers and lakes, contributes the major part to the sea-level change amplitudes. Rates of aquifer-eustatic sea-level change are still hard to decipher, however, reconstructions range from a very conservative minimum estimate of 0.04 mm/a (for longer time intervals) to 0.7 mm/a for shorter, probably asymmetric cycles. Remarkably, the process of climate-driven land water storage was recently recognized as an important component for today's sea-level budget, slowing down today's sea-level rise from melting ice and warming oceans. In a warming world, the hydrological cycle is intensified, influencing significantly the precipitation and its distribution from ocean to land which may result in charging continental aquifers over millenial timescales.

Inoceramids and the mid-Cretaceous saga

Walaszczyk I.*[1] & Bengtson P.[2]

[1] University of Warsaw, Poland. [2] Heidelberg University, Germany.

Corresponding author email: i.walaszczyk@uw.edu.pl

Keywords: Cretaceous, series subdivision, inoceramid bivalves.

Throughout the last four decades, the terms mid-Cretaceous and middle Cretaceous have been increasingly used in the literature, comprising everything from one single (Cenomanian) to seven (Barremian to Santonian) ages/stages. Although the lower and upper Cretaceous series are generally regarded as formal units, they have actually never been formally defined and ratified. This terminological limbo leads to confusion and calls for a formal division of the Cretaceous System. Most Phanerozoic systems/periods are divided into three series/epochs, even though they represent considerably shorter time spans than the Cretaceous. A Google internet search for "mid-Cretaceous" or "middle Cretaceous" yields well over half a million hits, clear evidence that these terms fulfil a need in stratigraphic terminology. Chronostratigraphic division is primarily linked to palaeontological events manifested in the rock record. Thus, identification of major taxonomic turnover events among the chronostratigraphically most important fossil groups will provide a basis for a practical division of the Cretaceous. As a first step, ammonite turnover events have been analysed in the broad 'mid-Cretaceous' interval, from base Barremian to base Santonian (Bengtson & Kakabadze, 2018). The results provide little support for a series boundary at the Albian–Cenomanian boundary, the informal (sic) lower–upper Cretaceous boundary adopted by most workers. Instead, the most significant ammonite turnover event occurred at the Aptian–Albian boundary, which thus emerges as a potential lower boundary of a middle Cretaceous series. Higher in the sequence, no similarly distinctive turnover event is found among the ammonites, although the turnover at the Cenomanian–Turonian boundary interval is slightly more pronounced. As a second step towards a solid database for a proposal of a formal division of the Cretaceous, taxonomic turnover events among the inoceramid bivalves have been analysed. Two aspects were addressed: (1) species-level diversity at the substage level and (2) phylogenetic history. Genus-level analysis, which in general should be less sensitive to taxonomic subjectivity, is poorly applicable in the case of inoceramids. Although some genus-level taxonomies have been published (e.g., Pokhialainen 1985), systematics at this taxonomic level is far from widely accepted. As with ammonites, inoceramid bivalves do not support a lower–upper Cretaceous series boundary at the base of the Albian–Cenomanian boundary. The two most significant taxonomic turnover events occur at the Aptian–Albian and the Coniacian–Santonian boundaries. The Aptian–Albian faunal change may, however, be biased due to sample-size effects, and further studies are needed to clarify if the observed increase in taxonomic diversity in the Albian compared to the Aptian is a true biological phenomenon. Three other levels with significant taxonomic turnovers among the inoceramids occur at the Cenomanian–Turonian and the Turonian-Coniacian boundaries, and at the base of the middle Coniacian. In order to provide a basis for a formal division of the Cretaceous, the ammonite and inoceramid data will be integrated with data on other chronostratigraphically significant fossil groups – such as foraminifers, calcareous nannofossils and dinoflagellates – and with magneto-, chemo- and cyclostratigraphy.

Bengtson P. & Kakabadze M.V. (2018) - Ammonites and the mid-Cretaceous saga. In: Bengtson, P. Ed., Cretaceous Ammonites: A Volume in Memory of Richard A. Reyment (1926–2016), Cretaceous Research, 88, 90-99.

Pokhialainen V.P. (1985) - An outline of supra-specific systematics of the Cretaceous inoceramid bivalves, 37 pp. Academy of Sciences of the USSR; Magadan.

High-resolution environmental archive for the mid-Maastrichtian Inoceramid Acme Event (IAE) – the geochemical proxies in sclerochronology of *Inoceramus (Platyceramus) salisburgensis*

Wierzbicki A.* & Kędzierski M.

Jagiellonian University, Institute of Geological Sciences, Kraków, Poland

Corresponding author email: adam.wierzbicki@doctoral.uj.edu.pl

Keywords: Inoceramid Acme Event, bivalve sclerochronology, Carpathians, stable oxygen and carbon isotopes.

Inoceramus (Platyceramus) salisburgensis belongs to the Late Cretaceous group of large inoceramid bivalve that are characterized by its shell height often exceeding a half of meter, supposing its significantly long life-span either. This species feature potentially can yield a high-resolution archive of environmental conditions (tens to hundreds of years of year-by-year continuous set) of mid-Maastrichtian IAE recorded in its shell. The detailed sclerochronological and geochemical analysis of shell composition allows us to determine seasonal or even inter-annual environmental fluctuations. Aim of the study is to scrutinize the course of changes in marine ecosystems during IAE, eventually leading to inoceramid disappearance. The inoceramid shells and rock samples were collected in outcrop located in Skole Nappe (SE Poland), south of the City of Przemyśl. The analyzed section embraces the Upper Cretaceous–Paleogene flysch deposits of Ropianka Formation and contains about 16th inocerams bearing interturbidite horizons set. They differ in thickness and inoceramid shell abundance and various shell's state of preservation (moderate-to-very good). This part of the section is stratigraphically referred to IAE and represent the last one *in-situ* accumulation of *Inoceramus* spp. across the whole Outer Carpathians. The study consists of microgrowth shell patterns and its geochemical analysis including stable oxygen (δ18O) and carbon (δ13C) isotope ratio values, cathodoluminescence (CL) microscope and field emission scanning electron microscope (FE-SEM). Every inoceramid shell or its fragments were screened for degree of diagenetic prior to further investigations. Moreover, rock samples of interturbidites surrounding bivalve fossils, were additionally tested on CaCO3 [%] content. The record of δ18O and δ13C stable isotope ratio values of inoceramid shells varies between specimens and within a single shell. Paleotemperature calculation based on δ18O record points out differences in values reaching up to 5 °C in a shell. Comparison of δ18O paleotemperatures between horizons show even higher differences. Moreover, changes in δ13C values, combined with shell growth pattern, may indicate *I.(P.) salisburgensis* ability to shift between suspension feeding and chemosymbiotic nutrition. The δ18O and δ13C values recorded in the last inoceram and other bivalve occurring directly above IAE indicate an abrupt environmental change, supposedly responsible for the inocerams disappearance, that was lasting nothing but dozen, or so, years.

Study sponsored by National Science Centre fund No. UMO-2014/15/B/ST10/04229.

Cretaceous stratigraphy and depositional environments at the eastern margin of the Anarak Metamorphic Complex (Central Iran)

Wilmsen M.*[1], Berensmeier M.[2], Fürsich F.T.[3], Hairapetian V.[4], Schlagintweit F.[5] & Majidifard M.R.[6]

[1] Senckenberg Naturhistorische Sammlungen Dresden, Museum für Mineralogie und Geologie, Germany. [2] Institut für Paläontologie, University of Vienna, Austria. [3] GeoZentrum Nordbayern, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany. [4] Department of Geology, Islamic Azad University Isfahan, Iran. [5] München, Germany. [6] Research Institute for Earth Sciences, Geological Survey of Iran, Tehran, Iran.

Corresponding author email: markus.wilmsen@senckenberg.de

Keywords: Yazd Block, integrated stratigraphy, facies analysis, onlap patterns, tectonic events.

Cretaceous strata are well-exposed in the northern part of the Yazd Block, Central Iran, where they attain a thickness of several kilometres in the Khur area. However, the record is substantially reduced in the north-western part of the study area towards the Anarak Metamorphic Complex (AMC), a basement uplift mainly consisting of Palaeozoic to Triassic rocks that obviously formed a positive area during Cretaceous times. The scope of our study is the understanding of the stratigraphy and depositional environments at the margin of this structure in the framework of the Cretaceous geodynamic evolution of Central Iran. To obtain these goals, several sections south of Chupanan have been logged and sampled in great detail. The Cretaceous succession rests on a pronounced palaeo-relief formed by basement rocks of the AMC. It starts with patchily developed continental red-beds of the Noqreh Formation, the uppermost part of which can be dated as (Late) Barremian by means of microfossils in first marginal marine intercalations. Up-section, well-bedded shallow-water carbonates of the up to 50-m-thick Upper Barremian–Lower Aptian Shah-Kuh Formation reflect the establishment of a first carbonate platform system dominated by rudists, benthic foraminifera and calcareous algae. It is followed by the increasingly deeper marine marls and nodular limestones of the Aptian–Albian Bazyab Formation (ca. 400 m thick). The deepening trend, interrupted by a major Late Aptian shallowing event, culminated in the Late Albian. In the Early Cenomanian, another rudist platform formed, documented by the massive carbonates of the lower Debarsu Formation (ca. 100 m thick). These strata onlap isolated basement highs that obviously remained emergent throughout the Early Cretaceous, forming isles of an archipelago at the eastern margin of the AMC. Above an intra-formational, Middle to (early) Late Cenomanian tectonic unconformity, the shallow-water carbonates of the lower Debarsu Formation were replaced by an upper marl member reflecting an overlapping deep-water setting during the Early and Middle Turonian. Another major Late Turonian–Coniacian tectonic unconformity related to substantial regional uplift is reflected by the erosional base of the overlying (Coniacian?) Santonian–Campanian Haftoman Formation. The up to 30-m-thick basal cobble-to-boulder conglomerate of the Haftoman Formation reflects rock-fall and proximal alluvial fan deposition and is followed by evaporites of sabkha origin. Up-section, lagoonal carbonates prevail in the Haftoman Formation. The Cretaceous succession at the margin of the AMC is strongly reduced in thickness compared to the succession around Khur and displays a more proximal character. Nevertheless, the area was characterized by a similar succession of depositional environments and affected by the same tectonic events that may have their causes in far-field effects of large-scale ophiolite emplacements in the Neotethys Ocean to the southwest.

A multistratigraphic study of the Campanian Postalm section (Northern Calcareous Alps, Austria)

Wolfgring E.*[1], Wagreich M.[1], Hohenegger J.[1], Dinarès-Turell J.[2], Spötl C.[3] & Sames B.[1]

[1] University of Vienna. [2] Istituto Nazionale di Geofisica e Vulcanologia. [3] University of Innsbruck.

Corresponding author email: erik.wolfgring@univie.ac.at

Keywords: Campanian, cyclostratigraphy, foraminifera, nannoplankton.

The Postalm section in the Gosau Group (Northern Calcareous Alps) exposes pelagic deposits of the northwestern Tethys. This study focuses on magneto-, biostratigraphy and cyclostratigraphy with special emphasis on the impact and rates of palaeoenvironmental changes. The section displays rhythmic deposits of Santonian to uppermost Campanian age. The Santonian/Campanian transition is characterised by condensed greyish packstones, while the younger deposits are reddish foraminiferal packstones. The latter consist of limestone-marl couplets, whereby each pair represents a precessional cycle of approximately 20 ka. A biostratigraphic framework based on planktonic foraminifera and calcareous nannofossils is supported by carbon and strontium isotope stratigraphic as well as magnetostratigraphic data. Stable isotope data from provide further means to correlate the Postalm section to Tethyan reference sections. Events such as the Late Campanian Event and the Base *Calcarata* Event were identified using $\delta^{13}C$ data. Spectral analyses of three proxies ($\delta^{13}C$, Fe content and thickness of limestone/marl couplets) identified 17 (model A) to 18 (model B) 405 ka eccentricity cycles spanning the middle to upper Campanian (*Contusotruncana plummerae* to *Gansserina gansseri* Zones or CC17/UC15 to CC23/UC16 nannofossil zones). A cyclostratigraphic model based on three proxies ($\delta^{13}C$, Fe and the variations in bed thickness of limestone/marl couplets) in combination with biostratigraphic data and ages of Chron boundaries gives insights into the duration of biozones and the timing of bioevents in the northwestern Tethys Ocean.

High-resolution integrated stratigraphy of the Hauterivian in Umbria-Marche (Central Italy)

Wouters S.*[1], Satolli S.[2], Martinez M.[3], Schnyder J.[4], Boulvain F.[1], Goovaerts T.[5], Meyvis B.[5] & Devleeschouwer X.[5]

[1] University of Liège. [2] University G. d'Annunzio of Chiety, Pescara. [3] University of Rennes. [4] Sorbonne Universities. [5] Royal Belgian Institute of Natural Sciences.

Corresponding author email: sebastien.wouters@doct.uliege.be

Keywords: Hauterivian, chert, black shales, integrated stratigraphy.

Lower Cretaceous Hauterivian sediments are found in Central Italy as part of the Maiolica Fm. These sediments present strongly contrasting lithologies. From the original radiolarian calcareous ooze that constituted the bulk of the initial deposits, biogenic silica exclusively migrated in cherts, while calcium carbonate reprecipitated into the limestones. Moreover, thin black shale levels and stylolites are enriched in insoluble elements and minerals, which contrast with the nearly pure limestone and chert (> 90 % $CaCO_3$ and SiO_2 respectively, mainly negative magnetic susceptibility for both).

In this context, as part of the CRASH (Checking the Reproducibility of Astrochronology in the Hauterivian) project, we are testing whether a Milankovitch imprint is preserved through these lithologies, despite the diagenetic processes implied by their contrasting nature. High-resolution sampling was performed for cyclo- and magnetostratigraphic purposes in order to avoid the accumulation of positioning uncertainty coming from compiling heterogeneous data sets. To deal with the data in a comprehensive way we developed the StratigrapheR package, available in the free software environment R (https://CRAN.R-project.org/package=StratigrapheR). It is designed to generate lithologs and to process stratigraphical information for cyclostratigraphy. For the investigated sections it allowed to create high-resolution logs that can be queried in the R environment. As the high-resolution lithologs show all the features observed in the field they can be used to reduce the positioning uncertainties for future field missions as much as possible. Additionally they can be used to compare overlapping parts of different sections. Our preliminary work allows to correlate bundles of thin black shale sequences between two sections spanning overlapping deposition intervals, using magnetostratigraphy as a stratigraphic reference. This is further confirmed by organic matter (OM) analyses, showing similar OM preservation trends between the sections. On the other hand chert layers patterns are more difficult to match between sections. Similarities can be found using the black shale levels as reference, but discrepancies are equally frequent. The ubiquity and regularity of chert layering make it generally difficult to identify any specific pattern. Furthermore we document the "Weissert" and Faraoni events in our sections. Both present a decrease of the natural remanent magnetisation intensity, which would imply an effect of these events on magnetite. Magnetite is indeed the main contributor for the primary component of magnetisation in the Maiolica Fm. (Channell et al., 1995). The Faraoni level also marks a decrease in the concentration of lithogenic elements and in magnetic susceptibility.

Channell J.E.T., Cecca F. & Erba E. (1995) - Correlations of Hauterivian and Barremian (Early Cretaceous) Stage Boundaries to Polarity Chrons. Earth Planet. Sci. Lett., 134, 125–40.

Size variations of calcareous nannoplankton in mid Barremian black shales from the Boreal Realm – evidence for an OAE?

Wulff L.*[1], Mutterlose J.[1] & Bornemann A.[2]

[1] Ruhr University Bochum, Germany. [2] Bundesanstalt für Geowissenschaften und Rohstoffe, Germany

Corresponding author email: lena.wulff@rub.de

Keywords: Early Cretaceous, OAEs, black shales, coccoliths, morphometry.

The Cretaceous interval, the warmest period in the Mesozoic, was characterized by warm, humid greenhouse conditions. Several geologically short termed climatic perturbations lead to so called oceanic anoxic events (OAE's), documented in the marine sedimentary record. During these events, ocean bottom waters were depleted in oxygen, causing the widespread deposition of black shales. OAE's, particularly the T-OAE (Toarcian; Jurassic), the OAE 1a (Aptian; Early Cretaceous) and the OAE 2 (Cenomanian; Late Cretaceous) have been intensively studied for more than 50 years. Apart from these well-known OAE's, black shales of mid Barremian age are currently discussed as a potential additional OAE. Particularly mid Barremian black shales from the Boreal Realm (northern Germany), which have been well documented in the past, possibly reflect this OAE. However, current models suggest that the anoxic bottom water conditions, which caused these black shales, were temperature controlled and reflect a regional signal. On the other hand, mid Barremian black shales have been recognized in the Tethys (Switzerland, Italy, France,) indicating rather a global distribution of this event. It has been documented, that marine biotas react sensitive to these environmental perturbations. In particular, size decreases of single calcareous nannoplankton species have been recorded from both, OAE 1a and OAE2 (Lübke & Mutterlose, 2016; Faucher et al., 2017). In order to understand whether the named Barremian black shales reflect a typical OAE signal, a core recently drilled in northwest Germany has been studied in detail for calcareous nannofossil biostratigraphy and –morphometry as well as stable isotopes.

Faucher G., Erba E., Bottini C. & Gambacorta G. (2017) - Calcareous nannoplankton response to the latest Cenomanian Oceanic Anoxic Event 2 perturbation. Riv. Ital. Paleontol. S., 123, 159-176.

Lübke N. & Mutterlose J. (2016) - The impact of OAE 1a on marine biota deciphered by size variations of coccoliths. Cretaceous Res., 61, 169-179.

ST3.9

Paleogene stratigraphy, timescales and global change

Conveners and Chairpersons

Simonetta Monechi (Università di Firenze)

Laia Alegret (Universidad de Zaragoza)

Aitor Payros (University of the Basque Country - UPV/EHU)

The Priabonian GSSP: a golden spike to drive

Agnini C.*[1], Backman J.[2], Boscolo-Galazzo F.[3], Condon D.[4], Fornaciari E.[1], Galeotti S.[5], Giusberti L.[1], Grandesso P.[1], Lanci L.[5], Luciani V.[6], Monechi S.[7], Muttoni G.[8], Pälike H.[9], Pampaloni M.L.[10], Papazzoni C.A.[11], Pignatti J.[12], Premoli Silva I.[8], Raffi I.[13], Rio D.[1], Rook L.[7], Sahy D.[4], Spofforth D.J.A.[14] & Stefani C.[1]

[1] Università di Padova, Italy. [2] Stockholm University, Sweden. [3] Cardiff University, United Kingdom. [4] British Geological Survey, United Kingdom. [5] Università di Urbino, Italy. [6] Università di Ferrara, Italy. [7] Università di Firenze, Italy. [8] Università di Milano, Italy. [9] University of Bremen, Germany. [10] Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA), Italy. [11] Università di Modena e Reggio Emilia, Italy. [12] Università La Sapienza, Italy. [13] Università "G. d'Annunzio" di Chieti-Pescara, Italy. [14] CGG MCNV (GeoSpec), United Kingdom

Corresponding author email: claudia.agnini@unipd.it

Keywords: GSSP, Priabonian, chronostratigraphy, Paleogene.

The base of the Priabonian Stage is one of the two stage boundaries in the Paleogene Period that remains to be formalized. The Priabonian Stage is named after the village of Priabona (eastern Lessini Mountains of northeastern Italy) where the historical stratotype is located. A working group composed of different expertise and nationalities has, during the last decade, focused on providing an appropriate candidate section and a shared, acceptable definition for this chronostratigraphic boundary. Here we present the most updated dataset available from the Alano di Piave section. This section was unanimously considered, by the Priabonian working group in 2012, as the perfect candidate for the Priabonian GSSP. The integrated stratigraphic approach that has been carried out in this sedimentary section has provided a unique bio-magneto-chemo-cyclostratigraphic framework that is the fundamental prerequisite for a GSSP. According to the guidelines of the International Commission on Stratigraphy (ICS), stages should be defined by their lower boundary, which is identified in a specific stratigraphic layer in a reference section, the GSSP. The ICS guidelines suggest first to identify a level in the section that can be characterized by a marker event of optimal correlation potential. In 2012, the working group voted by majority a tuff layer, the Tiziano bed, as the level by which to define the base of the Priabonian Stage. The Bartonian/Priabonian transition contains several events with high correlation potential (e.g., biostratigraphy, magnetostratigraphy) over wide geographic distances which forms several bio-magnetostratigraphic markers around the boundary rather than a single point. Thus, multiple primary markers exist to approximate the Priabonian Stage in and away of the Alano di Piave section. These markers include the shortly-spaced extinctions of the large acarininid group and of the genus *Morozovelloides* (planktonic foraminifera), the Base of common *Cribrocentrum erbae* and the Top of *Chiasmolithus grandis* (calcareous nannofossils), the base of Subchron C17n.2n and the base of Chron C17n (magnetostratigraphy).

The Paleogene record of northern Zealandia (Tasman Sea, southwest Pacific): new insights from IODP Expedition 371

Alegret L.*[1], Sutherland R.[2], Dickens G.R.[3], Blum P.[4] & Expedition 371 scientists

[1] University of Zaragoza, Spain. [2] Victoria University of Wellington, New Zealand. [3] Rice University, USA. [4] Texas A&M University, USA.

Corresponding author email: laia@unizar.es

Keywords: Paleogene, northern Zealandia, paleodepth, microfossils, Tonga-Kermadec subduction.

Zealandia is a largely submerged and relatively unexplored continent that separated from Gondwana during the Late Cretaceous. Its geological record cannot be explained simply by a rift-drift history, and several lines of evidence suggest that the formation and progression of the Tonga-Kermadec subduction system during the Eocene and Oligocene had a profound effect on the geography of this continent (Sutherland et al., 2019). Before 2017, only Deep Sea Drilling Project Sites 206, 207 and 208 had penetrated beneath upper Eocene strata in the submerged portion of northern Zealandia, and more data was needed to assess the timing of plate deformation, and the magnitude and timing of vertical motions. In 2017, International Ocean Discovery Program (IODP) Expedition 371 drilled six new sites in the Tasman Sea, providing the basis for correlating lithostratigraphic units across a substantial part of northern Zealandia. Paleogene sediments were recovered from all six sites, and they contain abundant and diverse microfossil groups that contribute to a better understanding of regional stratigraphy, subduction initiation, and the climatic evolution across the Paleogene. Benthic foraminifera are the most ubiquitous microfossils in the recovered sediments, and combined with ostracod and palynology assemblages, among other groups, they have been used to infer large changes in paleodepth during the Paleogene. The occurrence of shallow-water, neritic fossils at several sites that are now far from land supports the hypothesis that the Paleogene subduction zone initiation in the southwest Pacific deeply affected the geography of northern Zealandia.

Project CGL2017-84693-R (Spanish Ministry of Economy and Competitiveness and FEDER funds). The first author acknowledges the BBVA Foundation for a 2017 Leonardo Grant for Researchers and Cultural Creators. The Foundation accepts no responsibility for the statements and contents included, which are entirely the responsibility of the authors.

Sutherland R., Dickens G.R., Blum P., and the Expedition 371 Scientists, 2019. Tasman Frontier Subduction Initiation and Paleogene Climate. Proceedings of the International Ocean Discovery Program, 371: College Station, TX (International Ocean Discovery Program). ISSN World Wide Web: 2377-3189. https://doi.org/10.14379/iodp.proc.371.2019

Early Late Paleocene Event - New geochemical and micropaleontological data from the deep-sea

Bornemann A.*[1] & Jehle S.[2]

[1] Bundesanstalt für Geowissenschaften und Rohstoffe. [2] Universität Leipzig.

Corresponding author email: andre.bornemann@bgr.de

Keywords: Paleocene, planktic foraminifera, chemostratigraphy.

The Early Late Paleocene Event (ELPE, 59.3 Ma) is represented by carbonate dissolution and faunal turnover in planktic foraminifera as previously recorded at Shatsky Rise (Pacific, Petrizzo, 2005), Walvis Ridge (South Atlantic, Bralower et al., 2006), and Zumaia (Spain, Bernaola et al., 2007). Existing records further suggest a concurrent minor positive shift in $\delta^{13}C$ of less than 0.5‰ (Bernaola et al., 2007; Westerhold et al., 2011; Littler et al., 2014). Here, we studied the ELPE at three deep-sea sites (ODP Sites 1209 and 1262, IODP Site U1407) with respect to sedimentary geochemistry and planktic foraminifera. At all sites, the event is biostratigraphically located in the lower part of Biozone NP6 as identified by prominent peaks in Fe XRF core scanning intensities and magnetic susceptibility. Decreased carbonate contents indicate an increase in carbonate dissolution at the sea floor of different degrees in the three ocean basins. Our results suggest that the ELPE does not represent a classical Paleogene hyperthermal event, due to the lack of both negative $\delta^{13}C$ and $\delta^{18}O$ excursions. At Shatsky Rise, ~90% of the planktic foraminifera taxa can be considered to represent a warm, oligotrophic surface water environment (*Acarinina*, *Igorina* and *Morozovella*). At the midlatitude sites, the ELPE separates an *Igorina*-dominated assemblage below from an *Acarinina*-dominated assemblage above. At Site U1407, subsurface living subbotinids are a much more important component of the assemblage than at the other two sites. Long-term environmental changes are indicated by an overall increase in muricate taxa, specifically acarinids, indicating that the ELPE represents a transitional phase in the assemblage composition on a global scale.

Bernaola G., Baceta J.I., Orue-Etxebarria X., Alegret L., Martín-Rubio M., Arostegui J. & Dinarès-Turell J. (2007) - Evidence of an abrupt environmental disruption during the mid-Paleocene biotic event (Zumaia section, western Pyrenees). Geol. Soc. Am. Bull., 119(7-8), 785-795.

Bralower, T.J., Keller, K., & Urban, N. (2008, December). Statistical Analysis of Climate and Biotic Variability During the Paleocene Eocene Thermal Maximum. In AGU Fall Meeting Abstracts.

Littler K., Röhl U., Westerhold T. & Zachos J.C. (2014) - A high-resolution benthic stable-isotope record for the South Atlantic: Implications for orbital-scale changes in Late Paleocene–Early Eocene climate and carbon cycling. Earth Planet. Sc. Lett., 401, 18-30.

Petrizzo M.R. (2005) - An early late Paleocene event on Shatsky Rise, northwest Pacific Ocean (ODP Leg 198): Evidence from planktonic foraminiferal assemblages. Ocean Drilling Program.

Westerhold T., Röhl U., Donner B., McCarren H.K. & Zachos J.C. (2011) - A complete high-resolution Paleocene benthic stable isotope record for the central Pacific (ODP Site 1209). Paleoceanography, 26(2).

The Forada section (northeastern Italy): a candidate Auxiliary Boundary Stratigraphic Section and Point (ASSP) for the base of the Ypresian

Boscolo-Galazzo F.[1], Capraro L.[2], Fornaciari E.[2], Giusberti L.[2] & Luciani V.*[3]

[1] Cardiff University School of Earth and Ocean Sciences, United Kingdom. [2] Padova University Department of Geosciences, Italy. [3] Ferrara University Department of Physics and Earth Sciences, Italy.

Corresponding author email: eliana.fornaciari@unipd.it

Keywords: Stratigrahy, ASSP, Ypresian, Forada.

Since 2007, the Global Stratotype Section and Point (GSSP) of the base of the Ypresian is located at Dababiya section (Upper Nile Valley, Egypt). However, this GSSP demonstrated some criticisms linked to the selected stratigraphic section (e.g., deposition in outer shelf setting, barren interval in the basalmost Eocene, i.e. base of the Dababiya Quarry Member, etc.). Here we propose the deep-water Forada section (near Belluno, northeastern Italy) as ASSP candidate for the base of the Ypresian in order to constrain soundly the base of this stage. The Forada Paleocene-Eocene succession was deposited on a lower bathyal setting, and has been intensively studied over the last twelve years. Integrated bio-magneto-cyclostratigraphic approach provides robust stratigraphic and chronological frameworks for the upper Paleocene and lower Eocene. The Forada section hosts an expanded record of the Paleocene-Eocene transition and a virtually complete record of the Paleocene/Eocene Thermal Maximum (PETM). High-resolution stable isotopes, mineralogical and micropaleontological analyses across the Paleocene-Eocene transition consistently indicate the absence of an extensive carbonate dissolution interval coinciding with the base of PETM interval. Moreover, at Forada the onset of the Carbon Isotope Excursion (CIE), the best criterion used for recognition and correlation of the base of Ypresian, virtually coincides with the base of a ca. 3.3 m thick interval of clay marly sediments (Clay Marl Unit; CMU) a lithological anomaly easily detectable in the field. A bundle of biotic events and biohorizons are recorded just below and above the base of CMU. In particular, the benthic foraminiferal extinction event (BEE) is clearly recorded at Forada within the first 10 cm above the base of the CMU. The lower Ypresian is exceptionally expanded at Forada and rich in calcareous microfossils, including planktonic foraminifera and calcareous nannofossil excursion taxa. The coupling of stratigraphic and micropaleontological, geochemical (organic and inorganic geochemistry), mineralogical studies has provided one of the most thorough and chronologically detailed reconstructions of the environmental and associated biotic changes across the Paleocene/Eocene Thermal Maximum. We argue that this exceptional set of features, along with lack of tectonic deformation and the easy accessibility of the outcrop make the Forada section an ideal ASSP of the Ypresian GSSP.

Integrated calcareous nannofossil and stable isotope records across the early-middle Eocene transition at IODP Site U1410 (Northwest Atlantic Ocean): assemblage shifts and evolutionary trends through changing paleoenvironmental conditions

Cappelli C.*[1], Agnini C.[1-2], Bown P.R.[3], Westerhold T.[4], De Riu M.[1], Lobba V.[1] & Yamamoto Y.[5]

[1] Department of Geosciences, University of Padova. [2] Department of Geological Sciences, Stockholm University. [3] Department of Earth Sciences, University College London. [4] MARUM – Center for Marine Environmental Sciences, University of Bremen. [5] Center for Advanced Marine Core Research, Kochi University

Corresponding author email: carlotta.cappelli@unipd.it

Keywords: calcareous nannofossils, early-middle Eocene, biostratigraphy, evolutionary trends, paleoclimate.

The early-middle Eocene is an interval of profound change within the nannoplankton community, including the appearance and rise to dominance of the *Noelaerhabdaceae* (Agnini et al., 2006; Schneider et al., 2011). This shift represents initiation of the long transition towards a modern-like assemblage structure and encompasses the switch from peak warmth of the Paleogene, during the Early Eocene Climatic Optimum (EECO), to the onset of the long-term middle Eocene cooling (Zachos et al., 2001). In order to explore the relative timings of paleoenvironmental trends and the evolution of calcareous nannofossil assemblages, we generated an integrated calcareous nannofossil and bulk stable isotope record ($\delta^{18}O$, $\delta^{13}C$) across the early-middle Eocene transition at Integrated Ocean Drilling Program (IODP) Site U1410 (Southeast Newfoundland Ridge, Northwest Atlantic Ocean). At this Site, the early Lutetian coincides with the onset of clay-enriched drift-sedimentation sediments that are characterized by the presence of very well preserved nannofossils (Norris et al., 2012). Quantitative analysis of calcareous nannofossil assemblages was conducted throughout calcareous nannofossil Zones NP12–NP15 or CNE4-CNE12 (Martini, 1971; Agnini et al., 2014). Our data reveal that the major nannoplankton assemblage shifts were completed by the early Lutetian, when *Reticulofenestra* became the dominant taxon in the assemblages, at the expense of *Toweius, Discoaster, Sphenolithus* and *Zygrhablithus.* At Site U1410, this switch from warm-oligotrophic to temperate meso-eutrophic assemblages occurred in the aftermath of the EECO, when a positive trend in $\delta^{18}O$ values suggest temporary cooler sea-surface conditions. Immediately above the Ypresian-Lutetian boundary, an enigmatic and short-lived restoration of warmer conditions, concomitant with a negative excursion in $\delta^{13}C$, is associated with minor changes among taxa within *Discoaster* and *Sphenolithus*. The analysed portion of the middle Eocene documents relatively stable paleoenviromental conditions, during which the evolution of two taxonomic groups (sphenoliths and coccolithaceans) were analysed in detail with a combined light-microscope/scanning electron microscope study. The combination of morphological/optical characteristics and distinctive distribution ranges allowed us to provide a comprehensive model for the evolution of *Sphenolithus furcatolithoides* group. Similarly, morphometric data and analysis of central-area crossbars in large middle Eocene coccolithaceans have revealed the origin and evolution of the index species '*Chiasmolithus' gigas*. These new data strengthen the stability and reliability of calcareous nannofossil zonations and, at the same time, point out the possible relationship between the new equilibrium observed in calcareous nannoplankton assemblages and environmental conditions with a particular attention on iterative morphological features.

Agnini C., Fornaciari E., Raffi I., Catanzariti R., Pälike H., Backman J. & Rio D. (2014) - Biozonation and biochronology of Paleogene calcareous nannofossils from low and middle latitudes. Newsl. Stratigr., 47, 131-181.

Agnini C., Muttoni G., Kent D.V. & Rio D. (2006) - Eocene biostratigraphy and magnetic stratigraphy from Possagno, Italy: The calcareous nannofossil response to climate variability. Earth Planet. Sc. Lett., 241, 815-830.

Expedition 342 Scientists, 2012. Paleogene Newfoundland sediment drifts. IODP Prel. Rept., 342.

Martini E. (1971) - Standard Tertiary and Quaternary calcareous nannoplankton zonation. 5. In Farinacci A. Ed., Proceedings of the 2nd Planktonic Conference, 2, 739-78. Tecnoscienza, Roma.

Schneider L.J., Bralower T.J. & Kump L.R. (2011) - Response of nannoplankton to early Eocene ocean destratification. Palaeogeogr. Palaeocl. Palaeoecol., 310, 152-162.

Zachos J., Pagani M., Sloan L., Thomas E. & Billups K. (2001) - Trends, rhythms, and aberrations in global climate 65 Ma to present. Science, 292, 686-693.

Coherent new orbital tuning of the middle Eocene Contessa section (Umbrian Apennines, Italy) and significance for the Bartonian Stage GSSP

Dinarès-Turell J.*

Istituto Nazionale di Geofisica e Vulcanologia.

Corresponding author email: jaume.dinares@ingv.it

Keywords: Gubbio, scaglia, magnetostratigraphy, cyclostratigraphy, hyperthermal.

A Global Stratotype Section and Point (GSSP) for the base of the Bartonian Stage has not yet been established. The Lutetian/Bartonian boundary is usually approximated by the calcareous nannofossil *Reticulofenestra reticulata* LAD that seems to occur close to the C18r/C19n chron reversal boundary although evidence for lack of synchronicity of this datum exists. In any case, no formal criterion has been established for the definition of the base-Bartonian and the convenience of using either the top or the base of C19n has been argued bearing in mind the preservation of the historical concept for both the Lutetian and Bartonian stages (i.e. for the Barton clay traditional "unit stratotype" see Hooker & King, 2018). The original magnetostratigraphy (Lowrie et al, 1982) and calcareous plankton biostratigraphy (Monechi & Thierstein, 1985) for the middle Eocene Contessa Highway section were reexamined by Jovane et al. (2007) who studied the interval spanning the upper part of chron C21n up to C18n.1n along a 55m-long section across the Scaglia Variegata lithological unit. In that study, the position of chron boundaries including C19n were refined and the cyclic nature of the strata in the form of bundling of limestones-marl couplets was envisaged. In a subsequent work (Jovane et al., 2010) a cyclostratigraphy based on time series analysis of magnetic susceptibility/carbonate proxies along 10 m section enabled an astronomical tuning to the Laskar2004 orbital solution, and to assign absolute ages to biostratigraphic datums and chron boundaries embracing the potential position of the Bartonian base. However, studies of cyclic middle Eocene ODP/IODP deep-sea records (i.e. Westerhold & Röhl, 2013) and outcrops in the Basque-Cantabrian basin (Dinarès-Turell et al., 2018) have pointed out an awkward inconsistency on the Contessa section cycle identification and tuning that hampers its correlation with the otherwise consistent records from the Atlantic and Pacific Oceans. Thus, these works inferred a flawed cyclostratigraphic model interpretation and tuning for the Contessa study that is reassessed herein. Here, new paleomagnetic data across the C19n/C18r reversal and a thorough re-examination of the lithological cyclic pattern for the interval spanning from the top of C20n up to C18r is presented. The new interpretation and tuning to the more recent orbital solutions La10-La11 brings all records to a compatible correlation, delineating thus the chronostratigraphic framework for the expected base-Bartonian interval. In addition, the position of the Late Lutetian Thermal Maximum (LLTM) or chron C19r hyperthermal event at the section is inferred. Outstandingly, the potential of the Umbrian Scaglia succession to host the Bartonian GSSP is emphasized as long as an alternative more accessible/suitable succession to the Contessa talus section (actually covered by a steel mesh net fencing) is found.

Contribution to research project CGL2015–65404-R (MINECO/FEDER, EU).

Hooker J.J. & King C. (2019) - The Bartonian unit stratotype (S. England): Assessment of its correlation problems and potential. P. Geologist Assoc., 130(2), 157-169.

Jovane L., Florindo F., Coccioni R., Dinarès-Turell J., Marsili A., Monechi S., Roberts A.P. & Sprovieri M. (2007) - The middle Eocene climatic optimum event in the Contessa Highway section, Umbrian Apennines, Italy. Geol. Soc. Am. Bull., 119(3-4), 413-427.

Jovane L., Sprovieri M., Coccioni R., Florindo F., Marsili A. & Laskar J. (2010) - Astronomical calibration of the middle Eocene Contessa Highway section (Gubbio, Italy). Earth Planet. Sc. Lett., 298(1-2), 77-88.

Lowrie W., Alvarez W., Napoleone G., Perch-Nielsen K., Silva I.P. & Toumarkine M. (1982) - Paleogene magnetic stratigraphy in Umbrian pelagic carbonate rocks: The Contessa sections, Gubbio. Geol. Soc. Am. Bull., 93(5), 414-432.

Monechi S. & Thierstein H., (1985) - Late Cretaceous–Eocene nanofossil and magnetostratigraphic correlations near Gubbio, Italy. Mar. Micropaleontol., 9, 419–440.

The Bartonian GSSP: Identifying the Primary Guide Event

Fluegeman R.*[1], Alegret L.[2], Cotton L.[3], Dinarès-Turell J.[4], Franceschetti G.[5], Hooker J.[6], Iakovleva A.[7], Monechi S.[5] & Rivero-Cuesta L.[2]

[1] Ball State University, Muncie, IN USA. [2] Universidad de Zaragoza, Spain. [3] University of Bristol, UK. [4] Istituto Nazionale di Geofisica e Vulcanologia (INGV), Roma, Italy. [5] Università di Firenze, Italy. [6] Natural History Museum, London, UK. [7] Geological Institute, Russian Academy of Sciences, Moscow, Russia.

Corresponding author email: rfluegem@bsu.edu

Keywords: Bartonian, Alum Bay, guide events, C19n.

The Eocene Bartonian Stage does not yet have a defined Global Stratotype Section and Point (GSSP). It does however have two working proposals for the primary guide event. Both the base of magnetochron C19n (Fluegeman, 2007) and its top (Jovane et al., 2010) have been proposed as a potential primary guide event for the base of the Bartonian Stage. The association of the base of the Bartonian with C19n dates to the time scale of Hardenbol and Berggren (1978) who placed the base of the Bartonian within magnetic polarity Chron 19n. Subsequent Paleogene numerical time scales have continued to associate the base of the Bartonian with magnetic polarity Chron 19n. Although the GSSP of the Bartonian remains to be defined, the existing proposals for the primary guide event are consistent with the 40 year history of the Bartonian as a formal chronostratigraphic unit. Unresolved questions exist however as to the relationship of C19n to the "unit stratotype" of the Bartonian Stage in the Hampshire Basin of England. The Bartonian Stage in its type area has a long and complex history of usage with numerous definitions. Keeping (1887) placed the base of the Barton beds at the lowest occurrence of the large foraminifer *Nummulites prestwichianus*. This essentially made the Barton beds a unit defined on biostratigraphic content rather than lithology. This definition of the Barton beds remained in use for nearly a century and is the basis of the recognition of the Bartonian Stage as a formal chronostratigraphic unit of the Paleogene (Berggren, 1972). A recently completed magnetostratigraphic and biostratigraphic study of the Barton Clay in the Alum Bay section on the Isle of Wight has shown that the Nummulites prestwichianus bed is stratigraphically above C19n in the section. The verification of beds assignable to C19n below the *Nummulites prestwichianus* bed means that the selection of either the base or the top of C19n as the primary guide event for the base of the Bartonian Stage will not truncate the historical concept of the Bartonian Stage. Further work on the Bartonian will determine which of the proposed primary guide events provides the best opportunities to identify important biostratigraphic secondary guide events. While the primary guide event will define the Bartonian in the GSSP, the secondary events will facilitate correlation in diverse localities.

Berggren W.A. (1972) - A Cenozoic time scale-some implications for regional geology and paleobiogeography. Lethaia, 5:195-215.

Fluegeman R.H. (2007) - Unresolved issues in Cenozoic chronostratigraphy. Stratigraphy, 4, 109-116.

Keeping H. (1887) - On the discovery of the Nummulina elegans Zone at Whitecliff Bay, Isle of Wight. Geological Magazine, 3, 70-72.

Jovane L., Sprovieri M., Coccioni R., Florindo F., Marsili A., & Laskar J. (2010) - Astronomical calibration of the middle Eocene Contessa Highway section (Gubbio, Italy). Earth and Planetary Science Letters, 298, 77-88.

New data for a calibration of the Shallow Benthic Zones of the Paleocene

Fornaciari B.*[1], Papazzoni C.A.[1], Fornaciari E.[2], Giusberti L.[2], Bianco S.[2], Marconato S.[2], Plessi M.[1] & Simonato M.[2]

[1] University of Modena and Reggio Emilia, Italy. [2] University of Padova, Italy.

Corresponding author email: beatrice.fornaciari@unimore.it

Keywords: Paleocene, biostratigraphy, SB Zones, NP, CNP, larger foraminifera.

During the Paleocene the larger foraminifera recovered from the K/Pg crisis and underwent an evolutionary radiation culminating in the Eocene. This radiation started at the base of the SB2 Zone, which position is currently not well-defined (Serra-Kiel et al., 1998). The direct correlation of the SB Zones with other biostratigraphic schemes is therefore required to achieve a better time resolution. Here we present the data from three Paleocene sections from northern Italy: Tabiago (Lecco Province), Monte Giglio (Bergamo Province) and Ardo (Belluno Province). These sections consist of Scaglia-type basinal hemipelagites intercalated with shallow-water calciturbidites containing larger foraminifera. They have been sampled and studied to determine their content in calcareous nannofossils and larger foraminifera, respectively. According to our results, the Tabiago section spans the SB1-4, the NP2-9 (CNP3-11) Zones, the Ardo section the SB1-2, the NP1-P5 (CNP1-7) Zones, and the Monte Giglio section the SB2-3, the NP4-5 (CNP 7) Zones *sensu* Martini (1971) and Agnini et al. (2014) respectively. The three sections can be correlated, allowing to better precise the position of the SB boundaries. Our data indicate that the generic diversification of larger foraminifera, and therefore their first recovery after the K/Pg crisis, started much earlier than previously reported. It is questionable whether the climatic events of the Paleocene played a role in the larger foraminifera evolution. In fact, we detected that the orthophragminids, one of the most successful lineages of larger foraminifera, appeared before the environmental perturbation and evolutionary event known as the Early Late Paleocene Event (ELPE).

Agnini C., Fornaciari E., Raffi I., Catanzariti R., Pälike H., Backman J. & Rio D. (2014) - Biozonation and biochronology of Paleogene calcareous nannofossils from low and middle latitudes. Newsl. Stratigr., 47(2), 131-181.

Martini E. (1971) - Standard Tertiary and Quaternary calcareous nannoplankton zonation. In: Farinacci A. Ed., Proceedings of the Second Planktonic Conference Roma 1970, 2, 739-785.

Serra-Kiel J., Hottinger L., Caus E., Drobne K., Ferràndez C., Jauhri A.K., Less G., Pavlovec R., Pignatti J., Samsó J.M., Schaub H., Sirel E., Strougo A., Tambareau Y., Tosquella J. & Zakrevskaya E. (1998) - Larger foraminiferal biostratigraphy of the Tethyan Paleocene and Eocene. B. Soc. G. Fr., 169, 281–299.

Calcareous nannofossil biostratigraphy and cyclostratigraphy of the Ypresian Sopelana section (Basque-Cantabrian Basin)

Franceschetti G.[1], Martínez-Braceras N.[2], Payros A.[2] & Monechi S.*[1]

[1] Dipartimento di Scienze della Terra, Università degli Studi di Firenze. [2] Department of Stratigraphy and Paleontology, Faculty of Science and Technology, University of the Basque Country (UPV/EHU), Bilbao, Spain.

Corresponding author email: simonetta.monechi@unifi.it

Keywords: Biostratigraphy, calcareous nannofossils, Cyclostratigraphy, Ypresian, Sopelana section, Basque-Cantabrian basin.

The lower Eocene Sopelana section (Basque-Cantabrian basin) shows a rhythmic alternation of hemipelagic marls and limestones as a consequence of astronomically driven climate change (Martínez-Braceras et al., 2017). The couplets are related to precession cycles (21 ky each), whereas bundle formation was controlled by eccentricity cycles (100 ky). The calcareous nannofossil biostratigraphic study constrains accurately the age of the Sopelana section. The section spans from CNE1 to CNE3 (Agnini et al., 2014) and from NP10 to NP11 Zones (Martini 1971) with a well documented *Rhomboaster-Tribrachiatus* lineage. According to the biochronology of calcareous nannofossil events, the studied interval represents approximately 1 Ma, confirming the age obtained by counting short eccentricity bundles. The calcareous nannofossil changes observed within the studied section evidenced several distribution patterns of paleoecologically significant taxa (*Discoaster*, *Sphenolithus*, *C. pelagicus, Toweius* and *Braarudosphaera)*. The quantitative calcareous nannofossil variations correlate with the lithological alternation and the marl-limestone couplets, suggesting a response to changes in the characteristics of water masses, probably as a consequence of changes in insolation intensity. To better capture the changes in calcareous nannofossil assemblages in different lithologies (i.e. marls and limestones), a statistical approach, based on principal component (PCA) was used. Based on the analyses of the component's matrix of PCA we can hypothesize that the different correlation between PC1 and PC2 in the two different lithologies across the entire section supports the hypothesis that the marls can reflect more eutrophic and cooler waters, whereas limestones may reflect periods with oligotrophy and warmer sea waters. Thus, in the Sopelana section, the calcareous nannofossil analyses integrated with cyclostratigraphy leads us to hypothesize that the marlstone-limestone couplets are the expression of primary deposition and are associated with variations in fertility and productivity cycles.

Research funded by the University of Florence (GF-SM RICATEN15-18), and by the Spanish (CGL2015-65404-R, MINECO/FEDER, EU) and the Basque Government (IT-930-16).

Agnini C., Fornaciari E., Raffi I., Catanzariti R., Pälike H., Backman J. & Rio D. (2014) - Biozonation and biochronology of Paleogene calcareous nannofossils from low and middle latitudes. Newsletters on Stratigraphy, 47,131–181.

Martínez-Braceras N., Payros, A., Miniati F., Arostegi J. & Franceschetti G. (2017) - Contrasting environmental effects of astronomically driven climate change on three Eocene hemipelagic successions from the Basque–Cantabrian Basin. Sedimentology, 64, 960-986.

Martini E. (1971) - Standard Tertiary and Quaternary calcareous nannoplankton zonation. In: Farinacci, A. Ed., Proceedings 2nd International Conference Planktonic Microfossils Roma. Volume 2, 739–785. Edizione Tecnoscienza, Roma.

Towards a consistent Paleogene geochronology: where do we stand?

Galeotti S.*

Dipartimento di Scienze Pure e Applicate, Università degli Studi di Urbino Carlo Bo, Italy.

Corresponding author email: simone.galeotti@uniurb.it

Keywords: geochronology, Paleogene, radioisotopic dating, cyclochronological data, astrochronological data.

The geochronology of the Paleogene has significantly improved over the last decade mainly thanks to improvement in radioisotopic dating and the integration with cyclochronological and astrochronological data. The availability of proxy records with unprecedented resolution from both oceanic and land-based succession, together with recent developments of the available astronomical solutions, has been pivotal in this effort.

Consistent results in the construction of an astronomical time scale have been achieved down to the youngest part of the Middle Eocene. The consistency of the Paleocene cyclochronology has now been tested by several authors from different settings. Similarly, a consistent astrochronological framework is now available for the Early Eocene. Yet, the scarcity of highly resolved records from Middle Eocene sedimentary succession has so far prevented the achievement of a stable astrochronological interpretation for this time interval, which remains the main hindrance in the establishment of a comprehensive astronomical time scale for the cenozoic.

An integrated astrochronological and radioisotopic dating of the Alano di Piave section, proposed GSSP for the Priabonian

Galeotti S.*[1], Sahy D.[2], Agnini C.[3], Condon D.[2], Fornaciari E.[3], Francescone F.[1], Giusberti L.[3], Pälike H.[4], Spofforth D.J.A.[5] & Rio D.[1]

[1] Dipartimento di Scienze Pure e Applicate, Università degli Studi di Urbino Carlo Bo, Italy. [2] British Geological Survey, Keyworth, United Kingdom. [3] Dipartimento di Geoscienze, Università di Padova, Italy. [4] MARUM–Center for Marine Environmental Sciences, University of Bremen, Germany. [5] Robertson, CGG GeoSpec, Llandudno, UK.

Corresponding author email: simone.galeotti@uniurb.it

Keywords: Integrated Stratigraphy, Priabonian, GSSP, Alano di Piave.

The Alano di Piave section, located in the Southern Alps of the Veneto region (NE Italy), is a potential candidate as the GSSP of the Priabonian stage. Prominent crystal tuff layers occur throughout this ~120 m-thick sedimentary succession, prevalently consisting of bathyal grey marls, offering the possibility of radioisotopic determination of absolute age. The stratigraphic completeness of the record is supported by the available integrated high-resolution calcareous plankton biostratigraphy and detailed magnetostratigraphy. Here, we integrate these data with a new cyclostratigraphic model and radioisotopic data that provide a robust chronological framework and would eventually give all the elements to discuss the criteria that should be used for driving the choice of the "golden spike" of the Priabonian Stage. Integration of astrochronology and radioisotopic data provides a robust framework for the definition of absolute ages of the observed biostratigraphic and magnetostratigraphic boundaries. Furthermore, cycle counting allows determining the timing of late Bartonian-early Priabonian biostratigraphic and magnetostratigraphic events relative to the proposed GSSP, the regionally traceable crystal tuff layer "Tiziano Bed".

Oligocene diatom stratigraphy of Cenozoic key section in Western Kamchatka, Kamchatka Peninsula, Russia

Gladenkov A.*

Geological Institute of Russian Academy of Sciences, Moscow, Russia.

Corresponding author email: andreygladenkov@gmail.com

Keywords: Oligocene, diatom stratigraphy, Kamchatka Peninsula.

The stratigraphic section at the Kvachina Bay is a key section for the marine Cenozoic in Western Kamchatka with an essentially continuous sequence composed of about 500 m of Paleogene through Neogene sediments. Diverse preserved fossil marine diatoms have been documented in samples collected throughout the upper part (about 300 m thick) of this section. Analysis of stratigraphic occurrence of diatoms allowed determination of seven local zones for host deposits. Stratigraphically from bottom to top these are: *Odontella sawamurae* Local Zone, *Rhizosolenia oligocaenica* Local Zone, *Thalassiosira nansenii* Local Zone, *Cestodiscus kugleri* Local Zone, *Lisitzinia ornata* Local Zone, *Rocella gelida* Local Zone, and *Thalassiosira* cf. *praefraga* Local Zone. Their boundaries are characterized by the successive first occurrences of marker species in the section. The presence of biochronologically significant taxa including *O.*, *Ikebea tenuis*, *R. oligocaenica*, *Rh. miocenica*, *Kisseleviella carina*, *K. ezoensis*, *Cavitatus jouseanus*, *C. miocenicus*, *Eurossia irregularis*, *T. nansenii*, *Asteromphalus symmetricus*, *Cestodiscus kugleri*, *C. trochus*, *Pseudodimerogramma elegans*, *Sceptroneis tenue*, *Sc. humuncia*, *Sc. humuncia* var. *rondipoda*, *Lisitzinia ornata*, and *Rocella gelida* allowed correlation of the proposed local zones with the North Pacific Cenozoic diatom zonation and age determination of the host sediments. A correlation with the lower Oligocene to lower Miocene zones (the North Pacific *Rhizosolenia oligocaenica* Zone through *Thalassiosira praefraga* Zone) is supposed. As a result, it is inferred that the *Odontella sawamurae* Local Zone through *Lisitzinia ornata* Local Zone may be dated as early Oligocene (from the middle part to terminal part of the Rupelian Stage), the *Rocella gelida* Local Zone – as late Oligocene (the Chattian Stage excepting its terminal part), and the *Thalassiosira* cf. *praefraga* Local Zone - as latest Oligocene to earliest Miocene (within terminal part of the Chattian Stage to the Aquitanian Stage). It should be emphasized that some taxa including *Lisitzinia ornata*, *Thalassiosira nansenii*, *Th. irregulata*, *A. symmetricus*, *P. elegans*, *Eurossia irregularis*, *R. oligocaenica*. *Rh. miocenica*, *Rocella praenitida, R. gelida* var. *schraderi*, *S. humuncia*, *Sc. propinqua*, *Sc. ligulatus* are documented in West Kamchatka for the first time. Moreover, in their entirety and paleontological characteristics Oligocene assemblages from the studied section are the most representative among all assemblages of this age known in the whole Kamchatka region.

The study was supported by the Russian Foundation for Basic Research, project no. 19-05-00361.

The North Pacific Paleogene: problems of subdivision of geosynclinal formations

Gladenkov Yu.*

Geological Institute of Russian Academy of Sciences.

Corresponding author email: gladenkov2@gmail.com

Keywords: Paleogene, North Pacific, regional stages, stratigraphy.

