

## **Paleozoic Stratigraphy and Palaeogeography**



## **Stratigraphy and Carboniferous terrigenous sedimentation settings on the eastern flank of the Pre-Caspian depression**

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Results on bistratigraphic dissection of oil and gas bearing terrigenous deposits with identification of conodont and palynological zones are provided, sedimentation conditions are characterized.

**Keywords:** PreCaspian, Lower Carboniferous, sedimentation, conodonts, stratigraphy.

## **The Montalto Formation: a pre- to basal Ordovician succession in the Dúrico-Beirã area (northern Portugal)**

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The Montalto Formation consists of a succession of slate, greywacke, quartzites and polygenic conglomerates and outcrops in the Dúrico-Beirã area of northern Portugal. The Formation is of interest because it contains mixed volcanoclastic sequences that record changes in marginal-marine depositional environments and is associated with regional tectonic and magmatic processes. The Montalto Formation can be divided into three lithologic associations which record a shallowing-upward sequence.

**Keywords:** Schist-Greywacke Complex, Montalto Formation, Cambrian, basal Ordovician.

## **Early Cisuralian palynoflora from Apillapampa, Bolivia: biostratigraphic significance**

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Recent stratigraphic and palynologic data from marine and transitional rocks of the Copacabana Formation at Apillapampa in central Bolivia refine the age of Cisuralian palynomorphs in South America. Samples interbedded with volcanic ashes yielded palynomorph taxa arranged in two informal palynoassemblages: the lower assemblage *Vittatina costabilis* (Vc) was collected from one sample at the base of the Copacabana Formation, and the upper *Lueckisporites virkkiae* (Lv) assemblage occurs in overlying marine and coal-bearing transitional intervals. Ages were also independently refined by a modern review of microfossil (conodonts and fusulinids)

and five U-Pb radiometric ages (ID-TIMS of zircon-bearing interbedded tuffs) and confirmed that the Copacabana Formation at this location is Asselian and Sakmarian in age. *Lueckisporites virkkiae* and other palynomorphs are key species of palynozones utilized in South American and global Permian biostratigraphic reconstructions. Hence, a thorough global comparison of these palynofloras and correlations are addressed in this contribution considering first appearances of mainly cosmopolitan diagnostic taxa. Correlations are established with many similar Permian palynofloras, some also constrained with radiometric data, in South America (Brazil, Uruguay and Argentina) and elsewhere (Africa, Australia, Oman and Saudi Arabia).

**Keywords:** *Lueckisporites virkkiae*, Palynostratigraphy, Correlations, Cisuralian, Copacabana Formation, Bolivia.

## **Precambrian and Cambrian regional stratigraphy of Mongolia**

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In this paper we should like to demonstrate the Mongolian Precambrian and Cambrian stratigraphic classification of sedimentary, sedimentary-volcanogenic, volcanogenic and metamorphic rock sediments spread over the territory of Mongolia according to the new stratigraphic classification approved by the International Stratigraphic Commission. The Mongolian republic is situated in the central part of the Asiatic continent. Geologic studies in different parts of Mongolian territory began in the middle of the 20<sup>th</sup> century, but regular and extensive examination started in the seventies and eighties simultaneously with stratigraphical analyses of the oldest deposits within the sedimentary basins. The Joint Russian-Mongolian Scientific Research Geological and