In recent years there are few publications discussing the North Pacific Paleogene problems. Paleogene strata are widely spread in the region. Sedimentary formations have distinct specific features, i.e., great thickness, facial diversity, occurrences of volcanic bodies, etc. In addition, they are strongly dislocated. Their subdivision in Kamchatka and Sakhalin met many difficulties previously (earlier). Recently multidisciplinary investigations provided new approaches to solve many problems of Paleogene stratigraphy. The solution has been greatly advanced by detailed studies of some key Paleogene sections. For the first time bed-by-bed studies have been undertaken for rich bioassemblages of the sections - both benthic (mollusks and foraminifers) and planktonic (foraminifers, diatoms, dinocysts). This allowed subdividing thick paleoshelf strata into six regional stages and to follow them from the south to the north - from Japan and Sakhalin to Kamchatka and Alaska. Planktonic investigations yielded establishing zones based on diatoms, dinocysts and foraminifers, which helped to correlate the regional units to the International Stratigraphic Scale. Stage boundaries of Paleocene, Eocene and Oligocene have been first reliably established. Paleomagnetic and isotopic data made these reconstructions more substantiated. All the data received were used as a base for establishing regional and global geological events as well as making paleogeographic reconstructions. Among paleoevents, especial attention is drawn to paleoclimatical changes: noticeable Ipresian warming led to migration of paleobiota from the south to the north, while relative Oligocene cooling promoted appearance of boreal biota Another significant event was a tectogenesis phase of early middle Eocene resulted in dislocation of Cretaceous, Paleocene and lower Eocene formations and essential paleogeographical changes (particularly, appearance of Sea of Okhotsk basin, Aleutian Arc, etc.). The phase was followed by enormous middle Eocene-Oligocene transgression which covered many regions. The mentioned recent studies included the latest investigations of Paleogene formations in West Kamchatka at the Kvachina Bay. A section of sedimentary-volcanogenic deposits about 500 m thick was described in the Sea of Okhotsk cliffs. Previously the section was not subdivided and considered as a single or two formations. According to the paleontological evidence (benthic and planktonic groups) Paleogene stages and zones were outlined; some of them being correlated to the paleomagnetic scheme. The paleontological and lithological characteristics of the section enabled us to make a detailed scenario of paleogeographic and paleoclimatic changes.

The work was performed under the state assignment no. 0135-2019-0057 of Geological Institute RAS and was supported in part by the Russian Foundation for Basic Research (project no. 19-05-00361).

Eocene foraminiferal associations and paleoenvironmental changes at the Lutetian/Bartonian boundary in the North East of Tunisia

Karoui-Yaakoub N.*[1-2], Grira C.[1-2] & Hédi Negra M.[2-3]

[1] Faculty of Sciences of Bizerte, Department of geology, University of Carthage, Tunisia. [2] Laboratory of Research: Mineral Resources and Environment, LR01ES06, Faculty of Sciences of Tunis, University of El Manar, Tunisia. [3] Faculty of Sciences of Tunis, Department of geology, University of El Manar, Tunisia.

Corresponding author email: narjesskarouiyaakoub@gmail.com

Keywords: Lutetian/Bartonian, paleoenvironmental changes, foraminifera, Tunisia.

The foraminiferal assemblages from the Eocene series in the El Rahma section (North of Tunisia), are diversified and heterogeneous. The biostratigraphic analysis of the planktonic foraminifera enables the identification of 3 biozones: *Acarinina topilensis* E10 zone, *Morozovelloides lehneri* E11 zone and *Morozovelloides crassatus* E13 zone. The planktonic/benthic ratio (P/B), varies from 60 % to 88 %. This increase of this ratio can be related to an increase of the water depth. Planktonic foraminifera are more abundant and constitute more than 80% of the foraminiferal assemblages. The highly specialized and warm indices morozovellids (Wade, 2004) sharing the surface-water habitats with acarininids are dominant. We noticed the large distribution of *Morozovella gorrondatxensis* reaching the E10 zone and this was probably related to the frequency of warmer conditions in the Tethyan area. Benthic foraminiferal assemblages are diversified and mainly dominated by calcareous taxa. This indicates that the deposition is above the carbonate compensation depth and contains common bathyal to abyssal species such as *Oridorsalis umbonatus, Globocassidulina subglobosa, Cibicidoides eocaenus, Bulimina alazanensis, Aragonia aragonensis* (Holbourn et al., 2013). *Nuttallides truempyi* and *Aragonia aragonensis* are also present in the investigated section; in fact, they are described commonly as having an upper depth limit. Agglutinated species make up to 2 % of the assemblages on the upper part of the section and among them we cited calcareous-cemented species such as *Spiroplectammina, Dorothia* and organic cemented species like *Rhabdammina, Clavulinoides, Marssonella, Gaudryina*. Moreover, the assemblages were slightly to moderately dominated by infaunal morphogroups, their high abundance could be related to a significant transfer of the organic matter to the bottom of the sea as they proliferate in these environments (Molina et al., 2006).

Holbourn A., Henderson A. S. & Macleod N. (2013) - Atlas of benthic foraminifera. Natural History Museum, 642 pp.

Molina E., Gonzalvo C., Ortiz S. & Cruz L. E. (2006) - Foraminiferal turnover across the Eocene-Oligocene transition at Fuente Caldera, southern Spain: No cause-effect relationship between meteorite impacts and extinctions. Mar. Micropaleontol., 58, 270-286.

Wade B. S. (2004) - Planktonic foraminiferal biostratigraphy and mechanisms in the extinction of *Morozovella* in the late middle Eocene. Mar. Micropaleontol., 51, 23-38.

Understanding biological responses during the Early Eocene Climatic Optimum: demise of the planktic foraminifer genus *Morozovella* at ODP Site 1258 (Demerara Rise, western equatorial Atlantic)

Luciani V.[1], D'Onofrio R.*[1], Dickens G.R.[2], Wade B.S.[3] & Kirtland-Turner S.[4]

[1] University of Ferrara, Italy. [2] Rice University, USA. [3] University College London, United Kingdom. [4] Department of Earth Sciences, University of California, USA

Corresponding author email: valeria.luciani@unife.it

Keywords: Early Eocene Climatic Optimum, planktic foraminifera, paleoceanography.

Here we present new data on planktic foraminferal response to the Early Eocene Climatic Optimum (EECO, ~54-48 Ma) from the equatorial Atlantic Ocean Drilling Program (ODP) Site 1258 (Demerara Rise). *Morozovella,* a surface-dweller symbiont-bearing genus dominated early Paleogene planktic foraminiferal assemblages from tropical-subtropical regions. Our main result reveals that the relative abundance of this genus markedly and permanently declined at the beginning of the EECO moving from mean percentage of ~30% to less than ~10%. The EECO is the crucial interval of peak Cenozoic global warmth and high atmospheric CO_2 pressure. Planktic foraminifera represent an excellent class in which to examine how life evolved during this critical interval. The distinct decrease in *Morozovella* abundance occurred at Site 1258 within ~30 kyr before a negative $\delta^{13}C$ excursion known as the J event (~ 53.3 Ma), which marks the beginning of the EECO. The permanent decrease of morozovellids is associated with reduction in species diversity, but an increase in the abundanceand diversity of the genus *Acarinina*. The remarkable turnover from *Morozovella* to *Acarinina* assemblages was geographically widespread, and recorded at the start of the EECO in the subtropical Pacific (Site 577), Atlantic Sites 1051 and1263, and in the Tethyan region (Possagno section, northern Italy). Interestingly, the timing of the drop in abundance is close but different at each site. Our new data from Demerara Rise further the view that the morozovellid decline began first with unfavourable environmental conditions near the equatorial Atlantic Oceanand then extended to higher latitudes. The triggering mechanism for the striking planktic foraminiferal turnover remains elusive, because both *Morozovella* and *Acarinina*shared a similar palaeoecology and inhabited the mixed-layer. Most of the morozovellid species that became extinct within the EECO reduced their maximum size. Recent culturing and open ocean observations indicate that omega-calcite saturation statepreferentially affect larger planktic foraminifera thus reducing their calcification. The two dominant genera, *Morozovella* and *Acarinina*, may have had different tolerances to temperature and ocean chemistry. This would explain why anti-phase variations in their abundances occurred during several early Paleogene hyperthermals. The EECO interval may represent the time when optimal conditions for morozovellids diminished for a sufficiently long time, such that acarininids dominated surface water habitats afterward. Another marked change recorded at Site 1258 is the virtual absence of the deeper-dwellers chiloguembelinids that occurred between the J and K/X events, as already observed at the Atlantic Site 1263. This change can be explained with acontraction of deeper niches as triggered by rapid and shallower bacterial remineralization due to intense warming causing an upward shift in the Oxygen Minimum Zone and reduced food supply at depth.

Integrated stratigraphy at the Bartonian-Priabonian transition: correlation between shallow benthic and calcareous plankton zones (Varignano section, northern Italy)

Luciani V.[1], Fornaciari E.[2], Papazzoni C.A.[3], Dallanave E.*[4], Giusberti L.[2], Stefani C.[2] & Amante E.[1]

[1] University of Ferrara, Italy. [2] University of Padova, Italy. [3] University of Modena and Reggio Emilia
[4] University of Bremen, Germany.

Corresponding author email: edoardo@uni-bremen.de

Keywords: Bartonian-Priabonian boundary, shallow benthic biostratigraphy, calcareous plankton biostratigraphy, magnetostratigraphy, middle–late Eocene.

The Bartonian-Priabonian transition (middle-late Eocene) attracted great attention by biostratigraphers in the last decades in searching for a boundary stratotype section. The Alano di Piave section (NE Italy) isthe leading candidate for the base Priabonian Global Stratotype Section and Point (GSSP). The Alano section meets indeed the prerequisites for being a suitable GSSP, such as continuous outcrop, completeness, lacking deformation, richness in calcareous plankton, good magnetic properties, and easy accessibility. However, at Alano, larger foraminifera-bearing resedimented levels occur exclusively well below the critical interval, thus hindering the correlation with the shallow-water realm. The Varignano section (Trento province, northern Italy) provides an exceptional opportunity for a direct correlation between Shallow Benthic (SB) Zones and standard calcareous plankton zones around the Bartonian-Priabonian boundary. The middle bathyal Varignano section, located ~80 km west of the Alano section, preserves several coarse bioclastic levels rich in larger foraminifera throughout the section. These levels are intercalated with basinal marls, crystal tuff layers and an organic-rich interval. The Varignano section spans planktic foraminiferal Zones E10-11 to lower E14, calcareous nannofossil Zones MNP16Bc to MNP18 and Polarity Chrons C18n to C17n.2n. The last occurrence of Morozovelloides and the acme beginning of *Chiasmolithus erbae*, which are the calcareous plankton events proposed as primary base-Priabonian correlation tools, occur respectively within C17n.3n and C17n.2n. We correlate prominent crystal tuff layers exposed at Varignano with those outcropping at Alano, included the Tiziano bed that was also recommended as GSSP level. The combined stratigraphic framework deriving from our analyses provides a solid integration between calcareous plankton and shallow benthic events across the Bartonian-Priabonian transition. The Varignano section spans the upper SB17 and the lower SB18 Zones, with the zonal boundary marked by the first occurrence of the genus *Pellatispira*. This event occurs in the lower part of Zones E13 and MNP17A within C18n, well below all the potential criteria to identify the GSSP, including the base of Chron C17n.1n. We point out therefore that using the base of SB19 to approximate the base of the Priabonian, commonly adopted by shallow-water biostratigraphers, is inconsistent with all the primary criteria so far proposed.

The Shallow Benthic Zones: SBZ or SB?

Papazzoni C.A.*[1] & Pignatti J.[2]

[1] Department of Chemical and Geological Sciences, University of Modena and Reggio Emilia, Italy. [2] Department of Earth Sciences, University of Rome "La Sapienza", Italy

Corresponding author email: papazzoni@unimore.it

Keywords: Shallow Benthic Zones, nomenclature, larger foraminifera, Paleogene, Neogene.

The larger foraminiferal biozonation system currently adopted for shallow-water settings for the Cenozoic Neo-Tethys, namely the Shallow Benthic Zonation as defined by Cahuzac & Poignant (1997) and Serra-Kiel et al. (1998), retains a fundamental ambiguity in the acronym used to abbreviate the biozones. The prevalent use is to identify the zones as SBZ (Shallow Benthic Zones), followed by a number. We highlight here the inconsistencies of this use which, unique in all biozonation systems using acronyms and numbers for indicating biozones, retains the letter 'Z' to indicate the first letter of the word Zone. Indeed there are both historical and logical arguments against this use and in favor of using simply SB as abbreviation for the Shallow Benthic Zones; however, alternative solutions are discussed, We are confident that this shall help to increase clarity and promote uniformity with the planktic biozonation systems.

Cahuzac B. & Poignant, A. (1997) - Essai de biozonation de l'Oligo-Miocène dans les bassins européens à l'aide des grands foraminifères néritiques. Bull. Soc. Géol. France, 168, 155-169.

Serra-Kiel J., Hottinger L., Caus E., Drobne K., Ferràndez C., Jauhri A.K., Less G., Pavlovec R., Pignatti J., Samsó J.M., Schaub H., Sirel E., Strougo A., Tambareau Y., Tosquella J. & Zakrevskaya E. (1998) - Larger foraminiferal biostratigraphy of the Tethyan Paleocene and Eocene. Bull. Soc. Géol. France, 169, 281-299.

The Late Lutetian Thermal Maximum (C19r hyperthermal event, 41.5 Ma): insights from a continental margin section (Cape Oyambre, N Spain)

Payros A.*[1], Intxauspe-Zubiaurre B.[1], Martínez-Braceras N.[1], Ortiz S.[2], Dinarès-Turell J.[3] & Flores J.A.[4]

[1] University of the Basque Country (UPV/EHU). [2] PetroStrat Ltd. [3] Istituto Nazionale di Geofisica e Vulcanologia.
[4] University of Salamanca.

Corresponding author email: a.payros@ehu.eus

Keywords: Late Lutetian Thermal Maximum, Chron C19r event, Cape Oyambre, Northern Spain. calcareous nannofossils, benthic foraminifera.

The last Eocene hyperthermal event, the Late Lutetian Thermal Maximum (LLTM) or Chron C19r event, took place at 41.5 Ma during a long-term global cooling phase. This event was first identified in the Equatorial Atlantic ODP Site 1260 as an abrupt peak in bulk Fe content and a short-lived decline in stable isotopes and carbonate content. Additional studies have recently been completed in the Southern Atlantic ODP Sites 702 and 1263. However, many issues were not addressed at these sites and no land-based record of the event had been studied. Therefore, the beach cliff at Cape Oyambre (N Spain) was analyzed with the aim of identifying the LLTM and investigating its paleoenvironmental impact (Intxauspe-Zubiaurre et al., 2018). Using magnetostratigraphic and biostratigraphic information, the astronomically tuned cyclostratigraphic record from Oyambre was accurately correlated with ODP Site 1260 (Dinarès-Turell et al., 2018). This, combined with stable isotope data, allowed identification of the LLTM in a conspicuous dark marl. Given that the associated negative carbon isotope excursion extends for 2/3 of a precession-driven hemicouplet, a 7-11 kyr duration was estimated, which agrees with recent estimates from the Atlantic deep-sea sites. Exceptional insolation conditions were found to have accelerated the hydrological cycle, increasing rainfall and runoff on land and terrestrial sediment input to the sea, which resulted in relatively low carbonate content in the deep-sea sediments. The terrestrial input also caused seawater eutrophication and freshening, leading to low $\delta^{13}C$ and $\delta^{18}O$ values, increased abundance of autochthonous and reworked calcareous nannofossil taxa, peaks in the abundance of opportunistic *Reticulofenestra* <5 μm and opportunistic benthic foraminifera, and a reduction in the abundance of the oligotrophic calcareous nannofossil *Zygrhablithus bijugatus*. However, neither intensified carbon-gas driven greenhouse effect nor warming over and above natural fluctuations could be demonstrated from the Oyambre data.

Research funded by the Spanish Government (CGL2015-65404-R, MINECO/FEDER, EU) and the Basque Government (IT-930-16). BI-Z and NM-B received pre-doctoral grants from the University of the Basque Country and the Basque Government.

Dinarès-Turell J., Martínez-Braceras N. & Payros A. (2018) - High-resolution integrated cyclostratigraphy from the Oyambre section (Cantabria, N Iberian Peninsula): constraints for orbital tuning and correlation of middle Eocene Atlantic deep-sea records. Geochem. Geophys. Geosyst., 19, 2017GC007367.

Intxauspe-Zubiaurre B., Martínez-Braceras N., Payros A., Ortiz S., Dinarès-Turell J. & Flores J.A. (2018) - The last Eocene hyperthermal (Chron C19r event, ~41.5 Ma): chronological and paleoenvironmental insights from a continental margin (Cape Oyambre, N Spain). Palaeogeogr. Palaeoclim. Palaeoecol., 505, 198-216.

The C19r hyperthermal event at Site 702 (South Atlantic): a multiproxy approach

Rivero-Cuesta L.*[1], Westerhold T.[2] & Alegret L.[1]

[1] Departamento de Ciencias de la Tierra & IUCA, University of Zaragoza, Spain. [2] MARUM – Center for Marine Environmental Sciences, University of Bremen, Germany

Corresponding author email: lrivero@unizar.es

Keywords: Hyperthermal, C19r, LLTM, ODP Site 702, benthic foraminifera, MECO.

Recognizing past events of transient global warming triggered by release of carbon into the ocean-atmosphere system is important for understanding Earth's climate under elevated pCO_2 conditions. These events, called hyperthermals, are recognized in the marine geological record by shifts in the $\delta^{13}C$ and $\delta^{18}O$ in carbonate and shells. Several hyperthermal events are recorded within the Eocene, and here we investigate the chron C19r event (or Late Lutetian Thermal Maximum, LLTM; 41.52 Ma) at Ocean Drilling Program Site 702 (South Atlantic Ocean; lower bathyal paleodepth), where deep-sea temperatures increased by 2ºC (Westerhold et al., 2018). So far, no studies on the response of deep-sea biota to this event have been carried out, partly due to difficulties to pinpoint this event. In order to locate precisely the short-lived C19r event (duration 30 kyr) and to perform a detailed study of benthic foraminiferal assemblages (every 10 cm, ca. 8 kyr), we used high-resolution records of $\delta^{13}C$ and $\delta^{18}O$ in bulk sediment and foraminifera (negative shifts), and a positive peak in X-ray fluorescence core scanning Fe intensities (Westerhold et al., 2018). Quantitative analysis of benthic foraminifera reveals changes in the assemblages (but no extinctions) across the C19r event. The decrease in relative abundance of *Bulimina elongata* and the increase in *Oridorsalis umbonatus* point to a decrease in food supply to the seafloor. These changes predate the C19r event and coincide with a gradual decrease in $\delta^{13}C_{bulk}$, as observed across the middle Eocene Climatic Optimum (MECO; 40 Ma, duration 500 kyr, 4ºC warming) at this Site. The combination of high-resolution records across the C19r event and the MECO at various locations, combined with detailed studies on benthic foraminifera, will provide new insights into the nature of each event, the paleoenvironmental consequences and the biotic response of deep-sea fauna to hyperthermal events of different magnitude.

Project CGL2017-84693-R (Spanish Ministry of Economy and Competitiveness and FEDER funds).

Westerhold T., Röhl U., Donner B., Frederichs T., Kordesch W.E.C., Bohaty S.M., Hodell D.A., Laskar J. & Zeebe R.E. (2018) - Late Lutetian Thermal Maximum-Crossing a Thermal Threshold in Earth's Climate System? Geochem. Geophys. Geosy., 19, 1-10.

Eocene clavate and stellate foraminifers from the Western Carpathians: biostratigraphy, species diversity and paleoecology

Soták J.*, Fekete K. & Antolíková S.

Earth Science Institute of Slovak Academy of Sciences, Slovakia.

Corresponding author email: sotak@savbb.sk

Keywords: Eocene foraminifers, clavigerinellids, hantkeninids, biostratigraphy, paleoecology, Western Carpathians.

The clavate morphologies of Eocene planktonic foraminifers appeared in clavigerinellids. Their descendant species of hantkeninids evolved a tubulospinose chambers in response of metabolic effectivity and thermocline dwelling (Coxall et al., 2000, Coccioni & Bancala 2012). In the Western Carpathians, clavigerinellid acme occurred in Early Lutetian by radiation of basal species *Clavigerinella eocanica*, that evolved to highly clavate species (*C. caucasica*, *C. cf. jarvisi*) and transitional forms with constricted chambers (*Hantkenina gohrbandti*). Early species of *Hantkenina* show digitate morphologies with cylindrical projections on terminal chambers (*H. cf. singanoae*). Cancellate wall structure of earliest hantkeninids implies that they are congeneric with ancestral clavigerinellids. The most common hantkeninids provide distinctly stellate tests belonging to species *Hantkenina mexicana*. This species occurred in early Lutetian microfauna, which is also very rich in subbotinids and globigerinathekids (*G. kugleri* Zone – E9). The co-occurrence with cool-water subbotinids implies, that species *Hantkenina mexicana* inhabited a thermocline deep-water environment developing a tubulospines. These conditions were unfavourable for surface-water habitats (morozovellid demise), which gradual enhanced productivity during Lutetian (MECO) led to decline of hantkeninids. Late Lutetian–Bartonian hantkeninids inhabited a shallow shelf and periplatform areas, where they occur in marlstone interbeds of Nummulitic limestones. They exhibit a more compressed and less stellate morphotypes with slender tubulospines, which belong to species *Hantkenina dumblei*, *H. compressa* and *H. lehneri*. The stellate forms with backward curving tubulospines are close to species *Hantkenina australis*. These hantkeninids are associated with large-sized muricate species (*Acarinina topilensis, A. rohri*), specimens with muricocarina (*Morozovelloides bandyi*), smooth forms (*Pseudohastigerina micra*, *P. wilcoxensis*), bullae-like forms (*Globigerinatheka subconglobata*, *G. cf. korotkovi*) and spinose cancellate forms (*Subbotina eoceana*, *S. corpulenta*). Climatic deterioration led to disappearance of hantkeninids and muricate species in Late Eocene formations, which were replaced by temperate-water and eutrophic forms of globigerinathekids and subbotinids ("Globigerina Marls"), and later by dwarfing forms of globigerinids, pseudohastigerinids, and tenuitellids. (project: APVV-14-0118, VEGA 2/0034/16).

Coxall H.K., Pearson P.N., Shackleton N.J. & Hall M.A. (2000) - Hantkeninid depth adaptation: an evolving life strategy in a changing ocean. Geology, 28, 87-90.

Coccioni R. & Bancala G. (2012) - New insights into the pattern, timing, and duration of the evolutionary origin of the foraminiferal genus *Hantkenina*. Revue de micropaléontologie, 55, 71-81.

Oligocene tectonic and climatic signals in the Southern North-Sea Basin

Vandenberghe N.*

KU Leuven University, Belgium.

Corresponding author email: noel.vandenberghe@kuleuven.be

Keywords: Oligocene, climate, tectonic, cyclicity, North-Sea Basin.

Sediments of the Priabonian, Rupelian and Chattian in the Southern North-Sea Basin are siliciclastics and are developed as a synthem between the Pyrenean and Savian unconformities. These tectonic events make the area where Rupelian and Chattian historical stratotypes are defined unsuitable for modern boundary GSSP stratotype definition; detailed stratigraphic study of these former reference areas is however important to ensure that GSSP's are defined in line with the meaning of the original unit stratotypes. The transition from Eocene to Oligocene is marked by changes in clay minerals and by a stepwise cooling. In the Rupelian an earliest very widespread sequence is recognized; it corresponds to the marine part of the former 'Tongrian' regional stage. The retreat of the sea at the end of this earliest sequence is the time of the Grande Coupure faunal turnover and also a major cooling step is documented at this time. The estuarine and coastal plain deposits at the base of the subsequent marine Boom Clay deposition contain the Hoogbutsel bed and green clays typical for the earliest Oligocene. The Boom Clay is dominated by obliquity cycles expressed in clay/silt ratios associated with detrital organic matter beds. They are the local response to the waxing and waning of ice on Antarctica. Deposition of the thick marine Boom Clay deposit at the time of global sea-level lowering, a consequence of extensive ice build-up in Antarctica, is in itself an expression of regional tectonic basin subsidence which is most logically a loading effect by the ongoing Alpine orogeny. Preservation of detrital organic matter starts at the very same moment in different parts of the basin and therefore could indicate a tectonic event. Lower frequency orbital cycles are also detected but their effect interferes with the signature of local tectonic evolution. Eustacy signals are eliminated from the record by analysis of cycle thickness differences between boreholes rather than comparing their absolute thickness. Differential tectonic movements in the area start well before the end of the Rupelian and important clay masses are already eroded at the turn to the Chattian. The most prominent event at the start of the Chattian is the reactivation of the subsidence in the Lower Rhine graben with the preservation of several hundred meter of Chattian silicilastics. Outside the graben, erosion continued to dominate during the Chattian and even the Aquitanian; this long period above sea level is due to a combination of the Savian tectonic uplift pulse and a low sea level.

Vandenberghe N. (2017) - Tectonic and climatic signals in the Oligocene sediments of the Southern North-Sea Basin. Geol. Belg., 20(3-4), 105-123.

Vandenberghe N., De Craen M. & Wouters L. (2014). The Boom Clay geology from sedimentation to present-day occurrence. A review. Memoirs of the Geological Survey of Belgium, 60 ,76 pp.

A new benthic stable isotope composite reference sequence for the middle to late Eocene

Westerhold T.*[1], Röhl U.[1], Bohaty S.M.[2], Florindo F.[3], Frederichs T.[4], Zachos J.C.[5], Cappelli C.[6], Agnini C.[6] & Yamamoto Y.[7]

[1] MARUM - University of Bremen, Germany. [2] University of Southampton, UK. [3] Istituto Nazionale di Geofisica & Vulcanologia, Italy. [4] University of Bremen, Germany. [5] University of California Santa Cruz, USA. [6] Università degli Studi di Padova, Italy. [7] Kochi University, Japan.

Corresponding author email: twesterhold@marum.de

Keywords: astronomical tuning, Eocene, benthic stable isotopes.

Astronomical age models are key for climatic reconstructions because of their high resolution and accuracy. Exploring and understanding causal relationships of climate change during the past 100 million years strongly depends on assembling accurate age models of geological archives. Establishing a robust astronomical time scale for the middle to late Eocene between 34 and 48 Ma has previously proved difficult due to a lack of records of sufficient quality. Construction of an astrochronological framework for the middle Eocene, in particular, has proved challenging, and there is a middle Eocene 'gap' in the coverage of the Paleogene astronomical timescale. Astronomical tuning of bulk stable isotope and XRF core scanning data from ODP Sites 702 (ODP Exp. 114, Subantarctic South Atlantic) and 1263 (ODP Leg 208, Walvis Ridge, South Atlantic) covering the middle Eocene gap was recently challenged. According to XRF core scanning and paleomagnetic records from IODP Sites U1408 and U1410 (IODP Exp. 342, Paleogene Newfoundland Sediment Drifts, Northwest Atlantic) the duration of magnetic polarity Subchron C20r is about 500 kyr shorter in duration than in the 2012 Geomagnetic Polarity Time Scale (GPTS) and even more than 600-kyr shorter than the first cyclostratigraphic study from Sites 702 and 1263. Nannofossil biostratratigraphic analysis of the middle Eocene sections of Sites U1408 and U1410 indicates several intervals of condensation at both sites, which were not taken into account in previous work. Here we first present a revision of the composite record for Sites U1408 and U1410, and second a revised correlation between both sites reconfirmed by detailed paleomagnetic data. We also present new magnetostratigraphic as well as high-resolution bulk and benthic stable isotope records from ODP Site 1263 covering the entire middle to late Eocene interval (34–49 Ma, Chron 13 to 22). Our new high-resolution benthic stable isotope record from Site 1263 has an average resolution of 5 kyr encompassing the cooling after the Early Eocene Climate Optimum, the Late Lutetian Thermal Maximum, and the Middle Eocene Climate Optimum in unprecedented detail. The benthic carbon isotope record from Site 1263 reveals a dominant eccentricity forcing that was then utilized for astronomical tuning of the middle to late Eocene.

ST3.10
Integrated stratigraphy and paleoclimatic and paleoceanographic events in the Neogene

Conveners and Chairpersons
Elena Turco (Università degli Studi di Parma)
Kenneth G. Miller (Rutgers University)
Frits J. Hilgen (Utrecht University)
Isabella Raffi (Università "G. d'Annunzio" di Chieti-Pescara)

Upper Ocean vertical niche evolution linked to global cooling since the middle Miocene

Boscolo-Galazzo F.*[1], Crichton K.A.[1], Ridgwell A.[2] & Pearson P.N.[1]

[1] Cardiff University School of Earth and Ocean Sciences. [2] University of California Riverside Department of Earth Sciences

Corresponding author email: boscologalazzof@cardiff.ac.uk

Keywords: Late Neogene, planktonic foraminifera, ocean cooling, climate change.

The late Neogene (7.2-2.6 Ma), is characterized by a large radiation of planktonic foraminifera which involved groups such as the menardellids and globoconellids, and led to the origination of the truncorotalids and pulleniatinids[1]. Many new species appearing within these groups have a cosmopolitan distribution, and are widely used biostratigraphic markers. A peculiar feature of the late Neogene planktonic foraminifera radiation is that it mostly involved subsurface (lower euphotic zone) to deep dwelling species, with the truncorotalids exclusively comprising deep dwelling species live captured at up to > 2000 m water depth[2]. This pattern of subsurface water speciation in the late Neogene, occurred over a time of global cooling and polar ice-sheet expansion, suggesting a link with changing ocean temperatures. To test this hypothesis, we produced a multi-site equatorial to subpolar stable isotope compilation including all the most representative planktonic foraminifera species since the middle Miocene. The analysis focused on 7 time slices (15-0 Ma), and was aimed at reconstructing the evolution of the vertical niche partitioning of planktonic foraminifera species over the last 15 Ma cooling trend. We then used an Earth System Model of intermediate complexity (cGENIE) to convert planktonic foraminifera oxygen isotope ratios into depth habitats for all the species analyzed. cGENIE converted depths show that in the middle Miocene, planktonic foraminifera were almost exclusively living within the upper 200 m of the water column. Within this depth-range, most of the species occupied the upper 100 m at all the investigated sites. From the late middle Miocene on, species vertical niches start to stretch more evenly in the upper 200 m of the water column. By the early Pliocene new species belonging to the menardellids and pulleniatinids crowd subsurface depths (150-250 m) at tropical to subtropical sites, and by the late Pliocene truncorotalids and/or globoconellids populate depths comprised between 400-600 m. We find a modern-like vertical partitioning of planktonic foraminifera niches only by 0 Ma. Our new compilation indicates that the vertical niche partitioning exhibited by modern planktonic foraminifera is a recent acquisition. Planktonic foraminifera started to invade deeper habitats following the middle Miocene warmth, suggesting a strong connection with climate and ocean cooling. A temperature-dependent decrease in organic matter recycling rates may have been the key driver, allowing for more organic debris to reach greater depths in an increasingly colder ocean. The late Neogene radiation appears to be linked to a new availability of niches to exploit at depth, suggesting a major role of a climate-driven parapatric genetic separation in the evolution of the most recent lineages of planktonic foraminifera.

Tephra fingerprinting and tephrostratigraphy in the Miocene Pisco Formation (Peru)

Bosio G.*[1], Gioncada A.[2], Malinverno E.[1], Di Celma C.[3], Villa I.M.[4-5], Cataldi G.[2], Gariboldi K.[2], Collareta A.[2], Urbina M.[6] & Bianucci G.[2]

[1] Dipartimento di Scienze dell'Ambiente e della Terra, Università degli Studi di Milano-Bicocca, Italia. [2] Dipartimento di Scienze della Terra, Università di Pisa, Italia. [3] Scuola di Scienze e Tecnologie, Università di Camerino, Italia [4] Institut für Geologie, Universität Bern, Schweiz. [5] Centro Universitario Datazioni e Archeometria, Università degli Studi di Milano-Bicocca, Italia. [6] Departamento de Paleontología de Vertebrados, Museo de Historia Natural, Universidad Nacional Mayor de San Marcos, Perù.

Corresponding author email: giulia.bosio.giulia@gmail.com

Keywords: tephrostratigraphy, tephra fingerprinting, volcanic ash layers, Miocene, Peru.

Tephra fingerprinting is a unique tool for reconstructing a high resolution stratigraphy (Lowe, 2011; Smith et al., 2011). In the upper Miocene succession of the Pisco Formation (East Pisco Basin, Peru) the presence of distal volcanic ashes from the Central Andes represents a great opportunity for dating and correlating stratigraphic sections at distant localities. The importance of a detailed chronostratigraphic reconstruction is given by to the paleontological significance of this formation, which hosts a globally renowned marine vertebrate Fossil-Lagerstätte (Lambert et al., 2010; Bianucci et al., 2016). For reaching this goal, ^{39}Ar–^{40}Ar dating and tephra fingerprinting were applied on ash layers. Regarding to ^{39}Ar–^{40}Ar dating, an essential part of our work were electron microprobe tests of stoichiometry and monomodality, so as to only date unaltered, homogeneous tephra. Despite the similar glass composition and mineral assemblage, together with the shallow marine depositional environment limiting tephra preservation, correlations between distant localities can be realized by fingerprinting tephra layers on the basis of petrographic and compositional investigations, grain-size analyses, and glass shard morphology. Major element composition of biotite proved to be a valuable tool for discriminating ash layers and correlating different stratigraphic sections located several kilometers apart from each other. This study, in part published this year on the Journal of the Geological Society (Bosio et al., 2019), highlights the applicability of tephra fingerprinting in tephra archives as old as the Miocene as well as in unfavorable shallow marine environments, and allows a great increase of the chronostratigraphic detail.

Bianucci G., Di Celma C., Collareta A., Landini W., Post K., Tinelli C., de Muizon C., Bosio G., Gariboldi K., Gioncada A., Malinverno E., Cantalamessa G., Altamirano-Sierra A., Salas-Gismondi R., Urbina M. & Lambert O. (2016) - Fossil marine vertebrates of Cerro Los Quesos: distribution of cetaceans, seals, crocodiles, seabirds, sharks, and bony fish in a late Miocene locality of the Pisco Basin, Peru. JoM, 12, 1037-1046.

Bosio G., Gioncada A., Malinverno E., Di Celma C., Villa I.M., Cataldi G., Gariboldi K., Collareta A., Urbina M. & Bianucci G. (2019) - Chemical and petrographic fingerprinting of volcanic ashes as a tool for high-resolution stratigraphy of the upper Miocene Pisco Formation (Peru). J. Geol. Soc. London, 176, 13-28.

Lambert O., Bianucci G., Post K., de Muizon C., Salas-Gismondi R., Urbina M. & Reumer J. (2010) - The giant bite of a new raptorial sperm whale from the Miocene epoch of Peru. Nature, 466, 105-108.

Lowe D.J. (2011) - Tephrochronology and its application: A review. Quat. Geochronol., 6, 107-153.

Smith V.C., Pearce N.J.C., Matthews N.E., Westgate J.A., Petraglia M.D., Haslam M., Lane C.S., Korisettar R. & Pal J.N. (2011) - Geochemical fingerprinting of the widespread Toba tephra using biotite compositions. Quatern. Int., 246, 97-104.

Strontium Isotope Stratigraphy of Miocene sedimentary successions in the Peruvian East Pisco Basin

Bosio G.*[1], Malinverno E.[1], Collareta A.[2], Di Celma C.[3], Gioncada A.[2], Parente M.[4], Berra F.[5] & Bianucci G.[2]

[1] Dipartimento di Scienze dell'Ambiente e della Terra, Università degli Studi di Milano-Bicocca, Italia. [2] Dipartimento di Scienze della Terra, Università di Pisa, Italia. [3] Scuola di Scienze e Tecnologie, Università di Camerino, Italia. [4] Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse, Università degli Studi di Napoli Federico II, Italia. [5] Dipartimento di Scienze della Terra "Ardito Desio", Università degli Studi di Milano, Italia.

Corresponding author email: giulia.bosio.giulia@gmail.com

Keywords: strontium isotopes, stratigraphy, fossil invertebrates, Miocene, East Pisco Basin, Peru.

The $^{87}Sr/^{86}Sr$ ratio of oceanic seawater has varied through geological time and can be used to date marine minerals and correlate stratigraphic sections of marine deposits (McArthur et al., 2012). The Miocene Chilcatay and Pisco formations exposed in the East Pisco Basin (southern Peru) are well-known for their exceptional content of fossil marine vertebrates, but also contain a rich fossil invertebrate fauna. A chronostratigraphic reconstruction based on ^{39}Ar–^{40}Ar dating and biostratigraphy was recently pursued (Di Celma et al., 2017), but the age of the lowest allomember of the Pisco Formation, P0, remains unresolved. For dating P0, mollusks (i.e. ostreids and pectinids), barnacle shells, and shark teeth were collected for applying the Sr-isotope stratigraphy on carbonates and phosphates. Their preservation was studied with petrographic, morphological, chemical and cathodoluminescence analyses since diagenetic processes and weathering can alter the original $^{87}Sr/^{86}Sr$ of the shell (Ullmann & Korte, 2015). The samples thus selected include oysters and pectinids showing a well-preserved microstructure of the shell together with a homogeneous and low luminescence, the least porous and best-preserved part of barnacles, i.e. the sheat, and the least permeable tissue of shark teeth, i.e. the enameloid layer. Sr-isotopic results, made at the Ruhr-Universität of Bochum and elaborated with the LOWESS Table 5 made for the GTS2012 timescale (McArthur et al., 2012), gave Burdigalian ages for the Chilcatay Formation and Langhian to Serravallian ages for the P0 allomember. The obtained ages for the Chilcatay Formation perfectly agree with previous ^{39}Ar–^{40}Ar and biostratigraphic results, confirming the feasibility of the method in this succession. New middle Miocene ages for the P0 allomember agree with the age estimated by DeVries & Jud (2018) for the lowest Pisco Formation and with the archaic aspect of the cetacean assemblage (Di Celma et al., 2017; Marx et al., 2017).

DeVries T.J. & Jud N.A. (2018) - Lithofacies patterns and paleogeography of the Miocene Chilcatay and lower Pisco depositional sequences (East Pisco Basin, Peru). Bol. Soc. Geol. Perù, 8, 124-167.

Di Celma C., Malinverno E., Bosio G., Collareta A., Gariboldi K., Gioncada A., Molli G., Basso D., Varas-Malca R., Pierantoni P.P., Villa I.M., Lambert O., Landini W., Sarti G., Cantalamessa G., Urbina M. & Bianucci G. (2017) - Sequence stratigraphy and paleontology of the upper Miocene Pisco Formation along the western side of the lower Ica Valley (Ica Desert, Peru). Riv. Ital. Paleontol. S., 123(2), 255-273.

Marx F.G., Lambert O. & de Muizon C. (2017) - A new Miocene baleen whale from Peru deciphers the dawn of cetotheriids. R. Soc. open Sci., 4, 170560.

McArthur J.M., Howarth R.J. & Shields G.A. (2012) - Strontium Isotope Stratigraphy. In Gradstein F.M., Ogg J.G., Schmitz M., Ogg G. Eds., The Geologic Time Scale 2012, 127-144. Elsevier.

Ullmann C.V. & Korte C. (2015) - Diagenetic alteration in low-Mg calcite from macrofossils: a review. Geological Quarterly, 59(1), 3-20.

Upper Miocene C-isotope stratigraphy and C-cycle dynamics: the Central Mediterranean shallow-water record

Cornacchia I.*[1], Munnecke A.[1] & Brandano M.[2]

[1] GeoZentrumNordbayern, Fachgruppe Paläoumwelt University of Erlangen-Nuremberg. [2] Dipartimento di Scienze della Terra, Sapienza Università di Roma

Corresponding author email: irene.cornacchia@fau.de

Keywords: carbonate ramps, C-isotopes, Mediterranean, Miocene, Tortonian.

The late Miocene is an extremely important period concerning the global climatic evolution. It represents the transition from the Mid Miocene Climatic Optimum (MMCO) to the onset of the Arctic glaciation at the Miocene-Pliocene boundary (Zachos et al., 2001). Slightly warmer than the present, it could also represent a likely model for climate-driven carbon cycle future dynamics. An underrated global carbon cycle perturbation occurs in the early Tortonian, known in literature as Carbon Maximum 7 (CM7), almost contemporary to a glacial maximum (Mi5) (Miller et al., 1991). This work aims to identify the Central Mediterranean shallow-water carbonate system's record of the CM7, discriminating potential regional controlling factors related to the geodynamic evolution of the area, as well as the complex paleoceanographic evolution of the Mediterranean basin, which might have affected C-isotope ratios and carbonate production. The Tortonian $\delta^{13}C$ record has been analysed on bulk samples belonging to two different carbonate ramps: Latium-Abruzzi and the Apula platforms (Central Apennines, Italy). Age constraints are provided by integrated calcareous nannofossils and Sr Isotope stratigraphy. A detailed microfacies analyses and SEM observations have been carried out for the Apula platform succession in order to identify changes in the carbonate production as well as the diagenetic history of the limestones. A lower Tortonian positive C-isotope excursion has been identified in the $\delta^{13}C$ curves of both platforms and interpreted as the CM7. However, the late Miocene evolution of the two carbonate ramps is significantly different, being the Latium-Abruzzi platform characterised by a deepening upward trend, while the Apula platform shows a shallowing upward trend. In fact, the Latium-Abruzzi ramp drowns in the early Tortonian, immediately after the CM7, as testified by a hardground surface overlain by hemipelagic marls. Conversely, the lower Tortonian outer ramp deposits of the Apula platform are overlain by upper Tortonian inner ramp facies. These preliminary results imply that, despite the carbon cycle perturbation of the early Tortonian affected both the platforms, regional controlling factors, related to the migration of the Apennine accretionary wedge, ultimately controlled the evolution of the studied ramps.

Miller K.G., Wright J.D. & Fairbanks R.G. (1991) - Unlocking the ice house: Oligocene-Miocene oxygen isotopes, eustasy, and margin erosion. J. Geophys. Res.-Sol. Earth, 96(B4), 6829-6848.

Zachos J., Pagani M., Sloan L., Thomas E. & Billups K. (2001) - Trends, rhythms, and aberrations in global climate 65 Ma to present. Science, 292(5517), 686-693.

In search of the Burdigalian GSSP: new evidence from the Contessa Section (Italy)

Fabbrini A.[1], Baldassini N.[2], Caricchi C.[3], Foresi L.M.[1], Sagnotti L.[3], Dinarès-Turell J.[3], Di Stefano A.[2], Lirer F.[4], Menichetti M.[5], Winkler A.[3] & Distefano S.*[2]

[1] University of Siena, Italy. [2] University of Catania, Italy. [3] National Institute of Geophysics and Volcanology, Italy. [4] Marine science institute-CNR, Italy. [5] University of Urbino Carlo Bo, Italy.

Corresponding author email: distefan@unict.it

Keywords: Early Miocene, Integrated biostratigraphy, Planktonic Foraminifera, GSSP, Calcareous nannofossils.

The Contessa Section is a reference section for the early Miocene in the Mediterranean. Along this 36 m thick section 115 samples were collected and analysed for an integrated bio-magnetostratigraphic study through the Scaglia Cinerea and Bisciaro formations. Planktonic foraminifera were analysed semi-quantitatively, while calcareous nannofossils were examined using the standard quantitative method. A reliable biozonation for both fossil groups was then accomplished. The paleomagnetic analyses identified a sequence of magnetozones, then correlated with the ATNTS using the calcareous plankton bioevents. The investigated interval extends from foraminiferal Zone P22 (Chattian) to MMi2c (Burdigalian) and from calcareous nannofossils Zone MNP25a to MNN3a, thus from Chron C7An to C5En. Therefore, the section chronologically spans from 24.80 Ma to 18.10 Ma. Three hiatuses were recognised along the section: H1 at 0.63 m from the base (comprising a minimum time interval from 24.36 Ma to 23.38 Ma), H2 at 12.33 m (between 21.80 Ma and 21.35 Ma) and H3 at 34.03 (between 19.21 Ma and 18.40 Ma). All three hiatuses were correlated with regional megahiatuses identified in the North Atlantic Ocean and in the Paratethys area. Furthermore, the First Occurrence of the calcareous nannofossil *Helicosphera ampliaperta* is recognised within Chron C6An.2n at 19.77 m from the base (6 m above the volcaniclastic Raffaello Level). This event provisionally defines the Aquitanian/Burdigalian boundary according to the literature. Thus, the Contessa Section is a possible candidate for the definition of the Burdigalian Global Stratigraphic Section and Point. Finally, the age of the Raffaello Level (a regional marker horizon for the early Miocene) is discussed in this new integrated stratigraphic framework, falling in Chron C6AAn and dated between 21.09 Ma and 21.08 Ma.

Role of the Bering Strait in migrations of the Arctic and Pacific biotic assemblages in the Neogene

Gladenkov Yu.* & Gladenkov A.

Geological Institute of Russian Academy of Sciences.

Corresponding author email: gladenkov2@gmail.com

Keywords: Neogene, Bering Strait, marine biota, migration.

Beginning from the Early Cretaceous for nearly 100 mln years the Eurasia and North America constituted a single supercontinent. In place of the recent Bering Strait there was the Bering "Bridge" which provided migrations of terrestrial animals and plants from the Old World into the New one and visa verse. The Strait opening in the Neogene has led to hydrological changes in the Neogene basins, appearance of new ways of marine biota migration, and paleogeographical changes. The Bering Strait was first opened in the latest Miocene. It appeared as a result of tectonic processes combined possibly with eustatic rise of oceanic waters. As a consequence, Pacific marine biota migrated to the Arctic basin and farther to North America. This was reflected particularly in occurrences of Pacific mollusks in the Pliocene sections of Iceland and Great Beritain ("the *Serripes* Zone"). The Arctic and North Atlantic faunal forms migrated into the North Pacific basin (assemblages with *Astarte*) and spread in Alaska (the Milky River Formation), Kamchatka (the Limimtevayam Suite), Sakhalin (the Pomyr Suite), and Northern Japan (the Atsuga Formation). At the same time Pacific diatoms appeared in the Arctic basin. Occurrence of a diatom assemblage (with *Thalassiosira temperei*) of narrow time interval in the Alaska sample with *Astarte* allows dating the Bering Strait opening as about 5.4 mln years ago. It is interesting that the first Bering Strait opening was approximately coincident with the Mediterranean transgression after the Messinian crisis.

However, many problems of the geological history of the Bering Strait remained unsolved, particularly:

- reasons for asymmetry of migration flows of some molluscan species through the Bering Strait is not known. The flows from the Pacific into the Arctic dominated in the ratio 8:1; influence of the migrants on biocoeanoses formation of the Arctic and Pacific ecosystems is not adequately estimated;
- ways of migrations of the Pacific biota from the Bering Strait to North Atlantic areas (the Asian and Canadian ways) are not precisely defined;
- reasons for difference in migration rates of the biotic assemblages in the shelf zones of these basins are not clear (a migration rate of the *Astarte* assemblages in the North Pacific exceeds that of the Pacific assemblage with *Serripes* in the Atlantic basin); a role of sea currents is not also well understood;
- time periods of Bering Strait draining in the Pliocene is not precisely determined.

Comparative analysis of data on paleostraits of different regions (first of all, Panama and Malaysia straits) can promote deciphering many specific features of evolution of ancient basins and their biotic communities.

The work was performed under the state assignment no. 0135-2019-0057 of Geological Institute RAS and was supported in part by the Russian Foundation for Basic Research (project no. 19-05-00361).

Isotopic record of paleodiet in 7.4 Ma Hipparionine fossils from the central Loess Plateau, northern China: paleo-ecological and paleo-climatic implications

Li Y.F.*[1], Deng T.[2], Hua H.[1], Zhang Y.X.[1] & Wang J.D.[1]

[1] Northwest University. [2] Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences.

Corresponding author email: m1vst90www@126.com

Keywords: Northern Shaanxi, China, Late Miocene, enamel-δ13C and δ18O values, paleoecology, paleoclimate

The Wangdafuliang section is a famous location of the "Hipparion red clay" on the central Loess plateau. The C4 expansion of there for the first time was once considered in 7.4 Ma, which contradicts mainstream recognition. This results in less significance and attention for this representative section. In view of the isotopic record of paleodiet plays an important role in paleoecological and paleogeographic interpretations, we analyzed the enamel $\delta^{13}C$ and $\delta^{18}O$ values of the 7.4 Ma hipparionine from the Wangdafuliang section. The $\delta^{13}C$ values indicated a diet comprised entirely of C_3 plants. The $\delta^{18}O$ values reflecting the location is a possibly seasonal, mild continental climate in the Late Miocene, but without swap between wet and dry. The local landscape should be C_3 steppe which belonged to the west district of Neogene paleozoogeographical boundary of Northern China. Compared with the published isotopic records of the Late Miocene paleodiet from Linxia Basin (the western Loess Plateau), Yushe (the eastern Loess Plateau) and central Inner Mongolia, to provide further discussions about the scope of the then East Asian summer monsoon, and provide more evidence that the monsoon had shifted direction from the Late Miocene to the Pleistocene.

Regional tectonics versus global climate – impact on stratigraphy of the Central Paratethys?

Piller W.E*.[1], Harzhauser M.[2], Mandic O.[2], Kranner M.[1-2], Strauss P.[3] & Siedl W.[3]

[1] University of Graz, Austria. [2] Natural History Museum Vienna, Austria. [3] OMV Exploration & Production GmbH, Vienna, Austria.

Corresponding author email: werner.piller@uni-graz.at

Keywords: lithostratigraphy, biostratigraphy, seismostratigraphy, tectonics, climate, sea level.

The Paratethys is an Oligocene – Neogene semi-enclosed, epicontinental basin with highly variable connections to the Mediterranean, Indopacific and North Sea through time. The differentiation between the importance of tectonic movements versus expression of global sea level fluctuations is an ongoing discussion in interpreting depositional architecture of sedimentary basins and regional stratigraphy and its correlation with global chronostratigraphy. Large surface or subsurface outcrops, unconformity bound sedimentary bodies observable over a relevant distance, a detailed paleoecological analysis and a tight stratigraphic corset are the prerequisites for any attempt to evaluate the ratio between these mechanisms. Due to their highly active tectonic environment, the Central Paratethyan basins are exceptionally challenging targets to approach this problem. Herein we present the Vienna Basin, one of the best-studied pull-apart basins in the world with a major hydrocarbon reservoir. The Vienna basin also acts as an exemplary case to check for fits and misfits of the stratigraphic record with global climate and 3rd order sea level changes, based on new 3D-seismic surveys of the up to 6000 m thick Neogene basin fill coupled with an in-depth revision and reassessment of lithostratigraphy and biostratigraphic data from numerous wells in its central and northern parts. Especially the change of the tectonic regime, from piggy-back basins with halfgraben formation towards a pull-apart mechanism around the early/middle Miocene boundary is the pivotal point to compare the depositional regimes and their response to global climate change.

High-resolution integrated stratigraphy and astronomical tuning of the Monte Cardeto - Spiaggia della Scalaccia composite section (Ancona, Italy) between 17.3 and 16.2 Ma. The onset of the Miocene Climatic Optimum in the Mediterranean

Turco E.*[1], Cascella A.[2], Hilgen F.J.[3], Hüsing S.K.[4], Krijgsman W.[4] & Van Peer T.E.[5]

[1] Dipartimento di Scienze Chimiche, della Vita e Sostenibilità Ambientale, University of Parma, Italy. [2] Istituto Nazionale di Geofisica e Vulcanologia (INGV), Pisa, Italy. [3] Department of Earth Sciences, University of Utrecht, The Netherlands. [4] Paleomagnetic Laboratory ‚Fort Hoofddijk',University of Utrecht, The Netherlands. [5] Ocean and Earth Science, National Oceanography Centre Southampton, University of Southampton, UK.

Corresponding author email: elena.turco@unipr.it

Keywords: Integrated stratigraphy, late Burdigalian, Mediterranean, Miocene Climatic Optimum.

An integrated magneto-, bio- and cyclostratigraphy is presented for the hemipelagic Monte Cardeto – Spiaggia della Scalaccia composite section (Ancona, Italy). The section, characterized by cyclic alternations of marls and marly limestones, represents the downward extension of the upper Burdigalian in the La Vedova section (Turco et al., 2017) with a short overlap, covering the older part of the Miocene Climatic Optimum. The high-resolution magnetobiostratigraphic record of the studied section reveals a straightforward correlation to GTS2012 (Hilgen et al., 2012), encompassing the C5Dn/C5Cr to C5Cn.1r/C5Cn.1n chron boundaries. Spectral and wavelet analyses have been applied on the high resolution geochemical proxy records (e.g., CaCO3 and Rb/Sr) and magnetic susceptibility to validate the astronomical control on the sedimentary cyclicity. On the basis of CaCO3 content, Rb/Sr, Ba/Al, Ti/Al, Zr/Al, Mn/Al, V/Al, Si/Al and magnetic susceptibility, the phase relation between sedimentary cycles and astronomical cycles has been established allowing a first order calibration to eccentricity. Subsequently an astronomical tuning to precession was performed by correlating limestones of the basal small-scale cycles to boreal summer insolation maxima (i.e., precession minima). The obtained astronomical time scale allowed the calibration of magnetic reversals and calcareous plankton events. Astronomical ages of the magnetic reversals are in good agreement with those independently obtained through the astronomical tuning of the carbonate record of IODP Site U1336 (Kochhann et al., 2016). As in the younger La Vedova section, the Si/Al record shows mainly larger scale variations with higher values in the more indurated marly-limestone intervals indicating an increase in biogenic silica, possibly due to tectonic induced volcanism in the Early Miocene.

Hilgen F.J., Lourens L.J. & van Dam J. A. (2012) - The Neogene Period. In: Gradstein F., Ogg J., Schmitz M. & Ogg, G. Eds., The Geological Time Scale 2012. Elsevier, Amsterdam, 923–978.

Kochhann K.G.D., Holbourn A., Kuhnt W., Channell J.E.T., Lyle M., Shackford J.K., Wilkens R. H. & Andersen N. (2016) - Eccentricity pacing of eastern equatorial Pacific carbonate dissolution cycles during the Miocene Climatic Optimum. Paleoceanography, 31, 1176-1192. https://doi.org/10.1002/2016PA002988.

Turco E., Hüsing S., Hilgen F., Cascella A., Gennari R., Iaccarino S.M. & Sagnotti L. (2017) - Astronomical tuning of the La Vedova section between 16.3 and 15.0 Ma. Implications for the origin of megabeds and the Langhian GSSP. Newsletters on Stratigraphy, 50, 1-29. https://doi.org/10.1127/nos/2016/0302

ST3.11
Quaternary stratigraphy and chronostratigraphy

Conveners and Chairpersons

Martin J. Head (Brock University)

Jan A. Zalasiewicz (University of Leicester)

Colin N. Waters (University of Leicester)

Quaternary stratigraphy: what's the contribution of palynology from long, continuous terrestrial sedimentary successions? An example from the Lake Ohrid (Balkan peninsula)

Bertini A.*[1], Sadori L.[2], Combourieu-Nebout N.[3], Donders T.H.[4], Kouli K.[5], Koutsodendris A.[6], Kousis I.[6], Joannin S.[7], Masi A.[2], Mercuri A.M.[8], Panagiotopoulos K.[9], Peyron O.[7], Sinopoli G.[2], Torri P.[8], Francke A.[9-10], Wagner B.[9] & Zanchetta G.[11]

[1] Università di Firenze, Italy. [2] Università di Roma "La Sapienza", Italy. [3] Centre National de la Recherche scientifique - Muséum national d'Histoire naturelle, Paris, France. [4] Utrecht University, The Netherlands. [5] University of Athens, Greece. [6] Heidelberg University, Germany. [7] Université de Montpellier, France. [8] Università di Modena e Reggio Emilia, Italy. [9] University of Cologne, Germany. [10] University of Wollongong, Australia. [11] Università di Pisa, Italy.

Corresponding author email: adele.bertini@unifi.it

Keywords: Paleoclimatology, Quaternary stratigraphy, Marine Isotope Stages 1-43, Terrestrial environments, Lake Ohrid, Southern Europe.

Broad-scale syntheses concerning relationships between variations of the land–ocean–atmosphere system along the time need to be based on solid land-sea correlations. To this purpose the contribution of a sound regional terrestrial stratigraphy to the marine one is a mandatory step. Lake Ohrid (LO, Balkan peninsula) is the oldest European extant lake and one of the deepest and largest. Scientific drilling of the lake in 2013, in the frame of the International Continental Scientific Drilling Program (ICDP) within the scope of the Scientific Collaboration on Past Speciation Conditions in LO (SCOPSCO) resulted in a 584-m-long composite and continuous sediment succession from the lake centre. Palynological studies, performed on 697 samples by an international team (Bertini et al., 2016), document the main floristic, vegetation and climate changes at a millennial-scale resolution (Sadori et al., 2016; Wagner et al., 2017). The continuous sediment infill permitted to trace multiple non-forested/forested phases as a response to glacial/interglacial cycles (MISs 1-43) as well as to sub-Milankovitch climate changes. Additional palynological studies have been (with some still underway) realized over some key intervals (MIS 5-6: Sinopoli et al., 2018, 2019; MIS 11-12: Kousis et al., 2018, MIS 35-43; MIS 20-18) at higher resolution. The complete record of changes in flora composition and vegetation structure furnished indispensable insights for understanding the role of refugia, ecosystem resilience and maintenance of terrestrial biodiversity in the Mediterranean area. In the frame of Quaternary chronostratigraphic issues, overall palynological evidence from such a unique, terrestrial natural archive permits the refinement of age-depth relationships of the chronological framework established by tephras and magnetostratigraphy (Francke et al., 2016) as well as the documentation of key calibrated intervals (e.g. stadials, interstadials, terminations, climate optima; Zanchetta et al., 2016) which characterization provides a fantastic glance on the Quaternary climate variability throughout the last 1.36 Myr.

Bertini A., Sadori L., Combourieu-Nebout N., Donders, T.H., Kouli K., Koutsodendris A., Joannin S., Masi A., Mercuri A.M., Panagiotopoulos K., Peyron O., Sinopoli G., Torri P., Zanchetta G., Francke A. & Wagner B. (2016) - Alpine and Mediterranean Quaternary, 29 (2), 201–210.

Francke A., Wagner B., Just J., Leicher N., Gromig R., Baumgarten H., Vogel H., Lacey J.H., Sadori L., Wonik T. & Leng M.J. (2016) - Sedimentological processes and environmental variability at Lake Ohrid (Macedonia, Albania) between 637 ka and the present. Biogeosciences, 1, 1179–1196.

Kousis I., Koutsodendris A., Peyron O., Leicher N., Francke A., Wagner B., Giaccio B., Knippingf M. & Pross J. (2018) - Centennial-scale vegetation dynamics and climate variability in SE Europe during Marine Isotope Stage 11 based on a pollen record from Lake Ohrid. Quaternary Science Reviews, 190, 20-38.

Sadori L., Koutsodendris A., Panagiotopoulos K., Masi A., Bertini A., Combourieu-Nebout N., Francke A., Kouli K., Joannin S. & Mercuri A.M. (2016) - Pollen-based paleoenvironmental and paleoclimatic change at Lake Ohrid (south-eastern Europe) during the past 500 ka. Biogeosciences, 13, 1423–1437.

Sinopoli G., Masi A., Regattieri E., Wagner B., Francke A., Peyron O. & Sadori L. (2018) - Palynology of the Last Interglacial Complex at Lake Ohrid: palaeoenvironmental and palaeoclimatic inferences. Quaternary Science Reviews, 180, 177-192.

Sinopoli G., Peyron O., Masi A., Holtvoeth J., Francke A., Wagner B. & Sadori L. (2019) - Pollen-based temperature and precipitation changes in the Ohrid Basin (western Balkans) between 160 and 70 ka. Climate of the Past, 15, 53–71.

Wagner B., Wilke T., Francke A., Albrecht C., Baumgarten H., Bertini A., Combourieu-Nebout N., Cvetkoska A., D'Addabbo M., Donders T. H. et al. (2017) - The environmental and evolutionary history of Lake Ohrid (FYROM/ Albania): interim results from the SCOPSCO deep drilling project. Biogeosciences, 14 (8), 2033-2054.

Zanchetta G., Regattieri E., Giaccio B., Wagner B., Sulpizio R., Francke A., Vogel H., Sadori L., Masi A. & Sinopoli G. (2016) - Aligning and synchronization of MIS5 proxy records from Lake Ohrid (FYROM) with independently dated Mediterranean archives: implications for DEEP core chronology. Biogeosciences, 13, 2757-2768.

The buried Upper Pleistocene sedimentary succession of the Po Basin (Northern Italy): an expanded stratigraphic record of the Last Interglacial

Campo B.*[1], Bruno L.[2] & Amorosi A.[1]

[1] Dipartimento di Scienze Biologiche, Geologiche ed Ambientali (BiGeA), Università degli Studi di Bologna, Italy
[2] Dipartimento di Scienze Chimiche e Geologiche, Università degli Studi di Modena e Reggio Emilia, Italy.

Corresponding author email: bruno.campo2@unibo.it

Keywords: Upper Pleistocene, last interglacial, Po Basin, subsurface, expanded sedimentary succession.

The Middle-Upper Pleistocene boundary approximately coincides with the onset the Last Interglacial (Marine Isotope Substage – MIS - 5e, ~130 ky BP). This boundary commonly crops out in highly discontinuous successions. Subsurface sedimentary successions may not fulfill all formal requirements to be a GSSP. However, especially in rapidly subsiding basins, such expanded sedimentary successions can provide an almost continuous record of MIS 5e. In the subsurface of the rapidly subsiding Po Basin, the MIS 5e (Tyrrhenian) coastal wedge (TCW) represents a prominent stratigraphic marker that can be easily identified from core analysis (Amorosi et al., 2004).

Based on a high-resolution stratigraphic dataset, we reconstructed the 3D-geometry of Last Interglacial deposits from the Po Basin, with a focus on their along-strike and along-dip variations. Stratigraphic analysis relies upon published sedimentological, micropaleontological (foraminifers, ostracods, pollen) and chronological (electro-spin resonance) studies from 14 cores, up to 300 m long. Facies interpretations from 20 additional cores and lithologic information from hundreds of water-wells were used to increase data coverage.

Beneath the modern shoreline, above MIS 6 alluvial deposits, the TCW was continuously tracked along strike for over 110 km. Across the MIS 6/5e transition, pollen taxa show a sharp change, which is interpreted to represent the abrupt change from cold- to warm/temperate climatic conditions. The base of the TCW is marked by the upward transition from swamp and lagoon to transgressive-barrier facies. These deposits are overlain by shallow-marine and prodelta muds. The uppermost portion of the TCW is made up of beach-ridge and delta-front deposits that form a 10 m-thick sand body typically elongated along strike, that wedges out toward the south. Its top dips toward the north from ~20 m, down to 125 m below sea level. Along-dip correlations show the peculiar wedge-shaped geometry of the TCW, and the characteristic landward transition from shallow-marine and coastal facies to lagoonal, swamp and floodplain deposits.

Tyrrhenian strata are overlain by an up to 85-m-thick shallowing-upward succession, that records the stepped, basinward shift of facies related to the post-MIS5e sea-level fall. In particular, lagoon and swamp facies (MIS 5d-5a) are progressively replaced by floodplain and fluvial-channel deposits (MIS 4).

We also reconstructed coastal environments at the peak of the MIS 5e transgression, when the coastline shifted up to 35 km inland from the modern one, and organic-rich deposits extended up to 65 km landwards.

Amorosi A., Colalongo M.L., Fiorini F., Fusco F., Pasini G., Vaiani S.C. & Sarti G. (2004) - Palaeogeographic and palaeoclimatic evolution of the Po Plain from 150-ky core records. Glob. Planet. Change, 40, 55-78.

Bio- and lithostratigraphy of the lower Pleistocene Arda and Stirone River sections (Italy): calibrating the first occurrence of *Arctica islandica* in the Mediterranean Sea

Crippa G.*[1], Azzarone M.[2], Bottini C.[1], Crespi S.[1], Felletti F.[1], Marini M.[1], Petrizzo M.R.[1], Scarponi D.[2], Raffi S.[2] & Raineri G.[3]

[1] University of Milano. [2] University of Bologna. [3] Parco Regionale dello Stirone e del Piacenziano.

Corresponding author email: gaia.crippa@unimi.it

Keywords: northern guests, early Pleistocene, facies analysis, nannofossils, foraminifera.

The Arda and Stirone River marine successions (northern Italy) are key-sections for the early Pleistocene; they deposited continuously within a frame of climate change, recording the Calabrian cooling as testified by the occurrence of "northern guests", such as the bivalve *Arctica islandica*. The first occurrence of *A. islandica* in the Mediterranean Sea has a historical importance, as in the past it was used as one of the main criteria to mark the former Pliocene-Pleistocene boundary; however, the age of this bioevent was never well constrained. Here, i) we describe the Stirone depositional environment and constrain for the first time the age of the section using calcareous nannofossils and foraminifera biostratigraphy; ii) we correlate the Stirone section with the nearby Arda one, complementing biostratigraphic and magnetostratigraphic data available from the literature; iii) we map the occurrence of lower Pleistocene outcrops with *A. islandica* in the Mediterranean Sea and calibrate the first occurrence of this taxon. According to nannofossils and foraminifera biostratigraphy the Stirone River section has a Calabrian age, the same age recorded in the Arda section. It corresponds to the subaqueous extension of a fluvial system affected by hyperpycnal flows, with a lateral position with respect to the river mouth. The general regressive trend observed through the section, can be directly related to the tectonic activity and to the early Pleistocene climatic change. *A. islandica* first occurred in both the Arda and Stirone successions slightly below the top of the CNPL7 biozone (dated at 1.71 Ma). The comparison with other lower Pleistocene Mediterranean marine successions indicates that the stratigraphically lowest level where *A. islandica* first occurred in the Mediterranean Sea is in the Arda and Stirone sections; the paleoenvironmental conditions present in this region satisfy the ecological requirements for the establishment and the proliferation of the species, which only subsequently successfully colonized southern Italy sites and other areas of the Mediterranean Sea.

Isotopic signals from deep ice of the TALDICE core

Crotti I.*1, Barbante C.1-2, Frezzotti M.3, Jiang W.4, Landais A.5, Lu Z.-T. 4, Ritterbusch F.4, Stenni B.1-2, Turetta C.2 & Yang G.-M.4

[1] Department of Environmental Sciences, Informatics and Statistics, Ca' Foscari University of Venice, Italy. [2] Institute for the Dynamics of Environmental Processes, CNR, Venice, Italy. [3] Department of Science, Roma Tre University, Rome, Italy. [4] University of Science and Technology of China, Hefei, China. [5] Laboratoire des Sciences du Climat et de l'Environnement IPSL/CEA-CNRS-UVSQ UMR, Gif-sur-Yvette, France

Corresponding author email: ila.crotti@unive.it

Keywords: ice cores, Antarctica, paleoclimate reconstructions.

The deep portions of ice cores are still poorly investigated, however, they contain important paleoclimate information which can improve our knowledge of the past climate further back in time. The 1620 m deep ice core retrieved at Talos Dome (Antarctica), provided high-resolution climate reconstructions in the Ross Sea sector of Antarctica until the depth of ~1450 m (Stenni et al., 2011). In addition, the AICC 2012 chronology for this core was defined only until ~1438 m depth, coinciding with an age of about 154,000 years BP (Bazin et al., 2013). Our aim is to reconstruct the climate variability for the uninvestigated deep part of the TALDICE ice core and to propose a first dating. A ^{81}Kr radiometric dating was performed on ice from 1574 m to 1578 m depth. The obtained radiometric age is 459 ± 50 ky and suggests that the TALDICE deep portion is probably older than previously inferred. The thinning function profile obtained plotting ice age versus depth data, and including the new ^{81}Kr dating, shows the expected exponential shape, which is an indicator of regular ice thinning under conditions of vertical shear. High-resolution isotopic profiles ($^{18}O/^{16}O$ and D/H ratios) were obtained below the depth of 1547 m and compared with EPICA Dome C ones. The TALDICE high-resolution isotopic record suggests that up to a depth of 1557 m, probably corresponding to an age of 360 ky BP, the climatic signal is preserved. However, the lack of similarities with the EDC record below 1557 m depth, and the presence of unexpected large ice crystals suggest that ice-flow processes may have played a role in erasing the climatic signal in the deeper part of the core.

Bazin L., Landais A., Lemieux-Dudon B., H. Toye Mahamadou Kele H., Veres D., Parrenin F., Martinerie P., Ritz C., Capron E., Lipenkov V., Loutre M.F., Raynaud D., Vinther B., Svensson A., Rasmussen S.O., Severi M., Blunier T., Leuenberger M., Fischer H., Masson-Delmotte V., Chappellaz J.& and Wolff E. (2013) - An optimized multi-proxy, multi-site Antarctic ice and gas orbital chronology (AICC2012): 120–800 k. Climate of the Past, 9, 1715–1731.

Stenni B., Buiron D., Frezzotti M., Albani S., Barbante C., Bard E., Barnola J.M., Baroni M., Baumgartner M., Bonazza M., Capron E., Castellano E., Chappellaz J., Delmonte B., Falourd S., Genoni L., Iacumin P., Jouzel J., Kipfstuhl S. & Landais A. (2011) - Expression of the bipolar see-saw in Antarctic climate records during the last deglaciation. Nature Geoscience, 4, 46-49.

East Antarctic ice core dust stratigraphies and late Quaternary atmospheric circulation changes

Delmonte B.*, Baccolo G. & Maggi V.

DISAT, Dept. of Earth and Envroronmental Sciences, University Milano-Bicocca, Italy.

Corresponding author email: barbara.delmonte@unimib.it

Keywords: Ice cores, Antartica, climate change, atmospheric change, Quaternary.

Ice cores from Antarctica provide a wealth of information on late Quaternary glacial–interglacial climate and atmospheric change that are complementary to marine sediment records. Major impurities in polar ice originate from different sources such as oceans and continental landmasses. Mineral dust deflated from the austral continents reaches Antarctica after transport in the mid-to-high troposphere over very long distances (Lambert et al., 2008; Petit & Delmonte, 2009). After deposition onto the polar plateau, it is buried in snow and ice layers, and it can be studied in deep ice cores to document the past atmospheric circulation variability. We provide provide here an overview of eolian dust provenance and flux in central East Antarctica during the last glacial period and the Holocene (Delmonte et al., 2017). We discuss Holocene variability of dust transport in central East Antarctica in the light of new results obtained in the framework of the Franco-Italian SOLARICE research project. These new results confirm the variable strength and localization of troposphere air subsidence over Antarctica, which is related to local and regional atmospheric dynamics (Delmonte et al., 2005). We also compare central East Antarctic sites to peripheral regions located close to the Transantarctic Mountains, that are very sensitive to regional climate changes. In these peripheral areas, where high-elevation local rock outcrops and remobilization of volcanic material represent important dust sources, the dust cycle dynamics is intimately related to the local climate conditions and in particular to the opening of the Ross Sea (Baccolo et al., 2018; Albani et al., 2012).

Albani S., Delmonte B., Maggi V., Baroni C., Petit J.R., Stenni B., Mazzola C. & Frezzotti M. (2012) - Interpreting last glacial to Holocene dust changes at Talos Dome (East Antarctica): implications for atmospheric variations from regional to hemispheric scales. Clim. Past, 8, 741-750.

Baccolo G., Delmonte B., Albani S., Baroni C., Cibin G., Frezzotti M., Hampai D., Marcelli A., Revel M., Salvatore M.C., Stenni B. & Maggi V. (2018) - Regionalization of the atmospheric dust cycle on the periphery of the East Antarctic ice sheet since the last glacial maximum. Geochem. Geophys. Geosyst., 19(9), 3540-3554.

Delmonte B., Petit J. R., Krinner G., Maggi V., Jouzel J. & Udisti R. (2005) - Ice core evidence for secular variability and 200-year dipolar oscillations in atmospheric circulation over East Antarctica during the Holocene. Clim. Dynam., 24(6), 641-654.

Delmonte B., Paleari C.I., Andò S., Garzanti E., Andersson P.S., Petit J.R., Crosta X., Narcisi B., Baroni C., Salvatore M.C., Baccolo G. & Maggi V. (2017) - Causes of dust size variability in central East Antarctica (Dome B): Atmospheric transport from expanded South American sources during Marine Isotope Stage 2. Quaternary Sci. Rev., 168, 55-68.

Lambert F., Delmonte B., Petit J.R., Bigler M., Kaufmann P.R., Hutterli M.A., Stocker T.F., Ruth U., Steffensen J.P. & Maggi V. (2008) - Dust-climate couplings over the past 800,000 years from the EPICA Dome C ice core. Nature, 452, 616-619.

Petit J.R. & Delmonte B. (2009) - A model for large glacial–interglacial climate-induced changes in dust and sea salt concentrations in deep ice cores (central Antarctica): palaeoclimatic implications and prospects for refining ice core chronologies. Tellus B, 61(5), 768-790.

New candidate stratotype of lower boundary of Chinese Lower Pleistocene Nihewanian Stage

Deng T.*

Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing, China.

Corresponding author email: dengtao@ivpp.ac.cn

Keywords: Quaternary, Pleistocene, Nihewanian Stage, Longdan, mammalian fossil, China.

The Nihewanian Stage is the Lower Pleistocene stage of China. The previous proposed candidate stratotype of the Nihewanian Stage is located at Haojiatai in Yangyuan County, Hebei Province. The lower boundary of the Nihewanian Stage is identical with that of the Gelasian Stage at the Matsuyama/Gauss boundary with an age of 2.58 Ma. The Nihewan Basin is rich in fossils, especially represented by mammalian fossils of different orders in the Xiashagou Fauna; however, there is no any important fossil as a biostratigraphical marker for the lower boundary of the Nihewanian Stage in the proposed stratotype section. Initially, the lower boundary of the Quaternary was represented by the bottom of the marine Calabrian stage in Italy, and the lower boundary of the Villafranchian Stage, which was considered to correspond to the former in that time, was regarded as the lower boundary of the terrestrial Quaternary System. In 2009, the International Commission on Stratigraphy proposed and the International Union of Geological Sciences approved that the lower boundary of the Quaternary was modified to be represented by the lower boundary of the marine Gelasian stage, and determined its definition to close to the M/G boundary (Mascarelli, 2009). The earliest true horse *Equus simplicidens* appeared at 4.5 Ma in North America, rapidly diverged from the Late Pliocene, and migrated into Eurasia in the beginning of the Quaternary. As a result, the first appearance of the genus *Equus* has been regarded as a biostratigraphical marker for the lower boundary of the Quaternary in Eurasia. In the Nihewan Basin, *Equus sanmeniensis* firstly appeared in the Early Pleistocene, but not earlier than 2.0 Ma. The Longdan section in Nalesi Town, Dongxiang County, Gansu Province crosses the boundary between the Pliocene and Pleistocene series, and the lower part of its loess deposits includes the lower boundary of the Nihewanian Stage and bears very rich mammalian fossils (Qiu et al., 2014). Among them, the appearance of *Equus eisemannae* above the lower boundary of the Nihewanian Stage represents the first advent of the true horse in Eurasia. *E. eisenmannae* is more primitive than *E. sanmeniensis* in phylogenetical position, and the age of the first appearance of the former in the Longdan section is 2.55 Ma (Zan et al., 2016), which can be chosen as a biostratigraphical marker for the lower boundary of the Nihewanian Stage. In conclusion, we propose the Longdan section as the candidate stratotype of the terrestrial Nihewanian Stage in China.

Mascarelli A.L. (2009) - Quaternary geologists win timescale vote. Nature, 459, 624.

Qiu Z.X., Deng T. & Wang B.Y. (2004) - Early Pleistocene mammalian fauna from Longdan, Dongxiang, Gansu, China. Palaeont. Sin. New Ser. C, 27, 1-198.

Zan J., Fang X., Zhang W., Yan M. & Zhang T. (2016) - Palaeoenvironmental and chronological constraints on the Early Pleistocene mammal fauna from loess deposits in the Linxia Basin, NE Tibetan Plateau. Quat. Sci. Rev., 148, 234-242.

Formal subdivision of the Quaternary System/Period: present status and future directions

Head M.J.*

Brock University.

Corresponding author email: mjhead@brocku.ca

Keywords: Quaternary, Pleistocene, Holocene, subseries, Anthropocene.

The Quaternary System/Period and Pleistocene Series/Epoch were defined in 2009 by the Global boundary Stratotype Section and Point (GSSP) for the Gelasian Stage/Age (2.58 Ma) which aligns with Marine Isotope Stage (MIS) 103 and approximates the Gauss–Matuyama Chron boundary (Head & Gibbard, 2015). The Vrica GSSP (1.80 Ma) was repurposed in 2011 to define the Calabrian Stage, effectively completing the Lower Pleistocene Subseries/Subepoch. The candidate for the Middle Pleistocene Subseries (and proposed Chibanian Stage) GSSP (~774 ka) is the Chiba section, Japan. It aligns with MIS 19 and approximates the Matuyama–Brunhes Chron boundary (~773 ka). The Upper Pleistocene Subseries, with a base traditionally marked by the onset of the last interglacial, is not yet defined by GSSP. The Holocene Series was formally defined in 2008 by a GSSP in the NGRIP2 Greenland ice core, and in 2018 was subdivided, using climatic events at 8.2 and 4.2 ka, into the Greenlandian, Northgrippian and Meghalayan stages/ages and their corresponding Lower/Early, Middle, Upper/Late Holocene subseries/subepochs (Walker et al., 2018, in press). The Greenlandian GSSP (11,700 yr b2k – before 2000 CE) is defined in the NGRIP2 Greenland ice core, the Northgrippian GSSP (8236 yr b2k) in the NGRIP1 Greenland ice core, and the Meghalayan GSSP (4250 yr b2k) in a speleothem from Meghalaya, India. This subdivision formally introduces the rank of subseries/subepoch, and incorporates by far the briefest of all stages into the geological time scale. Using ice cores and a speleothem for GSSPs is unique to the Holocene. The presently undefined term Anthropocene is already used extensively and, like Holocene subdivisional terms, its functionality will be enhanced by formal definition. The Anthropocene should not be confused with anthropogenic: it reflects a tipping point in the Earth-system response to human impacts, not the impacts themselves. The Anthropocene as currently envisioned (Zalasiewicz et al., 2017) would start ~1950 having the rank of series/epoch, and terminate the Holocene without interfering with its subdivision other than to end the Meghalayan at a time when the Holocene is already evenly subdivided.

Head M.J. & Gibbard P.L. (2015) - Formal subdivision of the Quaternary System/Period: Past, present, and future. Quaternary International, 383, 4–35.

Walker M., Head M.H., Berklehammer M., Bjorck S., Cheng H., Cwynar L., Fisher D., Gkinis V., Long. A., Lowe J., Newnham R., Rasmussen S.O. & Weiss Ha. (2018) - Formal ratification of the subdivision of the Holocene Series/ Epoch (Quaternary System/Period): two new Global Boundary Stratotype Sections and Points (GSSPs) and three new stages/subseries. Episodes 41(4), 213–223.

Walker M., Head M.J., Lowe J., Berkelhammer M., Bjorck S., Cheng H., Cwynar L.C., Fisher D., Gkinis V., Long A., Newnham R., Rasmussen S.O. & Weiss H. (2019) - Subdividing the Holocene Series/Epoch: formalisation of Stages/ Ages and Subseries/Subepochs, and designation of GSSPs and Auxiliary Stratotypes. Journal of Quaternary Science, 34.

Zalasiewicz J., Waters C.N., Summerhayes C.P., Wolfe A.P., Barnosky A.D., Cearreta A. Crutzen P., Erle E., Fairchild I.J., Galuszka A., Haff P., Hajdas I., Head M.j. Ivar do Sul J.A., Jeandel C., Leinfelder R., McNeil J.R., Neal C., Odada E., Oreskes N., Steffen W., Syvitski J., Vidas D., Wagreicj M. & Williams M. (2017) - The Working Group on the Anthropocene: Summary of evidence and interim recommendations. Anthropocene, 19, 55-60.

Challenges in defining the Upper Pleistocene Subseries – an Antarctic ice core as a potential Global boundary Stratotype Section and Point (GSSP)

Head M.J.*

Brock University.

Corresponding author email: mjhead@brocku.ca

Keywords: Quaternary, Upper Pleistocene, GSSP, ice core.

Defining the Upper Pleistocene Subseries and its corresponding stage is now a priority for the ICS Subcommission on Quaternary Stratigraphy. During the Second International Conference of the Association pour l'etude du Quaternaire européen (a precursor of the International Quaternary Association [INQUA] and its congresses) in Leningrad in 1932, it was decided that the base of the Upper Pleistocene should coincide with that of the last interglacial (the Eemian regional Stage in Europe), and at the 12th INQUA Congress in Ottawa in 1987 a proposal was approved to use the base of Marine Isotope Stage (MIS) 5 (termination II) to define the boundary. However, the base of MIS 5 is now known to be about 6 kyr older than the base of the Eemian pollen stage. Moreover, isotope stratigraphy gives Atlantic over Pacific leads of several thousand years for the past six terminations, and North Atlantic high-latitude temperatures lag southern hemisphere records by several thousand years. Given these challenges, an Antarctic ice core should be considered for the Upper Pleistocene GSSP, with an abrupt methane rise at Termination II potentially serving as the primary guide. This methane rise represents a distinctive global event (Capron et al., 2014) closely related to rising temperatures in the higher northern latitudes. To provide a more recent comparison, methane lagged temperature rise by less than 30–70 years for the last glacial interval in Greenland (Wolff, 2011), and its abrupt increase during Termination II in Antarctica is thought to reflect essentially synchronous abrupt warming of the air above Greenland. Termination II has a gas orbital age of 132.4 ka at its midpoint, with a subsequent steep methane increase at 128.51±1.72 ka in the EPICA Dome C core (Bazin et al., 2013). This methane event appears synchronous with an abrupt increase in $\delta^{18}O$ in Chinese speleothem records reflecting a rapid intensification of the Asian summer monsoon (Govin et al., 2015), although it leads the onset of the Eemian in southern Europe by ~2 kyr. An ice core is no longer an unconventional choice for a Quaternary GSSP: the Lower and Middle Holocene subseries GSSPs are both defined in Greenland ice cores.

Bazin L., Landais A., Lemieux-Dudon B., Kele H.T.M., Veres D., Parrenin F., Martinerie P., Ritz C., Capron E., Lipenkov V., Loutre, M.F., Raynaud D., Vinther B., Svensson A., Rasmussen S.O., Severi M., Bluiner T., Leuenberger M., Fischer H., Masson-Delmotte V., Chappellaz J. & Wolff E.W. (2013) - An optimized multi-proxy, multi-site Antarctic ice and gas orbital chronology (AICC2012): 120–800 ka. Climate of the Past, 9, 1715–1731.

Capron E., Govin A., Stone E.J, Masson-Delmotte V., Mulitza S., Otto-Bliesner B., Rasmussen T.L., Sime L.C., Wealbroeck C. & Wolff E.W. (2014). Temporal and spatial structure of multi-millennial temperature changes at high latitudes during the Last Interglacial. Quaternary Science Reviews, 103, 116–133.

Govin A., Capron E., Tzedakis P.C., Verheyden S., Ghaleb B., Hillaire-Marcel C., St-Onge G., Stoner J.S. Bassinot F., Bazin L., Blunier T., Combourieu-Nebout N., Ouahabi A.E., Genty D., Gersonde R., Jimenez-Amat P., Landis A., Marart B., Masson-Delmotte V., Perrenin F., Seidenkrantz M.S. Veres D., Waelbroeck C. & Zahn R. (2015) - Sequence of events from the onset to the demise of the Last Interglacial: Evaluating strengths and limitations of chronologies used in climatic archives. Quaternary Science Reviews, 129, 1–36.

Wolff E.W. (2011) - Greenhouse gases in the Earth system: a palaeoclimate perspective. Philosophical Transactions of the Royal Society A, 369, 2133–2147.

Palaeoenvironmental evolution and integrated stratigraphy of the Kura Basin in the latest Pliocene - Middle Pleistocene: implication to the Caspian Sea region.

Lazarev S.*[1], Stoica M.[2], Jorissen E.[1], Bista D.[3], van de Velde S.[4], Rausch L.[2], Hoyle T.[1], van Baak C.[5], Flecker R.[3], Wesselingh F.[4] & Krijgsman W.[1]

[1] Utrecht University, the Netherlands. [2] Bucharest University, Romania. [3] University of Bristol, UK. [4] Naturalis Biodiversity Center, the Netherlands. [5] CASP, UK.

Corresponding author email: s.lazarev@uu.nl

Keywords: Caspian Sea, magnetostratigraphy, molluscs, ostracods, Kura Basin, Late Pliocene - Middle Pleistocene.

The Caspian Sea is the largest endorheic basin in the world and has high economic and environmental significance. The rich geological history of the isolated Caspian Sea started in the Late Miocene, when it became disconnected from the Eastern Paratethys due to complex climatic and tectonic processes. Intensification of climatic oscillations during Pliocene and Pleistocene resulted in large changes in the Caspian hydrological budget and dramatic water level fluctuations. Short episodic reconnections with the Black Sea and the global ocean triggered changes in water chemistry and salinity, and subsequent ecological turnovers. As such, the sedimentary archive of the Caspian Sea Basin provides a unique opportunity to study these biotic changes and the climatic and environmental history of Eurasia during Pliocene-Pleistocene. However, robust understanding of the connectivity history of the Caspian Sea is lacking, mainly due to poor age constraints for the sections and diverse, separated techniques used in identifying these events, which provide contradictory results.

The Kura Basin is an ancient embayment and the western extension of the South Caspian Basin formed in the Caucasian foreland. Active uplift together with high subsidence has provided a continuous, well-exposed sedimentary record. Here, we studied six key regional sections that expose the latest Pliocene – Middle Pleistocene regional stages – Akchagylian, Apsheronian, Bakunian and Khazarian. We used a multiproxy approach in order to better understand the timing and nature of basin connections and their impact on the evolution of the Pontocaspian biota. We review the existing data from the Caspian Sea region and combine them with our integrated magnetostratigraphic, (micro-) palaeontological and strontium isotopic ratio ($^{87}Sr/^{86}Sr$) data from studied sections. We specifically aim to provide a robust age model for the major biotic turnover events and thus clarifying the regional stratigraphy. Improved stratigraphic coverage enables us to establish and date the moments of interbasinal connectivity, while combined micropaleontological and $^{87}Sr/^{86}Sr$ data allow us to elucidate the paleoenvironmental changes and processes shaping the Caspian Basin.

This research was performed in the frame of the PRIDE project that has received funding from the European Union's Horizon 2020 research and innovation program under the Marie Skłodowska-Curie grant agreement No 642973.

Morphostratigraphy and its application to correlation of multiple till sequences in formerly glaciated terrains – an example from the eastern flank of the Scandinavian Ice Sheet

Lunkka J.P.*[1], Sarala P.[1-2] & Gibbard P.L.[3]

[1] University of Oulu, Finland. [2] Geological Survey of Finalnd, Finland. [3] University of Cambridge, U.K.

Corresponding author email: juha.pekka.lunkka@oulu.fi

Keywords: Pleistocene, Morphostratigraphy, LiDAR-DEM, Luminescence, Scandinavian Ice Sheet, Finland.

The identification and mapping of glacial depositional and erosional landforms have been commonly used to interpret relative chronologies in many formerly glaciated areas. Here we present the preliminary results of stratigraphical correlation between morphologically expressed subglacial lineation forms tied to chronology from Finland; an area, which was repeatedly covered by the Scandinavian Ice Sheet (SIS) during the Pleistocene. Mapping of subglacial glacial lineation forms (e.g. mega-scale lineations, drumlins, glacial flutings and glacially eroded basins) were carried out using digital elevation models (DEM) and GIS-software tools. DEMs at 25 m and 10 m resolution and LiDAR-data (Light Detection and Ranging with point density at least 0.5 points/m^2 and the vertical precision 0.3-1.0 m) produced by the National Land Survey of Finland were used in the landform mapping. Conventional sedimentological, and litho- and biostratigraphical methods, including till clast-fabric measurements, were carried out from sediment exposures and both optically stimulated and thermo-luminescence dating (OSL and TL) were applied to obtain age control of sediment sequences. The results of the litho-, bio- and morphostratigraphical investigations over an area of more than 10 000 km^2 in western Finland show that the oldest landforms in the study area relate with the lowest diamicton unit, both having been formed during the Late Saalian glaciation when the SIS covered the area. After the Late Pleistocene Eemian Stage interglacial two geomorphologically distinct lineation patterns and correlative diamicton units were formed during the Middle and Late Weichselian Substages. In addition to western Finland, investigations in southern Finnish Lapland and Koillismaa region, northern Finland of subglacial landform patterns with cross-cutting drumlin fields and transversal ribbed moraine fields and correlative diamicton units, show that subglacial landforms and their correlative diamicton units were also formed during the Middle and Late Weichselian Substages. Overall, this study demonstrates that interpretation of glacial lineation patterns from DEMs and their correlation to well-studied and dated sediment sequences provides a useful tool for reconstructing the stratigraphical framework in formerly glaciated terrains.

Influence of subpolar waters at central North Atlantic IODP Site U1313 during the Middle Pleistocene: insights from the dinoflagellate cyst record

Mantilla-Duran F.*[1], Head M.J.[2], Ferretti P.[3] & De Schepper S.[4]

[1] RPS Ichron, UK. [2] Brock University, Canada. [3] Universita' Ca' Foscari, Venezia. [4] NORCE Norwegian Research Centre, Bjerknes Centre for Climate Research, Norway.

Corresponding author email: fernando.mantilla@rpsgroup.com

Keywords: Biostratigraphy, Palynology, MIS16, North Atlantic, Pleistocene.

Marine Isotope Stage (MIS) 16 (676–621 ka; Middle Pleistocene) is a pronounced glacial event registering the heaviest benthic foraminiferal isotopic values for the entire Quaternary, and establishing a new mode for later Quaternary glaciations that were to support more extensive ice sheets than earlier. Significantly, MIS 16 is characterized by the first Heinrich event in the North Atlantic, marking a step-change in North Atlantic circulation and sedimentation. To address this critical transition in North Atlantic paleoceanography, 73 samples from central North Atlantic IODP Site U1313 have been analysed palynologically to resolve conflicting interpretations in sea-surface temperature obtained from foraminiferal Mg/Ca and alkenones during MIS 16. Our palynological analysis extends from upper MIS 18 to lower MIS 15 and uses the filtrate obtained from an earlier foraminiferal isotope study. Site U1313 is presently under the influence of the subtropical gyre. Dinoflagellate cyst (dinocyst) assemblages reveal the fluctuating influences of nutrient-rich subpolar waters, the North Atlantic Current, and warm oligotrophic waters of the subtropical gyre during the studied interval. Overall, the dinocyst assemblages suggest that glacial stages were characterized by high productivity surface waters. This increase in productivity seems linked to the southward shift of the Arctic Front during cold stages. Additionally, high abundances of *Bitectatodinium tepikiense* during MIS 16 may reflect water stratification resulting from iceberg discharge. Reworked palynomorphs indicate a Cretaceous provenance, as anticipated for the first Heinrich-like event.

Stratigraphic architecture and facies analyses of a quaternary lake (Northern Andes, Ecuador)

Martín-Merino G.[1]* & Roverato M.[1]

[1]School of Earth Sciences and Engineering, Yachay Tech, Ecuador.

Corresponding author email: gmartin@yachaytech.edu.ec

Keywords: Andean range, Quaternary, lacustrine sedimentation, strike slip basin, intermontane basin.

The present work discusses the San Miguel Formation (SMF), a ~100 m thick Pleistocene lacustrine sequence (~1.2 My B.P), which widely crops out in the Guayllabamba basin, an Andean intermontane depression located in northern Ecuador. The basin was formed by a tectonically and volcanically active strike-slip basin associated to a crustal-scale N–S dextral restraining-bend megashear. Its western border is constituted by the active quaternary Pujulí fault system which controlled the origin, subsidence evolution and sedimentation of the basin. The lacustrine sequence is truncate at the top by an angular unconformity and lies down on the > 200 m thick Pisque formation that is characterized by fluvial, alluvial, and volcaniclastic breccias and conglomerates. The E-W cross section here presented describes in detailed the faciological variations into the lacustrine succession. The basin displays a depocenter oriented approximately N-S and shows important differences between its western and eastern borders. The eastern part of the lake is characterized by massive and varved diatomites interbedded with volcaniclastic and gravity-flow type deposits, mafic to intermediate in composition. Whiles the western margin displays fluvial braided type and deltaic systems (Gilbert-types deltas) with clasts that show a more felsic character. This difference in composition is due to important changes in the source area and the facies variance is related to differences in the tectonic environment. In fact, the western border was tectonically more active, controlled by the Pujilí fault system that has driven the uplifting of the margin. This has forced to changes into the hydrography, which allowed the channelize, erosion and drainage of volcaniclastic sediments from west likely from the Pululahua volcano (chemically different to the eastern source area). In other words, the tectonic activity of Pujulí fault and volcanic activity in the western border controlled the origin, the geometry and stratigraphy architecture of the paleolake. It constitutes an excellent record of the tectonic and volcanic evolution of the last stages of the Andean uplift history.

New insights from the MIS 5 Fronte GSSP candidate Section (Taranto, Italy)

Negri A.*[1], Florindo F.[2], Marabini S.[3], Montagna P.[4], Morigi C.[5], Pons-Branchu E.[6] & Vai G.B.[7]

[1] Polytechnic University of Marche, Italy. [2] INGV Rome, Italy. [3] Independent Researcher , Italy
[4] CNR-ISMAR Bologna, Italy. [5] University of Pisa, Italy. [6] Laboratoire des Sciences du Climat et de l'Environnement, France. [7] University of Bologna, Italy

Corresponding author email: a.negri@univpm.it

Keywords: Marine Upper Pleistocene, MIS 5, U-series dating, benthic foraminifera, paleomagnetism.

We present new data collected at the Fronte locality near Taranto, where the Upper Pleistocene marine sedimentary succession is continuously exposed. Above a fossiliferous calcarenite yielding the "Senegalese" fauna, and abundant Cladocora, the 230Th/U age of which is consistent with Marine Isotope Stage (MIS) 5, a 6.25 m thick pelitic unit is characterized by lithologically homogeneous marine sediments in which stable oxygen isotope, micropaleontological and palynological analyses suggested a long and undisturbed sedimentary interval across the Marine Isotope Stage (MIS) 5.5 peak (plateau) (Negri et al., 2015). Two cores drilled in 2015 at the top of the cliff where the section crops out, show the same lithological succession sampled in the field. These cores were investigated for the geomagnetic palaeosecular variation and relative palaeointensity recorded in these sediments. Interestingly, the Paleomagnetic record contains several brief excursions of shallowed inclination. The most significant of these reaches inclinations of below 10°, suggesting a correlation with the Blake event (Negri et al., 2016). To further clarify the age of the sedimentary succession, two branches of *Cladocora* recovered at the top of the fossiliferous calcarenite have been U-series dated (coral aragonite) revealing an age of about 80Ka (further refining is ongoing while we are writing this abstract) while new benthic foraminiferal analyses in the pelitic unit above it, confirmed a frankly marine microfauna. According to these new data the whole MIS 5 or so appears to be constrained by the calcarenite, This suggest a climatic change switching the sedimentation from carbonate platform to pelite. The data so far collected which are consistent with the old data reported by dai Pra and Stearns (1977) indicate that at the Fronte section a record of the Termination II and the whole MIS 5 occur. This evidences the need to detail further the time interval recorded through a new set of U/Th dating and eventually the finding of appropriate stratigraphic indicators which may strengthen the potential of the section as GSSP.

Dai Pra G. & Stearns C.E. (1977) - Sul Tirreniano di Taranto. Datazioni su coralli con il metodo del 230Th/234U. Geologica Romana, 16, 231-242.

Negri A., Amorosi A., Antonioli F., Bertini A., Florindo F., Lurcock P.C., Marabini S., Mastronuzzi G., Regattieri E., Rossi V., Scarponi D., Taviani M., Zanchetta G. & Vai G.B. (2015) - A potential Global Boundary Stratotype Section and Point (GSSP) for the Tarentian Stage, Upper Pleistocene, from the Taranto area (Italy): Results and future perspectives. Quatern. Int., 383, 145-157.

Negri A., Florindo F., Lurcock P.C., Marabini S., Morigi C., Mastronuzzi G., Vetrone C. & Vai G.B (2016) - The Fronte candidate section for the upper Pleistocene GSSP: a short report. Alpine and Mediterranean Quaternary, 29(2), 137-142.

Evidences of early Holocene glacial advance in Lachman Beach, James Ross Island, Antarctica, and high latitude linkages in southern hemisphere

Romero M.*[1], Strelin J.A.[1-2] & Kaplan M.R.[3]

[1] CICTERRA-CONICET. National University of Córdoba, Argentina. [2] Instituto Antártico Argentino, Argentina.
[3] Lamont-Doherty Earth Observatory, Columbia University, United States.

Corresponding author email: matiasromero033@gmail.com

Keywords: paleoclimate, stratigraphy, Holocene, glaciations, Antarctica.

A recent stratigraphic survey on marine terraces in James Ross Island (JRI), northwestern Antarctic Peninsula (AP), provides evidences of early Holocene glacial advance. Several profiles of this glacial transgressive/regressive sequence were performed and sampled for radiocarbon dating (delta R= 829 ± 50), yielding minimum age of 7100 and maximum age of 7300 cal yrs BP for this glacier advance. The highest early Holocene marine terrace of JRI reaches up to 17 m.a.s.l, documenting the rapid isostatic uplift that produced falling relative sea level (RSL) for early Holocene after 8000 yrs BP (Hjort et al., 1997). The deglaciation is not only evidenced in terrestrial records from Lachman Beach but also in high resolution marine-core sediment records from Croft Bay, concluding that the bay was fully deglaciated by 7200 yrs BP (Minzoni et al., 2015). According to new age interpretation of southern Potter Cove, King George Island, the Holocene postglacial marine transgression initiated before 7650 yrs BP, and was locally interrupted by a glacier advance about 200 yrs later, shortly after 7285 yrs BP (Strelin et al., 2014a). Combining evidence from isolation basins and raised beaches, a new RSL curve was reconstructed for Fildes Peninsula, which fell after 7500 yrs BP as a consequence of isostatic uplift in response to regional deglaciation. However, a temporary pause in glacial isostatic rebound was found around 7200 yrs BP indicating a glacial advance close for this site (Watcham et al., 2011). Evidences for a less extended early Holocene glacier advance were also detected in Península Herminita and in Agassiz Este Valley, in Patagonia, which can be related with glacial advances in New Zealand for the same age (Strelin et al., 2014b). These robust evidences make on-land stratigraphic records from James Ross Island an important tool to complement other geochronology methods in order to have a broader perspective on past ice sheet dynamics; not only in Antarctica, but also in other high latitude regions.

Hjort C., Ingólfsson Ó., Möller P. & Lirio J. M. (1997) - Holocene glacial history and sea-level changes on James Ross Island, Antarctic Peninsula. Journal of Quaternary Science: Published for the Quaternary Research Association, 12(4), 259-273.

Strelin, J. A. *et al.,* (2014a) «XIX Congreso Geológico Argentino, Junio 2014, Córdoba».

Strelin J.A., Kaplan M.R., Vandergoes M.J., Denton G.H. & Schaefer J.M (2014b). Holocene glacier history of the Lago Argentino basin, southern Patagonian Icefield. Quaternary Science Reviews, 101, 124-145.

Minzoni R.T., Anderson J.B., Fernandez R. & Wellner J.S. (2015) - Marine record of Holocene climate, ocean, and cryosphere interactions: Herbert Sound, James Ross Island, Antarctica», Quaternary Science Reviews. Elsevier Ltd, 129, 239-259. https://doi.org/10.1016/j.quascirev.2015.09.009.

Watcham E.P., Bentley M.J., Hodgson D.A., Roberts S.J., Fretwell P.T., Lloyd J.M., Larter R.D., WhitehouseP.L., Leng M.J. MonienP. & Moreton S.G. (2011) - A new Holocene relative sea level curve for the South Shetland Islands, Antarctica. Quaternary Science Reviews. Elsevier Ltd, 30(21-22), 3152-3170. https://doi.org/10.1016/j.quascirev.2011.07.021

Proposals on the structure of the General Stratigraphic Chart for the Quaternary of Russia

Semenova L.P.* & Shkatova V.K.

Federal State Budgetary Institution, A.P. Karpinsky Russian Geological Research Institute (FGBU VSEGEI), St. Petersburg, Russia.

Corresponding author email: ljudmilasemenova@mail.ru

Keywords: General Stratigraphic Chart, Pleistocene, Holocene, Proposals.

Principles for constructing the International Stratigraphic Chart (ISC) and the General Stratigraphic Chart (GSC) for the Quaternary are similar in determining the high ranks of units, but they differ significantly in detail. System: *Quaternary.* The Quaternary in both the GSC and the ISC is subdivided into the *Pleistocene* and *Holocene*. In the ISC and in the GSC, they are series. Pleistocene. In the ISC, the *Pleistocene* series includes three subseries: the Lower, the Middle, and the Upper. In the ISC, the Gelazian and Calabrian stages were established for the Lower Pleistocene. For the Middle and Upper Pleistocene, no stages have been established. In the GSC, the Pleistocene series includes the Gelazian, Eopleistocene and Neopleistocene division. In the GSC, it is proposed the Pleistocene series to subdivide it into three subseries in compliance with the ISC: Lower, Middle, Upper. The Lower Pleistocene corresponds to the Gelazian and the Eopleistocene (according to the current GSC), the Middle Pleistocene, to the Lower and Middle Neopleistocene, and the Upper Pleistocene, to the Upper Neopleistocene. In the current GSC, two links for the Eopleistocene and three links for the Neopleistocene have been identified. It is proposed: (1) In the Lower subseries of the Pleistocene, the Gelazian division and Eopleistocene (Calabrian) division to be identified. The Gelazian, judging by the nature of climate change, we can expect the establishing of four links. For the Eopleistocene (Calabrian), two links are currently identified, but there is every reason to establish three links. (2) In the middle subseries Pleistocene, two links to be established on the average. The lower link includes eight steps, the upper link - six. (3) The upper subseries of the Pleistocene - includes four steps. The steps are correlated with the stages of the marine isotopic scale. (4) In the future, more detailed elaboration in compliance with the stages of MIS 5 is possible for the first step of the Upper Pleistocene. Holocene. In the GSC, the Holocene is identified as the last interglacial time with a general tendency toward warming, compared in age to MIS I. The Blytt-Sernander classification for Northern Europe is a paleoclimatic standard of Holocene periodization. It is proposed: 1. Subdivision of the Holocene series into three subseries: Lower, Middle, Upper (with dated boundaries) in compliance with the ISC. 2. In the future, the possible establishing of substeps is in the Holocene. In accordance with the Stratigraphic Code, stages should not be applied for the Quaternary. However, after increasing the Quaternary volume due to the inclusion of the Gelazian and Calabrian in it, it is quite possible that stages will be included in the Quaternary chart.

The late Pleistocene and Holocene Thecamoebians from lake Stará Jímka in the Šumava Mts.

Suchánek V.[1]* & Holcová K.[1]

[1]Faculty of Science Charles University, Prague, Czech Republic

Corresponding author email: suchanv@natur.cuni.cz

Keywords: Thecamoebians, *Šumava* Mts., Holocene, bøling, allerød, Stará Jímka.

At the end of the last glacial period after glacier retreat the today defunct lake Stará Jímka was created (Břízová & Mentlík, 2005a; Mentlík et al., 2010). Its sedimenatory record captures the climate changes in the last 15 000 years (periods bøling, allerød, younger dryas and early holocene), during recent It was buried (Mentlík & Břízová, 2005). For the study of the paleoenviroment of Šumava lake we can use testate amoebae alternatively Thecamoebians (Arcellinida), whose species composition is preserved in the sediment of the defunct Šumava lake Stará Jímka (Břízová & Mentlík, 2005a; Mentlík et al., 2010). In the past few years, dr. Lorencová and doc. Holcová were studying Thecamoebians from Šumava Mts. in the Czech Republic. Within the project GA AVČR „Actuoecology of freshwater Thecamoebians from the Šumava Mts“ they observed hydrological changes in the recent sediment of Lipno Dam. (Holcová & Lorencová, 2004b). After that Lorencová (2009) studied Thecamoebians from the Šumava Mts. A sedimentary well (profile thickness of 1.5 m, thickness of 3 cm, 36 selected layers) was taken from Stará Jímka Lake and provided by the Institute for the Environment. Communities of Thecamoebians were described from the collected samples. Most of the communities consists mainly of species with the agglutinated type of the test, because the sediment is composed mainly of particles of sand and sandy gravel. The individual samples differ not only in frequency and size, but also in species diversity, which includes only a few species, especially genus Difflugia. For some selected samples, higher tests damage can be observed.

The study was supported by the Charles Univesity, project GA UK No. 884218 and Institute of Geology and Paleontology.

Břízová E. & Mentlík P. (2005a) - Za tajemstvím Staré jímky na Prášilsku. Šumava, 11, 18-19. Vimperk.

Holcová K. & Lorencová M. (2004b) - Krytenky (Rhizopoda, Testacea) v nejmladších sedimentech Lipna – odraz srážkově výjimečných let 2002 a 2003, 104–109. In Dvořák L.& Šustr P. (eds.) Sborník z konference Aktuality šumavského výzkumu 2, Srní. Správa NP Šumava, Vimperk.

Lorencová M. (2009) - Thecamoebians from recent lake sediments from the Sumava Mts, Czech Republic. Bulletin of Geosciences, 84(2), 359-376.

Mentlík P. & Břízová E. (2005) - O staří sedimentů Staré jímky. Šumava, 11, podzim 2005,18-19. Vimperk.

Mentlík P., Minár J., Břízová E., Lisá L., Tábořík P. & Stacke V. (2010) - Glaciation in the surroundings of Prášilské Lake (Bohemian Forest, Czech Republic). Geomorphology, 117, 181-194.

Progress in the investigation for a potential Global Boundary Stratotype Section and Point (GSSP) for the Anthropocene Series

Waters C.N.*[1], Zalasiewicz J.[1], Head M.J.[2], McCarthy F.M.G.[2], Thomas E.R.[3], Kaiser J.[4], Ivar do Sul J.A.[4], Shotyk W.[5], DeLong K.L.[6], Barnosky A.D.[7], Hadly E.A.[7], Stegner M.A.[7], An Z.[8], Fairchild I.J.[9], Himson S.[1], Rose N.L.[10], Gałuszka A.[11], Hajdas I.[12], Wagreich M.[13], Summerhayes C.[14] & Williams M.[1]

[1] University of Leicester. [2] Brock University. [3] British Antarctic Survey. [4] Leibniz Institute for Baltic Sea Research Warnemüende. [5] University of Alberta. [6] Louisiana State University. [7] Stanford University. [8] Institute of Earth Environment China. [9] University of Birmingham. [10] University College London. [11] Jan Kochanowski University. [12] ETH Zurich. [13] University of Vienna. [14] Scott Polar Research Institute.

Corresponding author email: cw398@leicester.ac.uk

Keywords: Anthropocene, global boundary stratotype section and point.

The Working Group on the Anthropocene of the Subcommission on Quaternary Stratigraphy have provided interim recommendations, proposing formalisation of this unit at epoch/series rank based on a mid-20th century boundary (Zalasiewicz et al., 2017). Work has progressed to determine optimal environments and locations of a potential GSSP and auxiliary stratotypes for the Anthropocene Epoch/Series (Waters et al., 2018). Ten locations, spanning five continents, located in diverse environments preserving an extensive range of proxies, are being investigated by lead institutes/universities, co-funding collection and analysis alongside a transdisciplinary 2-year initiative, financed and managed by the Haus der Kulturen der Welt, Berlin. All sections will be in borehole cores, most showing annually resolved laminations that can be independently dated radiometrically to confirm a complete succession extending to pre-Industrial times. The locations studied include: one from a marine anoxic basin in the Baltic Sea; two within coral reefs at Little Cayman (Caribbean Sea) and the Great Barrier Reef; one within an estuary setting in San Francisco Bay; three within lakes, including the meromictic Crawford Lake, Ontario, Huguangyan maar lake, China, and the Searsville Reservoir, Jasper Ridge Biological Preserve, California; one from a peat bog,Etang de la Gruère, Switzerland; one in firn/ice layers from the Antarctic Peninsula; and one from a speleothem from Ernesto Cave, NE Italy, for which most analysis is already published. Other proposals adhering to strict suitability requirements can also be considered, in addition to the above. Airborne signals provide the most widespread and near-isochronous proxies, applicable across most environments, at around the mid-20th century level. Proxies to be analysed in most sites include: upturns in ^{239}Pu, ^{241}Am and ^{14}C radioisotopes, fly ash and nitrates abundance and downturn in $\delta^{13}C$ and $\delta^{15}N$ values. Additional means of correlation include appearance of microplastics and certain persistent organic pollutants, changed heavy metal concentrations and lead isotope ratios. Assemblage changes of microfossils will be analysed in marine, estuarine and lake settings in relation to changing environmental factors and biological invasions. Other signals of importance in ice cores include sulphur and sulphates, CO_2 and CH_4 concentrations and $\delta^{18}O$ values and sea surface temperature and pH proxies in corals. The collection of systematic and comprehensive datasets, with correlation established between sections, will be used to formulate a proposal for formalisation of the Anthropocene.

Waters C.N., Zalasiewicz J., Summerhayes C., Fairchild I.J., Rose N.L., Loader N.J. Shotyk W., Cearreta A., Head M.J., Syvitski J.P.M., Williams M., Wagreich M., Barnosky A.D., Zhisheng A., Leinfelder R., Jeandel C., Galuszka A., Ivar do Sul J.A., Gradstein F., Steffen W., McNeil J.R., Wing S., Poirier C & Edgeworth M. (2018) - Global Boundary Stratotype Section and Point (GSSP) for the Anthropocene Series: Where and how to look for potential candidates. Earth-Sci. Rev., 178, 379-429.

Zalasiewicz J., Waters C.N., Summerhayes C.P., Wolfe A.P., Barnosky A.D., Cearreta A. Crutzen P., Erle E., Fairchild I.J., Galuszka A., Haff P., Hajdas I., Head M.j. Ivar do Sul J.A., Jeandel C., Leinfelder R., McNeil J.R., Neal C., Odada E., Oreskes N., Steffen W., Syvitski J., Vidas D., Wagreicj M. & Williams M. (2017) - The Working Group on the Anthropocene: Summary of evidence and interim recommendations. Anthropocene, 19, 55-60.

ST4.1
High-resolution stratigraphy of Carbonate Platforms: unlocking the shallow-water archive of extreme palaeoenvironmental events

Conveners and Chairpersons
Mariano Parente (Università di Napoli)
Stephane Bodin (Aarhus University)
Gianluca Frijia (Università di Ferrara)
Thomas Steuber (Khalifa University)

Dienerian (Early Triassic) conodonts and carbonate carbon isotope record in Chongqing, Upper Yangtze Region, SW China

Chen B.*[1], Shi Z.Q.[1], Du Y.X.[2] & Franceschi M.[2]

[1] State Key Laboratory of Oil and Gas Reservoir Geology and Exploitation, Chengdu University of Technology, China
[2] Department of Geoscience, University of Padova, Italy.

Corresponding author email: 1018889420@qq.com

Keywords: Early Triassic, Dienerian, conodont, carbon isotope excursion.

After the latest Permian mass extinction (LPME), delayed biotic recovery occurred in the Early Triassic,but was punctuated by at least three smaller-scale extinction events (e.g., Stanley, 2009). Furthermore, multiple perturbations of the carbon cycle are recorded in the coeval carbonate succession of the Upper Yangtze Region, SW China (e.g. Payne et al., 2004). We report the identification of two conodont zones, *Neospathodus dieneri* zone and *Eurygnathodus costatus* zone, are identified in the Feixianguan Formation (Dienerian, Early Triassic) at the Beibei Section in Chongqing, Upper Yangtze Region. The strata yielding the *Neospathodus dieneri* zone are referred to the early-middle Dienerian (Lyu et al., 2019) and *Eurygnathodus costatus* has the widest geographic distribution and its first occurrence (FO) is in the upper part of Dienerian (Chen et al., 2016). New carbonate carbon isotope data collected from the Beibei section show that after a steady, slow increase during the early Dienarian, isotope ratios in the upper Dienerian undergo a sudden 4.66‰ drop followed by a 5.00‰ rise. The carbon isotope excursion coincides with the transition between the carbonates of the third member and the shales of the fourth member of the Feixianguan Formation. New biostratigraphic data and the features of the carbon isotope curve allow correlation to coeval records from Eastern Tethys (Guandao section, Payne et al., 2004) and to the Western Tethys (L`Om Picol/Cima Uomo section, Horacek et al., 2007). This indicates that the observed perturbation in the isotope record were related to an event that was at least Tethys wide. The occurrence of a potentially global carbon isotope excursion in a time of important biotic turnovers suggests that a common cause may exist behind the perturbation of the carbon cycle and the multiple extinction events of the Early Triassic.

Chen Y., Kolar-Jurkovšek T., Jurkovšek B. Aljinović D. & Richoz S. (2016) - Early Triassic conodonts and carbonate carbon isotope record of the Idrija–Žiri area, Slovenia. Palaeogeog. Palaeocl. Palaeoecol., 444, 84-100.

Horacek M., Brandner R. & Abart R. (2007) - Carbon isotope record of the P/T boundary and the Lower Triassic in the Southern Alps: Evidence for rapid changes in storage of organic carbon. Palaeogeog. Palaeocl. Palaeoecol., 252, 347-354.

Lyu Z., Orchard M.J., Chen Z. Wang X., Zhao L. & Han C. (2017) - Uppermost Permian to Lower Triassic conodont successions from the Enshi area, western Hubei Province, South China. Palaeogeogr. Palaeoclimatol. Palaeoecol., 519, 49-64.

Payne J.L., Lehrmann D.J., Wei J.J., Orchard M.J., Schrag D.P. & Knoll A.H. (2004) - Large perturbations of the carbon cycle during recovery from the end-Permian extinction. Science, 305, 506-509.

Stanley, S.M. (2009) - Evidence from ammonoids and conodonts for multiple Early Triassic mass extinctions. P. Natl. Acad. Sci. Usa, 106, 15264-15267.

Larger Foraminifera Biostratigraphy of the Maastrichtian-Paleocene shallow-water carbonates of Şahinkaya Member (Eastern Pontides, Trabzon, NE Turkey)

Consorti L.*[1], Köroğlu F.[2] & Sabbatino M.[1]

[1] University of Naples, Italy. [2] University of Ankara, Turkey.

Corresponding author email: lorenzo.consorti.es@gmail.com

Keywords: shallow-water carbonates, Pontides, larger Foraminifera biostratigraphy, K-Pg transition.

The Maastrichtian to Paleocene geological evolution of the Eastern Pontides in NE Turkey was driven by a plate subduction/collision event occurring by the Late Cretaceous that corresponds to the time of volcanic arc formation. The volcanic activity linked to this event was initiated on the northern shelf of the Neotethys Ocean due to the northward subduction of Neotethyan oceanic crust along the southern borders of the Sakarya Zone in Turkey. The subsequent convergence phases resulted in the formation of a collisional orogenic belt and transformation of the earlier volcanic arc into a back-arc basin throughout the Maastrichtian and the Paleocene. The Tonya Formation represents the Mesozoic-Paleocene sequence of the Eastern Pontides back-arc sedimentation. The formation, which is mostly composed by hemipelagic shales with planktonic foraminifers, also contains calciclastic rocks comprising shelf-derived carbonate clasts, such as fragments of bivalves, echinoderms, benthic foraminifers, red algae, corals and bryozoans. In some areas of the Eastern Pontides near to the back-arc basin edges, the Tonya Formation laterally pass to shallow-water carbonate platform deposits defined in the regional geology as Şahinkaya Member. The member is rich in larger Foraminifera, bryozoans, red algae and rare corals, and may contain some conglomerate levels deriving from dismantling of the pre-existing volcanic deposits. Although the vertical distribution of foraminifers and the relative age-derived constraints of the Şahinkaya Member have been partially discussed by few authors and published in local journals, a further detailed micropaleontological analysis is still necessary to obtain a precise chronostratigraphic frame and in order to better characterize the geological evolution of Eastern Pontides area during Maastrichtian and Paleocene. The aim of this contribution is to present the stratigraphic distribution of the larger Foraminifera found within the Şahinkaya Member in order to get a precise age for the top of the Cretaceous carbonates and the overlying Paleocene sequence. The few planktonic foraminifers occurring in these rocks have been also taken into consideration. The studied series, which thickness is about 100 m, is located near the city of Trabzon, in the Düzköy area.

The results have shown that:

i) the base of the Şahinkaya Member is upper Maastrichtian in age by the presence of the siderolitid species *Canalispina iapygia* and the co-occurrence of the planktic Foraminifera Racemiguembelina fructicosa;
ii) there is a stratigraphic gap covering part of the uppermost Maastrichtian and lower Danian;
iii) the Paleocene is represented by a thin Danian layer given by the occurrence of *Laffitteina bibensis*, by a thick Selandian rock pack containing several species referred to the genus Miscellanites and Rotorbinella, whereas the lower Thanetian is marked by the first appearance of *Discocyclina seunesi.*

The fate of rudist and coral bearing lithostratigraphic units of Early and middle Cretaceous ages

Császár G.*[1]

[1]Independent Researcher.

Corresponding author email: csaszar.geza@gmail.com

Keywords: rudist, coral, Transdanubian Range, Hungary.

The Trandanubian Range was part of a huge platform until the earliest phase of Early Jurassic. The first signal of the opening of the Penninic Ocean was the break of the carbonate platform system. The result of this process was the differentiation of the sedimentary environments into heights with comparatively thin, discontinuous and into deeper-water areas with condenced lithofacies, and thicker, continuous successions showing less condensation. There are differences in thickness and also in lithology of the Jurassic lithostratigraphic units in southwest and northeast direction in the Transdanubian Range. The oldest Jurassic unit is the oncoidic and ooidic Kardosrét Limestone, developed from the Dachstein Limestone in the Bakony Mts, but getting lacunose and thinning to the northeast direction and completely missing from the Gerecse Mts. The lithostratigraphic units are named based on their lithologic composition and on a geographic name, where it is considered to be its type locality. The present proposal want to give an other approach for naming the coral and rudist bearing Lower Cretaceous successions, a special type of development of one of the little bit different way. In Hungary the following Urgonian formations are known: Környe Limestone Fm (Vértes Mt), Zirc Limestone Fm (Bakony and Vértes Mts), Nagyharsány Limestone Fm (Villány Zone). Rudist-bearing limestone fragments are also found in the Köszörűkőbánya Conglomerate Member, and in the Magyaregregy Conglomerate Fm. In addition to the surface outcrops several boreholes penetrated Urgonian type limestones in the Vértes Foreland, in the Bakony Mts, in the Mecsek and Villány Mts, and also in several places in the Great Hungarian Plain and in the Villány - Bihor zone, in the East-Alpine - Carpathian and also in the Soviet Carpathians. There are rudisted and also corallic limestones in the neighbouring countries as well: Papuk Mts., in the Western Alps, in the Eastern Alps and in the Dinarides. Special type atoll is developed in the volcanic bodies in the Mecsek Mts. Plenty of successions and photos will be presented during the lecture. In addition to the neighbouring countries there are also rudisted and coral-bearing occurrances in the Meso-Hellenic Basin including Greece and Albania and the internal zones of Hellenides. This kind of successions are also developed in China, in Russia, in India and in Africa as well. Is there any chance that we can find solution for formulating a few common lithostratigraphic names?

Lower Aptian *Chondrodonta* beds in shallow-water carbonates of the Tethyan Realm

Del Viscio G.*[1], Frijia G.[1], Morsilli M.[1], Posenato R.[1] & Struck U.[2]

[1] University of Ferrara, Italy. [2] Museum fur Naturkunde, Berlin, Germany.

Corresponding author email: dlvgrl@unife.it

Keywords: Chondrodonta, Tethys, OAE1a, Apulia Carbonate Platform Arabian Plate.

Chondrodonta is an oyster-like bivalve quite common in Cretaceous carbonate platforms, with a worldwide distribution. A particularly high concentration of this organism seems to be present in stratigraphic intervals straddling the Oceanic Anoxic Events 1a and 2. However, a clear cause-effect relationship has not emerged yet and therefore it is not completely understood whether the environmental disturbances caused by the OAEs may have, someway, favored the flourishing of *Chondrodonta*. In this work we present a detailed stratigraphic, sedimentological and geochemical analysis of two stratigraphic sections from the Lower Aptian Apulia Carbonate Platform (Italy) and Arabian Plate (Oman), in which *Chondrodonta* beds are present. The *Chondrodonta* bed analyzed in the Apulia Carbonate Platform (Gargano Promontory) occurs within low-energy inner-platform peritidal cycles of the San Giovanni Rotondo Limestones. The bed, 140 cm thick, is a floatstone to rudstone in the lower part and becomes a boundstone, with shells in life-position, in the uppermost 50 cm. The shells are still articulated and show a high concentration increasing toward the top of the bed. The *Chondrodonta* bed sampled in the Arabian Peninsula (Jebel Akhdar, Northern Oman) occurs in the top-most part of the moderate-energy inner shelf limestones of the Shuaiba Formation. The bed, 40 cm thick, is a floatstone to rudstone with a high concentration of shells, mostly still articulated. Sedimentological and taphonomical data are presented in order to highlight similarities between the shell beds coming from the two different localities. Geochemical analyses, supported by biostratigraphic data, enable us to precisely correlate the two sections and place the timing of the OAE1a. Furthermore, they allow to characterize the *Chondrodonta* beds in terms of elemental and isotopic composition in order to discuss the possible link between these shell beds and the OAE1a.

Untangling palaeoenvironmental signals in nummulitid morphometry to enhance biostratigraphic diagnosis in shallow-marine carbonate deposits

Eder W.[1]*, Torres-Silva A.I.[1], Hohenegger J.[1], Briguglio A.[2] & Ćorić S.[3]

[1] Department of Palaeontology – University of Vienna. [2] Dipartimento di Scienze della Terra dell'Ambiente e della Vita – University of Genova. [3] Geological Survey of Austria (GBA).

Corresponding author email: wolfgang.eder@univie.ac.at

Keywords: larger foraminifera, Eocene, palaeoenvironment, palaeobiogeography, Nummulites.

Within the larger benthic foraminifera (LBF) the group with undivided chambers, Nummulitids, and the group with chambers subdivided into chamberlets, Heterosteginids, are well-known markers for biostratigraphic and palaeoenvironmental interpretation of Cenozoic shallow-marine carbonate deposits. Morphometric analyses of equatorial thin-sections have been widely used for the genera *Nummulites, Assilina* and *Heterostegina* to fine-tune relative dating based on the LBF biozonation, while palaeoenvironmental and palaeobiogeographic interpretations are based on assemblages. The presented studies show that palaeoenvironmental and palaeogeographic trends can be filtered by detailed investigation of diagnostic features in oriented thin-sections improving biostratigraphic interpretation. Until now, 149 isolated specimens of the genera *Nummulites*, *Operculinoides*, *Palaeonummulites* and *Heterostegina* have been investigated from seven different localities in western and central Cuba with a time range from early Lutetian to latest Priabonian (Rupelian?). By means of agglomerative cluster, principal component and canonical discriminant analyses based on morphometric data we could clearly differentiate trends along geological time and palaeoenvironmental/palaeobiogeographic gradients. To crosscheck these trends, our results have further been integrated with planktic foraminifera and nannoplankton biostratigraphy. Within Nummulitids, the tightly-coiled genus *Nummulites* exhibits the most prominent changes through time. This is primarily represented by the increasing size of the first embryonic chamber. *Operculinoides* and *Palaeonummulites* with varying laxity of the spiral exhibit weaker changes along geological time, which are mainly represented by spiral and chamber shape. In *Heterostegina*, changes through time are strongly reflected in chamber and chamberlet shape, while the size of the embryonic apparatus is less important. Generally, the laxity of spirals leading to higher morphological variability enabled a stronger response of test shape to palaeoenvironmental changes. These taxa span longer time intervals exhibiting weak evolutionary trends as has been observed in the studied sections by the genus *Operculinoides*.

Sedimentary evolution of the Lower Cretaceous carbonate platforms in the Manín Unit, Western Carpathians, Slovakia

Fekete K.*[1], Michalík J.[1], Boorová D.[2], Soták J.[1], Lintnerová O.[3] & Svobodová A.[4]

[1] Earth Science Institute of Slovak Academy of Sciences, Slovakia. [2] State Geological Institute of Dionýz Štúr, Slovakia [3] Comenius University, Faculty of Natural Sciences, Slovakia. [4] Institute of Geology of the Czech Academy of Sciences, v. v. i., Czech Republic.

Corresponding author email: kamil.fekete@savba.sk

Keywords: Lower Cretaceous, upper slope carbonate sedimentation, Manín Unit, biostratigraphy, planktonic foraminifers, C isotopes.

Lower Cretaceous sequence of the Manín Unit croping out in the Middle Váh Valley consists of Valanginian – Barremian pelagic carbonates and neritic carbonate complex (Urgonian facies s.l.). The demise of Lower Cretaceous platforms is considered to coincide with the 'mid-Aptian crisis' of the Tethyan platform systems. However, the input of clasts of platform sediments in allodapic facies indicated that the platform growth was still active during the Late Aptian – Albian, suggesting that the carbonate factory production in the Western Carpathians terminated later than in other Tethyan regions (Michalík et al., 2012; Fekete et al., 2017). The platform margin and upper slope facies of the "Urgonian", Barremian – Aptian – sequence, originally forming the higher highstand platform were eroded. Its former slope was overlain by platform margin and upper slope facies of the lowstand platform with planktonic foraminifers *Hedbergella trocoidea*, *Globigerinelloides ferreolensis*, *G. barri*, *G. algerianus* indicating Late Aptian Zones and *Ticinella primula*, *T. roberti* of the Ticinella primula Zone. Rare colomiellids *Colomiella mexicana*, *C. recta*, *Cadosina semiradiata olzae* with *Calcisphaerula innominata* also occur. Calcareous nannofossils are dominated by *Watznaueria*, *Nannoconus*, *Assipetra* and *Micrantholithus*. The upper slope facies passes upwards into peri-reef facies with caprinid rudists shell fragments and orbitolinids *Palorbitolina* ex gr. *lenticularis* and *Mesorbitolina* gr. *parva – texana*. $\delta^{13}C$ and $\delta^{18}O$ isotope values in the studied sequences share similarities. Distribution of $\delta^{13}C$ reveal eustatic sea level oscillation and suggest neritic conditions and continual marine diagenesis. During Late Aptian eustatic changes, this highstand carbonate platform sequence has been eroded. Carbonate clasts were accumulated on toe of the slope of the new mid-Albian lowstand carbonate platform. After stabilization and aggradation stage, carbonate platform growth was stopped and the platform collapsed. A hardground surface was formed, overlain by Albian-Cenomanian marls and marlstones with a thin layer of calcisphaerulid limestones including calcareous dinoflagellates of the Innominata Acme Zone and planktonic foraminifers of the Thalmanninella appenninica Zone.

This research was supported by VEGA grant 2/0034/16, and APVV-14-0118.

Fekete K., Soták J., Boorová D., Lintnerová O., Michalík J. & Grabowski J. (2017) - An Albian demise of the carbonate platform in the Manín Unit (Western Carpathians, Slovakia). Geol. Carpath., 68(5), 385-402.

Michalík J., Lintnerová O. Reháková D., Boorová D. & Šimo V. (2012) - Early Cretaceous sedimentary evolution of a pelagic basin margin (the Manín Unit, central Western Carpathians, Slovakia). Cretaceous Res., 38, 68-79.

Carbon isotope chemostratigraphy of the Middle and Upper Ordovician in South China and its global correlation

Li C.[1], Fan J.X.*[2], Chen Z.Y.[1], Chen Q.[1] & Zhang Y.D.[1]

[1] Nanjing Institute of Geology and Palaeontology and Center for Excellence in Life and Paleoenvironment, Chinese Academy of Sciences, China. [2] Nanjing University, China.

Corresponding author email: fanjunxuan@gmail.com

Keywords: chemostratigraphy, Middle and Upper Ordovician, carbon isotope zones, environmental change, South China.

In the recent decades many important progresses have been made to the carbon isotope chemostratigraphy of the Ordovician. Several carbon isotope events have been recognized from the Middle and Upper Ordovician in Laurentia (Bergström et al., 2007, 2010; Leslie et al., 2011) and Baltica (Kaljo et al., 2007; Ainsaar et al., 2010). Meanwhile a series of chemostratigraphic zones, which are called carbon isotope zones, have been proposed in Baltica (Ainsaar et al., 2010). Some of the carbon isotope zones can be well correlated between Laurentia and Baltica (Bergström et al., 2015), showing potential for global correlation. The Middle and Upper Ordovician (from upper Darriwilian to middle Katian) on the Yangtze Platform in South China is dominated by carbonate rocks with few graptolites, which makes it difficult to correlate with other plates. Carbon isotope stratigraphy provides the possibility to solve this problem. 426 samples for inorganic carbon isotope are collected from the Kuniutan, Miaopo, Pagoda and Linhsiang formations of two drill cores in Yichang area, South China. Seven carbon isotope events are recognized, including LDNICE, MDICE, Upper Kukruse Low, GICE, KOPE, Fairview and Waynesville. All of these events can be correlated with those in Laurentia and Baltica, and show the influences of some global environmental changes.

Ainsaar L., Kaljo D., Martma T., Meidla T., Männik P., Nõlvak J. & Tinn O. (2010) - Middle and Upper Ordovician carbon isotope chemostratigraphy in Baltoscandia: A correlation standard and clues to environmental history. Palaeogeography, Palaeoclimatology, Palaeoecology, 294 (3/4), 189-201.

Bergström S.M., Young S., Schmitz B. & Saltzman M.R. (2007) - Upper Ordovician (Katian) δ13C chemostratigraphy: a trans-Atlantic comparison. Acta Palaeontologica Sinica, 46, 37-39.

Bergström S.M., Young S. & Schmitz B. (2010) - Katian (Upper Ordovician) $\delta^{13}C$ chemostratigraphy and sequence stratigraphy in the United States and Baltoscandia: A regional comparison. Palaeogeography, Palaeoclimatology, Palaeoecology, 296(3/4), 217-234.

Bergström S.M., Saltzman M.R., Leslie S.A., Ferretti A. & Young S.A. (2015) - Trans-Atlantic application of the Baltic Middle and Upper Ordovician carbon isotope zonation. Estonian Journal of Earth Sciences, 64(1), 8-12.

Carbonate mud mounds in a late Carboniferous wedge-top basin (Cantabrian zone, N Spain)

Martín-Merino G.*[1], Bahamonde Rionda J.R.[2] & Fernández González L.P.[2]

[1] School of Earth Sciences and Engineering, Yachay Tech, Ecuador. [2] Departamento de Geología, Facultad de Geología, Universidad de Oviedo, Spain.

Corresponding author email: gmartin@yachaytech.edu.ec

Keywords: Mud-mounds, wedge-top basin, Cantabrian Zone, Carboniferous, carbonate ramp.

This study focuses on a Late Carboniferous (Myachkovian) mud-mound complex developed on the middle and outer reaches of a small carbonate-ramp system located in the La Pernía–Redondo thrust-top basin (Variscan foreland basin of the Cantabrian Zone, N Spain). Nucleation, growth and stacking patterns are interpreted as linked to the interplay between growth of fault-propagation anticlines during thrust emplacement and regional flexural subsidence. Mounds located in the middle ramp are 140–200 m wide and 10–40 m high, showing a depositional relief of 5–9 m and gentle (5–7º) and concave-upward slopes. Mounds in the outer ramp are wider (>500 m) and thicker (100–250 m high), reach ~100 m of depositional relief and display steeper (~23º) concave-upward slopes. The massive mound cores consist of microbial-induced carbonates (clotted peloidal micrite and incrusted micrite accretionary laminated structures), swarms of agglutinated worm tubes and fenestellid bryozoan colonies. The flank and inter-mound deposits comprise wackestone–packstone beds containing micritic intraclasts and skeletal grains of a diverse marine biota (mostly echinoderms and foraminifers). The shallow-ramp mud mounds are capped by thin wackestone–packstone beds containing foraminifers and abundant algae (phylloids, dasycladacean and beresellids) embedded in a homogeneous (structureless) micritic matrix with scattered tiny bioclasts. The onset of the carbonate ramp and the nucleation of the mound complex occurred on a prominent subaerial exposure surface, coinciding with a marked increase of subsidence rate. In the proximal ramp, shallow-water, well-bedded carbonate deposits (diverse biota skeletal wacke- to packstone) accumulated; whereas microbial algal-dominated mounds gradually thrived in the middle and outer sectors or the ramp system. The vertical stacking patterns of these mounds varies across the ramp from a laterally juxtaposed (with new mounds nucleating on previous inter-mound deposits) pattern in middle ramp, to a vertically accreted and retrogradational stacking pattern in outer ramp. This change in the mound stacking patterns across the ramp, is result of response of the mud-mounds growth to lateral variations in the accommodation space (subsidence) rates, directly related to tectonic activity.

Valanginian–Barremian biofacies linked to the main global stratigraphic events: the case of the shallow–water carbonate platform of the Southern Apennines (Italy)

Martino M.*[1], Amodio S.[2], Barattolo F.[1] & Parente M.[1]

[1] University of Naples "Federico II", Italy. [2] University of Naples "Parthenope", Italy.

Corresponding author email: martino.mr@libero.it

Keywords: Weissert Oceanic Anoxic Event, Selli Oceanic Anoxic Event, Cretaceous, Monte Monaco di Gioia massif.

Despite their abundant and high diversity fossil content, shallow-water carbonate records are often characterised by low stratigraphic resolution and poor chronostratigraphic calibration. In this work, we present a stratigraphic and sedimentological study of a Valanginian-Barremian carbonate platform section exposed in the southern Apennines of Italy. The studied section is exposed near San Lorenzello, at the base of the Monte Monaco di Gioia massif. For this section, about 240 m thick, we produced an high resolution dataset integrating sedimentology, biostratigraphy, isotope stratigraphy, cyclostratigraphy and sequence stratigraphy. The main aim of our work is to investigate how neritic biofacies responded to palaeonvironmental and palaeoceanographic changes in the time interval between two consecutive crises of carbonate production: the Weissert and Selli Oceanic Anoxic Events. Fossil assemblages, combined with lithofacies characteristics, are used to reconstruct the paleoenvironmental history of the section, which is part of a wide and shallow carbonate platform influenced by waves and/or storms. On this flat-topped subtropical platform, sea-level oscillations induced frequent and cyclic emersions of the platform, witnessed by karstification and pedogenesis. Detailed investigations lead to a considerable refinement of the biostratigraphy adopted by previous authors, producing also a better agreement between the position of the Valanginian-Hauterivian boundary indicated by biostratigraphy and that indicated by carbon-isotope stratigraphy. Moreover, numerous additional bioevents of benthic foraminifera and green algae have been identified and six biozones have been defined with reference to the main Tethyan biozonal schemes. Previous works, on the first 90m of the section, evidenced the eustatic control on the hierarchical organization of elementary sedimentary cycles into bundles and superbundles; the latter also interpreted in terms of depositional sequences. The present work identifies 24 depositional sequences along the 240m-thick interval. The boundaries of these depositional sequences are tentatively correlated to the the "global" Sequence Boundaries and to the revised Cretaceous eustatic curve of Haq (2014). The C-isotope correlation between neritic and pelagic sections of Amodio et al. (2008) suggested that only the upper part of the Weissert event is recorded in the San Lorenzello section, followed by a time of a global decrease of C-isotope values. In this work we present new isotope-stratigraphy data for the Hauterivian-Barremian interval. The preliminary chronostratigraphic calibration of the biostratigraphic events, performed by correlation to the eustatic curve, shows a correlation between benthic foraminiferal and calcareous algae turnover phases and eustatic events. First occurrence events are concentrated after the Weissert OAE, during the Valanginian-Hauterivian second order global sea level rise, while last occurrence events are mainly concentrated in the Barremian long-term sea level fall.

Quantifying the palaeogeographical driver of Cretaceous carbonate platforms development using niche modeling

Pohl A.[1], Laugié M.[2], Borgomano J.[1], Michel J.[1], Lanteaume C.[1], Scotese C.R.[3], Frau C.*[4], Poli E.[5] & Donnadieu Y.[1]

[1] Aix Marseille Univ, France. [2] MODIS Pau, France. [3] Northwestern University, USA. [4] Groupement d'Intérêt Paléontologique, Science et Exposition, France. [5] Total CSTJF, France.

Corresponding author email: camille_frau@hotmail.fr

Keywords: Paleoceanography, Carbonate factory, Environmental constraints, General circulation mode, Fuzzy logic, Aptian.

Platform carbonates are a major component of the Earth System but their extent is difficult to reconstruct back in geological time. Coupled niche modeling and deep-time general circulation models are used to predict their occurrence at the global scale throughout the Cretaceous. The niche model uses the fuzzy logic to predict a susceptibility of occurrence of the platform carbonates as a function of the surrounding environment. The predictive variables considered include sea-surface temperature, sea-surface salinity and net primary productivity as well as a binary bathymetry mask. The first three of these parameters derive from new Cretaceous simulations conducted using a coupled ocean-atmosphere general circulation model (MITgcm) while bathymetry is taken from our paleogeographical reconstructions. Model predictions are validated on the well-documented Aptian stage by comparison with abundant geological data. Simulations are subsequently extended to other Cretaceous time slices. Climatic simulations reasonably capture Aptian climate. Results of the niche model show overall agreement with Aptian database when an autotrophic affinity is considered for the rudist-dominated platform carbonates. The alternative, heterotrophic nutrition mode does not allow to satisfactorily reproduce the extent reported based on geological data. When changing the continental configuration, the model predicts an increase in the extent of the carbonate platforms in agreement with the geological record, mainly due to the increasing extent of shallow-water environments available to carbonate development. Results of the simulations identify the Cretaceous long-term rise in sea level as a major driver of the increase in platform carbonate extent throughout the Cretaceous.

Pohl A., Laugié M., Borgomano J., Michel J., Lanteaume C., Scotese C.R., Frau C., Poli E. & Donnadieu Y., (2018) - Quantifying the paleogeographic driver of Cretaceous carbonate platform development using paleoecological niche modeling. Palaeogeography, Palaeoclimatology, Palaeoecology, 514, 222–232. https://doi.org/10.1016/j.palaeo.2018.10.017

From the final demise of the Mesozoic carbonate platform to the Miocene transgression: high-resolution stratigraphy of the shallow-water carbonates of southern and central Apennines (Italy)

Sabbatino M.*[1], Consorti L.[1], Tavani S.[1], Vitale S.[1], Corradetti A.[2], Arienzo I.[3], §Cipriani A.[4], Lugli F.[4] & Parente M.[1]

[1] University of Naples Federico II. [2] Texas A&M University at Qatar. [3] National Institute of Geophysics and Volcanology (INGV) - Vesuvius Observatory (OV). [4] University of Modena and Reggio Emilia.

Corresponding author email: monia.sabbatino@unina.it

Keywords: Shallow-water carbonates, Apennines, Sr-isotopes, forebulge-unconformity, foraminifera.

The Apennine Carbonate Platform (ACP) of central and southern Italy witnesses almost continuous shallow-water carbonate sedimentation from the Late Triassic to the Late Cretaceous over very wide areas. Paleogene shallow-water carbonates are comparatively much less widespread and are generally represented by thin and stratigraphically discontinuous deposits. A last phase of shallow-water carbonate sedimentation is recorded during the Miocene by transgressive deposits overlying the Cretaceous or Paleogene substrate. The final demise came in the middle Miocene by drowning of the platform below the photic zone, followed by the deposition of deep-water siliciclastics and calciclastics in foredeep and wedge-top basins settings. The Miocene stratigraphy of the central-southern Apennine fold-and-thrust belt records the eastward migration of the accretionary wedge. The foreland plate progressively experienced uplift, erosion, and extension in the peripheral-bulge area, followed by bending and flexural subsidence. The stratigraphic expression of this tectonic stage is a regional forebulge unconformity at the top of the pre-orogenic passive margin mega-sequence, overlain by shallow-water carbonate deposits of the so-called "Miocene transgression", which represents the first phase of syn-orogenic sedimentation at the base of the foreland basin megasequence. The age of the transgressive carbonates sealing the forebulge unconformity is diachronous, becoming younger toward the northeast as a consequence of the progressive migration of the Apennine orogenic wedge. The main aims of this contribution are: (i) to obtain precise ages for the top of the Cretaceous carbonates underlying the forebulge unconformity and to use these ages to investigate the causes of the demise of the Mesozoic ACP; (ii) to define with precision the age of the base of the Miocene carbonates in order to better constrain the migration of the forebulge unconformity through space and time. We carried out a detailed stratigraphic study on many localities of the southern and central Apennines, from Northern Calabria to the Majella massif. By integrating larger benthic Foraminifera biostratigraphy and strontium isotope stratigraphy we generated a dataset achieving a resolution of 0.5-1 Ma for the age of the top of the Mesozoic platform and of <0.1-0.5 Ma for the age of the base of the Miocene transgression.

Internal agglutination: a peculiar 3-D test construction in a group of Middle Jurassic–Early Cretaceous Larger Benthic Foraminifera adapted to high-energy carbonate platform environments

Schlagintweit F.*

Independent researcher, Munich.

Corresponding author email: felix.schlagintweit@gmx.de

Keywords: Larger Benthic Foraminifera, Middle Jurassic, Lower Cretaceous.

Agglutinated foraminifera display "*a shell texture characterized by components gathered in the ambient environment and bound by organic or biomineralized cements produced by the cell*"…"*often the agglutination in the external and internal parts of the wall is differentiated but there are no sharp boundaries*" (Hottinger, 2006, p. 5). Confined to the wall and septa this feature can be referred to as "external agglutination". A specialized group of Middle Jurassic Early Cretaceous typically dimorphic larger benthic foraminifera (LBF) instead exhibits a peculiar test construction with foreign particles largely filling the chamber lumina. Following Bassoullet (1998, p. 186) this feature is herein termed "internal agglutination". The incorporated litho- and bioclasts are connected ("glued") by short columnar structures (= mineralized biogenic cements) thereby forming a three-dimensional composite texture (= composite endoskeleton). Because of the typically high amount of incorporated grains, it may be rather difficult to properly identify some characteristics of these taxa such as the exact number of chambers, structural details (e.g. exoskeleton), and foraminal features. The internally agglutinated taxa are characterized by very thin walls and septa. The following taxa are included in this group (in alphabetical order): *Bispiraloconulus* Schlagintweit, Bucur & Sudar, 2018 (monospecific; Berriasian), *Bostia* Bassoullet, 1998 (monospecific; Bathonian), *Robustoconus* Schlagintweit & Velić, 2013 (monospecific; Bajocian), *Spiraloconulus* Allemann & Schroeder, 1980 (three species; Aalenian–Berriasian) (? junior synonym of *Dhrumella* Redmond, 1965), and *Torremiroella* Brun & Canérot, 1972 (monospecific; Hauterivian–Lower Aptian). This peculiar internal structure obviously contributed considerably to test rigidity allowing an adaptation to agitated shoal environments of carbonate platforms. The grainstones/rudstones are typically dominated by these taxa in great abundances and are characterized by poorly diversified assemblages.

Allemann F. & Schroeder R. (1980) - *Spiraloconulus* nom. nov. for *Spiroconulus* Allemann & Schroeder 1972 (Foraminiferida). Rev. Esp. Micropaleont., 12, 358.

Bassoullet J.-P. (1998) - Un nouveau grand foraminifère *Bostia irregularis* n. gen., n. sp. (Lituolacea, Hauraniidae) du Jurassique moyen de Dordogne (France). Rev. Micropaléont., 41, 181-195.

Brun L. & Canérot J. (1979) - *Torremiroella hispanica* n. gen., n. sp. un nouveau Lituolidé (Foraminifère) du Barrémien Supérieur du Maestrazgo (Espagne). Bull. Centr. Rech. Explor.-Prod. Elf-Aquitaine, 3, 311-335.

Hottinger L. (2006) - Illustrated glossary of terms used in foraminiferal research. Carnets de Géologie / Notebooks on Geology - Memoir 2006/02, 1-126.

Redmond C.D. (1965) - Three new genera of foraminifera from the Jurassic of Saudi Arabia. Micropaleont., 11, 133-140.

Schlagintweit F., Bucur I.I. & Sudar M. (2018) - *Bispiraloconulus serbiacus* n. gen., n. sp., a giant arborescent benthic foraminifera from the Berriasian of Serbia. Cret. Res., 93, 98-106.

Schlagintweit F., Velić I. & Sokač B. (2013) - *Robustoconus tisljari* n. gen., n. sp., a new larger benthic foraminifer from the Middle Jurassic (Early Bajocian) of the Adriatic Carbonate Platform of Croatia. Geol. Croatica, 66, 15-28.

Benthic Foraminiferal Biostratigraphy of the Cenomanian Shallow-Water Platform Carbonates from the Northern Part of the Bey Dağları (Western Taurides, Turkey)

Solak C.*, Taslı K. & Koç H.

Mersin University, Engineering Faculty, Department of Geological Engineering, Çiftlikköy Campus, Yenişehir, Mersin.

Corresponding author email: cemilesolak@mersin.edu.tr

Keywords: Upper Cretaceous, Benthic foraminifera, Biostratigraphy, Bey Dağları, Turkey.

The study area is located at the İmecik and Ulucak areas which are northern part of the Bey Dağları Carbonate Platform (BDCP). This paper aims to document benthic foraminiferal taxa in the Cenomanian shallow-water limestones and to describe benthic foraminiferal biozones in the studied sections. Ulucak stratigraphic section represents northwestern part of the BDCP while İmecik represents northeastern part of the BDCP. Cenomanian shallow-water limestones composed of beige-cream, mostly thin and medium, well-bedded limestones including frequently laminated and fenestral fabrics. The lower parts of the sections are intercalated with dolostones. Breccia, gastropod and thin bivalve shell fragments are rare. Ulucak Cenomanian limestones are truncated by a disconformity surface and overlain by conglomerates with a pelagic matrix indicating Eocene age. İmecik Cenomanian limestones are conformably overlain by a few meters thick limestones with poor foraminiferal taxa interpreted as probable Turonian. Whereas in the southern part of the BDCP, the Cenomanian shallow-water carbonate sedimentation continued to the Turonian with a relatively rich benthic foraminiferal taxa (Solak & Taslı, 2018). İmecik probable Turonian limestones are unconformably overlain by conglomerates with a pelagic matrix suggesting Campanian-Maastrichtian age following a disconformity surface. Two benthic foraminiferal biozones and one subzone can be distinguished in the Cenomanian of the İmecik and Ulucak stratigraphic sections. These are; 1) *Sellialveolina* gr. *viallii* range zone, lower-middle Cenomanian; 2) *Pseudorhipidionina casertana* assemblage zone, upper Cenomanian; 2a) *Coxites zubariensis* range subzone, upper Cenomanian. While *S.* gr. *viallii* range zone and *P. casertana* assemblage zone are defined from both sections, *C. zubariensis* range subzone is defined from only Ulucak section. *S.* gr. *viallii* range zone comprises *Praealveolina iberica*, *Ovalveolina maccagnoae*, *Biconcava bentori*, *Biplanata peneropliformis*, *Spiroloculina cretacea*, *Pseudonummoloculina heimi*, *Nezzazata simplex*, *Nezzazata gyra*, *Nezzazatinella picardi*, *Cuneolina pavonia*. The conformably overlying *P. casertana* assemblage zone differs from the previous biozone in the absence of *S.* gr. *viallii*, *O. maccagnoae*, *P. iberica* and in the first occurrence of *P. casertana*, *Pseudorhapydionina laurinensis*, *P. dubia*, *Vidalina radoicicae*. *C. zubariensis* range subzone is defined from the upper part of the *P. casertana* assemblage zone and it has similar foraminifera content with this biozone.

This study was supported by the Scientific and Technological Research Council of Turkey (TUBITAK) with Project Number: 115Y130.

Solak C. & Taslı K. (2018) - A record of continuous Cenomanian-Turonian platform carbonate sedimentation: benthic foraminiferal biostratigraphy of the Finike section, Bey Dağları, Western Taurides. 9th International Symposium on Eastern Mediterranean Geology, Abstracts and Proceedings Book, ISBN: 978 605 4483 50-1, 218-222.

ST5.1 Stratigraphy and mapping volcanic areas

Conveners and Chairpersons

Gianluca Groppelli (Consiglio Nazionale delle Ricerche)

Federico Lucchi (Università di Bologna)

Joan Martí (National Research Council of Spain)

Atlas and map of Italian submarine volcanic structures

Fiorentino A.*[1], D'Angelo S.[1], Giordano G.[2], Pensa A.[2], Pinton A.[2] & Vita L.[1]

[1] Geological Survey of Italy – ISPRA. [2] Science Department, Roma Tre University, Italy.

Corresponding author email: andrea.fiorentino@isprambiente.it

Keywords: seamount, Tyrrhenian Sea, EMODnet Geology, geological events.

A large part of the post-orogenic volcanism in Italy is preserved in subaqueous domains of the Tyrrhenian Sea and the Sicily Channel. Over the years, several works, such as the DSDP-ODP Project and detailed bathymetric surveys (Marani et al., 2004), allowed a significant improvement of the knowledge of these volcanic environments. However, a comprehensive approach to the volcano types classification, based on available data and on the integration of different datasets, had not been attempted yet. A thorough review of publications, maps, conference presentations and cruises reports concerning submarine volcanic structures in Italian Seas, including islands, has been performed in order to deliver products to the EMODnet Geology Project. The Project, funded by the European Commission, aims at the collection and harmonization in European Seas of as many existing marine data as possible, to be represented on digital maps and made freely available through a dedicated portal (http://www.emodnet.eu/). The Geological Survey of Italy is Partner of the Project and Leader of Work Package 6 "Geological events and probabilities", which includes earthquakes, volcanoes, landslides, tsunamis, fluid emissions and Quaternary faults. The amount of data on volcanoes recorded, interpreted and harmonized, in the frame of EMODnet Geology, has led to the development of an original and complete national database. This systematic collection conducted to the publication of the "Atlas of Italian Submarine Volcanic Structures" (in press in the Geological Survey of Italy collection "Memorie Descrittive della Carta Geologica d'Italia", vol.104, under the auspices of EMODnet, IAVCEI and RomaTRE University). A total of 76 volcanic seamounts has been identified. Eighteen of these seamounts emerge above sea level as well-known volcanic islands, while three edifices had been recognised as volcanic in nature from older studies, but previously un-named; so we named them for the first time as Livia, Creusa and Tiro. Data collected allowed to classify edifices, based on morphology, chemistry, age and main structural lineaments. Significant effort has been dedicated to identify the extent of each volcanic edifice on the most detailed bathymetric maps available; this also allowed to estimate erupted volumes. Where possible, the age and style of the most recent eruptions, as well as the presence of active fluid emissions, have been listed in order to support future possible evaluation of volcanic hazard. The new map included in the volume represents the most updated cartographic representation of the subaqueous volcanic structures in Italy. This map allows to better evidence the main volcanic features outlining the recent geodynamical evolution of the Tyrrhenian Sea, such as the Eolian insular arc and back–arc basins and seamounts.

Marani M.P., Gamberi F. & Bonatti E. (2004) - From seafloor to deep mantle: architecture of the Tyrrhenian backarc basin. Mem. Descr. Carta Geol. d'It., 64, 196 pp.

Stratigraphy and mapping volcanic areas: methodological approach and perspectives

Groppelli G.[1]* on behalf of the Volcano Geology Commission

[1]Consiglio Nazionale delle Ricerche, Italy.

Corresponding author email: gianluca.groppelli@gmail.com

Keywords: geologica maps, field survey, lithostratigraphy, synthem, lithosome, volcanic activity unit.

IAVCEI Commission on Volcano Geology began its activity in 2015 and one of the main aims is the preparation of a common and as much as possible shared methodology to realize a geological map in volcanic areas. In fact, geological maps represent

1. the fundamental tool for understanding the evolution of an area,
2. the warehouse where to store in the objective way field data, including eruptive and inter-eruptive phenomena,
3. the basis for further and in depth studies (e.g. petrography, geochemistry and petrology, physical volcanology, geophysical modeling, volcanic hazard constraints, analogue and numerical modeling, ore geology, geothermal resources, etc.).

Recent geological maps in volcanic areas apply mainly stratigraphic units of different kind and rank during field survey and for the final realization of map. The use of stratigraphic units is fundamental because it is the only way to define the geological time and therefore to identify the evolution of an area based only on the stratigraphic position of rock bodies. Some geological maps are characterized by the use of multiple stratigraphic units, often in parallel, with the aim to better define the temporal and spatial evolution of a volcanic area. The basic unit is often the lithostratigraphy, used during the field survey and also in the display of the final map, because the lithologic features and stratigraphic relationships of rock bodies are the only characteristics immediately recognizable in the field. Laboratory data (e.g. petrographic, geochemical, radiometric analyses) only allow a subsequent, more comprehensive definition of a field-identified lithostratigraphic unit. In parallel to the lithostratigraphic units, lithosomatic, synthemic and volcanic activity units are applied to synthesize the volcanic evolution of the area and to distinguish major phases based on field characteristics. The application of the lithostratigraphy and synthems to volcanic areas faces problems of scale (temporal and spatial) respect to their application mapping large sedimentary basins, as usually hiatuses in volcanic areas are of short duration (days to 10 000 years), and the limited areal extent of units (restrictions to few kilometers as individual volcanic bodies or a volcano). On the other side the synthemic units allow distinguishing in objective way the main phases of volcanism and to relate them with the variation of the regional tectonic regime and other regional events, as eustatic sea level changes.

Stratigraphy and evolution of Pleistocene La Reforma caldera complex, Baja California Sur, Mexico

Pellicioli C.*[1-2], Groppelli G.[2], Sulpizio R.[2-4], Macías J.L.[3] & García Sánchez L.[3]

[1] Università degli Studi di Milano. [2] IDPA - Consiglio Nazionale delle Ricerche di Milano. [3] Universidad Nacional Autónoma de México. [4] Università degli Studi di Bari Aldo Moro

Corresponding author email: claudia.pellicioli@unimi.it

Keywords: evolution, geometry, resurgence.

La Reforma is a 10 km wide resurgent caldera complex lying NW of the Santa Rosalía town (Baja California Sur, Mexico). Quaternary calc-alkaline volcanic activity moved from La Reforma to Sierra Aguajito and finally to Las Tres Vírgenes complex (currently hosting the fourth Mexican largest producing geothermal field). The entire region is affected by an active transtensive tectonic regime (NW-SE trending right-lateral faults and NE-SW or N-S conjugate systems) that strongly influenced the evolution of La Reforma caldera complex, as testified by the trap-door geometry of the caldera collapse and the asymmetrical shape of the resurgent block. Detailed field mapping and structural study performed during 2015-17 allowed the identification of a pre-, syn- and post-caldera phases, as well as of at least two separated resurgence pulses. The pre-caldera phase mainly consisted in a stratovolcano built in a shallow marine setting, whose remnants are nowadays exposed in the south-eastern and north-western sectors. This sequence mainly includes fossiliferous sediments of the Santa Rosalia basin Formation, interlayered with effusive and explosive activity products (several pyroclastic flows and ignimbrites). The eruption of rhyolitic Los Balcones ignimbrite (1.35 Ma) triggered the formation of a caldera depression, that was then filled by lava flows alternated with scoriae (nowadays exposed in the central part of the caldera depression) and enlarged by La Reforma rhyolitic ignimbrite eruption (1.29 Ma). After the emission of mafic lava flows on the external slopes of the caldera, marking a clear compositional shift, the eruption of the Punta Arena caldera-filling ignimbrite (0.96 Ma) marks the end of the syn-caldera phase. Post-caldera activity mainly includes intra-caldera andesitic to basaltic-andesitic lava flows, domes, scoria cones and associated intrusions aligned along structures bordering the resurgent block and wide alluvial fans in the western sector, formed following resurgence-related volcano-dismantling processes. Conservative estimates of resurgence indicate a total vertical uplift between 700 and 840 m.

Geological mapping in volcanic areas and exploration for geo-resources

Principe C.[1]*

[1]Istituto di Geoscienze e Georisorse - CNR - Pisa, Italy

Corresponding author email: c.principe@igg.cnr.it

Keywords: geological mapping, volcanic stratigraphy, geothermal energy, ore deposits.

Many geothermal exploration projects in volcanic area have suffered from the lack of pertinent volcanological observations and interpretations. This is due to the prevailing quantitative character of the Geophysical and Fluid Geochemistry related portions of the explorative process and to the prevalence of the "only drilling is concrete" mentality. To front this mentality, in economic, minerals and geological hazard applications, volcanologic studies needs nowadays a strongly pragmatic approach to researches that takes into account the need of more and more quantitative results and the investment security problems of the investors. In this sense, geological maps are the most significant and tangible product of geological/volcanological investigations in geothermal and ore deposits exploration process. They represent the quantitative synthesis of the whole volcanic field observations process. In fact, the spatial relationships of observations and data collection points are the key to understanding the subsurface structure and are necessary in planning drilling operations. Producing maps and cross sections is one way to validate spatial observations (superimposition, stratigraphic control, cross-cutting relationships) and to control the consistencies and completeness of the field work. As in the other branches of the exploratory geological work of a given area, also geological mapping has to be approached by a reconnaissance phase, considering previous works and any kind of territorial information, in order to place the area of interest in a regional context. Only at this point the size of the area and the level of detail required can be determined, and specific areas selected for detailed mapping. For geothermal fields, the scale of the map can be determined by the size of the volcanic field with which it is associated, but also by the extension of the interaction between the existing hydrothermal system and the regional aquifer, resulting in a large-scale geological reconnaissance map. On the other hand, detailed plans are needs for defining the target area, topographic contours, geological contacts, lithology and structures to be encountered during the drilling phase. Volcanologic maps for geothermal and ore minerals purposes are based on general principle of geological mapping but have to deal with the following additional information: (i) group the co-genetic cartographic suites in order to define their chrono-stratigraphy and the evolution of the volcanic system/s; (ii) define the facies of volcanic rocks, that reflect their genesis; (iii) identify vent structures; (iv) distinguish between regional tectonic structural fabrics and local volcanic ones.

ST8.1
The value of integration between classical seismo-stratigraphic methods and new technologies in subsurface stratigraphy and in the linkage to their outcropping counterparts

Conveners and Chairpersons
Laura Alessandra Brioschi (ENI S.p.A.)
Alfonso Iunio Marini (Eni Upstream)

Integrating reprocessing of existing seismic profiles and outcrop studies for the improvement of stratigraphic reconstruction in the subsurface: the example of the CROP line M-2A/I (Bonifacio Straits)

Berra F.*[1], Stucchi E.M.[2] & Moretti S.[1-3]

[1] Università degli Studi di Milano, Dipartimento di Scienze della Terra "A. Desio". [2] Università degli Studi di Pisa, Dipartimento di Scienze della Terra. [3] Present address: ENI SpA.

Corresponding author email: fabrizio.berra@unimi.it

Keywords: CROP line M-2A/I, Mesozoic, stratigraphy, Corsica, Sardinia.

The shallowest part (about 3 sec two-way traveltime) of the CROP line M-2A/I, acquired during 1991 in the Bonifacio Strait (between Corsica and Sardinia), was reprocessed to improve its geological interpretation. The original target of the M-2A/I profile was the entire crust and therefore the shallowest part was only partially interpreted. In this context, the re-processing procedure was carried out to improve the signal-to-noise ratio and the resolution at shallow depth, in order to reconstruct the stratigraphic evolution of the offshore northern Sardinia coast. The geological interpretation of the reprocessed data led to the reconstruction of the sedimentary succession and the contact with the underlying Hercynian basement. The M-2A/I seismic profile was interpreted identifying diverse seismic facies, in relation with the geological units outcropping to the north (in Corsica) and to the south (in Sardinia) of the seismic profile. The study led to the identification of different sedimentary bodies separated by major unconformities. Comparison of the internal architecture of these major unconformity-bounded units with the sedimentary succession outcropping in northern Sardinia and southern Corsica supports the existence of a thick Mesozoic succession, onlapping the Hercynian basement, preserved below the Cenozoic succession in the Asinara Gulf, suggesting that the Triassic to Cretaceous succession of the Nurra (northern Sardinia) continues northward in the offshore. The Mesozoic succession is bordered by a major, east-dipping normal fault, east of the Asinara Island ridge. The faults recognized in the seismic profile indicate a prevailing strike-slip/transtensional tectonics, questioning the role of compressional tectonics suggested in a previous interpretation. The obtained results provide also indicate the potential of re-processing of existing seismic profiles, whose interpretation can be significantly updated thanks to the development of new processing procedures and to the continuous upgrade of the regional geological knowledge.

Reconciling deep stratigraphy and shallow depositional architecture of the Po Plain through the integration of seismic and core data

Bruno L.*[1], Campo B.[2], Costagli B.[2], Picotti V.[3] & Amorosi A.[2]

[1] University of Modena and Reggio Emilia. [2] University of Bologna. [3] ETH Zurich.

Corresponding author email: luigi.bruno@unimore.it

Keywords: deep stratal architecture, shallow depositional architecture, seismic line interpretation, sediment core correlation, paleogeographic reconstruction, Po Plain.

Since the early seventies, hydrocarbon exploration by ENI-Agip has produced increased knowledge of basin-scale stratigraphic architecture of the Po Plain (Pieri and Groppi, 1981). Through a dense network of seismic profiles and tens of exploration wells, the subsurface of the Po Plain was imaged down to ca. 8 km depth. The flat surface of the Po Plain hides an extremely complex stratal architecture, mainly shaped by the activity of Alpine and Apenninic thrust systems. Mesozoic to Early Pleistocene (Gelasian) strata are folded and thrusted by north-verging Apenninic faults, that were active mainly between the Late Miocene and Gelasian (Picotti & Pazzaglia, 2008).

The shallow subsurface of the Po Plain was investigated through integrated sedimentological, geochemical and paleontological analysis on 30 to 200 m-deep cores. These studies highlighted a dominant climatic control on the Middle-Late Pleistocene to Holocene stratigraphy (Amorosi et al., 2008). The influence of tectonics was considered negligible in this time window.

Due to the scarce resolution of industrial seismic lines at depths < 200 m and to the limited depth of core analysis deep stratigraphy and shallow depositional architecture of the Po Plain have been studied over the decades independently. The aim of this research is to estimate the extent to which the deep tectono-stratigraphic configuration may influence facies distribution in the shallow subsurface.

To this purpose, in a selected area of the eastern Po Plain we carried out: (i) the detailed reconstruction of Late Pleistocene and Holocene stratigraphy through sediment core correlation; and (ii) the interpretation of selected seismic profiles calibrated with nearby wells. Late Pleistocene and Holocene strata appear folded above the culmination of buried anticlines. On the other hand, a close inspection of seismic lines shows that post-Gelasian strata, basin-wide sealing older deformed strata with typical planar onlap geometry, appear deformed close to selected thrusts. Combined differential compaction and recent tectonic activity can be called into question to explain deformation observed in stratigraphic and seismic sections. Finally, paleogeographic reconstructions highlight the close relationship between structural framework and plan-view facies distribution, confirming the link between recent sedimentary evolution and deep stratigraphy.

Amorosi A., Pavesi M., Ricci Lucchi M., Sarti G. & Piccin A. (2008) - Climatic signature of cyclic fluvial architecture from the Quaternary of the central Po Plain, Italy. Sediment. Geol., 209, 58–68.

Picotti V. & Pazzaglia F.J. (2008) - A new active tectonic model for the construction of the Northern Apennines mountain front near Bologna (Italy). J. Geophys. Res., 113, B08412.

Pieri M. & Groppi G. (1981) - Subsurface geological structure of the Po Plain, Italy. P.F. Geodin., Publ. 414, C.N.R. Roma, 1-23.

Application of Outcrop Analogues in Reservoir Characterization and Modelling

Chiarella D.*

Clastic Sedimentology Investigation (CSI), Royal Holloway University of London, UK.

Corresponding author email: domenico.chiarella@rhul.ac.uk

Keywords: Outcrop analogues, subsurface, virtual outcrop, reservoir modelling.

The limited amount of subsurface data available to characterize subsurface reservoirs and de-risk uncertainty at different scale of observation represents one of the main challenges in exploration and production. A sound outcrop-based conceptual depositional model is key to reducing such uncertainties. In particular, outcrop analogues are key elements in the understanding of reservoir architecture and heterogeneities. Indeed, subsurface data often represent an extremely small fraction of the reservoir complexity (Chiarella et al., 2017; Rossi et al., 2017). Analogue data can be classified into four key types: *soft data*, which include information about the facies and their lateral and vertical relationship; *hard data*, which describe the dimensions and geometry of the geobody; *training images*, which record the dimensions, proportions and spatial relationship; and *analogue production data*, which provide data from direct subsurface production analogues (Howell et al., 2014). A step towards improving the applicability of outcrop analogues to subsurface case studies, has been the advent of Virtual Outcrop studies with the development of LiDAR and photogrammetric based acquisition systems. Virtual outcrops allow filling the gap between facies and seismic scales in a 3D environment and have the advantages of (i) analysing outcrops completely or partially inaccessible; (ii) obtaining a larger and more representative number of measurements; and (iii) being an effective space of fusion with other geological information in order to make more robust estimations. This has improved our ability to generate "reservoir models" of the outcrops, which can be flow simulated closing the loop between the outcrop and the subsurface. Further, the generation of synthetic seismic data from outcrops (e.g. Bakke et al., 2008) has also helped to close the gap between the outcrop analogue and the subsurface dataset. However, it is important to note that no two systems are identical and therefore the 'perfect' analogue does not exist. What we strive for is to combine studies from several partial analogues and to improve the conceptual geological model. In that respect, it is important to have clear in mind the purpose and scale of the study in order to select the appropriate analogues to incorporate.

Bakke K., Petersen A., Johansen T.A., Hustoft S., Jacobsen F.H. & Groth A. (2008) - Seismic modeling in the analysis of deep-water sandstone termination styles. AAPG Bulletin, 97, 1395-1418.

Chiarella D., Longhitano S.G. & Tropeano M. (2017) - Types of mixing and heterogeneities in siliciclastic-carbonate sediments. Mar. Petrol. Geol., 88, 617-627.

Howell J., Vassel Å. & Aune T. (2008) - Modelling of dipping clinoform barriers within deltaic outcrop analogues from the Cretaceous Western Interior Basin, USA. Geol. Soc. Lond. Spec. Publ., 309, 99–121.

Rossi V.M., Longhitano S.G., Mellere D., Dalrymple R.W., Steel R.J., Chiarella D., Olariu C. (2017) - Interplay of tidal and fluvial processes in an early Pleistocene, delta-fed, strait margin (Calabria, Southern Italy). Mar. Petrol. Geol., 87, 14-30.

From muddy to sandy contourites: insights into facies characterisation at core, well and seismic scales

De Castro S.*[1], Hernández-Molina F.J.[1], Rodríguez-Tovar F.J.[2], Llave E.[3], Mena A.[4] & Ng Z.L.[1]

[1] Royal Holloway University of London, UK. [2] Universidad de Granada, España. [3] Instituto Geológico y Minero de España, España. [4] Universidad de Vigo, España.

Corresponding author email: sandra.decastrosantos.2017@live.rhul.ac.uk

Keywords: Contourites, muddy, sandy, reworked turbidites.

The ability to differentiate contouritic from turbiditic facies is still an issue for the deep-marine sedimentologists. The models currently available for deep-water sedimentation bring us to the conclusion that they are inadequate to describe and interpret in reality the complexity of real depositional patterns developed by the interplay of alongslope and downslope sedimentary processes. Contourites show a greater spectrum of facies, which do not fix with the standard sequence, such as the enormous quantity and distribution of silts and sands. Between the two end members, as the sandy turbidites and sandy contourites, a number of intermediate variants could exist, as the Bottom Current Reworked Sands (BCRSs), where they show attributes of their respective facies depending on the interaction of dominant different sedimentological processes at the same time in a specific depositional environment. Furthermore, the wide range between fine- and coarse-grained contourites interlayering between hemipelagic or turbiditic deposits, concludes that a sedimentological approach in the characterisation of facies association involving core, well and seismic data, is needed. In order to try to solve the absence of widely accepted criteria to differentiate fine- and coarse-grained contourites from hemipelagic and sandy turbidites respectively at the core scale, we propose here a new and multidisciplinary approach to identify them and to establish their diagnostic criteria. This characterisation is based on the correlation between sediment recovered from Sites U1388 and U1389 from the Integrated Ocean Drilling Program (IODP) Expedition 339 along the southwestern Iberian Margin (SIM), within the Gulf of Cadiz and west of Portugal. These sites are located in the middle contouritic terrace, which is intersected by gravitational flow valleys in the central ridges/channels and proximal sectors of the Gulf of Cadiz, in the area close to the strait of Gibraltar, which is under the influence of the Mediterranean Outflow Water. Site U1389 is located in a mounded/sheeted drift, while U1388 in a large contouritic channel. From these two sites, six Pliocene-Holocene facies association models and their regional implications will be presented. This study is based on a correlation of grain size, microfacies, ichnological analyses and X-ray Florescence (XRF) scanning data as well as the correlation between reflection with seismic profiles across IODP Sites. The obtained results contribute to a better understanding of contourites and their interplay with other deep-water sedimentary processes. In addition, the studied deposits constitute recent / modern analogues of contourite systems which could be compared with similar ancient deposits and to evaluate their potential reservoir characteristics, as the examples recently identified in the Mozambique continental margin.

This project is funded by the Joint Industry Project supported by TOTAL, BP, ENI, ExxonMobil and Spectrum and is done in the framework of “The Drifters Research Group” at Royal Holloway University of London (RHUL).

Sequence and seismo-stratigraphy of deep-water fan systems: lessons from extensive outcrops and behind outcrop boreholes

Haughton P.*[1], Pierce C.[2], Obradors-Latre A.[3], Lacchia A.[1], Shannon P.[1], Barker S.[3] & Martinsen O.[3]

[1] Irish Centre for Research in Applied Geosciences (iCRAG) and UCD School of Earth Sciences, University College Dublin, Ireland. [2] CASP, Cambridge, United Kingdom. [3] Equinor ASA, Bergen, Norway.

Corresponding author email: peter.haughton@ucd.ie

Keywords: deep-sea fan, condensed sections, glacio-eustasy, ammonoids.

Seismic and sequence stratigraphy have revolutionised correlation in paralic and shelf successions, but deep-water settings have proved more challenging to subdivide and correlate using these tools. Many of the surfaces identified in shallower water stratigraphy are either poorly expressed, do not extend to, or are disconnected from related deep-water successions where parasequence-scale stacking patterns are absent and subtle autogenic changes in sea floor gradient can modify flow fields producing significant lateral compensation. Modern 3D seismic visualisation has revealed intricate details of the large-scale architecture of many deep-water systems, including stacking patterns in sandy deep-sea fans, but only where resolution and rock properties allow. There are many deep-water successions in the subsurface where seismic cannot offer much by way of internal detail or guidance as to fine-scale correlation and this is where outcrop analogues tied to borehole data and high-resolution biostratigraphy can provide value analogues and insights.

Here we focus on seismic-scale stratigraphy in well-exposed deposits in and behind high sea cliffs in the west of Ireland. Palaeo-equatorial Carboniferous basins of Europe and North America are characterised by striking shallow-water cyclothems that have been widely attributed to glacio-eustasy. Recent field observations, behind-outcrop cores and biostratigraphy support a new stratigraphic analysis of the 495 m thick Pennsylvanian Ross Fm, a down-dip, ice-house deep-sea fan and sheet system. The succession is composed of eight main units bound by condensed sections. The latter are variably expressed with those in the lower and upper Ross Fm forming prominent, albeit thin (m-scale), fine-grained intervals with a distinctive ammonoid assemblage and are interpreted to have draped the deep-water system and the surrounding confining slopes. They separate sheet (in the case of the lowermost cycle) and lobe complexes of the order of 60-70 m thick, a scale similar to younger Quaternary ice house eccentricity cycles. Mid-Ross Fm condensed sections are less well expressed, dcm rather than m-thick, commonly split or only locally preserved and they lack a diagnostic faunal assemblage. Although thin, they can be followed for 10s km, but locally interfinger with sandstones. They either bound similar duration (short eccentricity) cycles modulated by a longer term fall, or represent a higher frequency lowstand sequence set. A higher frequency 'beat' in the lower and upper Ross Fm is indicated by several hot shales contained in a single condensed section and subordinate condensed sections with a muted gamma response. The Ross condensed sections and associated intrafan mudstones are thin in comparison to other systems and by implication little fine-grained sediment reached the basin floor during highstands when sediment must have been sequestered in up-dip shorelines and coastal plains remote from the deep-water depocentre.

Modern geophysical interpretative approaches: A history in Between Seismic Geomorphology and Seismic Sequence Stratigraphy

Marini A.I.*, Lotti R. & Corrao A.

Eni.
Upstream & Technical Services, San Donato Milanese

Corresponding author email: alfonso.junio.marini@eni.com

Keywords: 3D, seismic stratigraphy, seismic geomorphology, neural networks, automated interpretation, seismic attributes.

The older generation of geologists and seismic interpreters can certainly recall the experiences of integrating stratigraphic data from wells to seismic sections, using well paper strips over seismic for tie, looking at reflection terminations, at internal and external geometries, and other visible characters to describe a seismic facies. Everything performed by pencils and ruler over papers; strictly on 2D profiles. Capture and managing stratigraphic information in three dimension was so a high demanding task to be handled manually, or even by a poor machine-support. The advent of 3D seismic in early 90's, generated as paradox a strong decrease of Seismic Stratigraphic interpretation projects, mainly by lack of 3D workflows and tools. Most of interpretation was structural, aided by amplitude values extraction over cube slices, to infer sedimentological pathways.The increase of graphic power after mid-90's didn't help for a whole 3D Seismic Stratigraphy; anyway imposed the concept of Seismic Paleo-Geomorphology from 3D visualization. Modern examples from near-Sea Bottom seismic images, particularly in Deep water, became used analogues to interpret fossil deposits in a more realistic mode. Geophysicists and sedimentologists increased the share of these experiences, and integrated more their disciplines. What's today's state of art? We will go through some examples form literature and oil industry experiences describing how geophysical technologies support sequence stratigraphic analyses. Seismic Geomorphology is still a powerful tool, since paleo-morphology and morphometrics are very suggestive information about type of deposits and analogues recalling. 3D visualization is not anymore a "nice to have" but a "must". Information Technology innovation facilitated a realistic Seismic Stratigraphy. First of all the access to seismic imaging, inversion and deconvolution techniques, for a better focus, higher resolution, supportive attributes and evocative images. Enhancers as spectral decomposition, satellite images processing techniques, or co-rendering, allows the straight extraction of more geological information from seismic 3D cubes. Faster and precise pattern recognition for automated seismic facies analyses can get advantage of recent Machine Learning developments, to describe both internal and external reflectors geometries. Second, generate an evolutionary and predictive geological model by sequential scans of images. Higher resolution interpretation systems are the modern workstation to depict sedimentary and structural changes in a relative geological time interval. Sequences and systems tracts virtualization fully replace nowadays the use of old-fashioned sketches. Finally, the capture and description of 3D voxel-based Geo-objects, is the base to speed up interpretation and analyses of sedimentary bodies for a more effective, realistic, and truly geological O&G exploration and exploitation.

Stratigraphy to Seismic (StS™) and Stratigraphic Forward Modelling (SFM) in the offshore of Cameroon: insights into the prospectivity of the margin through detailed integration of biostratigraphic and seismic data

Pardon A.*[1], Cetean C.[1], Loule J.P.[2], Gold D.P.[1], Angoua Biouele S.E.[2], Spofforth D.[3], Nguema P.[2], Culwick S.[3], Jifon F.[2] & Nformi E.[3]

[1] CGG Robertson. [2] Societe Nationale Des Hydrocarbures (SNH). [3] CGG MCNV, Geospec.

Corresponding author email: andrea.pardon@cgg.com

Keywords: Biostratigraphy, Seismic, Integration, stratigraphic forward modelling.

Stratigraphic reviews have been carried out on data from 12 offshore wells from Cameroon, located in the Douala and Kribi-Campo Sub-basins. The reviews incorporate all available biostratigraphic and lithological data, together with wireline logs, and selected data from drilling and geological reports. Ten of the study offshore wells were selected for Stratigraphy to Seismic (StS™) analysis, whereupon the geological well interpretations are tied to the seismic via a series of pseudo-wireline logs. The study wells contain significantly variable sediment thicknesses with a number of both regional and localised hiatuses identified by the discontinuity curve from Stratigraphy to Seismic (StS™). The technique confirmed that regionally, unconformities are present between Cretaceous sediments of the Logbaba Formation and Paleocene sediments of the N'Kapa Formation, with latest Maastrichtian and earliest Danian sediments missing as a minimum. The Paleogene to Neogene sediments are highly variable in thickness and contain a significant number of intra-formational breaks. A significant regional unconformity accounts for the absence of the Late Eocene, Priabonian and Early-Late Oligocene, Rupelian-Chattian of the Souellaba Formation in many of the study wells. The Middle Miocene regional unconformity has been identified across the study dataset, corresponding with the Serravallian-Langhian boundary. Seismic data over the Cenozoic interval of interest display progradational clinoform geometries. The high-resolution biostratigraphic analyses conducted over this interval constrained the ages of these depositional sequences and the palaeobathymetry in which they were deposited in. This information was used to build a fully quantitative three-dimensional stratigraphic forward model, constrained by well and seismic data, which successfully replicated the clinoform geometries and predicted the spatial distribution of facies leading to a greater understanding of the stratal evolution of the Douala and Kribi-Campo Sub-basins. Through the integration of seismic and biostratigraphic data, together with stratigraphic forward modelling, greater insights into the geological evolution of the area can be gained, leading to a reduction in exploration risk.

The late Pleistocene Po River lowstand wedge in the Adriatic Sea: controls on architecture variability and sediment partitioning

Pellegrini C.*[1], Asioli A.[1], Bohacs K.M.[2], Drexler T.M.[3], Feldman H.R.[3], Sweet M.L.[4], Tesi T.[1], Rovere M.[1], Gamberi F.[1], Maselli V.[1], Scarponi D.[5], Dalla Valle G.[1] & Trincardi F.[1]

[1] Institute of Marine Science (ISMAR-CNR), Bologna, Italy. [2] KMBohacs Geoconsulting, Houston, Texas, USA.[3] ExxonMobil Exploration Company, Spring, USA. [4] ExxonMobil Upstream Research Company, Spring, USA. [5] Dipartimento di Scienze Biologiche, Geologiche e Ambientali, University of Bologna, Italy.

Corresponding author email: claudio.pellegrini@bo.ismar.cnr.it

Keywords: continental margin, Quaternary geology, clinothems, sediment partitioning and prediction, paleoenvironmental reconstruction, sequence stratigraphy.

This study investigates the Adriatic sedimentary succession deposited during the Last Glacial Maximum (~17 kyr long) nourished by the ancestral Po River system. By using a multidisciplinary approach, we show clinothem characteristics, stacking patterns, and controls through the integration of seismic-reflection data with sediment attributes, paleontology, regional climate, eustasy, and high-resolution age control possible only in Quaternary sequences. The 350-m thick succession of the Po River Lowstand Wedge (PRLW) contains stratal architecture at a physical scale that is commonly attributed to much longer time intervals, with complex, systematically varying internal clinothem characteristics. Within the PRLW, three clinothem types are characterized by distinctive topset geometry, shelf-edge and onlap-point trajectory, internal seismic facies, and interpreted bottomset deposits: Type A) moderate topset aggradation, moderately ascending shelf-edge trajectories, and thin mass-transport bottomset deposits, Type B) eroded topset, descending shelf-edge trajectories, and bottomset distributary channel-lobe complexes, and Type C) maximal topset aggradation, ascending shelf-edge trajectories, and draped concordant bottomsets. Measured sediment accumulation rates suggest that Type A and C clinothems had reduced sediment bypass and delivery to the basin, whereas Type B clinothems were associated with short intervals of increased sediment export from the shelf to deep water and formation of distributary channel-lobe complexes. This interpretation is supported by micropaleontological analysis that highlight increased delivery of sediment and fresh water to the basin during the progradation of Type B clinothems, as suggested by the reduced frequency of *Cassidulina laevigata carinata* and the peak frequency in the abundance of *Nonion* species. All clinothems formed in very short interval, from 0.3 to 4.7 kyr, contemporaneous with significant eustatic and climate changes, but their stacking patterns resemble those of ancient successions with significantly longer duration indicating that: 1) the response time of ancient continental-margin-scale systems to high-frequency variations in eustasy and sediment supply could be as short as centuries, 2) even millennial- to centennial-scale stratal units can record substantial influence of allogenic controls, 3) sandy deposits at the slope base can be compartmentalized even in a short-duration lowstand systems tract, and 4) clinothems display either in sub-rounded or elongated depocenters denoting a varying influence of marine processes in controlling along-shore sediment dispersal. These notions can be used in ancient records to broaden the interpretation range where chronological resolution is inherently limited.

Workflow for seismic geomorphology analysis of a carbonate platform: unraveling the complexity of carbonate reservoir architecture

Ricci S.*, Borromeo O. & Brioschi L.

Eni SPA.

Corresponding author email: simone.ricci@eni.com

Keywords: seismic geometries, facies associations, carbonate platform.

The integration of subsurface data, such as the analysis of seismic geometries and seismic attribute response, in conjunction with well data and outcrop analogues is a key workflow to unravel the complexity of carbonate reservoir architecture through seismic geomorphology analysis. Interpretation of seismic geometries and facies helps us to make assumptions on depositional settings and spatial geometry of sedimentological facies associations for reservoir characterization and well planning. The first step is to map the key seismic reflectors in order to separate the main seismic sequences. Carbonate platforms evolve following different patterns which can be highlighted thanks to detailed thickness maps. Line drawing and morphological picking allow to detect clinoforms and flexure points in order to highlight the platform growth stages: aggradation, aggradation/progradation, progradation. Well biostratigraphic information, combined with log data, provide the main chronostratigraphic framework and a stratigraphic control on seismic at specific depth. The further step involves careful analysis of rock samples (cores, cuttings), which provides data on mineralogy, paleontology, textures, grain composition, paragenetic evolution and pore network, all needed to define a depositional framework and the impact of diagenetic modifications on reservoir properties. Seismic attributes and seismic character analysis (i.e. chaotic features, bright localized high amplitude features etc) are very important to determine the presence of karsts, or they may help to identify key morphological features (i.e. fractures pattern, location of the lagoon and the margin reef/slope). Integration of outcrop information, in terms of geometry and size of depositional bodies, offers the opportunity to make consistent assumptions on facies distribution, starting from an analogue to the subsurface case. In summary, the workflow for seismic geomorphology analysis of carbonate platform involves a strong in-depth integration between seismic, well, and outcrop information. Only by combining different types of data it is possible to properly investigate the carbonate platform reservoir architecture for facies prediction and reduction of the exploration risk.

Along-strike variability of regional submarine unconformities: how far can we go to assess the actual importance of subtle discontinuities in the stratigraphic record?

Rossi M.*

Eni Upstream & Technical Services, Italy

Corresponding author email: massimo.rossi@eni.com

Keywords: Submarine unconformity, sequence stratigraphy, seismic stratigraphy, hinged shelf margin, digital outcrop model, 3-D seismics.

A new type of regional submarine unconformity developing in shelf margin wedges and associated with networks of erosional surfaces has been recently described in outcrop and subsurface (Rossi et al., 2018). As opposed to localized, small and episodic subaqueous erosions occurring on relatively stable continental margins characterized by fairly continuous hemipelagic successions, such erosional surfaces develop along hinged margins undergoing increasing rates of tectonic accommodation, resulting in unconformities generated by the tilting and destabilization of shelves and slopes and laterally traced for hundreds of km. As opposed to the classical sequence boundaries driven by relative sea-level falls, they result from the drowning of shelf margins driven by basin reshaping, and pass laterally into paraconformities associated to stratigraphic lacunae of regional extent. This lateral variability adds further complexity to the simple 2D current sequence-stratigraphy paradigm (Burgess, 2016) implying that the erosional and non-depositional components of stratigraphic lacunae may often be decoupled and not necessarily decreasing seaward as usually argued. Such unconformities develop in synorogenic, strike slip and marine rift basins experiencing rapidly increasing and laterally changing subsidence rates. Seaward or landward tilting is common, causing hinge lines separating areas with different accommodation rates. Moving hinges (Madof et al., 2016) prevail on fixed ones due to morphostructural reorganizations, including rotation of structural trends either of local or regional significance. In such settings, networks of subaqueous erosional surfaces create a scalloped shelf-basin transition contrasting with the more regular and laterally persistent sigmoidal geometries exhibited by prograding continental margins. Features extending from collapsed shelfedges into oversteepened ramps include enhancement of ravinement surfaces, deepening and reshaping of incised valleys, gullies, sliding and large coalescing slump scars. Examples from actively-deforming basins will be looked through their outcrop and subsurface expressions, including the Tertiary Piedmont Basin (NW-Italy) where some of the Middle-Late Miocene stratotypes were established, discussing the tectonic unconformities generated meanwhile the Apennines were overriding the Alps. Focus is on type, variability and lateral extent of stratigraphic lacunae associated with such overlooked unconformities, showing the potential offered by digital outcrop models and 3D seismics to assess their actual importance.

Burgess P.M. (2016) - The future of the sequence stratigraphy paradigm: Dealing with a variable third dimension. Geology, 44, 335-336.

Madof A.S., Harris A.D. & Connell S.D. (2016) - Nearshore along-strike variability: Is the concept of the systems tract unhinged? Geology, 44, 315-318.

Rossi M., Minervini M. & Ghielmi M. (2018) - Drowning unconformities on hinged clastic shelves. Geology, 46, 439-442.

Integrated seismic- and sequence-stratigraphic characterization of a Lower Miocene fluvio-deltaic reservoir in the Maturin basin forebulge (Venezuela)

Skrynnikova A.*, Rossi M., Marini I., Corrao A., Torricelli S. & Balossino P.

Eni Upstream & Technical Services.

Corresponding author email: anna.skrynnikova@eni.com

Keywords: Detailed deposition model, petrophysical evaluation, advanced seismic interpretation, Maturin Basin, Orinoco Belt.

An integrated G&G study was carried out to generate a detailed depositional model of a heavy-oil field in the Orinoco belt. The reservoir was deposited during the Early Miocene in the Maturin Basin crossed by the paleo-Orinoco drainage system. The project challenge was to establish a reservoir layering based on petrophysical and image logs, core data and a 2D regional seismic grid. The first part of the study was aimed at understanding the relationships between seismic and well data according to spectral and S/N quality, synthetic seismograms to seismic tie, and TWT-Depth relationships, enabling well markers to be positioned on the correct seismic events. Following the first seismic interpretation run, it was clear that seismic resolution was not enough to tackle with target object sizes and their areal distribution. Therefore, seismic data were preconditioned using SVD (Singular Value Decomposition) and a Sparse Deconvolution technique was used to recover a broadband spectrum from the conventional seismic dataset. The process, based on the estimation of approximate reflectivity series, resulted in enhancing previously hidden geometries, whose realistic nature was validated by a high resolution well to seismic tie, including major erosional unconformities and increasing accommodation surfaces. The redefined sequences, systems tracts and genetically-related depositional systems show a coherent signature deriving from the comprehensive view of palynological, sedimentological and seismic features, well log stacking patterns and paleocurrent data from image logs. The stratigraphic framework and architecture highlighted a network of paleovalley/incised valley-fills separated by interfluves directly overlain by transgressive facies. The unconformable vs. paraconformable nature of bounding surfaces could be imaged. The obtained seismic resolution enabled to determine location, extent and geometry of the valleys, as well as their relatonships with syn-depositional faults. High-quality fluvial reservoirs are bounded at the base by a sequence boundary related to a base-level fall, and topped by an increasing-accommodation surface. Tidal ravinement surfaces are overlain by sand-prone to heterolithic facies, capped by a maximum flooding surface. Highstand deposits are often truncated or only partly preserved due to erosion caused by the next sequence boundary. More marine conditions occur in the upper part of the reservoir, where growth-faults controlled the local occurrence of delta front sandbodies with excellent reservoir properties. The timing of the faults, assessed on the basis of the local accommodation generated in different sequences, is variable and spans throughout the whole succession, implying a combination of structural compartmentalization and facies heterogeneity. Such a stratigraphic complexity resulted in variable water saturation, hydrocarbon types and pressure gradients, highlighting the presence of hydraulically-separated sandbodies.

Seismic Attributes Stratigraphy

Tellus S.*

Independent researcher.

Corresponding author email: sunjaytellus@gmail.com

Keywords: Seismic Stratigraphy, Seismic Geomorphology, Seismic Attributes, Seismic Sequence Analysis, Basin Stratigraphy.

Stratigraphical analysis -seismic stratigraphy involves the subdivision of seismic sections into sequences of reflections that are interpreted as the seismic expression of genetically related sedimentary sequences. Seismic sequence analysis, reflections are taken to define chronostratigraphical units, since the types of rock interface that produce reflections are stratal surfaces and unconformities; by contrast, the boundaries of diachronous lithological units tend to be transitional and not to produce reflections. Sedimentary sequences are typically bounded by angular unconformities variously representing onlap, downlap, toplap or erosion Layer-thickness determination and stratigraphic interpretation using spectral decomposition inversion using Local wavelet attributes (amplitude, phase and scale) for geological characterization, Geometric wavelet transform curvature attributes interpretation submarine channels for defining stratigraphic features of interest on horizons mapped in three-dimensional seismic data. Interpretation of seismic sections: structural analysis- reflector geometry on the basis of reflection times, and stratigraphical analysis (or seismic stratigraphy)- reflection sequences as the seismic expression of lithologically distinct depositional sequences. Seismic waves propagating in randomly multilayered media are subjected to stratigraphic filtering, whose physical reason is the multiple scattering by 1-D inhomogeneities. The direct consequence of multiple scattering is the wave localization, which appears approximately as an exponential attenuation of transmitted waves. Application of seismic geomorphology and stratigraphy of depositional elements in deep-water settings, detailed seismic interpretation and analysis of key stratal discontinuities- Seismic incision features interpreted as channels, continental slope and base-of-slope systems, for frontier hydrocarbon exploration-arctic petroleum systems. High resolution seismic stratigraphy using sub-bottom profiler (SBP) Acoustic Stratigraphy, for extracting the Quaternary facies by the Hilbert Huang transformation (HHT) nonlinear nonstationary chirp signal.

Unravelling the complex stratigraphy of one of Europe's largest oil fields (Schoonebeek) using palinspastic seismic reconstruction and well data

Vis G.-J.*[1], Smoor W.D.[2], Rutten K.W.[3], De Jager J.[2] & Mijnlieff H.F.[1]

[1] TNO - Geological Survey of the Netherlands. [2] VU University Amsterdam, the Netherlands. [3] Slokkert Consultancy, the Netherlands.

Corresponding author email: geert-jan.vis@tno.nl

Keywords: Early Cretaceous, tectonic control, the Netherlands, sandstone, reservoir.

The Schoonebeek oil field was discovered in 1943 and contained 164 mln m3 (1 bln bbl) STOIIP of oil (Vejbæk et al., 2010), making it one of Europe's largest oil fields. The sandstones of the Bentheim Sandstone Member form the reservoir rock of the field. While the sedimentology and depositional environment of the Bentheim Sandstone Member have been extensively studied, the relationship between sandstone geometry and tectonic activity in the Schoonebeek area remains poorly understood. Using the ezValidator software package (Rutten, 2004) we made palinspastic reconstructions for the Schoonebeek area based on seismic 3D data. This allowed us to unravel and clarify the stratigraphy and the local vertical movements of the Schoonebeek field. Additionally, we used 355 boreholes to study thickness and stratigraphic detail. We identified an eroded zone in the west of the field and an area where the original depositional thickness of the Bentheim Sandstone Member is still intact. Uplift of a local anticline played an important role in the erosion of the sandstone. Deposition of the sands of the Bentheim Sandstone Member and the overlying Vlieland Sandstone and Claystone formations occurred on an unstable changing palaeo-topography. The instability was probably driven by halokinetic movement of the underlying Late Permian Zechstein salt. Syn-depositional tectonic movements affected local thickness variations in the Bentheim Sandstone Member in the west of the field, leading to westward thinning. Other thickness changes of the Bentheim Sandstone Member were gradual, without correlation to closely spaced fault patterns.

Rutten K.W. (2004) - Validating Seismic Correlations by Unfaulting and Multi-Horizon Flattening. 66th EAGE Conference & Exhibition. EAGE, Paris.

Vejbæk O.V., Andersen C., Dusar M., Herngreen G.F.W., Krabbe H., Leszczyñski K., Lott G.K., Mutterlose J. & Van der Molen A.S. (2010) - Cretaceous. In: Doornenbal J.C. & Stevenson A.G. (eds) Petroleum Geological Atlas of the Southern Permian Basin Area. EAGE Publications b.v., Houten, 195-209.

Sedimentary and Stratigraphic Characterisation of Key Pre-Salt Reservoirs, Offshore Kwanza Basin, Angola

Wilson T.* & McAfee A.

Core Laboratories UK.

Corresponding author email: tom.wilson@corelab.com

Keywords: sedimentology, stratigraphy, Angola, pre-salt, cyclostratigraphy.

Detailed integration of sedimentology, biostratigraphy and cyclostratigraphy from onshore, shelfal and deepwater wells in the Kwanza Basin has provided useful insights into the Pre-Salt evolution of the Angolan Margin, allowing additional calibration of key surfaces and depositional packages observed on regional seismic. Tectono-stratigraphic evaluation of the rock succession across the margin reveals two main rift packages, Neocomian Rift 1 & Barremian – Early Aptian Rift 2, a 'Rift Transition Phase' (Early Aptian Rift T3) is also present which sits above a regional unconformity and below the salt. Along the onshore and inboard rift margin it is possible to map both sand-rich and mud-dominated packages associated with each of these three main tectonic phases, but in the sand-poor shelfal and deepwater domains the stratigraphy is more complex. Here, the late rift and rift transition succession is subdivided into 'Lower Sag' and Upper Sag' packages that are widely recognized on seismic. The base of the sag phase is identified as a prominent regional surface (K38 in Petrobras scheme) separating the highly faulted syn-rift grabens below, from the relatively unfaulted broader basins above. Biostratigraphic (ostracods and miospores) and sedimentological data from recently drilled deepwater wells & legacy shelfal wells have been combined with cyclostratigraphic techniques to identify correlatable sequences. A number of higher resolution lacustrine flooding surfaces have also been recognised during the cyclostratigraphic analysis, which facilitate recognition of the 'Upper Rift' and 'Sag' packages seen on seismic. Regional paleogeographic mapping of the sequences has highlighted the importance of structural and volcanic features in controlling the location and quality of sandstone and carbonate reservoirs in the rift basin. It is observed that the 'Base Sag Surface', recognisable on seismic in the offshore domain, appears to coincide with a major regressive surface within inboard and shelfal wells. These wells are located close to fault-controlled sand feeder systems. Elsewhere in the shelfal domain carbonate-prone locations show increased interbedding of claystones relative to the underlying Rift 2 package and a gradual change from mainly dolomite (below) to mainly limestone (above). In the deep-water areas starved of sediment microbialite carbonates developed above the 'Base Sag surface', these sediments are associated with increasingly saline / alkaline lacustrine conditions.

ST8.2

Integrated bio- and chemo-stratigraphic approaches in a subsurface perspective: industrial and academic applications

Conveners and Chairpersons

Andrea Piva (ENI S.p.A.)

Elena Menichetti (Università di Urbino)

Evidence of sub-millennial paleoceanographic variability during Sapropel 1 in the Adriatic basin by a multidisciplinary approach

Asioli A.*[1], Pellegrini C.[1], Schieber J.[2], Minisini D.[3], Tesi T.[1] & Trincardi F.[1]

[1] CNR, Istituto di Scienze Marine, Sede Bologna, Italy. [2] Indiana University, Bloomington, Indiana, USA. [3] Shell Technology Center Houston, Houston, TX, USA.

Corresponding author email: alessandra.asioli@bo.ismar.cnr.it

Keywords: Sapropel1, foraminifera, $\delta^{18}O$, XRF, Adriatic, Holocene.

Three cores collected along a shelf-basin transect in the Central and Southern Adriatic (260-1085 m w.d.) were studied from the base of the Holocene (ca. 12kyrs BP) to 6 kyrs BP, which includes the deposition of Sapropel 1. Oxygen stable isotopes, planktic and benthic foraminifera, and excess of sulphur (S/Ti ratio as proxy of reduction condition) analysis revealed oscillations between markedly different oceanographic regimes, at sub-millennial scale. These short-term oscillations, well described by the $\delta^{18}O$ *Globigerina bulloides* record, start at ca. 9.2 kyrs BP within Sapropel 1a, just after the culmination of a trend of decreasing values of $\delta^{18}O$ since the base of the Holocene. Intervals of reduced abundance of warm planktic foraminifera correlate with shifts to heavier $\delta^{18}O$, suggesting temperature as an important factor that forced the oscillations. Two of these oscillations, centred at 8.2 and 7.5 ka, ca, can be related to well-known Holocene oscillations, while the others may correlate oscillations recorded in Oman caves that reflect intervals of reduced precipitation/Nile hydrological activity, which in turn affected the ventilation in the Mediterranean Levantine basin. The benthic foraminifera record of the southern Adriatic sediment core collected in a muddy contourites drift impacted by thermohaline circulation (Levantine Intermediate Water, LIW)/off-shelf cascading (North Adriatic Deep Water) indicates a recovery of deep ventilation during some of these $\delta^{18}O$ oscillations. This is also suggested by the S/Ti ratio, showing minor sulphide reduction. Partial recovery of LIW production also may occur during shifts to heavier $\delta^{18}O$, as also suggested by the presence of epibenthic taxa (Schonfeld, 2002), indicating somehow while dense water (NAdDW) cascading is indicated by reworked shelf benthic taxa. Epoxy stabilized thin sections from unconsolidated mud samples show imbricated rip-up clasts or pervasive bioturbation within laminated deposits during two shifts toward heavier $\delta^{18}O$ values, both suggesting enhanced bottom circulation. All these observations document an onset of sub-millennial paleoenvironmental instability within the Sapropel 1a interval, and lasting at least until 6ka ca.

Schonfeld J. (2002) - A new benthic foraminiferal proxy for near-bottom current velocities in the Gulf of Cadiz, northeastern Atlantic Ocean. Deep-Sea Res. I, 49, 1853–1875.

The $\delta^{13}C_{carb}$ record as a chemostratigraphic tool in correlating organic matter rich carbonates - case study from the Maastrichtian-Danian oil shales of Jordan

Beik I.*[1], Giraldo-Gómez V.[2], Podlaha O.[3] & Mutterlose J.[1]

[1] Ruhr-Universität Bochum, Germany. [2] University of Milan, Italy. [3] Shell Global Solutions International B.V., The Netherlands.

Corresponding author email: Ibtisam.Beik@rub.de

Keywords: carbon isotope stratigraphy, Maastrichtian-Danian, oil shales, diagensis.

Stable carbon isotopes are employed as a significant chemostratigraphic tool used in local to cross-regional correlations for Cretaceous strata worldwide. The sensitive nature of the $\delta^{13}C_{carb}$ signal to diagenesis acquires caution when samples are being selected and interpretations made. Typically, biospecies such as foraminifera, belemnites or the secondary layer of brachiopods are being utilized to provide pristine carbonate material (e.g., Zachos et al., 2001). These are believed to be the least altered and hence display the closest to the original sea water carbon isotope signal. Otherwise, whole rock samples of carbonates that consist of almost single species accumulations, e.g., the Chalks of Denmark or Britain have been investigated (e.g., Korte et al., 2009). In such cases, slight negative shifts in the $\delta^{13}C_{carb}$ have been observed due to the effects of diagenesis. Nevertheless, such records remain readily used in correlating sections exhibiting carbon excursion events of variable magnitude. In this study, an attempt to correlate Maastrichtian-Danian organic matter (OM) rich marls (oil shales) from two Jordanian sections with records from deep pelagic successions deposited in the tropical realm is made within a combined stratigraphic framework based on calcareous nannofossils and the $\delta^{13}C_{carb}$ record. Typically, the oxidation of the OM in sediments is a source for ^{12}C enrichment in the secondary carbonate mineral phases. CO_2 derived from OM oxidation dissolves and alters the pH of the porewater. This can lead to primary carbonate dissolution, and with ongoing burial oversaturated pore fluids from which a secondary carbonate mineral phase precipitates. The result is a ^{13}C depleted isotope signal in comparison to the original primary carbonate (Scholle and Arthur, 1980). To tackle this matter in the Jordanian marls, a simple isotope mass balance equation for calculating isotopic abundances in pools was employed to derive the amount of TOC oxidized post-depositionally and subsequently incorporated into the carbonate mineral phases. As a result, major globally recognized carbon excursion events have been cautiously delineated for the Maastrichtian and the Danian successions from Jordan. These include parts of the Campanian-Maastrichtian boundary Event, the Middle Maastrichtian Event, the Cretaceous-Paleogene Event, and potentially the Latest Danian Event.

Korte C., Hesselbo S.P., Jenkyns H.C., Rickaby R.E. & Spötl C. (2009) - Palaeoenvironmental significance of carbon- and oxygen-isotope stratigraphy of marine Triassic–Jurassic boundary sections in SW Britain. J. of the Geological Society,166, 431-445.

Scholle P.A. & Arthur M.A. (1980) - Carbon Isotope Fluctuations in Cretaceous Pelagic Limestones: Potential Stratigraphic and Petroleum Exploration Tool. AAPG Bulletin, 64, 67-87.

Zachos J., Pagani M., Sloan L., Thomas E. & Billups K. (2001) - Trends, Rhythms, and Aberrations in Global Climate 65 Ma to Present. Science, 292, 686-693.

C-isotope stratigraphy and outcrop based ɣ-ray measurements of the Natih Formation in Jabel Akdhar area of Oman: a mean to improve surface to sub-surface correlation

Frijia G.*[1], Scharf A.[2], Morsilli M.[1], Humood Salim N.[2], Belushi A.[2] & Struck U.[3]

[1] Dipartimento di Fisica e Scienza della Terra, Università di Ferrara, Ferrara, Italy. [2] Department of Earth Sciences, Sultan Qaboos University, Muscat, Oman. [3] Museum für Naturkunde, Berlin, Germany.

Corresponding author email: gianluca.frijia@unife.it

Keywords: ɣ-ray profiles, C-isotopes, correlations.

The upper Albian to Lower Turonian Natih Fm. of Oman (and equivalent stratigraphic formations in the Arabian Peninsula) is one of the most studied, prolific source rock interval and hydrocarbon reservoirs of the country. It rests conformably on the Lower Cretaceous carbonate/clastic Nahr Umr Fm. whereas its top is marked by a regional unconformity known as Aruma-Wasia Break. Beside this major unconformity the deposition of the Natih Fm. was interrupted several times by subaerial exposures with emersion and incision. All these erosional events caused locally different stratigraphic patterns making a precise correlation of this formation from East to West and from subsurface to surface somewhat challenging. The Natih Fm. has been subdivided in the subsurface into seven informal members (g to a, from bottom to top) based on cores and on characteristics pattern of gamma-ray and density log curves. The adaptation of this subsurface nomenclature into surface lithostratigraphic "members" is extensively used mainly because of the need to study outcrop sections as analogues of the subsurface. However, correlations among members are not quite straight forward. Significant heterogeneity in platform growth associated to complex diachronous infill of accommodation and erosional episodes can be found from East to West of the Jabal Akhdar. Furthermore, the lithological properties and boundaries of these members can locally be very confusing and a rock outcrop-comprehensive description of them is still lacking, thus, hampering a precise comparison with well data. The aim of the study is to integrate high resolution outcrop-based C-isotopes and ɣ-ray profiles throughout Natih Fm. members "e" to "a" in order to build a solid stratigraphic framework. The studied sections are located in the southern part of the Jabel Akdhar area and represent an ideal transect from platform top to intrashelf setting. The obtained scheme will serve as reference for the Natih Fm. in surface sections and will be anchored to detailed facies analyses and bioevents. This will in turn result in high-resolution correlation with subsurface data improving the understanding of the hydrocarbons field in term of the geometry of the depositional system and lateral facies evolution and heterogeneities. Finally, our stratigraphic scheme could help to clearly define and precise the boundaries of the "informal" Natih members.

Aptian age to post-salt section in brazilian Southeastern coastal basins: new biochronostratigraphic insights about South Atlantic evolution

Lima F.H.O.*[1], Sanjinés A.E.S.[1], Maizatto J.R.[1], Ferreira E.P.[1], Ng C.[1], Costa D.S.[1], Zerfass G.S.A.[1], Alves C.F.[2], Strohschoen Jr O.[1], Viviers M.C.[3], Lana C.C.[2], Arai M.[4], Beurlen G.[1] & Shimabukuro S.[1]

[1] Research & Development Center - Petrobras. [2] Rio de Janeiro Federal University. [3] Pernambuco Federal University. [4] São Paulo State University.

Corresponding author email: henriquel@petrobras.com.br

Keywords: Aptian, South Atlantic Ocean, Microfossils, Brazil.

Current chronostratigraphic charts from Santos, Campos and Espírito Santo basins point to an Albian age for the post-salt rocks which comprises the first marine sedimentation in the embrionic South Atlantic Ocean (Milani, 2007). The biozones supporting this age assignment were defined in a shallow marine context, mainly represented by high-energy carbonates. Under these depositional conditions, important index planktonic microfossils were absent, precluding accurate global and chronostratigraphic correlations. Since 2007, new biostratigraphical data (Lima et al., 2018; Viviers et al., 2018) provided by samples from deep and ultra-deep waters drilling campaign, unravel a microfossil assemblage older than previously assumed. The recovered assemblages include more than 30 Aptian species of planktonic foraminifera. Based on their distribution, were recognized the global Late Aptian G. ferreolensis to P. rohri biozones above the evaporites. In addition, the systematic analyses of microfossils on thin sections, allowed the identification of bioevents correlated to the succession of biohorizons present in the Aptian-Albian boundary of other marine basins around the world, such as the Gulf of Mexico and the Carparthian basins. Additionally, the calpionellids C. recta and C. mexicana; calcispherulids C. ex gr. semiradiata and C. heliosphaera; incertae sedis M. diversus; and foraminifera on thin sections all occur in this interval. Aptian species of calcareous nannofossils were described, N. troelsenii and B. pseudobatilliformis (Alves et al., 2107. As well, among miospores C. cearensis, Q. reticulatus, T. reticulatus, D. microfoveolatus, S. tenuiverrucata and E. maculosus were spotlight linked to miospores whereas dinoflagellates were represented by P. securigerum and “S./P. santosense”. The integrated studies carried out on planktonic foraminifera, nannofossils, palynomorphs and microfossils on thin sections, point to an Aptian marine sequence up to 800m thick above the evaporites. The presence of such microfossil assemblages in Brazilian southern coastal basins implies that there were deep marine conditions 5 to 10Ma older than previous assumptions.

Alves C.F., Lima F.H.O. & Shimabukuro S. (2017) - New Aptian calcareous nannofossil species from Brazil. Jour. Nannoplankton Res., 37(1), 15-23.

Lima F.H.O., Sanjinés A.E.S., Maizatto J.R., Ferreira E.P., Ng C., Costa D.S., Zerfass G.S.A., Alves C.F., Strohschoen Jr. O., Viviers M.C., Lana C.C., Arai M., Beurlen G., Shimabukuro S. & Galm P.C. (2018) - Aptian marine post-salt rocks in Santos, Campos and Espírito Santo basins, Brazil: a biochronostratigraphical approach. Cong. Brasil. Geol., 49, Abs. 1:2023.

Milani E.J. (Coord.) (2007) - Cartas estratigráficas. Bol. Geoc. PETROBRAS, 15(2), 1-573.

Viviers M.C., Sanjinés A.E.S., Costa D.S., Zerfass G.S.A., Beurlen G. & Strohschoen Jr. O. (2018) - Aptian planktonic foraminifera occurrence in the southeastern Brazilian marginal basins. Cong. Brasil. Geol., 49, Abs. 1:2027.

Earlier South Atlantic marine ingression in brazilian Southeastern basins, based on Aptian planktonic foraminifera evidences

Sanjinés A.E.S.*[1], Viviers M.C.[2], Costa D.S.[1], Zerfass G.S.A.[1], Johnsson C.C.[1], Strohschoen Jr O.[1], Beurlen G.[1] & Lima F.H.O.[1]

[1] Research & Development Center - Petrobras.
[2] Pernambuco Federal University.

Corresponding author email: henriquel@petrobras.com.br

Keywords: Aptian, South Atlantic Ocean, Planktonic Foraminifera, Brazil.

Petrobras exploratory offensive carried out in the 2000s in deep and ultra-deep waters allowed the recovery of a rich Aptian planktonic foraminifera assemblage from the Brazilian southeastern basins. This new data lead to a revision of 26 wells drilled through the post salt section, which recovered sediments related to Camburi, Macaé and Barra Nova Groups in Santos, Campos and Espírito Santo basins, respectively. From the analysis of cutting samples, core and sidewall core samples, more than 30 Aptian species were identified. The diagnostic assemblage is mainly composed by Favusella ex. gr. washitensis, Hedbergella gorbachikae, H. aptiana, H. kuznetsovae, H. luterbacheri, H. maslakovae, H. praetrocoidea, H. ex gr. sigali, H. excelsa, H. infracretacea, H. occulta, H. similis, H. trocoidea, Globigerinelloides aptiensis, G. ferreolensis, G. blowi and G. barri. In addition, scarce specimens of Paraticinella rohri and P. transitoria were registered. This fauna is similar to assemblages previously described by different authors (Longoria, 1974; Koutsoukos, 1992; Huber & Leckie, 2011; Petrizzo et al., 2012), showing a biogeographic affinity between the studied basins with Tethyan and other Atlantic basins. Biostratigraphically, the planktonic foraminifera assemblage corresponds to the set of the Globigerinelloides ferreolensis, G. algerianus, Hedbergella infracretacea and Paraticinella rohri biozones, related to Late Aptian age (Ogg et al., 2016). The recognition of a typical Aptian planktonic foraminifera assemblage in the post salt section, previously attributed to Albian, indicate that marine conditions in Brazilian southeastern basins were established earlier than previously assumed. Consequently, part of the marine section is now assigned to a Late Aptian age. These results imply directly in the timing of South Atlantic Ocean basins evolution.

Huber B.T. & Leckie R.M. (2011) - Planktic foraminiferal species turnover across deep-sea Aptian/Albian boundary sections. Journal of Foraminiferal Research, 41(1), 53–95.
Koutsoukos E.A.M. (1992) - Late Aptian to Maastrichtian foraminiferal biogeography and palaeoceanography of the Sergipe Basin, Brazil. Palaeogeography, Palaeoclimatology, Palaeoecology, 92, 295-324.
Longoria J.F. (1974) - Stratigraphic, morphologic and taxonomic studies of Aptian planktonic foraminifera. Rev. Española de Micropaleontología, Num. extraordinario, 107p.
Ogg J. G., Ogg G. & Gradstein F. (2016) - A Concise Geologic Time Scale 2016. Elsevier. 229p.
Petrizzo M.R., Huber B.T., Gale A.S., Barchetta A. & Jenkyns H.C. (2012) - Abrupt planktic foraminiferal turnover across the Niveau Killian at Col de Pré-Guittard (Vocotian Basin, southeast France): new criteria for defining the Aptian/Albian boundary. Newsletters on Stratigraphy, 45, 55-74.

Using high-resolution XRF analyses and biostratigraphic markers as sequence stratigraphic tool in a mudstone-dominated succession (Early Cretaceous, Lower Saxony Basin, Northern Germany)

Thöle H.[1], Bornemann A.[2], Heimhofer U.[1], Luppold F.W.[3], Blumenberg M.[2], Dohrmann R.[2-3] & Erbacher J.*[2-3]

[1] Institute for Geology, Leibniz University Hannover, Germany. [2] Federal Institute for Geosciences and Natural Resources (BGR), Hannover, Germany. [3] State Authority for Mining, Energy and Geology (LBEG), Hannover, Germany.

Corresponding author email: jochen.erbacher@bgr.de

Keywords: Lower Cretaceous, chemostratigraphy, sedimentology, Weissert-Event, XRF core scanning

Delineation of stratigraphic sequences and their component systems tracts in mudstone-dominated successions is challenging due to the relatively homogenous, fine-grained nature of the strata. High-resolution elemental intensity data from X-ray fluorescence (XRF) core scanning is used in order to develop a sequence stratigraphic framework for the Lower Cretaceous monotonous mudstone succession in the eastern Lower Saxony Basin (LSB). The study is based on four drill cores covering the Berriasian to Aptian interval. In addition, carbon isotope ($\delta^{13}C_{org}$), grain size and $CaCO_3$ analyses were carried out on discrete samples. The studied cores represent both proximal and distal basinal environments of the eastern LSB and can be reliably correlated by utilizing variations in selected XRF elemental ratios. K/Ti data have proven to be particularly suitable in this regard. The core correlation shows that chemostratigraphic variability within the studied succession is laterally reproducible in the eastern LSB, and can be used to establish a sequence stratigraphic framework. Further, Si/Al and Ca/Ti ratios have been applied to characterize the cores in terms of variation in grain size and $CaCO_3$ content, respectively. Vertical grading trends inferred from Si/Al changes were used to identify transgressive and regressive systems tracts within the studied succession. An important regression in the uppermost lower Valanginian coincides with the onset of the Valanginian Weissert Event, as indicated by the well-known positive $\delta^{13}C$ shift, and, thus, supports the idea that the initial interval of this event corresponds to enhanced supply of terrigenous material. Our results are also in agreement with previously recognized transgressive-regressive trends in the LSB and adjacent areas. This clearly shows that systematic geochemical variations recorded in mudstone-dominated basinal settings are suitable to establish sequence stratigraphic frameworks.

Paleoceanographic Evolution of mid-Cretaceous Paleobioproductivity and Paleoredox Chemometric Signals. Link to Cretaceous Long-term Eustatic Climax from a Central Atlantic Well Sequence

Viaggi P.*[1], Scotti P.[1], Previde Massara E.[1], Knezaurek G.[2], Menichetti E.[2], Piva A.[2], Torricelli S.[2] & Gambacorta G.[2]

[1] ENI S.p.A. Upstream Research and Technological Innovation, San Donato Milanese, MI, Italy.
[2] ENI S.p.A. Upstream and Technical Services, San Donato Milanese, MI, Italy.

Corresponding author email: paolo.viaggi@eni.com

Keywords: Chemometry, Paleobioproductivity, Paleoredox, mid-Cretaceous, Atlantic, Paleoceanographic evolution.

A high quality cuttings-based Late Aptian-Early Campanian thermal immature well sequence has been characterized by organic and inorganic geochemistry with the aim of investigate the processes governing organic-rich facies deposition. Total organic carbon (TOC), Rock-Eval pyrolysis (petroleum potential, S2; hydrogen index, HI), mineralogy by X-Ray diffraction and both majors and trace elements by X-Ray fluorescence bulk data were acquired for 194 samples. Integrated nannofossil, foraminifera and palynological investigations were undertaken to provide a complete biochronostratigraphic framework and paleoenvironmental reconstruction. A chemometric approach by principal components analysis was applied to handle the integrated organic and inorganic geochemical dataset, exploiting the 'latent variables' (factors) in the data reflecting high-order depositional and geochemical processes. Several Oceanic Anoxic Events (OAEs) have been recognized by integrating geochemical and biostratigraphic data (OAE1c, OAE1d, OAE2 and OAE3). A positive covariance factor among TOC, HI, S2, U, S, pyrite (redox-related preservation signal), along with V, Mo, Ni, Zn, Se, P (nutrient-related paleobioproductivity signal) (Arrigo, 2005; Tribovillard et al., 2006; Twining & Baines, 2013), is linked to the long-term (LT) eustatic curve of Haq (2014). The Cenomanian-Turonian (CT) OAE2 (Bonarelli Event), is located within the LT maximum of paleoproductivity & preservation factor and correlates to the Cretaceous LT eustatic climax (+250 m) and terrigenous supply minimum. Within the OAE2's maximum anoxia, a peculiar depletion of the nutrient-related trace metals, together to a calcareous plankton abundance decrease, is interpreted as temporary "nutrient crisis" induced by starved and stagnant conditions of central Atlantic basin during CT climax time ("basin reservoir effect") (Algeo & Lyons, 2006). The OAE2 calcareous plankton crisis may be also due to excess volcanogenic CO_2 preventing biocalcification in nannoplankton and foraminifers (Erba, 2004). This study suggests a covariance model between "enhanced productivity" and "enhanced preservation", whose synergistic expression can lead to the deposition of organic-rich facies.

Algeo T.J. & Lyons T.W. (2006) - Mo–total organic carbon covariation in modern anoxic marine environments: Implications for analysis of paleoredox and paleohydrographic conditions. Paleoceanogr., 21, 1-23.
Arrigo K.R. (2005) - Marine microorganisms and global nutrient cycles. Nature, 437, 15.
Erba E. (2004) - Calcareous nannofossils and Mesozoic oceanic anoxic events. Mar. Micropal., 52, 85-106.
Haq B.U. (2014) - Cretaceous eustasy revisited. Global and Planet. Change, 113, 44-58.
Tribovillard N., Algeo T.J., Lyons T. & Riboulleau A. (2006) - Trace metals as paleoredox and paleoproductivity proxies:An update. Chem. Geol., 232, 12-32.
Twining B.S. & Baines S.B. (2013) - The Trace Metal Composition of Marine Phytoplankton. Annual Rev. of Mar.Science, 2013, 5, 191-215.

ST9.1

Natural time subdivisions from latest Permian to the middle Triassic: the fundamental role of the biotic to abiotic couplings

Conveners and Chairpersons

Mark W. Hounslow (Lancaster University)

Hugo Bucher (University of Zurich)

Charles Henderson (University of Calgary)

Spencer G. Lucas (New Mexico Museum of Natural History and Science)

The latest Permian Red Ammonoid Limestone and the basal Triassic Sponge-Microbial buildups, Time Specific Facies on the Cimmerian margin of Central Iran and Armenia

Baud A.*[1] & Richoz S.[2]

[1] Independent researcher, Lausanne, Switzerland. [2] Department of Geology, Lund University, Sweden.

Corresponding author email: aymon.baud@unil.ch

Keywords: Changhsingian, Induan, bio-events, Neotethys.

Walliser (1984) introduced the term "Time-Specific Facies" (TSF) to refer to unique facies typical of particular narrow intervals, some of which are related to bio-events or to biological crisis. The latest Permian Red Ammonoid Limestone, 4-5 m thick (Leda et al., 2014) is one of these TSF. It was deposited just before the Permian great dying on the Cimmerian side of the Neotethys (Central Iran, NW Iran and Armenia) and records the most complete ammonoid and conodont succession of the late Changhsingian (8 ammonoid horizons and 6 conodont zones, Korn et al., 2015). Absent during Induan time, this TSF come out again during the lower Olenekian on the Gondwana side of the Neotethys, from Timor to Oman (Baud, 2013). This Facies is similar to the condensed younger Triassic cephalopod limestone known as red Hallstatt limestone. The next TSF consists of the Sponge-microbial buildups (SMB) deposited on the same Cimmerian margin just following the end-Permian great extinction up to the basal Dienerian (Early Induan). The main localities are Shahreza (Central Iran, Baud et al., 2018) and Chanakhchi (S Armenia, Sahakyan et al., 2017, Friesenbichler et al., 2018). It differs from the well-known South China Permian-Triassic boundary short-lasting microbialites (PTBms) by longer duration, deeper water deposition, and cohabitation of sponges with microbialites. The unique, oxygenated, deep ramp setting of the Cimmerian margin at the Permian-Triassic transition allowed the expansion of these two TSF.

Baud A. (2013) - The Olenekian (Early Triassic) Red Ammonoid Limestone, a Time-Specific Facies on the Gondwana Margin: Timor - Roof of the World - Oman Connection. Acta Geologica Sinica, 87, 894-895.

Baud A., Richoz S., Brandner R., Krystyn L., Heindel K., Mohtat T. & Mohtat-Aghai P. (2018) - Sponge Microbial Build–up: A New View on the Enigmatic Basal Triassic Crystal Layer Records from Central Iran. 20thISC, Quebec, Abstract 184-Qdty-163

Friesenbichler E., Richoz S., Baud A., Krystyn L., Sahakyan L., Vardanyan S., Peckmann J., Reitner J. & Heindel K. (2018) - Sponge-microbial build-ups from the lowermost Triassic Chanakhchi section in southern Armenia: Microfacies and stable carbon isotopes. Palaeogeogr., Palaeoclimatol., Palaeoecol., 490, 653-672.

Korn D., Ghaderi A., Leda L., Schobben M. & Ashouri A.R. (2016) - The ammonoids from the Late Permian Paratirolites Limestone of Julfa (East Azerbaijan, Iran). J. Sys. Pal., 14, 841–890.

Leda L., Korn D., Ghaderi A., Hairapetian V., Struck U. & Reimold W.U. (2014) - Lithostratigraphy and carbonate microfacies across the Permian–Triassic boundary near Julfa (NW Iran) and in the Baghuk Mountains (Central Iran). Facies, 60, 295-325.

Sahakyan L., Baud A., Grigoryan A., Friesenbichler E. & Richoz S. (Eds) (2017) - The Permian-Triassic transition in Southern Armenia. 5th IGCP 630 Conference, Yerevan, Field Guide Book, 1-53.

Walliser, O.H., 1984. Geologic processes and global events. Terra Cognita, 4, 17–20.

Intrinsic engineer driving ecosystem rebuilding after the end-Permian mass extinction: Sponge pump and arms race in Triassic oceans

Chen Z.Q.*[1], Wu S.Q.[1], Feng X.Q.[1], Benton M.J.[2] & Harper D.A.T.[3]

[1] State Key Laboratory of Biogeology and Environmental Geology, China University of Geosciences (Wuhan), China. [2] School of Biological Sciences, University of Bristol, UK. [3] Palaeoecosystems Group, Department of Earth Sciences, Durham University, UK.

Corresponding author email: zhong.qiang.chen@cug.edu.cn

Keywords: Permian-Triassic, mass extinction, recovery, sponge pumping, arms race.

The main driver – extrinsic or intrinsic factors- of biotic macroevolution has long been debated. Similarly, whether physical environmental amelioration or biotic interactions, such as competition and predation driving ecosystem's recovery from major mass extinction has long remained unsolved. Here, we report two biotic interaction cases from South China that likely facilitated ecosystem's rebuilding in the aftermath of the end-Permian mass extinction. The first finding is an association of the Burgess Shale-type sponge Crumillospongia (Rigby) and Triassic-type brachiopod Meishanorhychia from a deep-water oxygen-deficient niche immediately after the Permian-Triassic extinction. This Cambrian-type sponge is characterized by the pronounced pores on side walls and a distinct mouth (osculum) on the top, which suggest the same water circulation system as sponge pump observed in modern oceans. The living demosponge is often found in association with cyanobacteria or other microbes, and the sponge-microbe complex acts as the primary producer in marine ecosystem, and produces 3-5 times oxygen and dissolved organic matters (DOM) than that they can consume. The earliest Triassic sponges therefore are interpreted as an ecosystem engineer driving biotic recovery following the end-Permian crisis. Another case is the finding that worm's bulldozing behavior and predatory interactions between arthropods and worms and between various arthropods, which are observed from a diverse assemblage of superficial arthropod trackways and burrows from the Lower Triassic Daye Formation of Dangwu, Guizhou Province, China. The traces were produced by various arthropods, worms, and others. These include evidence of predation interactions between horseshoe crabs and other small arthropods, and arthropods feeding on polychaetes and other worms. The majority of mobile arthropods, infaunal suspension feeders (crustaceans), and deposit feeders (polychaetes or worm-like organisms) in Dangwu ichnofaunas may also manifest the bulldozing hypothesis proposed by Thayer. In his scenario, sediment bulldozers are the most efficient bioturbators, with their ability to displace sediment, manipulate sediment in burrowing and crawling, and manipulate sediment externally in feeding. Thus the polychaetes or worm-like organisms in Dangwu ichnofaunas bulldozed the oxygen-depleted sediments to make the substrate more habitable, and attracted an increasing number of trace-making organisms to inhabit. These worm-like organisms were eventually eaten by the returning arthropods, such as horseshoe crabs. Accordingly, the post-extinction sponge pump, worm-like organism's bulldozing and arms race between arthropods may become important ecological engineer driving biotic recovery in the Early Triassic.

A Natural Induan-Olenekian Boundary

Henderson C.M.[1]*

Department of Geoscience, University of Calgary, Canada.

Corresponding author email: cmhender@ucalgary.ca

Keywords: Induan, Olenekian, GSSP, sequence boundary, biostratigraphy, Lower Triassic.

The development of the Geologic Time Scale from its infancy in the days of Smith, Sedgwick and Murchison was focused on unconformities, because the time gap meant distinct fossil assemblages occurred on either side of the unconformity. Many sequence boundary (SB) unconformities are more-or-less correlatable because they are generated by global and nearly synchronous changes in base level. The correlative conformity or maximum regressive surface (MRS) of each sequence could be viewed as a potential natural boundary because the current GSSP approach considers completeness of the rock record. Natural selection operating on marine subpopulations, isolated during relative sea-level lowstand, could lead to significant evolutionary events coinciding with MRS generation. Perhaps the best example of a comparable base level change and evolution event is the base-Lopingian (Upper Permian) GSSP at the Penglaitan section, Guangxi Province, south China. In this case, the evolution of a new conodont genus near the MRS in the Laibin Limestone is associated with the most significant Phanerozoic lowstand. This biotic-abiotic coupling results in a highly correlatable chronostratigraphic framework since the age of the MRS is no younger than the oldest biozone above the SB (*Clarkina dukouensis*). The interval under consideration for the Induan-Olenekian boundary (IOB) also comprises a SB and lowstand succession. Tozer originally defined the base Smithian in the Canadian Arctic, an informal substage approximating lower Olenekian, by the occurrence of *Eufleminites romunderi* above the SB and *Vavilovites sverdrupi* below the SB in the Blind Fiord Formation. Tozer later added the *H. hedenstroemi* Zone to the lower Smithian based on occurrences elsewhere. This pattern of *Euflemingites* occurring above the SB is repeated in many other regions including in Western Canada and at Nammal Gorge in the Salt Range, Pakistan. The first occurrence of *Novispathodus waageni sensu lato* within the early transgressive systems tract above the SB may represent a good GSSP definition; alternatively, an evolutionary event like that for *Eurygnathodus costatus* or *N. waageni eowaageni* or *Flemingites nanus* within the MRS interval may represent a natural boundary. Two of the potential IOB GSSP sections at Mud (Spiti, Indian Himalaya) and Chaohu (Anhui Province, China) represent distal successions that may comprise the MRS interval under consideration. At these locations a relatively condensed thin-bedded carbonate succession records the first major radiation of ammonoids and conodonts following the end-Permian mass extinction and as such may well represent an ideal stage boundary to mark biotic recovery from the EPME. Additional tools for correlation of this boundary include the proximity to the LT3n magnetochron and a positive shift or peak in the carbon isotopic trend. The Chaohu section also includes astronomically tuned cyclostratigraphy that suggests an age for the boundary of about 250 Ma.

$\delta^{13}C_{org}$ investigation of the latest Permian-early Triassic Deltadalen section, Spitzbergen/ Norway: integrated with bio- and magnetostratigraphic data

Horacek M.*[1-2] & Hounslow M.W.[3]

[1] Institute of Lithospheric Research, Vienna University, Austria. [2] HBLFA Francisco-Josephinum – BLT Wieselburg, Wieselburg, Austria. [3] Lancaster Environment Centre, Lancaster University, Great Britain.

Corresponding author email: untertrias@gmail.com

Keywords: Late Permian, Lower Triassic, biostratigraphy, chemostratigraphy, magnetostratigraphy.

The Deltadalen section has already been investigated for its magnetostratigraphy in combination with its ammonite biostratigraphy and palynology. We have also analysed the samples to construct the $\delta^{13}C_{org}$ isotope curve. The basalmost sample, directly above the hiatus following the Permian Kapp Starostin Formation (marking the beginning of the section = 0 m) has a low $\delta^{13}C_{org}$ isotope value of below -31‰ V-PDB. As this is lower than the subsequently following samples it hints to a "post-event" latest Permian age and the range of *O. boreale* supports this interpretation. Generally, the basal $\delta^{13}C_{org}$ values range between -31 and -29‰ until ca. 40 m and then increase until a maximum at ca. 52 m, which is regarded as representing a maximum near the Dienerian-Smithian boundary (possessing the highest $\delta^{13}C_{org}$ values of the entire section), correlating with a normal polarity magnetozone. The isotope data indicates this boundary is lower in the section than previously inferred based on scant biostratigraphy and T-R cycles. At 64 m follows the next positive excursion of similar magnitude, likely representing the younger limb of the Dienerian-Smithian boundary excursion, seen within a reverse polarity interval. At ca. 75 m occurs another, but less pronounced, positive excursion, which should be within the early Smithian, above *Ns. svalbardensis* occurrence and relating to the upper boundary of a normal magnetozone. Upwards $\delta^{13}C_{org}$ decreases to values well below -30 ‰ (with lowest values reaching almost -35‰), but rapidly increase above-150 m within the *A. tardus* Zone with highest values probably between 160 and 170 m (not exactly known due to an unsampled interval), marking the Smithian-Spathian boundary interval. $\delta^{13}C_{org}$ values then, decrease until a minimum in the late Spathian (early *K. subrobustus* Zone) around 220 m and then continuously increase to a maximum around ca. 260 m, representing the Spathian-Anisian boundary forming the top of the section.

$\delta^{13}C_{org}$ data demonstrates that the curve shape differs to some extent from the well-known Tethyan low-latitude (and usually shallow-water) sections. The carbon isotope excursion at around the Dienerian-Smithian boundary seems well represented. Potentially, there might be some influence of terrigenous $\delta^{13}C_{org}$ on the values, but the generally very low isotope values and the absence of a positive correlation between amount and isotope value of $\delta^{13}C_{org}$ do not support such an assumption.

New conodont and stable isotopic data from the Guryul Ravine (Kashmir, India) Permian-Triassic boundary (PTB): a stratigraphic update

Horacek M.*[1], Krystyn L.[2], Brandner R.[3] & Parcha S.[4]

[1] Institute of Lithospheric Research, Vienna University, Austria. [2] Institute of Palaeontology, Vienna University, Austria. [3] Institute of Geology and Palaeontology, Innsbruck University, Austria. [4] Wadia Institute of Himalayan Geology, Dehradun, Uttarakhand, India.

Corresponding author email: untertrias@gmail.com

Keywords: Late Permian, Lower Triassic, biostratigraphy, chemostratigraphy, Event Boundary, Tethys.

Guryul Ravine is unique as the only ammonoid bearing expanded and complete PTB section along the entire southern Tethys margin. Its stratigraphy was studied intensively within the last hundred years. We present a comprehensive Permian conodont fauna record and add extended range data for Griesbachian guide conodonts allowing a precise correlation with the PTB GSSP. First Changhsingian conodonts occur 30m above the Wuchiapingian *Colaniella* bearing sandy limestones, 47m below the LPME-event beds (boundary shale). We found *Mesogondolella hendersoni* and *Vjalovognathus carinatus*, indicating the Peri-Gondwana Cool Water Conodont Province (PCWP), and *Cyclolobus walkeri*. The late Changhsingian, from 4m below to the top of the Zewan Formation, is verified by *M. sheni* and *M. orchardi* together with *Hindeodus typicalis*, and disappearance of *V. carinatus*. This interval is correlated to the *M. sheni* zone of the Tibetan Himalaya. Within the overlaying 3m thick boundary shale (including the 30cm thick first Event Bed) follow two very thin zones: a basal 50cm thick interval with a mixed PCWP and EWWP (Equatorial Warm Water Province) conodont fauna including *M. sheni*, *M. orchardi, Clarkina* cf. *changxingensis* and *Cl. deflecta,* and above a ca. 80cm thick *Hindeodus* dominated interval. Both intervals together document a continuous rise in sea water temperature with southward expansion of the EWWP. A Permian age of the remaining 1,7m conodont-free boundary shale is evidenced by the megafauna. The Triassic starts with a maximal 40cm thin *H. parvus* zone with rare *H. praeparvus* and *H.* cf. *parvus*, overlain by a 5,5m thick *Isarcicella staeschei* zone, with both zones correlating to the *Otoceras woodwardi* zone of the early Griesbachian. A gondolellid dominated *Cl. carinata* – *Cl. krystyni* zone occupies 8m of the late Griesbachian. The *Ophiceras tibeticum* zone grossly equals to the latter conodont zone. Above follow *Neoclarkina discreta* and *Sweetospathodus kummeli* zones, both with 0,5 respectively 1m again comparably thin. Carbon isotopes give moderately positive values between ca. +2 and +4‰ V-PDB for the basal more than 30m, persisting until the first biostratigraphic markers evidence a Changhsingian age. Slightly higher occurs a jump to values between +4 and +5‰ until 22m below the first event bed, from where the values steadily decrease, reaching negative values around the event boundary. The decrease continues further and reaches a minimum below -3‰ at ca. 9m above the event boundary within the *C. krystyni* zone. Then the values increase quickly to a small maximum of ca. -2‰ at ca. 12m above the event, before rapidly falling again to a second minimum below -3‰ at ca. 16m. From there the values again rapidly increase until passing over to positive values around ca. 20m above the event. The Guryul Ravine conodont record is important as late proof of the validity of the Meishan GSSP confirming also in an expanded sequence a very thin and rather short-lived *H. parvus* zone.

Palynological assemblage of the Nadkrasnokamenskaya Formation (Middle Triassic) in the Bolshesyninskaya depression, Pre-Urals foreland basin, the Timan-Northern Urals region, Russia

Ilyina N.*

Institute of Geology, Komi Science Centre, Ural Branch of the Russian Academy of Sciences, Syktyvkar, Russia

Corresponding author email: ilyina@geo.komisc.ru

Keywords: Triassic, palynology, Timan-Northern Urals region, Russia.

Middle Triassic strata are distributed throughout the Timan-Northern Urals region. Faunal remains are very rare. The detailed stratigraphic chart is primary based on studies of miospores. The present contribution focuses on the Bolshesyninskaya depression as a whole and Nadkrasnokamenskaya Formation in particular, where it crops out along the river banks and contains citing faunal data. The formation is composed of variegated clays and gray-colored aleurolites with subordinate sandstone interlayers, single lenticular interlayers of conglomerates and characterized by tetrapods, bivalves, conchostracans, plant megafossils and miospores. The tetrapod association belongs to the *Mastodonsaurus* fauna and defines Ladinian age of enclosing rocks. The burial conditions of tetrapods indicate a frequent change in the water regime during sedimentation: the river bed, the relatively deep-water part of a large basin, the coastal part of the lagoon basin (Novikov, 1994). Miospores composition studied from the locality of tetrapods is very close to those from the Ladinian deposits in the other Triassic basins, but it shows a slight dominance of spores. Based on botanical affinity the following groups of miospores were found: 14% of bryophytes (genera *Nevesisporites*, *Polycingulatisporites* and species *Taurocusporites* sp. A); 16% lycophytes of genera *Aratrisporites*, *Carnisporites*, *Camarozonosporites* and species *Kraeuselisporites cooksonae*, *Uvaesporites* sp.; 22% of ferns of species *Acanthotriletes ilekensis*, *Apiculatisporites* sp., *Baculatisporites verus*, *Camptotriletes cerebriformis*, *Concentricisporites* sp., *Converrucosisporites* sp., *Cyclogranisporites* sp., *Cyclotriletes oligogranifer*, *Deltoidospora* sp., *Leschikisporites aduncus*, *Marattisporites* sp., *Polypodiisporites ipsviciensis*, *Punctatosporites walkomi*, *Punctatisporites* sp., *Zebrasporites* sp and genera *Dictyophyllidites* spp., *Duplexisporites* spp., *Todisporites* spp., *Verrucosisporites* spp.; 2% of horsetails *Calamospora* spp.; 8% of seed ferns *Falcisporites* spp., *Sulcatisporites* spp., *Vitreisporites pallidus*, 8% of confers *Enzonalasporites* sp, *Lueckisporites triassicus*, *Minutosaccus* spp., *Ovalipollis* spp., *Piceaepollenites* sp., *Pinuspollenites* sp., *Podocarpidites* spp., *Protodiploxypinus* spp., *Voltziaceaesporites heteromorpha*; 7% of conifers/seed ferns *Alisporites* spp., *Chordasporites* spp., *Platysaccus* spp.; 2% of cycadophytes *Chasmatosporites* spp. together with 19% of *Cycadopites* sp. as well as some other isolated miospores. Thus, the results of palynological investigations showed the existence in Ladinian of a rich and diverse vegetation on the research territory, growing within a vast plain with large water bodies, a developed river system and a hilly terrain in a very warm and humid climate.

The research is supported by the Programs of Fundamental Research of UB RAS, project No 18-5-5-50.

Novikov I.V. (1994) - Continental Triassic biostratigraphy of the Timan-North Urals region using tetrapod fauna. Nauka. Moscow.

Westernmost Tethyan occurrence of marine pelagic ammonoid and conodont fauna in the Smithian (Early Triassic): The Brceli section in Montenegro

Krystyn L.*[1], Horacek M.[2], Đaković M.[3] & Brandner R.[4]

[1] Institute of Palaeontology, Vienna University, Austria. [2] Institute of Lithospheric Research, Vienna University, Austria. [3] Geological Survey of Montenegro, Podgorica, Montenegro. [4] Institute of Geology and Palaeontology, Innsbruck, Austria.

Corresponding author email: leopold.krystyn@univie.ac.at

Keywords: Smithian, Early Triassic, Ammonoid, Budva Zone, Montenegro.

Smithian deposits of the western Tethys are generally evidencing restricted, proximal marine facies (Werfen type). Open marine faunas and/or off-shore facies have been reported only from the Caucasus and Oman on eastwards. An exception is the Brceli section in the Budva zone of Montenegro, exposing a succession of ca. 30 metres with a diverse middle Smithian ammonoid fauna. It consists of 14 genera (*Cordillerites*, *Hemiprionites*, *Owenites*, *Pseudosageceras*, *Wyomingites*, *Pseudoflemingites, Hanielites*, *Galfettites, Parahedenstroemia, Dieneroceras, Truempyceras, Aspenites, Pseudaspenites, Lingyunites*) and displays a cosmopolitan character. The accompanying conodont fauna shows beside common *Pachycladina* also *Discretella discreta* and *Neospathodus spitiensis*. Consistently negative carbon isotope data around -3‰ V-PDB yield typical values for the middle Smithian interval. The paleogeographic location of the Budva zone up to now is rather enigmatic, because east of Apulia open marine conditions during this time are generally regarded as hint of a Palaeotethys origin. This, however, is only possible if the today eastward following Dinarides where originally a lateral counterpart of the western palaeogeographic margin of the Budva zone and have been – besides the well-known and prominent west-directed detachment – thrusted also in southward direction upon the latter.

A review of conodont indices for the Induan-Olenekian boundary (Lower Triassic)

Lyu Z.Y.*[1], Orchard M.J.[1-3], Zhao L.S.[1] & Chen Z.Q.[2]

[1] State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences (Wuhan), Wuhan, China. [2] State Key Laboratory of Biogeology and Environmental Geology, China University of Geosciences (Wuhan), Wuhan, China. [3] Natural Resources Canada, Geological Survey of Canada, Vancouver, BC, Canada.

Corresponding author email: lszhao@cug.edu.cn

Keywords: Induan–Olenekian boundary, Novispathodus waageni, Eurygnathodus, ontogenesis, evolutionary lineage, South China.

The boundary between the Induan and Olenekian stages (=IOB) of the Lower Triassic remains undefined, although potential conodont indices have been proposed, i.e. *Novoispathodus waageni* (Sweet) and *Eurygnathodus costatus* (Staesche). Populations of each of these taxa have been intensively studied to determine their ontogenetic variability and/or their evolutionary trajectories, and thereby make them more effective index fossils. Original data comes from the complete Lower Triassic sections in Jianshi and Chaohu in South China. For *Nv. waageni*, new study shows that *Nv. waageni* typically possesses: 1) an approximately equi-dimentional P1 blade element, 2) an arcuate upper profile with denticle height descending in both directions, 3) a denticulated posterior edge (lower denticles posterior of the highest denticle), and 4) a round basal cavity outline. Proposed subspecies include *Nv. waageni waageni* (Sweet, 1970) and *Nv. w. eowaageni* (Zhao and Orchard, 2005), which are differentiated by the former's 1) slightly higher length/height ratio (holotypes = 1.30:1.23); 2) thicker blade, sometimes with medial thickening, 3) fewer (broader) denticles per unit length, 4) generally recurved denticles, not straight and upright, 5) highest denticles closer to posterior, 6) common differentiation of a posterior cusp, and 7) more sinuous basal profile, with increased posterior upturning. A third subspecies illustrated as *Nv. waageni* n. subsp. A by Goudemand, 2014 lacks the diagnostic features of the *Nv. waageni* group. Abundant new materials demonstrate a clear ontogenesis for *Nv. w. eowaageni*, indicating that the subspecies occurring at the IOB is rather stable. Small elements from Jianshi, referred to as morphotype A, and are thought likely to have evolved from *Ns. dieneri* Morphotype 3, and be the precursor of *Nv. w. eowaageni*. Based on the FO of *Nv. w. eowaageni,* the IOB is placed in Chaohu at Bed 24-16, and at Jianshi at Bed 225 + 40 cm. Diverse growth stages of a second conodont species, *Eurygnathodus costatus*, appear in Bed 225+10 cm at Jianshi, 30 cm below the IOB. In Chaohu, *Eu. costatus* first occurs in bed 25-22, 1.82 m above the IOB. In a second IOB section at Mud, Spiti, the FO of both *Nv. waageni* and *Eu. costatus* occur in Bed 12(B-C). Based on the both original collections of *Eu. costatus*, and comprehensive data from other lower Triassic sections in the world, we propose an ontogenesis for *Eu. costatus* involving four growth stages (A→B→C→D). These are based on characteristics of the denticles (nodes or ridges), platform, basal cavity, margins profile, and crimp. A further seven informal species of *Eurygnathodus* are differentiated as potential stratigraphic or biogeographic indicators. We propose the following evolutionary lineage: *Sweetospathodus kummeli →Eurygnathodus costatus →Eu.* sp. *D →Eurygnathodus hamadai*. From this study, the FO of *Eu. costatus* can be seen as a significant auxiliary mark for the IOB.

New Ladinian magnetostratigraphy from the Dolomites (Italy) and implications for the Geomagnetic Polarity Timescale of the Triassic

Maron M.*[1], Muttoni G.[1], Rigo M.[2], Gianolla P.[3] & Kent D.V.[4-5]

[1] Department of Earth Sciences "Ardito Desio", University of Milan, Italy. [2] Department of Geosciences, University of Padova, Italy. [3] Department of Physics and Earth Sciences, University of Ferrara, Italy. [4] Department of Earth and Planetary Sciences, Rutgers University, U.S.A. [5] Lamont-Doherty Earth Observatory, Columbia University, U.S.A.

Corresponding author email: matteo.maron@unimi.it

Keywords: Triassic, Ladinian, Geochronology, Magnetostratigraphy, Timescale.

A new magnetostratigraphy has been obtained from the Ladinian (Middle Triassic) stratigraphic sections of Rio Frommer and Rio Nigra (Alpe di Siusi, Dolomites, northern Italy) (Maron et al., 2019). Biostratigraphy (ammonoids and conodonts) constrains these two sections to the Longobardian (late Ladinian); the Rio Nigra section is also calibrated with a U-Pb zircon date (237.77 ± 0.05 Ma; Mietto et al., 2012). These data provide new constraints to Middle Triassic chronology and have been used as a starting point for the revision of the Geomagnetic Polarity Time Scale (GPTS) for the Triassic. Starting from a selection of Tethyan marine sections, characterized by reliable associated radiometric datings and/or cyclostratigraphy as well as biostratigraphic datums for Stage boundary definitions, we constructed a composite Early-Middle Triassic GPTS, which has been appended to the Late Triassic Newark-APTS. The duration of the Early Triassic is then ~4.6 Myr-long, Middle Triassic is ~10.5 Myr-long, and the Late Triassic is ~35.4 Myr-long, for a total duration of the Triassic System of ~50.5 Myr. Our timescale can be improved in the future by augmenting the stratigraphic coverage in the late Ladinian, providing additional numeric age constraints for the Ladinian – Carnian, Carnian – Norian and Norian – Rhaetian boundaries, acquiring additional paleomagnetic data across the Carnian gap between the early Carnian marine sections and the Newark-APTS, and delineating new 405 kyr astronomically-tuned magnetostratigraphic sections from the Middle Triassic.

Maron M., Muttoni G., Rigo M., Gianolla P. & Kent D.V. (2019) - New magnetobiostratigraphic results from the Ladinian of the Dolomites and implications for the Triassic geomagnetic polarity timescale. Palaeogeogr. Palaeoclimatol. Palaeoecol., 517, 52-73.

Mietto P., Manfrin S., Preto N., Rigo M., Roghi G., Furin S., Gianolla P., Posenato R., Muttoni G., Nicora A., Buratti N., Cirilli S., Spötl C., Ramezani J., & Bowring S.A. (2012) - The Global Stratotype Section and Point (GSSP) of the Carnian Stage (Late Triassic) at Prati di Stuores/Stuores Wiesen Section (Southern Alps, NE Italy). Episodes, 35, 414-430.

Chronology of the Muschelkalk, Latemàr, Seceda, and Felsőörs

Menning M.*

Helmholtz-Zentrum Potsdam, Deutsches GeoForschungsZentrum GFZ.

Corresponding author email: menne@gfz-potsdam.de

Keywords: Geochronology, Middle Triassic, Germany, Alps, Hungary, accumulation rates.

The Muschelkalk Group is of middle Anisian (Pelsonian) through early Ladinian (Fassanian) age. Its subdivision into regional geochronological units: Folge m1 to m9 is based on widespread marker beds which allow a virtually isochronous correlation over large parts of the German Basin. In combination with gamma-ray logs, these subunits define sedimentary cycles which are interpreted as of orbital-climatic origin and their durations of ≈ 400 ka and ≈ 100 ka are used to calibrate the Regional Stratigraphic Scale (RSS) of Central Europe. On that basis, the Muschelkalk has a duration of 4.8 or 5.2 Ma, which is consistent to a large extent with global radio-isotopic age determinations (RIA). The Anisian-Ladinian boundary, located in the Upper Muschelkalk and dated at ≈ 241.8 Ma, is the only global stage boundary within the Muschelkalk Group. In contrast, to the Muschelkalk Group, the numerical calibration of the Middle Triassic in the Global Stratigraphic Scale (GSS) is based exclusively on RIA data, which are based on slightly different dating methods. This results in three time lines: (1) Balaton multi-grain time line (Felsőörs), (2) Southern Alps TIMS time line, (3) South-China – Alps CA-TIMS time line. This results in a better integration of RIA, a more sound Middle Triassic time scale, and in combination with weighted thicknesses, a robust estimated duration of biozones and substages. Few biostratigraphic markers are available to correlate the RSS and GSS. Magnetozones are used to place more precisely the Olenekian-Anisian boundary within the early Folge s7 (Upper Buntsandstein, Röt Formation). Combined global RIA data and the regional Muschelkalk cycles constrain the geochronometry of the Muschelkalk and the Tethyan Middle Triassic. On this basis, the Muschelkalk-Transgression corresponds to the Prezzo-Transgression. Net rates of accumulation are much different: ≈ 200 m/Ma in the late Buntsandstein and ≈ 75 m/Ma in the Muschelkalk, both in the migrating depocentre of the Central European Basin, ≈ 13 m/Ma in the Reifling Formation of the Northern Calcareous Alps, ≈ 8 m/Ma in the Buchenstein Formation in the Seceda borehole (92–64 m) and in Bagolino, and ≈ 200 m/Ma in the Latemàr carbonates, all in the Southern Alps. Stratigraphic cycles with a duration of ≈ 40 ka (obliquity; ≈ 40 cm thick) characterize the hemipelagic Buchenstein Formation. The ≈ 90 cm cycles of the Latemàr carbonates have a sub-Milankovitch duration of ≈ 4 ka, while ≈ 400 ka and ≈ 100 ka cycles (long and short eccentricity) are typical for the Muschelkalk. These durations are consistent with global RIA (Menning 2019).

Menning M. (2019) - Geochronologie des Muschelkalks. In: Deutsche Stratigraphische Kommission (ed.; coord. + editing: Hagdorn, H. & Simon, T.), Stratigraphie von Deutschland XIII. Muschelkalk. Schr.-R. Dt. Ges. Geowiss., 91: x-x; Hannover.

High precision CA-IDTIMS dating of the Permian – Triassic boundary on the eastern margin of the Sydney Basin, New South Wales, Australia

Nicoll R.S.*[1], McLoughlin S.[2], Vajda V.[2], Mays C.[2], Bocking M.[3], Fielding C.R.[4], Frank T.[4] & Crowley J. [5]

[1] Geoscience Australia, GPO Box 378 Canberra, ACT 2601, Australia. [2] Swedish Museum of Natural History, Svante Arrhenius v. 9, SE-104 05, Stockholm, Sweden. [3] Bocking Associates, 8Tahlee Close, Castle Hill, NSW Australia. [4] Dep. of Earth & Atmospheric Sciences, University of Nebraska-Lincoln, 126 Bessey Hall, Lincoln, NE 68588-0340, USA. [5] Bosie State University Bosie, Idaho, USA.

Corresponding author email: bnicoll@velocitynet.com.au

Keywords: Permian – Triassic boundary, palynomorphs, macroflora, terrestrial extincion.

Classically the Permian – Triassic boundary in the Sydney Basin, eastern Australia has been placed at the top of the youngest coal bed, usually the Bulli Coal south of Sydney and the Vales Point Coal to the north. These coal seams are overlain, respectively, by the correlative Coal Cliff Sandstone and the Dooralong Shale, both of the Narrabeen Group. The boundary appears para-conformable, and preliminary dating suggests any time break between the Late Permian Bulli Coal (252.60), the overlying black shale (252.31) and the Coal Cliff Sandstone (251.31) is less than 600 ky. Sedimentologically the Narrabeen Group is composed of shales and sandstones with occasional riverine channel conglomerates such as the Munmorah Conglomerate and equivalents, cross-cutting the finer sediments. Occasional tuff beds allow high precision age control.

The presence of frequent datable tuff beds and identifiable palynomorphs and macroflora have enabled us to demonstrate that the dramatic change from a terresterial flora dominated by Permian type vegetation, *Glossopteris*, to one of Triassic aspect, *Playfordiasporia crenulata* and *Lepidopteris callipteroides*, took place some 370 ky prior to the marine faunal change demonstrated in the precisely dated Meishan GSSP section. These floras are separated by an interval dominated by charcoal and fungal spores.

Tuff beds collected from the section have yet to be dated. It is hoped they will provide chronologic control to be able to relate the timing of the Australian sedimentation to the Permian – Triassic chronology of the Meishan GSSP section and to establish a precise P-T boundary level and event chronology in Gondwanan terrestrial sediments. This chronology may also help to explain the apparent terrestrial extinction some 370 ky prior to the marine extinction event.

Correlation of Triassic palynozones

Nowak H.*[1], Roghi G.[2] & Kustatscher E.[1-3-4]

[1] Naturmuseum Südtirol/Museo di Scienze Naturali dell'Alto Adige, Bozen/Bolzano, Italy. [2] Istituto di Geoscienze e Georisorse – CNR, Padova, Italy. [3] Department of Earth and Environmental Sciences, Paleontology & Geobiology, Ludwig-Maximilians-Universität München, Germany. [4] SNSB-Bayerische Staatssammlung für Paläontologie und Geologie, Germany.

Corresponding author email: Hendrik.Nowak@naturmuseum.it

Keywords: Palynomorphs, spores, pollen, Permian, Triassic.

Palynomorphs – primarily spores and pollen, as well as dinoflagellates from the Late Triassic onward – are often used for biostratigraphical dating in the Triassic. The Triassic period is bracketed by two of the "Big Five" mass extinctions and encompasses, among others, the extended recovery phase following the end-Permian mass extinction and the Carnian Pluvial Event. These and other ecological perturbations are reflected in palaeofloras and consequently in palynofloras. Biozones based on palynomorphs have been defined for many regions, but only in recent years have there been targeted efforts to correlate the different zonation schemes (Cirilli, 2010; Kustatscher et al., 2018; Nowak et al., 2018). We now provide a correlated overview of the Triassic palynozones. Correlation is often difficult due to a lack of independent dating. Additionally, provinciality of (micro-)floras as well as different approaches to palynostratigraphy limit the comparability of zonations. The various schemes are also of variable extent. The most complete and best dated sequences are available for Australia (Mantle et al., 2010), the Barents Sea region (Vigran et al., 2014), and the Germanic Basin (Kürschner & Herngreen, 2010). Palynozones from other regions are correlated with these schemes and with the current international chronostratigraphic units as far as possible.

Cirilli S. (2010) - Upper Triassic–lowermost Jurassic palynology and palynostratigraphy: a review. Geol. Soc. Lond. Spec. Publ., 334, 285-314.

Kürschner W.M. & Herngreen G.F.W. (2010) - Triassic palynology of central and northwestern Europe: a review of palynofloral diversity patterns and biostratigraphic subdivisions. Geol. Soc. Lond. Spec. Publ., 334, 263-283.

Kustatscher E., Ash S.R., Karasev E., Pott C., Vajda V., Yu J. & McLoughlin S. (2018) - Flora of the Late Triassic, in: Tanner L.H. Ed., The Late Triassic World, Topics in Geobiology, 545-622. Springer, Cham.

Mantle D.J., Kelman A.P., Nicoll R.S. & Laurie J.R. (2010) - Australian biozonation chart 2010. Part 1: Australian and selected international biozonation schemes tied to the GTS 2004 geological timescale. Geoscience Australia, Canberra.

Nowak H., Schneebeli-Hermann E. & Kustatscher E. (2018) - Correlation of Lopingian to Middle Triassic Palynozones. J. Earth Sci., 29, 755-777.

Vigran J.O. (2014) - Palynology and geology of the Triassic succession of Svalbard and the Barents Sea, Geological Survey of Norway special publication. Norges geologiske undersoekelse, Trondheim.

Statistical observations on floral changes between the Induan and Olenekian

Nowak H.[1] & Kustatscher E.*[1-2]

[1] Museum of Nature South Tyrol, Italy. [2] Ludwig-Maximilians-Universität München, Germany. [3] SNSB-Bayerische Staatssammlung für Paläontologie und Geologie, Germany.

Corresponding author email: evelyn.kustatscher@naturmuseum.it

Keywords: palynolog, plant fossils, Early Triassic, Smithian–Spathian.

The common view on Early Triassic palaeofloras is that following the end-Permian mass extinction they are impoverished in terms of diversity and often dominated by lycopsids such as *Pleuromeia* (Looy et al., 1999) – up to the Smithian–Spathian boundary, when gymnosperms again proliferated (Saito et al., 2016). Based on the supplementary data of Nowak et al. (2019), we analysed the occurrence data of land plant macrofossils and sporomorphs quantitatively for significant changes across the Induan–Olenekian boundary. Macrofossils of land plants from the Early Triassic are rare compared to other times (Nowak et al., 2019). This means that observations based on the available data are of limited reliability, but can nevertheless show a more complete picture than individual or selected fossil floras. Our analysis indicates that sphenophytes are the overall most common plant group in fossil floras from the Lower Triassic. Lycophytes are the most common group in the Induan, followed by pteridophytes (ferns) and sphenophytes. In the Olenekian, conifer occurrences triple, becoming the most abundant group, while lycophytes decrease. The latter is mostly due to the extinction of *Tomiostrobus*, the most common plant genus of the Induan. On the other hand, *Pleuromeia* increases and becomes the most common genus in the Olenekian, with more than 10% of all occurrences. This fits the observation that *Densoisporites nejburgii*, the dispersed spore taxon of *Pleuromeia sternbergii*, reaches an acme approximately at the Induan–Olenekian boundary in several regions (Nowak et al., 2018). In total, the frequency of macrofossils of the pollen-producing gymnosperms in the Induan is much lower than that of spore-producing plants (bryophytes, sphenophytes, lycophytes and ferns). In the Olenekian, gymnosperms and spore-plants occur with almost equal frequency. By contrast, in palynomorph assemblages pollen and spores are recorded with approximately equal frequency in the Induan, while in the Olenekian spores are almost twice as common as pollen. The discrepancies between the sporomorph and macrofossil records are most likely the result of a combination of taphonomic and sampling bias as well as unresolved taxonomic issues. To isolate the underlying biological signal is thus an ongoing challenge.

Looy C.V., Brugman W.A., Dilcher D.L. & Visscher H. (1999) - The delayed resurgence of equatorial forests after the Permian–Triassic ecologic crisis. Proc. Natl. Acad. Sci., 96, 13857-13862.

Nowak H., Schneebeli-Hermann E. & Kustatscher E. (2019) - No mass extinction for land plants at the Permian–Triassic transition. Nat. Commun., 10, 1-8.

Nowak H., Schneebeli-Hermann E. & Kustatscher E. (2018) - Correlation of Lopingian to Middle Triassic Palynozones. J. Earth Sci., 29, 755-777.

Saito R., Kaiho K., Oba M., Takahashi S., Chen Z.-Q. & Tong J. (2013) - A terrestrial vegetation turnover in the middle of the Early Triassic. Glob. Planet. Change, 105, 152-159.

Paired organic and inorganic carbon isotopes of the Early Triassic from Chaohu area, South China

Song H.Y.[1]*, Tong J.[1], Du Y.[1], Zhu Y.[1] & Qiu H.[1]

China University of Geosciences, Wuhan, China.

Corresponding author email: songhuyue@126.com

Keywords: organic carbon isotopes, inorganic carbon isotopes, Early Triassic, Chaohu, South China.

The Early Triassic recorded the delayed biotic recovery and several catastrophic events. The multiple significant excursions of $\delta^{13}C_{carb}$ during the Early Triassic have been well studied. Several hypotheses have been supposed as the causes of the changes of the $\delta^{13}C_{carb}$: including marine productivity changes; terrestrial weathering influx, repeat massive volcanisms, methane release/accumulations, stratified ocean and turnover. However, these mechanisms remain contentious, and there is little study focus on the paired (organic and inorganic) carbon isotopes of the same samples in Early Triassic. In this study, we report high-resolution paired carbon isotopes of ~264 samples from the Lower Triassic successions in Chaohu area, South China. There is no distinct change of the $\delta^{13}C_{org}$ during the Griesbachian to Dienerian interval. After that, a slight positive excursion of the $\delta^{13}C_{org}$ happened above the Dienerian-Smithian (Induan-Olenekian) boundary. The $\delta^{13}C_{org}$ compositions show two negative excursions during the Smithian and mid-Spathian, which are coincide with the results from other locations. We have not found any correlation between the net isotopic fractionation ($\Delta^{13}C_{carb-org}$) of Chaohu section and the temperature changes in the Early Triassic. In addition, the relationship between the C/N ratio and $\Delta^{13}C_{carb-org}$ implies the $\Delta^{13}C_{carb-org}$ corresponds to the increasing proportion of land organic matter and rebound of land vegetation for Smithian-Spathian interval.

The Lower Triassic of Chaohu, Anhui Province: basis and progress

Tong J.N.[1]*

[1]State Key Laboratory of Biogeology and Environmental Geology and School of Earth Sciences, China University of Geosciences, Wuhan 430074, China.

Corresponding author email: jntong@cug.edu.cn

Keywords: Lower Triassic, integrative stratigraphy, Chaohu, South China.

Chaohu was located in the deep part of the northern carbonate ramp on the Yangtze block during the Early Triassic and a complete Lower Triassic sequence was deposited containing rich fossils till the latest Early Triassic when the main part of the Yangtze block became a shallow dolomite facies with the collision of the Yangtze block with the North China block. Consequently, the Lower Triassic of Chaohu is the classic sequence to construct the standard Chinese stratigraphic succession. The two Lower Triassic Chinese stages are named the Induan and Chaohuan and their stratotype sections are defined at Meishan and Chaohu, respectively. The Lower Triassic of Chaohu has been extensively studied. The basic stratigraphic sequence of Lower Triassic was well established during the 1980s once the strata were discovered in the regional geological survey in the area, including lithostratigraphy, ammonoid and conodont biostratigraphy, paleontology, lithofacies, as well as the Permian-Triassic boundary study. Intensive study on the Lower Triassic stratigraphy of Chaohu was during the first decade of this century. Though the study was at first emphasized on the Induan-Olenekian boundary, the whole Lower Triassic sequence had been comprehensively studied in its entirety. It involves almost all aspects of the sequence such as the refined conodont zonation, ammonoid-bivalve biostratigraphy, carbon isotopes, magnetostratigraphy, and cyclostratigraphy. In addition, the Smithian/Spathian boundary also was well studied and defined at Chaohu based on the conodont and carbon isotope data. Consequently, the Lower Triassic sequence of Chaohu has formed a firm base to correlate regional and even global stratigraphic sequences and date the Early Triassic biotic and environmental events. In the last few years the study on the Lower Triassic of Chaohu has focused mainly on the environmental changes and biotic recovery on the basis of the firm bio-chronostratigraphic results. Various methods have been applied for understanding the environmental condition and evolution of the seawater and atmosphere during the great Permian-Triassic transition and turbulent Early Triassic recovery process based on the elementary and isotopic geochemistry of the rocks and conodont specimens as well as biomarkers and fossils from Chaohu. Meanwhile, new excavation of the Spathian vertebrate fauna in Chaohu has resulted in a more diverse vertebrate-dominated community, implying the construction of an innovative Mesozoic ecosystem in recovery. In addition, since the Chaohu city was put under the Hefei city, the capital of Anhui Province, it has become one of the core areas of the expanded Hefei city and the transportation becomes more convenient. A high-speed railway station is built in Chaohu and the area is environmentally conserved but all the classic geological sites including the stratigraphic sections are saved and can be visited and studied because the area is the classic field education base for geological students of over 30 universities and colleges.

Turning hothouse to icehouse: timing and genesis of the end-Smithian extinction during the Early Triassic biotic recovery

Widmann P.*[1], Bucher H.[2], Leu M.[2], Venneman T.[3], Bagherpour B.[2], Hermann E.[2] & Schaltegger U.[1]

[1] University of Geneva. [2] University of Zurich. [3] University of Lausanne.

Corresponding author email: Philipp.widmann@unige.ch

Keywords: Early Triassic, Smithian-Spathian boundary, carbon cycle, CA-ID-TIMS U-Pb, zircon, Bayesian age-depth model.

Within the entire Triassic, the most drastic extinction of ammonoids and conodonts occurred during the latest Smithian, that is characterized by a global positive carbon isotope excursion (CIE) culminating at or close to the Smithian-Spathian boundary (SSB). The scenario of hot sea surface temperatures accompanied by the expansion of the oxygen minimum zone (Sun et al., 2015) is questioned by studies documenting (i): a cooling during the latest Smithian and basal Spathian (Goudemand et al., 2019), (ii): a major change from lycopod- to gymnosperm-dominated vegetation indicating a change toward drier climate (Hochuli et al., 2016) (iii): a global eustatic sea-level drop (Embry & Beauchamp, 2008) and variations of chemical weathering (Zhang et al., 2015). The late Smithian was further accompanied by an enhanced rate of organic carbon burial of terrestrial origin on continental shelves (Hermann et al., 2011). We present a new temporal calibration and quantification of the SSB, the late Smithian CIE and the associated faunal turnover by using high precision, chemical abrasion isotope dilution thermal ionization mass spectrometry (CA-ID-TIMS) U-Pb dating technique from single zircon crystals recovered from volcanic ashes of the Nanpanjiang Basin (South China). These U-Pb ages are intercalibrated with conodont- and preliminary ammonoid Unitary Association zones and serve as basis for a Bayesian age-depth model. The new timeframe allows distinguishing between potential causal mechanisms operating at different time scales that can have a sufficient serve impact on the carbon cycle to cause a climate cooling. We propose a new model for cascading events that lead into the late Smithian exciton.

Embry A. & Beauchamp B. (2008) - Sverdrup Basin. In: The Sedimentary Basins of the United States and Canada. Elsevier.

Goudemand N., Romano C., Leu M., Bucher H., Trotter J. & Williams I. (2019) - Dynamic interplay between climate and marine biodiversity upheavals during the Early Triassic Smithian-Spathian biotic crisis. Earth Sci. Rev., in press.

Hermann E., Hochuli P.A., Méhay S., Bucher H., Brühwiler T., Ware D., Hautmann M., Roohi G., ur-Rehman K. & Yaseen A. (2011) - Organic matter and palaeoenvironmental signals during the Early Triassic biotic recovery: The Salt Range and Surghar Range records. Sediment. Geol., 234, 19–41.

Hochuli P.A., Sanson-Barrera A., Schneebeli-Hermann E. & Bucher H. (2016) - Severest crisis overlooked—Worst disruption of terrestrial environments postdates the Permian–Triassic mass extinction. Sci. Rep., 6.

Sun Y.D., Wignall P.B., Joachimski M.M., Bond D.P.G., Grasby S.E., Sun S., Yan C.B., Wang L.N., Chen Y.L. & Lai X.L. (2015) - High amplitude redox changes in the late Early Triassic of South China and the Smithian – Spathian extinction. Palaeogeogr. Palaeoclimatol. Palaeoecol., 427, 62–78.

Zhang L., Zhao L., Chen Z.Q., Algeo T.J., Li Y. & Cao L. (2015) - Amelioration of marine environments at the Smithian-Spathian boundary, Early Triassic. Biogeosciences, 12, 1597–1613.

New findings of Lower Triassic xenoceltitid ammonoids in South Primorye (Russian Far East) and their significance for the improvement of the lower Olenekian regional stratigraphical zonality

Zakharov Y.D.*, Popov A.M. & Bondarenko L.G.

Far Eastern Geological Institute, Russian Academy of Sciences (Far Eastern Branch), Russia

Corresponding author email: yurizakh@mail.ru

Keywords: Ammonoids, brachioipods, conodonts, biostratigraphy, Triassic, Russian.

Currently, information on latest early Olenekian ammonoids is available from only six regions of the world: Salt Range (Pakistan), Spiti (India), South Tibet, Utah, Nevada (USA) and Primorye (e.g., Brühwiler et al., 2012a, b; Zakharov et al., 2016; Jenks and Brayard, 2018; Ware et al., 2018). New latest early Olenekian ammonoids from South Primorye were collected in two localities: the SMID (eastern profile) and Golyj sections. This finding provides additional material on systematialc composition of the ammonoid assemblage of the recently identified Shimanskyites shimanskyi Zone, overlying the Anasibirites nevolini Zone. The base of the former is defined by the first occurrences of ammonoids Shimanskyites shimanskyi and Glyptophiceras sp. nov. (Xenoceltitidae), brachiopods Bittnerihyris margaritovi and Nudirostralina tazawai, as well as by the negative C-isotope shift (Zakharov et al., 2018). However, there are many species, common for both these zones (e.g., "Arctoceras" subhydaspis, Churkites syaskoi, Anasibirites simanenkoi, Prionites markevichi, Xenoceltites? subvariocostatus, Monneticeras kalinkini, Hemiprionites klugi, Prionites markevichi). No conodonts, characteristic of the Anasibirites nevolini Zone (with the exception of Hindeodella budurovi), have been found in the Shimanskyites shimanskyi Zone. The problems of global correlation of the zonal subdivisions of the Lower Olenekian substage are discussed.

This research was funded by the grant RFBR 18-05-00023.

Brühwiler T., Bucher H., Ware D., Hermann E., Hochuli P. A., Roohi G., Rehman K. & Yaseen A. (2012a) - Smithian (Early Triassic) ammonoids from the Salt Range, Pakistan. Spec. Papers in Palaeotology, 88, 1–114.

Brühwiler T., Bucher H. & Krystyn L. (2012b) - Middle and late Smithian (Early Triassic) ammonoids from Spiti, India. Spec. Papers in Palaeotology, 88, 115–174.

Jenks J. & Brayard A. (2018) - Smithian (Early Triassic) ammonoids from Crittenden Springs, Elko county, Nevada: taxonomy, biostratigraphy and biogeography. New Mexico Mus. Nat. Hist. & Sci., Bull. 78, 175 pp.

Ware D., Bucher H., Brühwiler T. et al. (2018) - Dienerian (Early Triassic) ammonoids from the Northern Indian Margin. Lethaia Foundation. 63, 241 pp.

Zakharov Y.D., Horacek M., Smyshlyaeva O.P. et al. (2016) - Early Olenekian ammonoids from the Kamenushka River basin. In: Barskov I.S., Leonova T.B., Nikolaeva S.B. et al., Golden age of Russian malacology. Saratov Univ., Moscow–Saratov, 167–177 (in Russian).

Zakharov Y.D., Horacek M., Popov A.M. & Bondarenko L.G. (2018) - Nitrogen and carbon isotope data of Olenekian to Anisian deposits from Kamenushka/South Primorye, Far-Eastern Russia and their palaeoenvironmental significance. Jour. Earth Sci., 29(4), 837–853.

New data on stable N-isotope composition of Permian-Triassic mudstone from northeastern Asia (Verkhoyansk area) and their application to palaeoclimatological problem

Zakharov Y.D.*[1], Biakov A.S.[2] & Horacek M.[3-4]

[1] Far Eastern Geological Institute, Russian Academy of Sciences (Far Eastern Branch), Vladivostok, Russia. [2] N.A. Shilo North-East Interdisciplinary Scientific Research Institute, Russian Academy of Sciences (Far Eastern Branch), Magadan, Russia.[3] Institute of Lithospheric Research, Vienna University, Austria. [4] BLT Wieselburg Research Center HBLFA Francisco-Josephinum, Austria.

Corresponding author email: yurizakh@mail.ru

Keywords: N isotopes, ammonoids, Permian-Triassic, Siberia.

According to data available from the Neoproterozoic─Phanerozoic (Algeo et al., 2014), clayey deposits of marine origin, accumulated in glacial periods under cool conditions are characterised by relatively high $\delta^{15}N$ values, while sedimentary deposits corresponding to periods with greenhouse conditions have relatively lower values. The possibility of using the N isotopic data to make temperature/climate palaeoreconsructions has been recently supported by some authors (e.g., Zakharov et al., 2018). New N isotopic data obtained from clayey deposits of the Verkhoyansk area (Pravyj Suol section), assigned to the P─T-boundary transition, are in agreement with those obtained from the Pautovaya section, Kolyma-Omolon region, which have revealed that just after the latest Changhsingian Putoran basalt event, a general climatic trend towards higher temperatures took place, apparently, in Northeastern Asia. We propose to distinguish the five N–isotope intervals (a─e) in *Otoceras*-bearing sequences, *concavum* and *boreale* zones of the Pravyj Suol section, which may have been associated with climatic changes. Absence of $\delta^{15}N$ values below ─1‰ in the P─T sections of the Boreal Superrealm (Verkhoyansk, Kolyma-Omolon and Ellesmere, Arctic Canada) compared with the sections of more southern palaeolatitudes of the Tethys can be explained by the accumulation of their sediments in cooler conditions. In contrast to the P─T section of the Verkhoyansk area, mudstones from the Kolyma-Omolon and Ellesmere areas in the Boreal Superrealm are characterised by only positive $\delta^{15}N$ values. We explain this by the accumulation of their sediments in somewhat deeper conditions. There exists evidence of the extinction of land plants (one of the large groups of gymnosperms ─ Glossopteridales) at the P─T boundary in Norway, however, no clear signs of marine mass extinction just at the P─T boundary in northern Siberia (e.g., Biakov et al., 2018). A possible explanation might be the regional persistence of a cool water environment in higher palaeolatitudes (taking into account the available N isotopic and palaeontological data ─ e.g., presence of a cool-requiring *Otoceras* fauna in both the uppermost Changhsingian *concavum* Zone and the lowermost Induan *boreale* Zone in the Pravyj Suol section, Verkhoyansk).

This research was funded by the grants RFBR 17-05-00109 and 18-05-00023.

Algeo T.J., Meyers P.A., Robinson R.S., Rowe H. & Jiang G.Q. (2014) - Icehouse-greenhouse variations in marine denitrification. Biogeosciences, 11, 1273-1295.

Biakov A.S., Kutygin R.V., Goryachev N.A., Burnatny S.S., Naumov A.N., Yadrenkin A.V., Vedernikov I.L., Tretyakov M.F. & Brynko I.V. (2018) - Discovery of the late Changhsingian bivalve complex and two fauna extinction episodes in Northeastern Asia at the end of the Permian. Doklady Biol. Sci., 480, 78-81.

Zakharov Y.D., Horacek M., Shigeta Y., Popov A.M. & Bondarenko L.G (2018) - N and C isotopic composition of the Lower Triassic of Southern Primorye and reconstruction of the habitat conditions of marine organisms. Stratigraphy and Geol. Correlation, 26(5), 534-551.

A proposed evolutionary lineage of *Novoispathodus waageni eowaageni* from South China and its role in defining the base of the Olenekian (Lower Triassic)

Zhao L.S.[1*], Lyu Z.Y.[1], Chen Z.Q.[2], Tong J.N.[2], Chi C.[3] & Weng H.Q.[1]

[1] State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences (Wuhan), China. [2] State Key Laboratory of Biogeology and Environmental Geology, China University of Geosciences (Wuhan), China. [3] Yifu Museum, China University of Geosciences (Wuhan), China.

Corresponding author email: zlscug@163.com

Keywords: Lower Triassic, Induan–Olenekian boundary, Novispathodus waageni eowaageni, evolutionary lineage, South China.

The Lower Triassic includes the Induan and Olenekian stages. The GSSP of the Permian-Triassic boundary (PTB) (also the base of the Induan) was selected in the Meishan Section, Zhejiang Province, South China, in which the first appearance of conodont *Hindeodus parvus* marks the PTB, while the Induan-Olenekian boundary (IOB) remains undefined. The Jianshi area in South China was situated on a carbonate ramp at the northeastern margin of the Upper Yangtze Platform, which was located in the low-latitude eastern Tethys during the Early Triassic. The Uppermost Permian through Lower Triassic successions of the Jianshi section has been well studied by systematically sampling for conodont biostratigraphy, and a total of nine conodont zones has been established, in which the IOB placed at Bed 225 + 40 cm based on the FO of *Nv*. *waageni eowaageni*. The Enshi conodont zones overall correlate well with those recognized elsewhere in South China and worldwide. Based upon the conodont data from Jianshi section, an ontogenetic and evolutionary model for *Novispathodus waageni eowaageni* has been proposed in this study. Abundant specimens allow recognition of ontogenic variations of the *waageni* species that occur around the IOB. For instance, conodont specimens derived from Bed 230 and Bed 232, respectively of the Jianshi section show that the size variation in *Nv. w. eowaageni* specimens are accompanied by little change in morphology, and implies that *Nv. w. eowaageni* is rather stable near the IOB. Moreover, the new materials of small, early individuals (from Bed 225 in Jianshi), referred to as *Nv. w. eowaageni* Morphotype A, likely evolved from *Ns*. *dieneri* Morphotype 3, and leads to typical mature elements of *Nv. w. eowaageni* more common in higher horizons. The collections of *Nv*. *w*. *eowaageni* from Jianshi section have enriched the inventory of the reported *Nv. w. eowaageni* materials. They supplement the study of conodont evolution around the IOB, and demonstrate the wide distribution of the taxon beyond the candidate GSSP Chaohu section. The first appearance datum of *Nv. w. eowaageni* therefore is an ideal mark defining the IOB.

ST9.2

Calibrating rates and dates in stratigraphy

Conveners and Chairpersons

Urs Schaltegger (University of Geneva)

Daniel Condon (British Geological Survey)

EARTHTIME and the International Commission on Stratigraphy: The International Subcommission on Timescale Calibration

Cramer B.*[1], Schmitz M.[2] & Da Silva A.C.[3]

[1] University of Iowa. [2] Boise State University. [3] Universite de Liege.

Corresponding author email: bradley-cramer@uiowa.edu

Keywords: EARTHTIME, IUGS, ICS, timescale, calibration.

The International Commission on Stratigraphy (ICS), and its subcommissions on each geologic period, remains the 'official' timekeeper of the Geologic Time Scale (GTS). However, chronostratigraphy remains the first, and often only, consideration of the ICS and the international subcommissions (at least for the Phanerozoic). At present, very few geochronologists serve as voting members of subcommissions of the ICS, and as a result, these two disparate communities often find it difficult to communicate effectively, let alone work in direct collaboration towards a high-precision temporally calibrated geologic timescale.

In response to a growing movement of geoscientists who increasingly work at the intersection of time and stratigraphy, and to provide a platform for promoting integration between the traditionally stratigraphic communities of the ICS with the radioisotopic communities that traditionally have not been a central component of the ICS enterprise, we have formally proposed a new International Subcommission on Timescale Calibration (ISTC). The objective of this new subcommission is not to 'certify' or 'approve' any particular numerical calibration of the International Chronostratigraphic Chart, but rather, to provide advice and counsel to existing ICS Subcommissions on geochronological issues, to delineate best practices and the role of inter-laboratory calibrations to chronostratigraphic and timescale problems, and to provide a venue for increasing collaboration between chronostratigraphic and geochronologic research.

The Geologic Time Scale According to Re-Os (Rhenium-Osmium)

Stein H.*[1-2] & Hannah J.[1-2]

[1] AIRIE Program, Colorado State University, USA. [2] Geosciences, University of Oslo, Norway.

Corresponding author email: holly.stein@colostate.edu

Keywords: Rhenium-Osmium, geochronology, black shales, GSSP.

The ^{187}Re-^{187}Os radiometric clock increasingly brings value to the geologic time scale (GTS) by assigning accurate ages to organic-rich shales and their biota. The typically referenced unit by stratigraphers for a GSSP is the stage, and stage boundaries are defined by biotic changes. Thus, Re-Os dating of shales effectively pins the ages of stage boundaries. What are the key issues dissuading stratigraphers from using Re-Os shale ages as Golden Spikes? Re-Os has the advantage of directly dating the unit hosting biotic change. Dating the shale is dating the fossil horizon. Our sampling protocol to correctly dismember a stratigraphic interval and pick apart the laminae for points on an isochron is now in wide use by others. Differences in data reduction and error assessment among different working groups, however, can lead to disparate results. This leads to confusion among the uninitiated and ultimately to a lack of trust in the technique. In this presentation, we will discuss these varied approaches and suggest ways the community might reach agreement on methods and reporting protocols, to create a more widely accepted chronometer. As with all radiometric dating techniques, Re-Os is not infallible. We will discuss the processes that have the potential to disturb this normally robust radiometric clock. The concept of closure temperature is not relevant for Re-Os, but post-depositional oxidation can wreak havoc on the Re-Os clock. We will discuss why seemingly fresh outcrop samples of black shale may be difficult to date, whereas the same shale unit in drill core yields an excellent Re-Os isochron. We will discuss factors that help predict Re-Os isochroneity in advance of undertaking expensive and time-consuming Re-Os analytical work in the lab. With a now expansive database of Re-Os isochron ages for black shales, we can better predict whether a shale will be easy to date. Shale sections associated with melting of snowball earth events are prone to noisy Re-Os isotope data. In part, this explains the paucity of published points on Neoproterozoic isochrons. Acquiring an 8-10 point isochron from a Neoproterozoic meltwater shale rarely gives precise Re-Os ages. Other periods in earth history are also prone to scatter in data on an isochron diagram. The uppermost Jurassic-lowermost Cretaceous and the lower Triassic are notorious for isotopic scatter. Still, other periods in earth history provide well-behaved isochrons with precise ages and MSWDs near unity. By focusing on processes that produce scatter, we will explain why we observe the phenomenon of data scatter on isochrons for some time periods in earth history. Finally, we will present a comprehensive time scale according to Re-Os, and we will update the Os seawater curve through time.

Work financed by the Norwegian petroleum industry, notably Eni Norge, Equinor, Lundin, and AkerBP. Colorado State University provides no salary or operational support for the AIRIE Program.

High-precision calibration of the Middle Triassic volcano-sedimentary record in the Southern Alps (Italy)

Storck J.C., Wotzlaw J.-F. & Brack P.*

Department of Earth Sciences, ETH Zurich

Corresponding author email: peter.brack@erdw.ethz.ch

Keywords: geochronology, Middle Triassic, climate dynamics.

Marine sediments are prime archives of past climate and biological evolution. High-precision geochronology of interbedded volcanic ash beds, provides independent constraints on the timing of evolutionary turnovers and the dynamics and rates of climate change. In the Southern Alps of northern Italy, evenly bedded nodular limestones extending across the Anisian-Ladinian boundary interval can be traced over several hundred kilometres. Numerous sections of the so-called Buchenstein Formation (e.g. Bagolino, Seceda, Passo Feudo) are intercalated by volcanic ash layers providing an excellent opportunity for studying the processes governing the spectacularly exposed bedding patterns in the Dolomites and Eastern Lombardy.

We present a high-precision chronostratigraphic framework for the hemipelagic limestones from several sections of the Middle Triassic Buchenstein Formation. Radiometric age constraints obtained by CA-ID-TIMS zircon U-Pb geochronology extracted from volcanic ash beds provide precise age constraints for the investigated sedimentary interval (Wotzlaw et al., 2018; Storck et al., 2019). Various eruption age interpretations are compared and implemented into continuous age-depths models providing a continuous numerical calibration of the Anisian-Ladinian boundary interval. The resulting age models further deliver model sediment accumulation rates, the timing of radiation and evolution of fossil fauna (e.g. ammonoid species) and magnetic reversals. In addition, correlation of several sections extends the calibrated record throughout the Southern Alpine domain and reveals reoccurring cyclic bedding patterns. These bedding patterns provide a high-resolution record of Middle Triassic climate dynamics governed by orbital-forcing with superimposed sub-Milankovitch frequencies. This high-resolution temporal framework provides a firm basis for future interdisciplinary research on the exceptional Middle Triassic marine archives of the Southern Alps and the global correlation and calibration of the Middle Triassic timescale.

Storck J.C., Brack P., Wotzlaw J.W. & Ulmer P. (2019) - Timing and evolution of Middle Triassic Magmatism in the Southern Alps (northern Italy). J Geol. Soc. London, 176(2), 253-268.

Wotzlaw J.F., Brack P. & Storck J.C. (2018) - High-resolution stratigraphy and zircon U-Pb geochronology of the Middle Triassic Buchenstein Formation (Dolomites, northern Italy): precession-forcing of hemipelagic carbonate sedimentation and calibration of the Anisian-Ladinian boundary interval. J Geol. Soc. London, 175(1), 71–85.

ST11.2

Stratigraphy and distribution of Mesozoic Oceanic Anoxic Events: recent progresses and new perspectives

Conveners and Chairpersons

Gabriele Gambacorta (Eni S.p.A. - Upstream and Technical Services)

Helmut Weissert (ETH Zürich)

Integrated calcareous plankton biostratigraphy and chemostratigraphy of Cretaceous Oceanic Anoxic Events: implications for their dating, definition and significance

Bottini C.[1]*, Erba E.[1], Falzoni F.[1], Gilardoni S.[1], Gambacorta G.[1] & Petrizzo M.R.[1]

[1]University of Milan, Department of Earth Sciences.

Corresponding author email: cinzia.bottini@unimi.it

Keywords: OAEs, Cretaceous, plankton, carbon isotope.

The Cretaceous was punctuated by peculiar time intervals, known as Oceanic Anoxic Events (OAE)s, which represent widespread ocean anoxia occurred under extreme climatic and environmental conditions. The perturbation of the C-cycle associated with the OAEs is recorded in the carbon isotopic record which marks each OAE with a unique distinctive anomaly. Decades of multidisciplinary research were dedicated to the characterization of OAEs, which constitute case-histories for the understanding of our planet functioning during perturbations of the C cycle. The profound environmental changes during OAEs had a significant impact on marine biota, including calcareous nannoplankton and planktonic foraminifera, with major changes in abundance and assemblage composition. The Cretaceous OAEs corresponded to important turnovers in calcareous nannoplankton with originations of new species and few extinctions suggesting resilience of this phytoplankton group capable of overcome the environmental stress. Chronostratigraphy of OAEs is fundamental for time assessment (when? duration? synchroneity? diachroneity?), regional to global correlations, and reconstruction of causes and consequences. The operational definition of OAEs has partially changed through time, and various authors based OAE boundaries (onset and termination) on either lithostratigraphic or chemostratigraphic data. In most cases biostratigraphy was used to constrain age attribution and possibly identify/confirm/exclude hiatuses eliding part of the OAEs. The sedimentary expression of Cretaceous OAEs, namely the Bonarelli, Selli, Weissert and Toarcian events have been recognized in a variety of sedimentary basins but in many cases black shales are diachronous. Calcareous nannofossil and planktonic foraminifera biostratigraphy are proven to be reliable tools for dating and correlating, although assessment of reproducibility of nannofossil and foraminifera biohorizons is under ongoing revision and integration. This study is focused on nannofossil and planktonic foraminifera biostratigraphic events across the late Valanginian Weissert-OAE, the early Aptian OAE 1a, the late Albian OAE 1d and the latest Cenomanian OAE 2. Updated and new micropaleontological and chemostratigraphic data were collected and integrated for middle to low latitudinal pelagic sections to provide an intercalibrated bio(nannofossil-foraminifera)-chemostratigraphy to constrains the OAEs.

Is the OAE-2 recorded in Oman? New data from the Natih Formation in the Oman Mountains

Frijia G.*[1], Godet A.[2], Morsilli M.[1], Rigo M.[3], Struck U.[4], Humood Salim N.[5] & Saleh Salim Alshaqsi A.[5]

[1] Dipartimento di Fisica e Scienza della Terra,Università di Ferrara, Ferrara, Italy. [2] Department of Geological Sciences, The University of Texas at San Antonio, San Antonio,USA. [3] Dipartimento di Geoscienze, Università di Padova, Padova, Italy. [4] Museum für Naturkunde,Berlin, Germany. [5] Department of Earth Sciences, Sultan Qaboos University, Muscat, Oman

Corresponding author email: gianluca.frijia@unife.it

Keywords: OAE-2, Oman, paleoenvironmental changes, global perturbations.

Oceanic Anoxic Event 2 (OAE-2), spanning the Cenomanian–Turonian boundary, represents a major perturbation of the global carbon cycle with an extensive deposition of organic-carbon rich sediments (black shales) in ocean basins worldwide. This event strongly impacted deep and shallow-water ecosystems as well as continental ones. Shallow shelves account for most of the global ocean bioproductivity and, in the meantime, are environments highly sensitive to ocean acidification. However, despite their importance as ecological indicators, until now only a few localities in the World have been studied in detail for their ecological response across the OAE-2. Those are mainly confined in the proto Atlantic (Mexico Platform) or the peri-Adriatic domain in North western Tethys (Apennine and Adriatic platforms) whereas, little is known from the southern Tethys Arabian Platform despite the wealth of sedimentological and stratigraphic studies linked to petroleum exploration. In this work we present new data from the mid Cenomanian-Turonian interval of the Natih Formation in the Oman mountains which comprises quantitative facies analyses, C-isotope stratigraphy (carbonates and organic matter) and trace and major elements data. Our approach allows us to:

– build a high-resolution stratigraphic framework which enables us to observe the evolution of the platform prior and during the OAE-2
– reconstruct the paleoenvironmental conditions using facies and geochemical data
– discuss whether the observed record could reflect a response to global perturbations associated to the OAE2 or rather local environmental conditions able to modulate the global signal.

A revision of the stratigraphic distribution of Cretaceous OAEs in Central and South Atlantic

Gambacorta G.*[1], Erba E.[2], Esegbue O.[3], Petrizzo M.R.[2], Miniati F.[2], Bottini C.[2] & Wagner T.[3]

[1] Eni S.p.A., Italy. [2] University of Milano, Italy. [3] Heriot Watt University, UK.

Corresponding author email: gabriele.gambacorta@eni.com

Keywords: OAEs, stratigraphy, IODP, Cretaceous.

Oceanic Anoxic Events (OAEs) represent major perturbations in the global climate and ocean system (Jenkyns, 2010), whose causes and effects are still not fully quantified, mainly because of the lack of high-resolution integrated stratigraphy of oceanic records (Robinson et al., 2017). We present the outcomes of an integrated research program placing time constraints on the distribution of Cretaceous OAEs in four Cretaceous sedimentary basins from Central and Southern Atlantic (Senegal, Tano, Kwanza, Orange). We studied for bio- and chemostratigraphy >900 samples from five ODP/DSDP wells (ODP 367, ODP Site 959 and 962, ODP 364, DSDP 361), which are known to cover key OAEs in the Cretaceous from tropical to sub-polar climate zones. From a stratigraphic perspective the oldest (Berriasian-Hauterivian) interval, containing the Weissert-OAE, is only covered in the North Atlantic Senegal Basin (DSDP Site 367), leaving a rather limited view into the wider basin development. This situation significantly improves for the Aptian to Santonian interval, with its critical global carbon-climate perturbations (OAEs 1-3). These OAEs are not recovered at all sites, but enable the identification of general similarities and differences between basins. The Upper Cretaceous Campanian-Maastrichtian is also represented at 3 sites, however, there is no evidence that they were relevant for enhanced carbon burial. Available data show different developments along the western African margin across the Cretaceous over time, representing the diverse evolution of marginal basins and ocean gateways as Pangaea gradually broke up in the Mesozoic to develop the modern configuration of continents, main ocean basins and circulation.

Jenkyns H.C. (2010) - Geochemistry of oceanic anoxic events. Geochemistry, Geophysics, Geosystems, 11(3).

Robinson S.A., Heimhofer U., Hesselbo S.P. & Petrizzo M.R. (2017) - Mesozoic climates and oceans – a tribute to Hugh Jenkyns and Helmut Weissert. Sedimentology, 64, 1-15.

Calcareous nannofossil biostratigraphy and paleoecology of Oceanic Anoxic Event 3

Miniati F.[1]*, Bottini C.[1], Moller C.[1] & Erba E.[1]

University of Milan, Dipartimento di Scienze della Terra "A. Desio".

Corresponding author email: francesco.miniati@unimi.it

Keywords: Oceanic Anoxic Event 3, Calcareous nannofossils, Atlantic Ocean, Indian Ocean, Biostratigraphy, Paleoecology.

During the Cretaceous several perturbed periods of the global climate-ocean system lead to widespread organic carbon-rich marine black shale deposition, termed Oceanic Anoxic Events (OAEs). The youngest of these events, named OAE 3, occurred during the Coniacian-Santonian time interval. Compared to older anoxic events, OAE 3 is considered to have a regional extension restricted to the equatorial-south Atlantic Ocean and the adjacent basin (e.g. Caribbean Basin, Western Interior Basin). In addition, the temporal distribution of the organic-rich sediments seems to be diachronous and associated to minor C isotopic positive excursions instead of a distinctive $\delta^{13}C$ anomaly (Wegreich, 2009; Wagreich, 2012). While the geochemical characterization of OAE 3 is relatively complete, very little is known for planktonic changes. For this reason, a biostratigraphic and quantitative investigation of calcareous nannofossil assemblages across the Coniacian-Santonian time interval of selected ODP/DSDP site in the Atlantic Ocean has been carried out. The study was extended to the Indian Ocean, sampled at the Tanzania Drilling Program Site 39 (TDP39) and ODP Site 763 that recovered Coniacian-Santonian boundary sections from, with the aim of characterizing the OAE 3 outside the Atlantic Ocean. Calcareous nannofossil data show a general increase in abundance of *Micula* spp. across OAE 3 in the Atlantic Ocean, although with individual enrichment intervals during the late Coniacian-early Santonian; similar patterns were detected also in the Indian Ocean. Our findings are relevant for a biostratigraphic and paleoecologic constrain of OAE 3, with implications for estimates of the duration of this event, intra- and inter-regional correlations and paleoceanographic reconstructions.

Wagreich M. (2009) - Coniacian-Santonian oceanic red beds and their link to Oceanic Anoxic Event 3. In: Hu X. Wang C., Scott R.W., Wagreich M., and Jansa L. (eds.), Cretaceous Oceanic Red Beds Stratigraphy, Composition, Origins, and Paleoceanographic and Paleoclimatic Significance., L., 91, 235–242. SEPM Spec. Pub.

Wagreich M. (2012) - OAE 3-regional Atlantic organic carbon burial during the Coniacian Santonian. Climate of the Past, 8(5),1447.

Calcareous nannofossil biostratigraphy as a tool to better constrain the Toarcian Oceanic Anoxic Event: a comparison between Tethyan and Boreal sections

Visentin S.*[1], Erba E.[1] & Mutterlose J.[2]

[1] Dipartimento di Scienze della Terra, Università degli Studi di Milano, Italy. [2] Institut für Geologie, Mineralogie und Geophysik, Ruhr-Universität Bochum, Germany.

Corresponding author email: stefano.visentin@unimi.it

Keywords: Nannofossil biostratigraphy, C isotope excursion, Pliensbachian-Toarcian.

Calcareous nannofossil biostratigraphy was carried out in the Upper Pliensbachian – Lower Toarcian containing the Toarcian Oceanic Anoxic Event (T-OAE) interval. In particular, semiquantitative analyses were performed: (a) on a total of 158 samples in the composite Sogno Core (Lombardy Basin, Southern Alps) representing a pelagic Tethyan section, and (b) on a total of 334 samples across the Amaltheenton Fm. and Posidonienschiefer Fm., in three cores and a section from the Boreal realm, in the Lower Saxony Basin (Northern Germany). Primary and secondary events of the Tethyan (Mattioli & Erba, 1999) and Boreal zonations (Bown et al., 1988: Bown & Cooper 1998) were recognized allowing the identifications of the NJT5, NJT6 for the Sogno Core and NJ5, NJ6, NJ7 Zones for the German cores/sections, respectively. The sequence of nannofossil biohorizons is generally consistent with data available for various areas at lower and higher latitudes, confirming their reproducibility and reliability for intra and inter-regional correlations. Geochemistry evidences the presence of the negative C isotopic excursion across the "Fish Level" black shale interval expression of the T-OAE in the Sogno Core. The same anomaly is recorded in the German successions at the base of the Posidonia Shale witnessing the passage from well oxygenated to predominantly anoxic conditions. Our results show that the T-OAE C isotopic excursion recorded in the Sogno Core is excellently constrained by the FO of *Carinolithus superbus* at the onset and the LO of *Mitrolithus jansae* at the end. Moreover, a significant decrease in abundance and size of *Schizosphaerella punctulata* (the so called "*S. punctulata* crisis") and a *M. jansae* abundance drop further characterise the T-OAE perturbation. Only *S. punctulata* shows a recovery at the end of the T-OAE, while *M. jansae* barely survived the palaeoenviromental stress and disappeared soon after its termination. The extreme rareness of *S. punctulata* and the absence of *M. jansae* in the Boreal domain prevent the recognition of the "*S. punctulata* crisis" and *M. jansae* decline. Nevertheless, our preliminary study reveals the LOs of *Crepidolithus granulatus* and *Parabdolithus liasicus* together with the FO of *C. superbus* as additional events marking the onset of the C isotopic excursion exclusively in the German cores/sections. Nannofossil biostratigraphy permits the effective dating and correlating of Lower Jurassic major palaeoceanographic events and particularly of the T-OAE which are of a great importance to derive a definitive model for the Posidonia Shale deposition.

Bown P.R., Cooper M.K.E. & Lord A.R. (1988) - A Calcareous Nannofossil Biozonation Scheme for the early to mid-Mesozoic. Newsl. Stratigr., 20, 91-114.

Bown P.R. & Copper M.K.E. (1998) - Jurassic. In: Bown P.R. (Ed.). Calcareous nannofossil biostratigraphy. British Micropaleontol. Soc. Pub. Series: 34-85. Kluwer Academic Publishers, London.

Mattioli E. & Erba E. (1999) - Synthesis of calcareous nannofossil events in Tethyan Lower and Middle Jurassic successions. Riv. It. Paleontol. Strat., 105(3), 343-376.

The 'Dudelange-Neischmelz' core, an exceptionally expanded Pliensbachian-Toarcian succession in the NE Paris Basin (Grand Duchy of Luxembourg) providing new insights into Early Jurassic palaeo-environmental change

Weis R.*[1], Münzberger P.[2], Colbach R.[2], Lacroix P.[3], Di Cencio A.[1], Korte C.[4], Winther Hougaard I.[4] & Thuy B.[1]

[1] National Museum of Natural History, Luxembourg. [2] Geological Survey, Luxembourg. [3] Independent researcher, France. [4] University of Copenhagen, Denmark.

Corresponding author email: rweis@mnhn.lu

Keywords: biostratigraphy, lithostratigraphy, chemostratigraphy, ammonites, echinoderms, T-OAE.

The geothermal research core 'Dudelange-Neischmelz' presents an outstanding potential for stratigraphic and palaeo-environmental research in the NE Paris Basin with focus on the Pliensbachian-Toarcian boundary, a time period characterized by a major oceanic anoxic event (Toarcian OAE). The drilling is located in the Trier-Luxembourg Basin (TLB), which was in the Jurassic a sub-basin of the Paris Basin. The area of Dudelange is part of a 5 to 10 km wide SW–NE trending Permian graben structure postulated by Schintgen & Förster (2013). The thickness of the Mesozoic cover, overlying the Palaeozoic basement, is here at least 900 m, which is roughly 400 m more than known from comparable other successions in the TLB. Therefore, the drill core yields an extended and near-complete Sinemurian to Toarcian rock sequence without longer depositional gaps. Ongoing multidisciplinary research comprises litho-, bio-, and chemostratigraphic analyses, as well as palaeontological investigations:

Significant geological markers already allow correlation with the SW-German sediment strata. Geochemical, litho- and biofacies examinations by the Geological Survey of Luxembourg will provide a more detailed picture of depositional factors as well as a precise lithostratigraphic subdivision.

A preliminary biostratigraphic study of 211 ammonite specimens from the upper succession of the core revealed the consistently presence of 8 biozones from the Margaritatus Zone (upper Pliensbachian) to the Thouarsense Zone (upper Toarcian).

Carbonate stable isotope analyses on 344 bulk rock samples and 70 macro fossils (mostly belemnites) collected from the uppermost Pliensbachian and lower Toarcian portion of the core (sampling resolution of 0.25 m for the bulk rocks) are currently in progress at the Department of Geosciences at the University of Copenhagen.

The Pliensbachian-Toarcian boundary interval, corresponding to roughly 10 metres of marls and clays between the last occurrence of the ammonite *Pleuroceras* and the first occurrence of *Harpoceras*, was sampled for microfossils in steps of 0.3 m in an attempt to resolve the fine-level biostratigraphy of this interval by using ostracods and foraminifera. Apart from these index microfossils, the samples prepared at the Natural History Museum Luxembourg yield an unexpected and previously undocumented diversity of echinoderm microfossils, some of these belonging to new taxa.

The integration of the litho-, bio-, and chemostratigraphy, the synthesis of palaeontological and palaeoenvironmental data as well as the exceptionally expanded succession have the potential to establish the 'Dudelange-Neischmelz' core as a new reference succession for the Sinemurian-Toarcian of the NE Paris Basin.

Schintgen T. & Förster A. (2013) - Geology and basin structure of the Trier-Luxembourg Basin - Implications for the existence of a buried Rotliegend graben. Z. Dt. Ges. Geowiss. (German J. Geol.), 164(4), 615-637.

ST11.4

General session on Stratigraphy

CONVENERS AND CHAIRPERSONS

Valeria Luciani (University of Ferrara)

Claudia Agnini (University of Padova)

Appy Sluijs (Utrecht University)

Edoardo Dallanave (University of Bremen)

Proposal for a new upper Miocene formation in the Northwestern Rif belt (Morocco): the Saf Lahmame formation

Abbassi A.*1, Cipollari P.1, Zaghloul M.N.2 & Cosentino D.1

[1] University of Roma Tre. [2] University of Abdel Malek Essaâdi Tangier.

Corresponding author email: anas.abbassi@uniroma3.it

Keywords: Lithostratigraphy, Late Miocene, Northwestern Rif Belt, Morocco.

We report on a new formation in the Upper Miocene deposits of the northwestern Rif Belt: The Saf Lahmame Formation. The study area is located east of Hajra en Nahal village, 30 km to the south of Tanger City, where sandy-clayey deposits unconformably overlie the varicolored clays of the External Tanger Intrarif sub-domain. The present proposal is based on new geological mapping coupled with lithostratigraphic logging and sampling for biostratigraphical analyses. Field observations revealed that the Saf Lahmame Formation can be subdivided into two members. The lower member is made by glauconite-bearing quartz- to sublith-arenites, which unconformably overlie the highly deformed Upper Oligocene varicolored clays and marls. The upper member is slightly unconformable onto the lower one and is characterized by alternation of thin-bedded turbidites and grey-bluish marls, which evolve upwards to light colored marls. The medium- to fine-grained sandstones of the lower member show graded and massive amalgamated beds, organized in thinning and fining upward successions due to high density turbidity flows. The upper member is characterized by fine-grained turbiditic sandstones interbedded in grey, bluish clays reflecting a deep marine environment. The deep character of the depositional environment is also confirmed by the abundant presence of ichnofossils that includes *Zoophycos*, *Paleodictyon*, and *Planolites*. The deposits we are now grouping into the Saf Lahmam Formation were formerly considered as Chattian-lower Burdigalian (Durand Delga & Didon, 1985). Subsequently, Hoyez (1989) performed the analysis of a stratigraphic section in the area of Saf Lahmame, constraining to an early Burdigalian age its uppermost part. Later on, Zaghloul et al. (2005) performed a detailed sedimentological study and a preliminary calcareous plankton biostratigraphy for the top of the same section, which provided an age not older than the late Serravallian. Both these biostratigraphical analyses were carried out on deposits coming from the lower member of the Saf Lahmame Formation.

Recently, biostratigraphic quantitative analyses on calcareous nannofossil assemblages provided new ages for these deposits. In particular, the lower member of the Saf Lahmame Formation is constrained to the late Tortonian, whereas late Tortonian to early Messinian ages have been provided for the upper member.

Durand-Delga M., Didon J., Feinberg H., Magne J., Medioni R., Suter G. & Werneli R. (1985) - Carte Géologique du Rif Tanger- Al Manzla 1: 50.000. Not. Mém. Serv. Géol. Maroc., 294 pp.

Hoyez D. (1989) - Le Numidien et les flysch Oligo-Miocènes de la bordure sud de la Méditerranée occidentale. Thèse Univ. Lille, 459 pp.

Zaghloul M.N., Di Staso A., Gigliuto L.G., Maniscalco R. & Puglisi D. (2005) - Stratigraphy and provenance of Lower and Middle Miocene strata within the External Tanger Unit (Intra-Rif sub-Domain, External Domain; Rif, Morocco): first evidence. Geol. Carpath., 56, 517–530.

Conochitina Symmetrica a worldwide chitinozoan marker for correlation of early Ordovician sequences

Achab A.*[1] & Asselin E.[2]

[1] Institut national de la recherche scientifique, INRS-ETE, Québec. [2] Ressources naturelles Canada, Québec.

Corresponding author email: aicha.achab@ete.inrs.ca

Keywords: Chitinozoans, Lower Ordovician, Floian, Tremadocian, Conochitina symmetrica.

The Global Stratotype Section and Point (GSSP) of the Floian - the second stage of the Ordovician- was defined by the first appearance of the graptolite *Tetragraptus approximatus* at the Diabasbrottet Quarry at Hunneberg, southwestern Sweden. The Floian succeeds the Tremadocian, with which it forms the Early Ordovician epoch. In North America, the Early Ordovician is referred, in the older literature, to the Canadian Series with its type area at the Lévis area on the south shore of the St-Lawrence River in front of Quebec City. Lower Ordovician strata of the Lévis area are composed of two units: the Lauzon and the Lévis formations; both well known for their graptolite, trilobite and chitinozoan faunas. At the Lévis G locality, a *Conochitina symmetrica* Zone was defined (Achab, 1980) in the lowermost part of the section just above a conglomerate within an interval belonging to the graptolite Zone A of Raymond that contains *T. approximatus*. Consequently the zone was attributed to the Floian. Because *C. symmetrica* is a cosmopolitan species also recognized in various areas of Northern Gondwana, the *C. symmetrica* Zone was considered as an unqualified marker of the base of the Floian. However, during the past decades, several occurrences of *C. symmetrica* have been reported from Avalonia and southern China, but also from Northern Gondwana in older strata of the Tremadocian *A. murrayi* Zone. It was naturally concluded that *C. symmetrica* has a wider range and characterizes the upper Tremadocian – lower Floian interval. Maletz (1997) on the basis of the stratigraphic range of graptolites established correlation between sections of the Lévis and the Lauzon formations. This provided a frame on which the chitinozoan distribution of the two units can be reported and compared. Chitinozoans of the Lauzon N section show two distinct assemblages. The lower one containing *L. maxima* occurs below the conglomerate, in strata correlated with the Tremadocian *A. victoriae* graptolite Zone. Above the conglomerate in levels attributed to the Tremadocian A. *murrayi* Zone a distinct assemblage is characterized by *C. symmetrica*. The graptolite range charts established by Maletz for the N section clearly indicates that the *C. symmetrica* assemblage occurs below the FAD of *T. approximatus*. This is also true at the Lévis G locality, where the *C. symmetrica* Zone also lies under the FAD of *T. approximatus*. These observations demonstrate that the *C. symmetrica* chitinozoan Biozone can no longer be considered to mark, as it was previously thought, the base of the Floian; it rather correlates with the upper Tremadocian *A. murrayi* graptolite Zone.

Achab A. (1980) - Chitinozoaires de l'Arenig inférieur de la Formation de Lévis (Quebec, Canada). Rev. Palaeobot. Palynol., 31, 219-239.

Maletz J. (1997) - Arenig biostratigraphy of the Pointe-de-Levy slice, Quebec Appalachians, Canada. Can. J. Earth Sci., 34, 733-752.

Peat-based correlation and mapping as an effective tool to assess post-depositional strata deformation: an example from the mid-late Holocene Po delta plain succession (Northern Italy)

Campo B.*[1], Bruno L.[2], Di Martino A.[1], Hong W.[3] & Amorosi A.[1]

[1] Dipartimento di Scienze Biologiche, Geologiche ed Ambientali (BiGeA), Università degli Studi di Bologna, Italy.[2] Dipartimento di Scienze Chimiche e Geologiche, Università degli Studi di Modena e Reggio Emilia, Italy. [3] KIGAM Korea Institute of Geoscience and Mineral Resources, Daejeon, Korea.

Corresponding author email: bruno.campo2@unibo.it

Keywords: Holocene, peat layer, Po coastal plain, strata deformation.

Peat is a common feature of many Holocene delta plains (van Asselen et al., 2009). Widespread peat-layer deposition started after the post-glacial (early Holocene) sea-level rise, when alluvial plains were progressively flooded. Peat-based correlations were used to assess the deformation of Holocene strata in the Po coastal plain (Northern Italy). About 30 km inland from the modern shoreline, the Holocene succession (up to 23 m thick) is made up of peat-bearing, estuarine and deltaic strata (Amorosi et al., 2017). The analysis of 31 core data and 100 cone penetration tests led to the identification and mapping of three 10-40 cm-thick peat layers (T1-T3) dated to 6.6-5.8, 5.5-5.0 and 3.3-2.7 cal ky BP, respectively. Within the studied succession, these peat layers showed very high correlability, thus proving to be reliable stratigraphic markers. Peat correlation, supported by 72 radiocarbon dates allowed the reconstruction of the mid-late Holocene paleogeography at the time of accumulation of each peat layer. Paleogeographic maps depict a typical upper delta plain environment, characterized by ribbon-shaped distributary channels and swamp interdistributary areas. Peat horizons accumulated under low sediment supply conditions mainly driven by autogenic processes. Peat layers show an overall dip towards ENE, with gradients decreasing upsection from ~ 0.021% (T1) to 0.016% (T3). The gradient of the oldest peat horizon (T1) is one order of magnitude larger than the slope of the modern delta plain (~ 0.0025%). Progressively increasing inclinations of older strata suggest an ongoing deformation after burial, likely due to the combined effect of differential compaction of underlying sediments and recent tectonic activity. Analysis set of isochore maps suggests that higher sedimentation rates in topographically depressed areas partially compensated the ongoing deformation, with no substantial alteration of the topographic gradient. This study shows that peat-based correlation and mapping can be useful to unravel the mechanisms of strata deposition and deformation in deltaic settings, representing an important tool for the reconstruction of delta evolution.

Amorosi A., Bruno L., Campo B., Morelli A., Rossi V., Scarponi D., Hong W., Bohacs K. M. & Drexler T. M. (2017) - Global sea-level control on local parasequence architecture from the Holocene record of the Po Plain, Italy. Mar. Petrol. Geol., 87, 99-111.

Tornqvist T.E., Bick S.J., van der Borg K. & de Jong A.F.M. (2006) - How stable is the Mississippi Delta? Geology, 34, 697-700.

van Asselen S., Stouthamer E. & van Asch T.W.J. (2009) - Effects of peat compaction on delta evolution: A review on processes, responses, measuring and modeling. Earth-Sci. Rev., 92, 35-51.

Detailed stratigraphy as a tool for tectonics reconstruction: the record of the geological sheet Antrodoco, 1:50.000 scale (northern-central Apennines – Italy)

Capotorti F.*, Berti D., D'Ambrogi C., Marino M., Muraro C., Perini P., Pichezzi R.M., Ricci V., Rossi M. & Silvestri S.

Servizio Geologico d'Italia - Sezione Rilevamento Geologico, Biostratigrafia e Modellazione del sottosuolo

Corresponding author email: franco.capotorti@isprambiente.it

Keywords: Antrodoco sheet, geological complexity, paleo-tectonic, stratigraphy, Apennines.

The Servizio Geologico d'Italia (SGI) has recently completed the mapping of the Geological sheet Antrodoco, 1:50.000 scale. The area includes the NW portion of Latium-Abruzzi (L-A) Platform and the surrounding Umbro-Sabino (U-S) and Gran Sasso Basins (G-S), and is crossed by Olevano-Antrodoco-Sibillini, M. Gabbia and M. Mozzano thrusts. Due to the high vertical and lateral variability of the characteristics of the rock-bodies, more than 60 marine litostratigraphic units have been identified and mapped as evidence of the geological complexity of the studied area. These deposits are related to different pre-and syn-orogenic geodynamic contexts and various sedimentary environments, ranging from inner platform to margin-slope and basin, carbonate ramp, and foredeep, spanning from Late Triassic up to Late Miocene. Moreover, several continental units are related to the evolution of six Quaternary intermountain basins in the post-orogenic extensional tectonic regime. This contribution aims to show how the use of detailed stratigraphy has made it possible to identify six pre-orogenic extensional tectonic phases (Early Jurassic, Bajocian, Turonian-Coniacian, Late Paleocene, Late Eocene and Late Miocene in age) recorded by the marine units. The Early Jurassic rifting caused the onset of the L-A Platform and the U-S and G-S basins hosting pelagic carbonate platforms (PCPs), identified by Lower-to-Middle Jurassic condensed pelagic carbonates; three of these have been identified in the area. Unlike the latter, the M. Giano PCP has formed during Bajocian and has been newly catch up by Tithonian shallow water facies. The Late Cretaceous and Paleogene tectonic phases caused, together with eustatic and biological factors, the drowning of the NW portion of the L-A Platform and the creation of a complex paleotopography, with the previous margin and inner carbonate platform draped by "condensed scaglia" facies and onlapped by typical basinal "scaglia" facies. During the Oligocene and early-middle Miocene time the stop of tectonics allowed the levelling of the topography and the installation of an homogeneous carbonate ramp environment. Finally, the Late Miocene extensional tectonic, related to the peripheral bulge flexuration, created confined foredeep basins (e.g. Antrodoco basin), put in evidence through the relationships of the siliciclastics with the previous marine units.

Integrated stratigraphy of the Fucino Basin (central Apennines, Italy): new constraints for the late-orogenic to post-orogenic transition in the tectonic evolution of the central Apennines (Italy)

Cosentino D.*[1], Mondati G.[1], Spadi M.[2], Gliozzi E.[1], Cavinato G.P.[3], Cifelli F.[1], Mattei M.[1], Romano C.[1], Cipollari P.[1], Nocentini M.[3] & Tallini M.[2]

[1] University of Roma Tre, Italy. [2] University of L'Aquila, Italy.
[3] Istituto di Geologia Ambientale e Geoingegneria - CNR

Corresponding author email: domenico.cosentino@uniroma3.it

Keywords: Messinian Lago-Mare, continental stratigraphy, Fucino Basin, late-orogenic sedimentary basins, post-orogenic sedimentary basins.

To figure out the transition from compressional to extensional deformation in the evolution of an orogenic belt is a major challenge. These different types of deformation are related to processes that include (1) convergence and rollback of the subducting plate (compressional domain) and (2) mantle upwelling responsible for the hinterland tectonics (extensional domain). In the Fucino Basin, integrated stratigraphy based on field observations, ostracod assemblages, magnetostratigraphy, Raman spectroscopy, and re-interpretation of reflection seismic profiles provide new constraints to find out the transition between compressional and extensional tectonics in the evolution of the central Apennines. The stratigraphic analysis carried out at the northeastern side of the Fucino Basin, between Paterno and Pescina, allowed to distinguish two different synthems that unconformably overlie the highly deformed Meso-Cenozoic units of the Apennine chain. The older synthem mainly consists of a silty-sandy succession, gently tilted toward the Fucino Basin. In some places, this synthem contains thick layers of black clays rich in organic matter. Samples from this synthem collected in the Belvedere and Collarmele areas yielded a diversified ostracod fauna pertaining to the late Messinian *Loxocorniculina djafarovi* Zone. This result points to a late Messinian Lago-Mare age for these deposits, which were previously referred to the lower Messinian flysch or to Quaternary deposit. In the same areas, lacustrine deposits of a younger unconformity-bounded unit, which consist mainly of silts, sands, and conglomerates, contain ostracod assemblages that include several species of *Caspiocypris* and in particular *C. tiberina*. This result, together with the normal polarity detected from the Casa Colombaia section, point to correlate the lower portion of the lacustrine deposits of the Fucino Basin to the basal part of the Fosso Bianco Unit (Gauss normal epoch, upper Piacenzian) of the Tiberino ancient lake (Spadi et al., 2018). In addition, the re-interpretation of commercial seismic lines crossing the Fucino Basin shows a large growth syncline deforming the Messinian Lago-Mare deposits, which unconformably lie on the lower Messinian flysch and the Meso-Cenozoic carbonates. Above the late Messinian growth syncline, the unconformable upper Piacenzian-Gelasian lacustrine deposits show synextensional growth strata. In conclusion, the integrated stratigraphy of the Fucino Basin allows us to figure out that, in this area, the compressional tectonics ended with the late Messinian-early Zanclean tectonic event, whereas the post-orogenic extensional tectonics started in the late Piacenzian (ca. 3 Ma), like in the Tiberino and L'Aquila basins.

Spadi M., Gliozzi E. & Medici M.C. (2018) - A Plio–Pleistocene *Caspiocypris* species flock (Candoninae, Ostracoda) from the Palaeolake Tiberino (Umbria, central Italy). J. Syst. Palaeontol., 16, 417-434.

High-resolution carbon isotope stratigraphy across the Cenozoic: purpose, power and problems

Dickens G.R.*[1] & Sluijs A.[2]

[1] Rice University, Houston, USA. [2] Utrecht University, Nederland.

Corresponding author email: jerry@rice.edu

Keywords: carbon isotope, carbon cycle, stratigraphy.

Greater than five thousand stable carbon isotope records have been generated using carbonate or organic carbon components deposited during the Cenozoic. These records, generally expressed in d13C, show major changes over time and between different carbon-bearing components. New records, where the d13C compositions of multiple phases are determined across short intervals of time at the same location, highlight these aspects. Cenozoic d13C records remain crucially interesting and important. Across many time intervals, the d13C composition of multiple phases and at multiple locations shift coherently, at least on the 1000-year cycling time of carbon across Earth's surface. This has been an amazing revelation to the field of stratigraphy, and makes complete sense at a basic level, once one recognizes how carbon moves between the ocean, biosphere and atmosphere. However, the variations in d13C also raise a major problem when one considers requisite carbon masses. Almost assuredly, Earth has at least one major carbon capacitor outside conventional carbon cycle models throughout the Cenozoic and before. A deep view of "carbon isotope stratigraphy" forces one to think outside the box.

Sequence stratigraphy, sedimentary facies and depositional environments of Upper Pliocene deposits in northern Sahel, (Eastern Tunisia)

Frigui M.[1]* & Ben Youssef M.[1]

[1]Georesources Laboratory, LR15CERTE01, Water Researches and Technologies Center, Tunisia

Corresponding author email: frigui_mouna@yahoo.fr

Keywords: Upper Pliocene, facies associations, depositional environments, sequence stratigraphy, northern Sahel.

In Eastern Tunisia particularly the Sahel area, previous works assert that the outcropping Pliocene deposits were ranged in time only to the Upper Pliocene however the Lower Pliocene was missing. Burollet (1961) considered the recognized deposits in the Sahel area to be terrestrial Mio-Plio-Quaternary and coeval to "Segui" formation. Besème & Kamoun (1988) distinguished continental and marine pliocene deposits. They assigned the marine deposits to "Porto Farina" formation (Burollet, 1951). However, our studies carried out on well exposed sections afford new data to develop sedimentological model. In fact, Upper Pliocene deposits exist under a variety of facies in such a way that their belonging to only one formation seemed impossible. On the basis of sedimentological and ichnological data twenty lithofacies were identified and grouped in to eight facies associations (facies association 1 to facies association 8). Their interpretation leads us to recognize eight depositional environments whose vertical succession records in places some variations. These facies associations indicate depositional environments starting with coastal plain, beach dune, backshore, foreshore, lagoon, shoal, shoreface and. ending with upper offshore. Moreover, this study provides new data concerning the second and third order cycles. Two third order sequences S1 and S2 were evidenced and correspond to 3.7 and 3.8 sequences of TB3 second order sequence. All the recognized sequences are rarely complete (partially eroded) and this shows that the sedimentary and stratigraphic evolution is tectonically controlled as witnessed by the recognition of three angular unconformities. Another outcome of the study is the recognition that the coast line during Pliocene interval is presented by a mosaic of depositional environments. Some of them are restricted to areas particularly affected by tectonic activity attested by the recognition of slump, flame structures and load casts.

Advances in the Ordovician stratigraphy of Peru: the Floian to ?Hirnantian succession from the Apurímac River valley, Cordillera Oriental

Gutiérrez-Marco J.C.*[1], Bernárdez E.[2], Lorenzo S.[3], Carlorosi J.[4] & Chacaltana C.A.[5]

[1] Instituto de Geociencias (CSIC-UCM), Madrid, Spain. [2] Universidad de Atacama, Copiapó, Chile. [3] Universidad de Castilla-La Mancha, Almadén, Spain. [4]Instituto Superior de Correlación Geológica (UNT-CONICET), Tucumán, Argentina. [5] Instituto Geológico, Minero y Metalúrgico (INGEMMET), Lima, Perú.

Corresponding author email: jcgrapto@ucm.es

Keywords: Ordovician, Peru, Central Andean Basin, new Formation, Biostratigraphy, Correlation.

In the northern part of the Central Andean Basin, Ordovician rocks crop out extensively in the Cordillera Oriental of Peru and also occur sporadically in some parts of the Peruvian Altiplano. The Ordovician succession in the Cordillera Oriental differs from those in the Altiplano, comprising three sedimentary units, namely (in ascending order) the San José Formation (massive organic-rich shales, up to 3500 m thick), the Sandia Formation (quartzose sandstones with interbedded shales, up to 3000 m thick) and the San Gabán Formation (glaciomarine diamictites with some sandstones, ca. 160 m thick). Graptolites are abundant in the oldest formation but being restricted to a short interval in the Middle to basal Upper Ordovician (Maletz et al., 2010), and there is a single occurrence of upper Floian (Lower Ordovician) conodonts in the lower part. Biostratigraphic data from the other two formations are much more scarce, having been referred to the Sandbian and the Hirnantian through Llandovery intervals, respectively. Field work recently conducted along the northeastern margin of the Apurímac River valley, northeast of the city of Ayacucho, led to the discovery of new sections in the area mapped by Monge et al. (1998), which were measured and sampled biostratigraphically in detail. The San José Formation lies unconformably on a Neoproterozoic metamorphic complex, reaching a maximum thickness of about 700 m. This formation has yielded basal Floian graptolites in its lower –not most basal- part, and these are succeeded by a complete biostratigraphic record documenting the existence of upper Floian, Dapingian, Darriwilian and lower Sandbian strata, which include graptolites, trilobites, brachiopods, molluscs and ostracods, as well as some conodonts and other fossils. The upper part of the San José Formation is unconformably overlain by a thick sandy succession, previously assigned to the Sandia Formation, but here as the newly defined Kimbiri Formation. It consits of 80 m of massive sandstones with a basal member of glaciomarine diamictites measuring up to 90 m thick and locally resting on a basal quartzite. The diamictites also rarely occur interbedded in the main sandstone member and show some ressemblance to the San Gabán Fm, that has been reinterpreted as lower Silurian turbidites and gravity flows instead of autochthonous glacial deposits contemporaneous to the end-Ordovician glaciation. Some fossiliferous pebbles in the Kimbiri Fm come from deeply eroded areas of the San José Fm.

This is a contribution to CGL2017-87631-P and IGCP 653 projects.

Maletz J., Reimann C., Spiske M., Bahlburg H. & Brussa E.D. (2010) - Darriwilian (Middle Ordovician) graptolite faunas of the Sandia Region, southern Peru. Geological Magazine, 45, 397–411.

Monge R., Valencia M. & Sánchez J. (1998) - Geología de los cuadrángulos de Llochegua, río Picha y San Francisco. Boletín, 120, 1–253.

A correlation of the Ordovician of the Anti-Atlas (Morocco) with reference to the global and regional chronostratigraphic scales

Gutiérrez-Marco J.C.*[1], Sá A.A.[2], Álvaro J.J.[1], Rábano I.[3], Zamora S.[3], Colmenar J.[4], Pereira S.[5] & García-Bellido D.C.[6]

[1] Instituto de Geociencias (CSIC-UCM), Spain. [2] Universidade de Trás-os-Montes e Alto Douro, Vila Real, Portugal. [3] Instituto Geológico y Minero de España, Spain. [4] Instituto Dom Luiz & Universidade de Lisboa, Portugal. [5] Universidade Nova de Lisboa, Portugal. [6] University of Adelaide and South Australian Museum, Australia

Corresponding author email: jcgrapto@ucm.es

Keywords: Ordovician, Morocco, chronostratigraphy, regional scale, global scale.

The Anti-Atlas Range of Morocco comprises *ca.* 24,000 km^2 of surface exposures of Ordovician rocks that are highly fossiliferous and which contribute to the renowned 'fossil industry' of the area (Gutiérrez-Marco & García-Bellido, 2018). The Ordovician sedimentary environments include all types of shallow-water inshore facies (except limestones) which are mainly developed on muddy to coarse-sand substrates at high latitudinal –peri-polar– areas on the Gondwanan shelf. Lithostratigraphically, the Ordovician succession is divided in 14 formations belonging to 4 groups ranging from the lower Tremadocian to the uppermost Hirnantian. Despite the highly fossiliferous character of most of these units, problems to achieve an accurate chronostratigraphic correlation arise due to the generalised absence of the key graptolites and conodonts that define the global series, stages and lower divisions of the Ordovician System. This is caused by the unsuitable environments for the survival and preservation of some mesopelagic and warm-water graptolites and the scarcity of carbonate interbeds from which to obtain conodonts. However, the Moroccan record of other fossils, such as chitinozoans, brachiopods, trilobites, molluscs and echinoderms, serves to assign the different units to the South Polar regional scale, which includes several stages defined in Bohemia and Iberia (Gutiérrez-Marco et al*.,* 2017). Thus, the Tachilla, Taddrist, Bou-Zeroual and Guezzart formations are representative of successive divisions of the Oretanian; the Ouine-Inirne and Izegguirene formations of the Dobrotivian; the Lower Ktaoua Fm. of the lower to lower upper Berounian; the Upper Tiouririne Fm. of the upper Berounian–lowermost Kralodvorian; the Upper Ktaoua Fm. of the Kralodvorian, and Lower Second Bani Fm. of the uppermost Kralodvorian–lower Hirnantian. Tentative correlation between the regional and global scales (Gutiérrez-Marco et al., 2017) indicates that the Lower Ordovician is represented by the Lower Fezouata (Tr1-Tr3), Upper Fezouata (Fl1-Fl3) and Zini (Fl2-Fl3) formations; Middle Ordovician by the Tachilla (Dw1-Dw2), Taddrist (Dw2/3), Bou Zeroual, Guezzart and Ouine-Inirne (all Dw3) formations; and finally, the Upper Ordovician by the Izegguirene (Sa1), Lower Ktaoua (Sa1-Ka2), Upper Tiouririne (Ka2-Ka3), Upper Ktaoua (Ka3-Ka4), Lower Second Bani (Ka4-Hi1) and Upper Second Bani (Hi2) formations.

Gutiérrez-Marco J.C. & García-Bellido D.C. (2018) - The international fossil trade from the Paleozoic of the Anti-Atlas, Morocco. In: Hunter A.W., Álvaro J.J., Lefebvre B., van Roy P. & Zamora S. (eds), The Great Ordovician Biodiversification Event: Insights from the Tafilalt Biota, Morocco. The Geological Society, London, Special Publications, 485. doi: 10.1144/SP485.1.

Gutiérrez-Marco J.C., Sá A.A., García-Bellido D.C. & Rábano I. (2017) - The Bohemo-Iberian regional chronostratigraphic scale for the Ordovician System and palaeontological correlations within South Gondwana. Lethaia, 50, 258–295.

Biostratigratigraphic review of the synextensionnal Upper Aptian-Early Albian boundary from Sidi Salem-Messella structure (Northeastern of Tunisia)

Hichi M.*[1] & Ben Youssef M.[2]

[1] University of science of Bizerte, Tunisia. [2] Géo-ressources Laboratory, Centre de Recherches et des Technologies des Eaux de Borj Cedria, Tunisia.

Corresponding author email: hichimeriem2@gmail.com

Keywords: Aptian, Albian, hiatus, Pt. eubejaouensis, Normal faults, tilted blocks.

Despite several studies based on ammonite's data, especially in Fahden area, the Aptian- Albian boundary was for a long-time difficult to identify along the foreland basin of Tunisian Atlas. The present revision of the Aptian-Albian series of Sidi Salem–Messella structure, northeastern part of the Tunisian dorsal, provides new information on this boundary interval. The Djebel Sidi Salem structure preserves a complete recording of Aptian-Albian interval with no sign of redeposition; this singular section presents a rich fauna of planktic foraminifera. It leads to a chronological appearance of index species giving six zones from Gargasian to middle Albian:" *Ticinella algerianus* Zone"," *Ticinella trocoidea* Zone"," *Planomalina cheniourensis* Zone"," *Paraticinella eubejaouensis*/*Ticinella roberti* Zone"," *Hedbergella planispira* Zone" and" *Ticinella primula* Zone". *Pt. eubejaouensis* has never been identified yet in the Sidi Salem series, since the lower Albian was often considered as incomplete. This species is a real find in this studied section. This later shows a very remarkable abundance and even an exclusive presence in some samples, here, the" *Pt. eubejaouensis* Total/Abundant Range Zone" allows to identify the Upper Albian boundary and proves the continued sedimentation of the Aptian-Albian boundary thus a non-generalization of the famous notion of" Lower Albian hiatus" at least at the Sidi Salem structure. This work suggests a close relationship between sedimentary recording and tectonic event. The extensional tectonic activity is associated with ENE- trending normal faults that are associated with significant thickness and/or facies variations comprising abundant syntectonic sequences. Normal faults controlled the Aptian Albian sedimentation where the deposits were thicker and demonstrate growth strata architectures in the hanging wall. The biostratigraphic correlation of the Aptian-Albian provides listric extensional growth faults draws the structural architecture of the south Tethyan margin in Northern Tunisian Atlas. Therefore, the tectonic and structural works come to reinforce the biostratigraphic and sedimentological data by explaining the geodynamic evolution of Sidi Salem-Messella structure in tilted blocks during Aptian-Albian crisis with a continuous sedimentation in an open marine environment allowing to a considerable biostratigraphic resolution of the Upper Aptian-lower Albian boundary.

Rift basin sequence stratigraphy: the role of climate upon the stratigraphic signature

Holz M.*

Universidade Federal da Bahia.

Corresponding author email: michael.holz@ufba.br

Keywords: rift basin, paleclimate, Cretaceous.

The *stratigraphic signature* of the infill a basin is characterized by several attributes (e.g., sediment type, stacking patterns) controlled by the four allogenic factors: tectonics, eustasy, climate and sedimentary supply. The fundamental concept of sequence stratigraphy adopts two premises: (1) the sedimentary input is constant along the base level cycle; (2) the climate factor is negligible as a variable. Thus, tectonics and eustasy remain as determinants of the stratigraphic signature of a basin, and these two translate into the concept of *accommodation space*. In the case of continental rift basin, tectonics has an essential role as control mechanism of the sedimentary infill, and "eustasy" is conceptually replaced by "lake level". But, what about "climate"? Considering that continental rift basins evolve to lacustrine systems, and that lakes are very sensitive to climate changes, what is the climatic influence on a rift basins stratigraphy? That is what this paper intends to discuss. Paleoclimates changed cyclically during geologic time, and climatic cycles are caused by a variety of physical mechanisms, involving magnitudes from 101 to 106 years, divided into seven different magnitudes (Holz et al., 2017). Since lakes are systems very sensitive to climatic changes, it is important to consider climate cycles. Modern analogues provided by the East African rift lakes (Malawi, Victoria, Tanganyika) show level variations of hundred of meters in relatively short time spans (tens to hundreds of thousand years, *e.g.*, Bergner et al. (2009). Hence, during lake highstands, deltaic deposition occurs at the shoreline and gravity-driven deposits (debrites, turbidites) in the depocenter; while during lowstands, coarse sediment accumulates in fluvial channels on the basin margins and in delta systems prograding into lakes that are considerably reduced in size. The low-stand deltas and associated deposits are covered by the sediments of the next highstand, so that in a given stratigraphic profile deep-water deposits may appear covered directly by lowstand deltas and marking an intra-rift unconformity, as depictured by some Cretaceous Brazilian rift basin. The vertical lake levels changes of hundreds of meters may occur over time spans of hundreds of thousands of years, producing "climatic sequences". On a short-term scale (3rd order or less, considering the aforementioned climate cycles hierarchy), the climatic overprint is clearly present, and climatically controlled lake level fluctuations may be expressive enough to imprint a stratigraphic signature to rift basins sedimentary record.

Bergner A.G.N., Strecker M.R., Trauth M.H., Deino B., Gasse F., Blisniuk P., Duenforth. M. (2009) - Tectonic and climatic control on evolution of rift lakes in the Central Kenya Rift, East Africa. Quat. Scie. Rev., 28, 2804–2816.

Holz M., Vilas-Boas, D.B., Troccoli, E.B., Santana, V.C. & Vidigal-Souza P.A. (2017) - Conceptual models for sequence stratigraphy of continental rift successions. Stratigraphy & Timescales, 2, p. 119-186.

Calciclastics in the Rosso Ammonitico Fm from the Umbria-Sabina Apennine (Central Italy): new evidence for Toarcian synsedimentary tectonics

Innamorati G.*[1], Cipriani A.[1], Zuccari C.[1], Marino M.C.[2] & Petti F.M.[3]

[1] University of Rome, Italy. [2] University of Catania, Italy. [3] Muse – Museo delle Scienze di Trento.

Corresponding author email: giulia.innamorati@uniroma1.it

Keywords: mass-transport deposits, Pelagic Carbonate Platform, palaeofaults, debris flow.

Toarcian calciclastic deposits made of pelagic carbonate elements embedded in other pelagic carbonates were identified in two key-sectors of the Umbria-Sabina Apennine: the Reatini and Narnesi-Amerini Mts. The studied outcrops pertain to basinal successions of the Umbria-Marche-Sabina type and, in particular, to the Rosso Ammonitico Fm of three different Pelagic Carbonate Platform-Basin systems. The pelagic successions of these areas onlap Early Jurassic rift-related structural highs. These clastic bodies are mass-transport deposits (MTDs) which partially replace the typical Toarcian reddish marls and shales at different stratigraphic levels. The clasts, ranging from blocks to megablocks, are dominated by facies typical of the Corniola Fm (Pliensbachian *p.p.*), coupled with Rosso Ammonitico Fm intraclasts and, sporadically, Calcare Massiccio Fm (Hettangian-lower-Pliensbachian) extraclasts. The internal architecture (source and accumulation areas) of the MTDs and their potential emplacement processes were identified. Three distinct lithofacies characterise the clastic bodies, each one corresponding to a different emplacement process or to a different portion of the flow. The occurrence of lithified megablocks (>20 m across) of Corniola Fm suggests the exhumation of buried portion of the unit. Synsedimentary extensional tectonics more than differential compaction is the most likely triggering mechanism. Stratigraphic-sedimentological analysis and geological mapping of the study areas reveal the key role played by Pelagic Carbonate Platforms in the genesis of these MTDs. The early Toarcian reactivation of the Hettangian palaeofaults bounding the structural highs is inferred. These faults, characterised by moderate offsets, crosscut the onlap wedges of the hangingwall successions, exhuming the older and lithified portion of Corniola Fm. The planes of the no more active faults were then eroded producing palaeoescarpments. Their backstepping, coupled with seismic shocks, produced the accumulation of the study clastic bodies.

Late Miocene Suidae from Siwaliks, Northern Pakistan: Biostratigraphy

Khan M.A.*, Babar M.A. & Abbas S.G.

Dr. Abu Bakr Fossil Display & Research Centre, Zoology Department, University of the Punjab, Quaid-e-Azam Campus, Lahore (54590), Punjab, Pakistan

Corresponding author email: akbar.zool@pu.edu.pk

Keywords: Propotamochoerus, Tetraconodon, Sivachoerus, Lophochoerus, Paleontology.

Late Miocene of the Siwalik Group has produced a diverse suid taxa. This time frame has been designated as the Middle Siwalik Subgroup in context of the Siwaliks. Recently, new suid fossils from the outcrops of the Middle Siwaliks of Pakistan are excavated by the team of paleontologists from University of the Punjab, Lahore, Pakistan. The newly recovered fossils belong to the four late Miocene suid species *Lophochoerus nagrii*, *Propotamochoerus hysudricus*, *Tetraconodon magnus* and *Sivachoerus prior*. *Lophochoerus nagrii*, a rare taxon is found exclusively from the Nagri Formation (early Late Miocene) of the Siwalik Group. Previously, this species is only known from the Indian Siwaliks and have been recovered from Haritalyangar, Himachel Pardesh in India. In this article, we are describing a maxillary fragment bearing P3-M3 from the Nagri type locality named Sethi-Nagri in district Chakwal, Pakistan; it is the first report of the upper dentition of *L. nagrii* in the Siwalik Group. The newly collected specimens provide additional anatomical characters of *P. hysudricus*. *Tetraconodon magnus* and *Sivachoerus prior* are rare tetraconodonts. *Tetraconodon* is believed to be occurred in the upper Dhok Pathan (Early Pliocene) and Tatrot formations (Pliocene) of the Siwalik Group. However, the specimens described here from the mid Dhok Pathan Formation are important in relieving the long-held notion of the previous researchers. Similarly, *Sivachoerusprior* appeared earlier than it was thought previously. The discovery of *L.nagrii* from Pakistan extends its stratigraphic and geographic range from Pakistan to India.

Stable isotope paleobiology from Early Eocene planktic foraminifer *Chiloguembelina* (Atlantic Ocean): implication for paleocenographic reconstructions

Luciani V.*, D'Onofrio R. & Filippi G.

University of Ferrara, Italy

Corresponding author email: valeria.luciani@unife.it

Keywords: Planktic foraminifera, Early Eocene, paleobiology, stable isotopes.

The planktic foraminiferal chiloguembelinids, characterized by biserial disposition of chambers, attracted the scientific interest because they thrived in correspondence with extreme global climatic and paleoceanographic events. The genus *Chiloguembelina* is characterized by relatively long stratigraphic ranges as originating in the Late Albian from the biserial Heterohelix, diversified in the Late Cretaceous and survive to the present day, even though their abundance is highly variable through time and space. However, paleobiology of Cenozoic biserial planktic foraminifera is not fully established. Largely accepted ecological interpretation ascribes them as eutrophic dwellers and low-oxygen tolerant inhabiting the Oxygen Minimum Zone (OMZ) that thrived in stressed environments. However, this general ecological interpretation does not agree with all available records. Stable isotope data on earliest Eocene chiloguembelinids from eastern North Atlantic reveal surface mixed layer habitat for this group. Similar habitat was derived for middle Eocene-Late Oligocene *Chiloguembellina cubensis*. Conversely, *Chiloguembelina ototara* from northwest Atlantic Ocean proved to inhabit thermocline habitat (Eocene Zone E14). These evidences indicate that planktic biserial taxa may have changed their ecological niches through time and over their geographic distribution. Stable isotope data on chiloguembelinids were so far lacking from the Early Eocene Climatic Optimum (EECO, ~54-48 Ma). The EECO is the crucial interval when temperatures across Earth's surface and pCO2 rose toward the peak of Cenozoic. Paleoceanographic reconstructions are essential to understand climatic changes occurred during the EECO interval therefore we need a true knowledge of ecological characters of chiloguembelinids during this time. Interestingly, a marked decline in abundance of *Chiloguembelina* up to virtual absence occurred at the beginning of the EECO between the negative carbon isotope shifts known as J and K/X events in the subtropical, equatorial and temperate Atlantic sites. We present here new chiloguembelinids oxygen and carbon stable isotope data from early Eocene sub-tropical northwestern Atlantic Ocean Drilling Program (ODP) Site 1051, equatorial ODP Site 1258, south Atlantic ODP Site 1263 and the Antarctic Weddel Sea ODP Site 689B that have good sedimentary recovery and complete lower Eocene successions. Our analysis was performed at the beginning of the EECO on *Chiloguembelina* wilcoxensisand *C. trinitatensis* and on known surface and deep-dweller species belonging to Zone E5, such as *Morozovella*, *Acarinina*, *Subbotina* and benthic forms. Our findings provide critical implications for the paleoceanographic reconstruction of the upper water column and its changes occurred during the EECO.

Stratigraphic Table of Germany 2016

Menning M.* & German Stratigraphic Commission

Helmholtz-Zentrum Potsdam, Deutsches GeoForschungsZentrum GFZ.

Corresponding author email: menne@gfz-potsdam.de

Keywords: Germany, Phanerozoic, Geochronology, Lithostratigraphy.

Primarily, the German Stratigraphic Commission developed the Stratigraphic Table of Germany in 2002 (STG 2002, in German) to present a general overview on sections and strata of Germany after its reunification in 1990, with reference to the Global Stratigraphic Scale (GSS) and taking stratigraphic codes into account.

The Stratigraphic Table of Germany 2016 (STG 2016, in German) is the updated STG 2002 in format B0 (www.stratigraphie.de/std/index.html). It reflects the current state of stratigraphic knowledge. Unfortunately, regional geology and stratigraphy are no longer prominent topics in German research institutions and universities, even though they are the base of all geological work. Because of the value of such knowledge, several STG publications have become geological bestsellers. Altogether 105000 copies were printed in between 2002 and 2017. The Stratigraphic Table of Germany Compact 2012 (STGC 2012, in German and English, format A4) and the STGC 2017 (in German) also contain information on natural resources, geological reservoirs and fossils. They are available without charge via GFZ Potsdam (http://www.stratigraphie.de/ergebnisse/index.html).

In the STG 2016, the positions of several strata of Central Europe according to the GSS are not finally settled. Arrows emphasize this problem at numerous strata boundaries. Despite considerable improvements, the STG 2016 is still inhomogeneous in part. Thus, there are breaks between a few systems and, locally, within a system. The Quaternary was updated by insertion of mappable units such as the sediments of the Drenthe and Warthe Stadials and numerous new lithostratigraphic units. Thus, as many stratigraphic units as possible are shown with their most recent names and, for some, with their traditional ones as well. No agreement exists on certain basin-wide hiatuses, e.g. in the Keuper, whereas such gaps are now mainly accepted in the North German Basin in the Rotliegend and at the Cretaceous-Tertiary boundary.

The STG 2016 uses Geological Time Scale 2012 from the Ediacaran to the Silurian and from the Late Triassic to the Quaternary. An individual scale has been developed for the Devonian. The time scale of the STG 2002 for the Carboniferous and Permian is also used and the time scale for the Early and Middle Triassic is based on the Explanations 2005 on the Stratigraphic Table of Germany 2002 (in German). The ages of the boundaries of the Palaeozoic and Mesozoic stages are rounded to 0.5 Ma and 1 Ma respectively.

Menning M. (2018) - The Stratigraphic Table of Germany 2016 (STG 2016) / Die Stratigraphische Tabelle von Deutschland 2016 (STD 2016). German J. Geology, 169, 2: 105-128.

The stratigraphy of the Apennine Carbonate Platform: a review

Parente M.*[1], Iannace A.[1] & Frijia G.[2]

[1] University of Naples, Italy. [2] University of Ferrara, Italy.

Corresponding author email: maparent@unina.it

Keywords: Biostratigraphy, Isotope stratigraphy, cyclostratigraphy, Mesozoic, Apennine Carbonate Platform, southern Italy.

The Mesozoic Apennine Carbonate Platform preserves a very long history (ca 160 My, Late Triassic to middle Campanian) of shallow-water carbonate sedimentation in the subtropical Tethys. Its rich record of carbonate-shelled fossils and microfossils is an invaluable archive of the evolution of neritic ecosystems and a precious lab to investigate their response to local and global paleoenvironmental perturbations. Its thick column (>4000 m) of carbonate rocks is a treasure of geochemical proxies, preserving a record of the major biogeochemical cycles, of the chemistry and redox state of the ocean and of global climate changes. We have only started to scratch the top of this record; a large part of the treasure remains well hidden and protected. Stratigraphy is the key to open the treasure room, but there are two main locks that we have to pick: 1) we need to increase stratigraphic resolution, pushing to its edge our ability to measure time (and with it, rate of changes), possibly down to the limit of 10^5 to 10^4 ky; 2) we need to establish a precise chronostratigraphic calibration and secure detailed correlation with the complementary pelagic record of epicontinental and oceanic basins. The first task can be achieved only through cyclostratigraphy. The second one can be tackled by integrating biostratigraphy with carbon- and strontium-isotope stratigraphy. Floating orbital cyclostratigraphies, based on lithofacies and microfacies analysis, have been so far produced only for some sections spanning the Valanginian to Albian interval (see for instance D'Argenio et al., 2011 and references therein) and the Santonian (Buonocunto et al., 2002). High-resolution chronostratigraphic calibration and correlation to coeval reference pelagic sections have been achieved by integrating biostratigraphy and isotope stratigraphy for the late Cenomanian to middle Campanian interval and for short intervals bracketing the early Toarcian, Selli and Bonarelli Oceanic Anoxic Events (Parente et al., 2008; Di Lucia et al., 2012; Trecalli et al., 2012, Frijia et al., 2015). For the stratigraphic intervals corresponding to Late Triassic and for most of the Jurassic only biostratigraphy has been worked out, mostly plagued by very low resolution and poor chronostratigraphic calibration. In this work we will review the knowledges on the stratigraphy of the Apennine Carbonate Platform, discuss the merits and pitfalls of cyclostratigraphy and isotope stratigraphy in shallow-water carbonates and highlight the most promising avenues for future research.

Buonocunto F.P., Sprovieri M., Bellanca A., D'Argenio B., Ferreri V., Neri R. & Ferruzza G. (2012) - Cyclostratigraphy and high-frequency carbon isotope fluctuations in Upper Cretaceous shallow-water carbonates, southern Italy. Sedimentology, 49, 1321–1337.

D'Argenio B., Ferreri V. & Amodio S. (2011) - Eustatic cycles and tectonics in the Cretaceous shallow Tethys, Central-Southern Apennines. Italian Journal of Geosciences, 130, 119–127.

Di Lucia M., Trecalli A., Mutti M. & Parente M. (2012) - Bio-chemostratigraphy of the Barremian-Aptian shallow-water carbonates of the southern Apennines (Italy): pinpointing the OAE1a in a Tethyan carbonate platform. Solid Earth, 3, 1–28.

Frijia G., Parente M., Di Lucia M. & Mutti M. (2015) - Carbon and strontium isotope stratigraphy of the Upper Cretaceous (Cenomanian-Campanian) shallow-water carbonates of southern Italy: Chronostratigraphic calibration of larger foraminifera biostratigraphy. Cretaceous Research, 53, 110–139.

Trecalli A., Spangenberg J., Adatte T., Föllmi K.B. & Parente M. (2012) - Carbonate platform evidence of ocean acidification at the onset of the early Toarcian oceanic anoxic event. Earth and Planetary Science Letters, 357-358, 214–225.

First data on brachiopod and plant fossils from the uppermost Olenekian (Lower Triassic) of South Primorye, Russian Far East and their stratigraphical and palaeoclimatological significance

Popov A.M.*[1], Zakharov Y.D.[1], Volynets E.B.[2] & Ushkova M.A.[1]

[1] Far Eastern Geological Institute, Russian Academy of Sciences. [2] Federal Research Center for Terrestrial Biota Biodiversity of East Asia, Russian Academy of Sciences (Far Eastern Branch).

Corresponding author email: popov_alexander@list.ru

Keywords: Lower Triassic, brachiopods, plants, biostratigraphy,palaeoclimatology, South Primorye.

The latest Olenekian brachiopod assemblage, firstly discovered in South Primorye, is represented by *Paranorellina parisi* Dagys (dominant), *Lepismatina* sp., Lepismatinidae gen. et sp. nov. and some other species. It was found in the Paris and Tchernyshev sections on the Russian Island, directly below the lower Anisian *Ussuriphyllites amurensis* Zone, but above deposits yielding the ammonoid *Subfengshanites multiformis* (Kiparisova). From the brachiopod assemblage of the upper Olenekian *Neocolumbites insignis* Zone, most fully investigated in the sections of the Kamenushka River basin, this assemblage is distinguished by the presence of *Paranorellina parisi* Dagys and the absence of *Bittnerithyris margaritovi* (Bittner). Brachiopods of the stratigraphic level under consideration are found in association with ammonoids, including representatives of the genus *Prohungarites*, which is characteristic of the Lower−Middle Triassic boundary transition in many regions of the world. Until recently, the *Subfengshanites multiformis* Zone was considered to be the uppermost stratigraphic unit of the Lower Triassic in South Primorye (Zakharov & Moussavi Abnavi, 2013). The findings of *Prohungarites* sp. in the Paris section and the representative brachiopods assemblage in the Paris and Tchernyshev sections allow to distinguish a new stratigraphical unit in the Lower Triassic of South Primorye: *Prohungarites* sp. - *Paranorellina parisi* Beds, occupying a higher stratigraphical position than the *Subfengshanites multiformis* Zone.The finding of fossil plants *Pleuromeia obrutschevi* Elias and *P. stenbergi* Münster in the upper Olenekian *Neocolumbites insignis* Zone (Markevich & Zakharov, 2004) and *Cladophlebis gracilis* Sze (V.I. Burago's determination; Markevich & Zakharov, 2004) and *Neocalamites* sp. (this study) in the uppermost Olenekian interval allows supposing that climatic conditions in South Primorye evolved gradually from hot and dry in middle Olenekian to cooler and humid during the late Olenekian.

This research was funded by the grant RFBR 18-05-00023.

Dagys A.S. (1974) - Triassic brachiopods (morphology, classification, phylogeny, stratigraphical significance and biogeography). Nauka, Novosibirsk (in Russian).

Markevich P.V. & Zakharov Y.D. (2004) - Triassic and Jurassic of the Sikhote-Alin. Book 1. Terrigenous assemblage. Dalnauka, Vladivostok (in Russian).

Zakharov Y.D.& Mousavi Abnavi N. (2013) - The ammonoid recovery after the end-Permian mass extinction: Evidence from the Iran−Transcaucasia area, Siberia, Primorye, and Kazakhstan. Acta Palaeontol. Pol., 58(1), 127-147.

Increasing understanding of agglutinated structures in the fossil record: a fresh look at the composition and structure of *Lagis koreni* (Polychaetae, Annelida) tubes

Ren X.Y.*[1], Qiu H.[2], Tamaxia A.[2], Zhu X.F.[3], Liu Y.[2], Wang Q.[3], Li J.H.[2], Strotz L.[1] & Zhang Z.F.[1]

[1] Shaanxi Key laboratory of Early Life and Environments, State Key Laboratory of Continental Dynamics and Department of Geology, Northwest University, Xi'an, P.R. China. [2] State Key Laboratory of Earth and Planetary Physics, Insititute of Geology and Geophysics, Chinese Academy of Sciences, Beijing, China. [3] Key Laboratory of Vertebrate Evolution and Human Origin of Chinese Academy of Sciences, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing, China.

Corresponding author email: 18717281991@163.com

Keywords: Lagis Koreni, mineralization, Micro-CT, fossil, SEM.

Lagis koreni is a species of polychaete annelid with a short life span (approximately one year – Nicolaidou., 1983) that lives in boreal offshore muddy and sandy environments (Jones., 1950) and feeds by filter feeding (Fridiric et al., 1996). This species is particularly characterized by a hard mineralized tube that the worm inhabits throughout its life. This tube is composed of sedimentary particles and is constructed from the surrounding sediment using a sticky glue secreted by the worm through a process that can be considered a form of passive mineralization. The aim of our study is to quantify the structure and composition of the mineralized tube constructed by *Lagis koreni* to increase understanding of how similar agglutinated structures found in the fossil record may have been created and if these structures might increase the preservation potential of the non-mineralized organisms contained within them. To achieve this aim, we examine in close detail a single specimen of *Lagis koreni* from Lysekil, Sweden. The specimen consists of a small horn shaped tube, 4 centimeters long and 0.5 centimeters wide. After collection, the worm was removed from its mineralized tube, the sample was encased in resin and then cut in half for analysis. Scanning Electron Microscopy (SEM) and Micro Computed Tomography (Micro CT) were used to examine the tube morphology. Energy Dispersive Spectroscopy (EDS), Raman Spectroscopy, X-Ray Fluorescence (XRF) and Nano Secondary Ion Mass Spectrometry (Nanosims) were used to analyze the tube's composition. SEM and Micro CT results show that the diameter of the grains that make up the tube differ widely, ranging from 0.20 - 3.01 millimeters. The grains come from both abiotic and biotic sources. The biotic components consist of echinoderm parts, foraminifera and other shell material composed of calcium carbonate. The aspect ratio of the grains is generally large (0.25-0.5) and the nature of the grains make it clear that the grains are collected from the surrounding environment, not produced by the worm itself. The angular nature of the grains suggest they were collected close to the living organism and thus are representative of its surrounding environment. Results of SEM-EDS indicate that the tube is primarily composed of calcium carbonate, iron sulfide and silica. This is further supported by results for Raman spectroscopy, which identified grains composed of calcite, labradorite, quartz, illite and aragonite. XRF results indicate that the biological cement secreted by the worm is rich in Al, Cl, K, Mn, Na, and Sr elements whereas the mineral grains that make up the tube consist of Ca, Si, Fe, Mg, P, and S. The difference in composition between cement and grains further supports that the tube is an agglutinated structure, formed by harvesting particles from the surrounding environment and not of purely biotic origin. Notably, the tube is composed of elements previously demonstrated to increase fossilization potential. The most commonly occurring diagenetic minerals associated with exceptional preservation are pyrite, carbonates and phosphates (Zhang X.L & Shu DG, 2001), all minerals composed of the elements that are the same as those that primarily make up the tube of *Lagis koreni*. Thus the agglutinated tube inhabited by *Lagis koreni* may actually help to better preserve the non-mineralized soft tissue of the worm, increasing fossilization potential. Based upon our SEM-EDS results, inside an echinoderm fragment that makes up the tube, we identify several framboids of pyrite (FeS_2) wrapped in organic glue clearly secreted by the worm. Similar structures have been identified in the valves of the Cambrian species *Yuganotheca elegans* composed of iron oxide. It is possible that the iron oxide composition in the fossil material is oxidized pyrite, and the structures found in the Cambrian taxon are analogous to those found on *Lagis koreni*. The configuration of the agglutinated component of *Yuganotheca elegans* in Cambrian also bears many similarities to the results obtained for *Lagis koreni*. If the two structures are truly equivalent, then *Lagis koreni* represents a suitable model organism to elucidate the process of agglutination in the fossil record, to understand how taphonomic processes effect the preservation potential of both the agglutinated structure and its inhabitant, and to increase understanding of the process of biomineralization more broadly.

Fridiric O., Nicolas D. & Christian R. (1996) - Habitat selection and adult-recruit interactions in Pectinaria Koreni (Malmgren) (Annelida: polychaeta) post-larval populations: results of flume experiments, Journal of Sea Research, 36, 217-226.

Gabbott S.E., Hou X.G., Norry M.J. & Siveter D.J. (2004) - Preservation of Early Cambrian animals of the Chengjiang biota, Geology, 32, 901-904.

Jones N.S. (1950) - Marine bottom communities. Biological Reviews. 25, 283-313.

Nicolaidou A. (1983) - Life History and Productivity of Pectinaria koreni Malmgren (Polychaeta), Estuarine, Coastal and Shelf Science, 17, 31-43.

Zhang X.L. & Shu D.G. (2001) - Preservation Mechanisms of Non-mineralized Animal Tissues, Acta Sedimentologica Sinica. Volume 19, 13-19.

Key role of organic-rich facies in Early Eocene red-beds (Cuzco Region, Peru) for copper trapping during migration of basinal fluids

Rosas S.*[1], Fontboté L.[2] & Spangenberg J.[3]

[1] Especialidad Ingeniería Geológica, Pontificia Universidad Católica del Perú, Lima, Perù. [2] Departement of Earth Sciences , University of Geneva, Switzerland.
[3] Institute of Earth Surface Dynamics, University of Lausanne, Switzerland

Corresponding author email: brosas@pucp.edu.pe

Keywords: Lower Eocene, red beds, Southeastern Peru, Cu in sediments.

In Cenozoic detrital sequences in the Central Andes, the occurrence of, mostly small, stratabound copper deposits in red beds is common. Here, we focus on the key role played by sedimentology on the formation of the Tambomachay copper deposit (12 km N of Cuzco). It occurs in an Early Eocene – Early Oligocene red-bed sequence known as San Jerónimo Group (> 6000 m thickness), that discordantly overlies Cambrian – Cretaceous sedimentary rocks and is interpreted to be deposited in a fluvial environment in a foreland basin of the Western Cordillera of the Central Andes (Carlotto et al., 2011). The ore deposit is hosted in the upper part of the Early Eocene Kayra Formation (minimum thickness of 1500 m measured 10 km of Tambomachay), the oldest unit inside the San Jerónimo Group (Carlotto et al., 1996, 2011). The Kayra Formation consists of red arkosic sandstones, displaying cross-bedding in places, with some intercalations of greenish gray fine grained sandstones or greywackes. This twofold lithology corresponds to different sedimentary domains of an alluvial system. The red sandstones represent permeable fluvial sand bars and channels, allowing post depositional fluid circulation. The greenish gray greywackes rather stand for flooding plain organic-rich deposits in a swamp-like environment that prevented surface oxidation (Rosas et al., 2019). At Tambomachay, copper ore minerals (mainly bornite, chalcopyrite, digenite and covelite) cement veinlets, intergranular pores and other open spaces. The main control for the ore deposition is a local fault, whose fault plain is “carpeted“ by copper sulfides. The occurrence of the copper sulfides in the greenish gray reducing layers, the presence of organic matter in interstices between the hypogene sulfides, and the sulfur composition of the sulfides ($d\,^{34}S$ between -16.9 and -12.4‰ vs VCDT) pointing to bacterial sulfate reduction, are strong arguments to propose that the flooding plain swamp like environment was key to produce post-depositional redox boundaries in the dominantly red bed sequence. Mineralization took place when copper-bearing oxidizing saline basinal fluids met reduced sulfur at these redox boundaries and precipitated copper sulfides in organic matter-rich horizons. The structural control of the Tambomachay deposit suggests that faults acted as feeders for the oxidizing basinal copper-bearing fluids.

Carlotto V., Gil W., Cárdenas J. & Chávez R. (1996) - Geología de los cuadrángulos de Urubamba y Calca: INGEMMET. Bol N° 65. Serie A. 247pp.
Carlotto V., Cárdenas J. & Carlier G. (2011) -Geología del cuadrángulo de Cuzco. INGEMMET. Boletín N° 138. Serie A. 255 p.
Rosas S., Fontboté L., Salcedo C., Robles M., Vallance J., Sáez J. & Spangenberg J. (2019) - Copper hosted in red beds at the Tambomachay deposit (Cuzco, Peru), trapped by bacterially reduced sulfur during migration of Basinal Fluids. SME2019, extended abstracts.

The Senonian – Eocene of Tellian Domain in northern Tunisia, synorogenic deposits

Saadi J.*[1], Karoui N.[1], Turki D.[2], Daha F.[3] & Salaj J.[4]

[1] University of Carthage, Tunisia. [2] University Elmanar, Tunisia. [3] Off.Nat.Mines, Tunisia. [4] Bratislava, Czechoslovakia.

Corresponding author email: saadijalila496@gmail.com

Keywords: Tellian domain, Senonian, Eocene, Nappes, Marnes à boules jaunes.

The sedimentologic study of carbonated series, from Senonian to Eocene, at the Fernana - Ain Draham area (north of Tunisia) improves paleogeography and understanding of internal domains of the Magrebine Chain. Named Mogod and Kroumirie, the studied domain is situated at the northwest part of Tunisia, close to the Algerian border, and corresponds to the external Tellian domain of the Alpine Chain. Major objectives of this work are to describe the type of deposits in syntectonic basins created by progressive deformation in an accretionary wedge. On the other side, this work tries to elucidate complex structural zones by news stratigraphics results, as a relationship between Ediss / Adissa / Atafa Units and the "autochthone" and "paraautochtone" sensu Rouvier (1985). The comparison between stratigraphic logs studied at the autochtone, paraautochtone, Ediss Unit and Ain draham - Adissa Unit and the stratigraphic's revision support, in general, these structural units, with news results.

Senonian: The Adissa/Ain draham unit corresponds to the distal domain of the basin and are represented by thin slumped limestones turbidites (late Campanian to Maastrichtian). The autochtone/paraautochtone and Ediss unit correspond to the proximal globally hemipelagic carbonated slope deposits (entirely Campanian in age). The Maastrichtian-Paleocene is represented by a large olistostrom series (marnes à boules jaunes of Rouvier 1985, over 1000 m in thickness), showing lateral grading of olistoliths from north-west to south-east.

Eocene (Ypresian): We distinguish three major domains: Adissa/Ain Draham unit, Ediss/Kasseb unit and autochtone/paraautochtone unit corresponding respectively to distal basin (thin slumped limestones turbidites), hemipelagic slope and an isolated carbonated shelf.

Our paper highlights the effects of the deep tectonics during the sedimentation in the period from the beginning of the tectonic inversion (middle-late Cretaceous) to the activation of the nappe tectonics.

Rouvier H. (1985) – Géologie de l'extrême-nord tunisien: tectoniques et paléogéographies superposes à l'extrémité orientale de la chaîne nord-magrébine. Annales des mines et de la géologie, n°29, Tunis.

An up-to-date stratigraphic framework of the synrift Lower Jurassic carbonate succession of the Prealps around Brescia (Southern Alps, Italy)

Schirolli P.*[1], Meister C.[2] & Dommergues J.-L.[3]

[1] Museum of Natural Sciences of Brescia, Italy. [2] Museum of Natural History of Genève, Switzerland. [3] UMR CNRS 5561 University of Dijon, France.

Corresponding author email: geoschiro@gmail.com

Keywords: Early Jurassic, integrated stratigraphy, rifting stage, Southern Alps, N-Italy, Brescian Prealps.

An up-to-date biostratigraphical framework of the ammonite horizon sequence for central-western Brescian Prealps during the Sinemurian to basal Toarcian time (Meister et al., 2017) allowed to provide a more precise regional stratigraphic setting of this part of Southern Alps, referred to the synrift Lower Jurassic carbonate succession cropping out in the surroundings of Brescia. At the beginning of Jurassic the region was subjected to the rifting stage involving the forthcoming southern margin of Neo-Tethys. Brescian Prealps were located on the eastern border of the wide Lombardian Basin. Rifting locally induced the block-faulting of the Corna platform, developing an articulated fault-system today trending from Brescia to the North. It separated a growing western basinal area (Val Trompia-Sebino Basin) to the eastern Botticino structural high and its northward extension. After the drowning of the platform, a very thick (ca.1000m) succession of well-stratified cherty marly limestones of the Medolo Group (Gardone Val Trompia Lm. and Domaro Lm., ?Hettangian to basal Toarcian) accumulated in the Val Trompia-Sebino Basin, whereas a coeval reduced deepening sequence (50m thick) including the calcarenites/siltites of the Rezzato Encrinite and the overlying thinly-bedded, sometimes nodular, ammonitic marly limestones of the Botticino Corso Rosso covered the Corna Fm. in the Botticino High. If in Trompia Valley we can still suppose the onset of basinal sedimentation already by Hettangian(?), the biostratigraphical framework around Brescia highlights the diachronous birthing of the basinal area also in a N-S direction, not only in W-E direction, as widely known. Brescia was near a transitional zone of fault-induced slope between the Botticino High and the basin extended westward. In the Botticino High, a new ammonite assemblage from the uppermost part of Corna Fm. fixes to the Early Sinemurian the last stage of productivity of the Jurassic platform. The well-known *Arnioceras* bed overlying the Corna top in the Botticino Mattina, Lassa and St. Eufemia sections can be restricted to the beginning of Late Sinemurian. Therefore the drowning of Corna platform can be likely referred to the transition Early-Late Sinemurian. Moreover, nearby Brescia, in the basinal sector closer to the Botticino High, a faunal assemblage is recorded in the topmost bed of the informal Mt. Denno Unit (Schirolli, 1997), just before the beginning of Medolo deposition, also fixing the onset of slope-to-basin sedimentation around the transition Early-Late Sinemurian.

Meister C., Schirolli P. & Dommergues J.L. (2017) - Early Jurassic (Sinemurian to basal Toarcian) ammonites of the Brescian Prealps (Southern Alps, Italy). Riv. It. Paleontol. Strat., 123(1), 79-148.

Schirolli P. (1997) - La successione liassica nelle Prealpi bresciane centro-occidentali (Alpi Meridionali, Italia): stratigrafia, evoluzione paleogeografico-strutturale ed eventi connessi al rifting. Atti Tic. Sc. Terra, s.s. 6, 1-137.

Progress in the Ordovician stratigraphy of the Yunkai area, South China

Wang Z.H.*[1-2], Niu Z.J.[1-2] & Yao H.Z.[1-2]

[1] Wuhan Center of China Geological Survey, China. [2] Key Laboratory for Paleontology and Coevolution of Life and Environment, CGS, China.

Corresponding author email: cugwzh@gmail.com

Keywords: Yunkai massif, Ordovician, bivalve, trilobite, Palaeo-South China Ocean.

Collision and amalgamation boundaries, time limit, collision mechanism and time-spatial evolution of the Yangtze and Cathaysian blocks are a key issue that puzzles the tectonic evolution of South China. The pioneers have carried out a large number of isotope chronology and rock geochemistry work, however, the collision and amalgamation age between the Yangtze and Cathaysian blocks has Jinning period (~820Ma), Caledonian period, Haixi-Indosinian period, etc. The core of controversy is whether there exists the Palaeo-South China Ocean between the Yangtze and Cathaysian blocks in Early Paleozoic. Therefore, the Caledonian orogeny is a major episode in the history of geological evolution of South China. Additionally, the Early Paleozoic is a window to gain a hint of Caledonian orogeny. The long Early Paleozoic, especially the middle-late Ordovician stage, is a key period for the transition from mature passive continental margin to closed orogenic phase on the southeastern margin of the Yangtze block while the conglomerate and siliceous rocks widely distributed. Based on the comprehensive study of early Paleozoic strata and tectonic paleogeographic pattern, some new understanding of Palaeo-South China Ocean is proposed. The main results of our research are as follows:

1. A newly late Ordovician fauna in Deqing, western Guangdong, including the distribution of fossil horizons and assembly of fossil groups is discovered. The fauna preserved in argillaceous siltstone, previously assigned to the middle Ordovician Dongchong Formation, is re-defined to the late Ordovician Lanweng Formation. The fauna consists mainly of trilobites, accompanied by brachiopods, echinoderms and machaeridians.

2. Very abundant bivalves have been found from the Dongchong Formation, Yunkai area. The bivalve fauna consists of *Praenucula* cf. *sharpie* Babin and Gutierrez-Marco, *P.* sp., *Homilodonta regularis*(Portlock), *Similodonta similis*, *S.* cf. *cerys* Cope,*S.* sp.,*Trigonoconcha acula* Sanchez, *Concavodonta* sp., *Arcodonta* sp., *Sthenodonta* cf. *eastii*(Tata), *S.* sp., *Nuculites* cf. *cylindricus*(Portlock),*N.* sp., *Phestia* sp., *Cardiolaria*? sp., *Inaequidens* cf. *davisi* Pojeta and Gilbert-Tomlinson, sp., *Mytilarca* sp., *Cyrtodonta* sp., *Modiolopsis* sp., *Carminodonta* sp., *Famatinodonta* sp. and several un-named new genera, being featured by small individual size, high abundance and diversity, palaeotaxodont assuming absolute superiority.

3. At the late Ordovician fossils site of Daidong, the trilobite genus of *Nankinolithus* is collected, which makes a very reliable indication of strata age. In addition, the *Nankinolithus wanyuanensis* appears only in Katian. Moreover, the *Nankinolithus* is a typical benthonic organism. The previous study on *Nankinolithus* in China has a strong indicator that this genus restricted in the Yangtze area. It suggests that the Palaeo-South China Ocean does not exist at least after the Late Ordovician.

Deciphering the timing and course of tectonic processes by micropalaeontology – a case study on the Late Cretaceous inversion in northern Germany

Wulff L.* & Mutterlose J.

Ruhr University Bochum, Germany.

Corresponding author email: lena.wulff@rub.de

Keywords: basin inversion, northern Germany, micropalaeontology, calcareous nannofossils.

Biostratigraphy is a powerful tool, which has been developed for understanding the chronology of geological processes. Here we want to demonstrate that micropalaeontological methods can help to reconstruct the timing and the course of tectonic activities. In this case study we analysed the timing of a classical inversion structure in northwest Germany, the Lower Saxony Basin and the Münsterland Basin, which experienced differential subsidence and uplift during the Late Cretaceous. Following a eustatic sea-level rise in the early Late Cretaceous (Cenomanian, Turonian), which caused a flooding of the Münsterland Basin, northern Germany experienced an inversion in the mid Late Cretaceous (Coniacian, Santonian). The area north of the Münsterland Basin, the former Lower Saxony Basin, underwent uplift along a large fault zone, the Osning Fault. At the same time the Münsterland subsided and formed a major depositional centre for sediments supplied by the uplifted area in the north. Two quarries positioned next to the Osning Fault zone expose an extended and complete succession of lower Cenomanian to lower Coniacian marine sediments, which play a crucial role for the understanding of the tectonic setting and the Late Cretaceous inversion of northern Germany. The 350 m thick sedimentary sequence mainly consists of limestones and limestone-marl alternations. The uppermost part of the sequence is characterised by chaotic structural conditions. Reworked sediments and phacoid rock bodies up to several meters in diameter are the dominant features. They are associated with submarine slides, which presumably occurred during the Coniacian. Previous studies already analysed and dated these slides and phacoids, but the poor preservation of foraminifera was a great obstacle in those days and did not allow a high resolution biostratigraphic dating. The current study uses for the first time calcareous nannofossils to date the reworked sediments in this section. The results point to a three-phase model of the depositional history of the analysed sediments, thereby indicating, that first tectonic movements occurred during the Middle Turonian.

Vendian system of Russia

Yakobson K., Krupenik V., Anisimova S.* & Vovshina A.

Federal State Budgetary Institution, A. P. Karpinsky Russian Geological Research Institute (FGBU VSEGEI), St. Petersburg, Russia

Corresponding author email: Svetlana_Anisimova@vsegei.ru

Keywords: Vendian, the East European platform, the Siberian platform, the Olenek uplift, the Yudoma Group, fluidities.

The Vendian – Vendian system – upper Proterozoic unit of the General stratigraphic scale of Russia (CSS), following the Riphean Eonothem and preceding the Cambrian Tomotian stage. Under this name, B. S. Sokolov in 1950 in the North-West of the East European platform (EEP) described a sandy-clay complex of rocks lying on the Foundation and covered by the Baltic series of the Cambrian. The results of geological surveys showed that the section of the Vendian is supplemented by the layers of coarse-grained sandstones and main volcanites to the South of the area studied by B. S. Sokolov. Taking into account the dual composition of the Vendian E. P. Bruns called the upper division of the Valdai, and the lower - Volyn series. As a result of deep drilling, it was found that the Valdai series, leaving under the Paleozoic cover, is the base of the platform cover of the EEP. A great influence on the idea of the Genesis of coarse-grained sandstones of the Volyn series was exerted by the assumption of E. Bruns about their glacial nature (1987). Despite the lack of sufficient evidence, most researchers began to consider these sandstones analogues Precambrian glacial rocks of Norwegian Lapland. The result of many years of research was the inclusion of Vendian in the GSS as the Proterozoic system with two series. The lower Vendian boundary with the age of 600 ± 10 million years was established at the bottom of the Lapland ice horizon, which was adopted as a characteristic Lower Vendian subdivision; and the upper – at the bottom of the Cambrian with the age of 555 million years (Sokolov, 1985, 1991). This system in the European territory of Russia included the Lapland (Lower Vendien), Redkin, Kotlin and Rovensk (Upper Vendian) Horizons (Additions to the Stratigraphic code of Russia, 2000). Later found that rocks like sandstones Lapland glacial horizon, were regarded as tillites (Chumakov, 1978) were determined as fluiditis (tuffisites) (H. Cloos, 1941; Yakobson, 2014). Lower Vendian of glacial formations characteristic of Norwegian Lapland have not been proven reliably on the Russian territory of the EEP (Jacobson, 2014). On the Siberian platform the Vendian predominantly refers to the carbonate of the Yudoma Group with the most fully studied sections on the Olenek uplift and in the Uchur-Maya region (Chumakov, Semikhatov, Sergeev 2013). On the Olenek uplift in the Yudoma Group prints of Metazoa was established, which confirms the Late Vendian age of sediments. In the Uchur-Maya region the Vendian section is fuller. The upper part is correlated with Olenek the Yudoma Group; the lower part according to M. A. Semikhatov (2004) is based on the Sr isotope chemostratigraphy of the Lapland glaciation. In further studies, it is necessary to study further by geochemical methods the known sections of the lower Vendian in order to establish the Genesis of the deposits.

Event stratigraphy of pumice gravel layers of northern Taiwan: submarine eruptions and tsunamis in southern backarc Okinawa Trough of the NW Pacific

Yu N.T.*[1], Yen J.Y.[2] & Chu M.F.[3]

[1] National Tsing Hua University. [2] National Dong Hwa University. [3] National Taiwan University

Corresponding author email: ntyu@mx.nthu.edu.tw

Keywords: event stratigraphy, pumice gravel layer, Taiwan, NW Pacific, tsunami, submarine eruption.

Marine inundation events result in coastal deposits that provide clues to the event origins and recurrence intervals, such as tsunamis. Stranded pumices on beaches might be reworked by tsunamis and preserved in backshore inland settings, and accordingly record the regional volcanic activities. Pumice-bearing event stratigraphy of northern Taiwan is here presented to disclose the tsunamis and submarine eruptions in southern backarc Okinawa Trough in the NW Pacific during the last two millennia, which would be otherwise underestimated by the short and vague histories in the region. Taiwan is associated with a disastrous tsunami in the north coast in AD 1867, and five submarine eruptions from the late 19th to the early 20th centuries. Geological evidences of these historical event deposits are also reported. Marine sediments were buried on inland floodplains and on high backshore platforms by the extensive inundations and tall run-ups of the AD 1867 tsunami, respectively. Pumice rafts were produced by the AD 1924 eruption near the southern Ryukyu islands and were widespread on the regional shorelines, including Taiwan's north coast. In the 19th century, pumices were washed ashore on the north coast, particularly in abundance after typhoons. Six event layers of marine inundations were identified in this study on the impacted areas of the AD 1867 tsunami, and were related to the prehistorical tsunamis that occurred between 300 and 2300 yr BP. The younger three events are represented by the coastal-derived quartz sands in the floodplain borehole cores that are located up to 500 to 800 m inland, and by the offshore-derived pumice gravels in the sea cliff taluses that are located at 9 to 11.5 m above sea level. The older three events are represented by the offshore-derived pumice gravels in the sea cliff taluses from 3 to 5 m above sea level, and are higher than the maximum height of typhoon surge at 2.0 m. The pumices are usually dividable into two components of approximately equal amounts, including the black pumice of trachyte-trachyandesite composition and the white pumice of dacite-rhyolite composition. The middle of the three older event layers is composed of only the white pumice. The seven historical and prehistorical tsunami deposits indicate a recurrence interval of approximately 200-600 years, which reflects the typical low-frequency occurrences of tsunamis and verifies the unforeseeable threat of disastrous tsunamis in the region. The common and abundant pumice occurrences in the tsunami layers furthermore extend the violent history of the submarine eruptions in the NE offshore back to at least two thousand years ago. Furthermore, on account of the poor preservation potentials of the pumices and the relatively long recurrence intervals, the submarine eruptions could be more frequent and productive than the event layer occurrences and pose an even dangerous threat in this segment of the western circum Pacific seismic zone.

Sequence stratigraphy framework and chronostratigraphy of the sedimentary succession at Wadi Al Batin north east of Saudi Arabia

Zahrani A.M.*[1], Al Ghamdi A.S.[1] & Nasser A.H.[1]

[1]Saudi Geological Survey, Jeddah, Saudi Arabia.

Corresponding author email: Zahrani.AM2@sgs.org.sa

Keywords: Sequence stratigraphy, Saudi Arabia, isotopic dating.

Sequence stratigraphy combines the two approaches correlation of rocks using erosional contacts and isotope – age – dating of K/Ar of basalt and other stratigraphical techniques, that help to understand deposits of strata each of which was deposited during a cycle of relative sea-level change and/or changing sediment supply and relationship with sedimentary chronostratigraphy and Sequence stratigraphy framework. In northern Saudi Arabia, the Tertiary deposits provides two age of the classic Dibdibba gravels, that associated with the feeding of a stream from alluvial fan of clasts coming from Arabian Shield during Pleistocene humid climate toward eastern slope in Saudi Arabia and along Saudi/Kuwaiti borders, to Shatt Al Arab in Iraq for about 500 km. sequence stratigraphic and chronostratigraphic in Wadi Al Batin sedimentation indicate to existence of extensive Umm Radhuma limestone (Paleocene) plain that underlies the Ajfar Formation(mid-Miocene). The Dibdibba gravels (Neogene) appears above the Ajfar Formation and abundant basalt clasts that occur in the upper part of the deposit that are not present in the lower part of the deposit. After deposition of the Dibdibba gravels, faulting was originated in the Central Arabian Graben System during the late Pliocene to early Pleistocene and a karst was formed along the Wadi Al Batin and eroded by the local runoff and only seen along the sides of the Wadi Al Batin as karst landforms. Wadi Al Batin is a strike-slip fault trends ENE. Arabian Shield/ Shelf is the western geographic border. The fault seems to cut through older Upper Cretaceous rocks of Arumah Formation. The exposed rock unites are Paleogene rocks of Umm Radhmah Formation Neogene rocks of Ajfar formation and Dibidbah gravel. The fault has maximum lateral movement 600 m meters measured by satellite data. Several cross section along the fault zone, suggest that there are vertical displacement reaches up to 10 m as well.

PLENARY LECTURES

Dates and Rates: Advances in Geochronology applied to the Stratigraphic Record

Daniel Condon

British Geological Survey

Corresponding author email: dcondon@bgs.ac.uk

Advances in radio-isotopic dating methods over the past two decades have accelerated increases in the temporal resolution that can be achieved. Such increases in precision have presented many challenges, both analytical and interpretational, which feed directly into the application of geochronology to stratigraphy. This step change in our ability to quantify geological time has also opened up many opportunities – the unprecedented integration of stratigraphy with absolute chronologies, to constrain rates of change, and to develop highly-resolved 4D frameworks to drive data integration, test and evolve models of Earth System operation. This talk will review some of these developments, highlighting the community approach, the advances made and new questions arising, and conclude with a forward look – geochronology in the age of 'big' and FAIR (Findable, Accessible, Interoperable and Reproducible) data.

Dolomites: a treasure chest of stratigraphy

Piero Gianolla

Università degli Studi di Ferrara

Corresponding author email: glr@unife.it

The Dolomites are a special place, their fame being due to the scientific recognition of their geological values since the end of the eighteenth century. Their interest was therefore first of all due to a scientific discovery and only then they become the iconic mountains that the whole world knows. Scientists were fascinated by these places and described also their incredible beauty, helping to create the myth of a place where geology becomes beauty. The name itself derives from the French naturalist Dieudonné de Dolomieu, who discovered in these places the mineral dolomite. In the open-air laboratory of the Dolomites the geological dispute between Neptunists and Plutonists was resolved at last, and the most influential scientists of the time came to see and touch outcrops around the small village of Predazzo. Stratigraphic and paleontological studies made this area of the Alps a world reference area for the stratigraphy of the whole Triassic since the beginning of the 19th century, some of the milestones about Triassic literature were written here. Maria Mathilda Ogilvie Gordon, the first woman to be awarded a Doctor of Science from University of London and the first woman to be awarded a PhD from the University of Munich, worked and studied here.

The Dolomites have been therefore an important place for stratigraphy and continue to be an open-air laboratory and a source of inspiration, where researchers from all over the world debate and study, as demonstrated by dozens of articles published every year and by the great numbers of students and scholars that visit the area.

For these reasons too, the Dolomites were included in the UNESCO World Natural Heritage List in 2009. The Outstanding Universal Value declaration (Seville, 29 June, 2009) well underlines the link between natural beauty, geology and scientific importance: "*The nine components of The Dolomites World Heritage property protect a series of highly distinctive mountain landscapes that are of exceptional natural beauty. Their dramatic vertical and pale colored peaks in a variety of distinctive sculptural forms is extraordinary in a global context. This property also contains an internationally important combination of earth science values. The quantity and concentration of highly varied limestone formations is extraordinary in a global context, whilst the superbly exposed geology provides an insight into the recovery of marine life in the Triassic period, after the greatest extinction event recorded in the history of life on Earth. The sublime, monumental and colorful landscapes of the Dolomites have also long attracted hosts of travelers and a history of scientific and artistic interpretations of its values*".

Integrating Chronostratigraphies with Geochronology in the Late Triassic

Dennis V. Kent[1] & CPCP Team

[1]Earth and Planetary Sciences, Rutgers University, Piscataway, NJ & Lamont-Doherty Earth Observatory, Palisades, NY USA

Corresponding author email: dvk@ldeo.columbia.edu

Rhythmic climate cycles of various assumed frequencies recorded in sedimentary archives are increasingly used to construct a continuous geologic time scale. The Newark–Hartford astrochronostratigraphic polarity timescale (APTS) was developed using a theoretically constant 405-kiloyear eccentricity cycle as a tuning target and provides a major timing calibration for about 30 million years of Late Triassic and earliest Jurassic time. While the 405-kyr cycle is both unimodal and the most metronomic of the major orbital cycles thought to pace Earth's climate in numerical solutions, there has been little empirical confirmation of that behavior, especially back before the limits of orbital solutions at about 50 million years before present. Moreover, the APTS is anchored only at its younger end (Central Atlantic Magmatic Province) by U–Pb zircon dates at 201.6 million years before present and could even be missing a number of 405-kyr cycles. To test the validity of the dangling APTS and orbital periodicities, Kent et al. (2018) recovered a diagnostic magnetic polarity sequence in the volcaniclastic-bearing Chinle Formation in a scientific drill core from Petrified Forest National Park (Arizona) that provides an unambiguous correlation to the APTS. New high precision U–Pb detrital zircon dates from the core are indistinguishable from ages predicted by the APTS back to 215 million years before present. The agreement shows that the APTS is continuous and supports a stable 405-kiloyear cycle well beyond theoretical solutions. The validated Newark–Hartford APTS can be used as a robust framework to help differentiate provinciality from global temporal patterns in biostratigraphies in the Late Triassic, amongst other problems (e.g., Olsen et al., 2019).

Kent D.V., Olsen P.E., Rasmussen C., Lepre C, Mundil R., Irmis R.B., Gehrels G.E., Giesler D., Geissman J.W. & Parker W.G. (2018) - Empirical evidence for stability of the 405-kiloyear Jupiter-Venus eccentricity cycle over hundreds of millions of years. Proceedings of the National Academy of Sciences 115, 6153-6158.

Olsen P.E., Laskar J., Kent D.V., Kinney S.T., Reynolds D.J., Sha J. & Whiteside J.H. (2019) - Mapping solar system chaos with the Geological Orrery. Proceedings of the National Academy of Sciences. www.pnas.org/cgi/doi/10.1073/pnas.1813901116.

Sophisticated Stratigraphy: How we got here

Andrew D. Miall

University of Toronto

Corresponding author email: miall@geology.utoronto.ca

A historical review of the evolution of the component parts of modern stratigraphy, the purpose of which is to demonstrate that stratigraphy is now an essential amalgam of all the former aspects of sedimentary geology: how sequence stratigraphy replaced litho- and biostratigraphy; the concept of cyclicity and the development of facies analysis; the essential contribution of reflection-seismic data; chronostratigraphy and the geologic time scale; the modern focus on high-resolution dating and correlation and implications for the rates and time scales of geological processes.

PATRONAGE

SPONSORED BY

eni

XXXVI GEOLOGORUM CONVENTUS DELHI - INDIA 2020 MENTE ET MALLEO

1926 SEPM Society for Sedimentary Geology

UNIVERSITÀ DEGLI STUDI DI MILANO
DIPARTIMENTO DI SCIENZE DELLA TERRA "ARDITO DESIO"

9 788894 269680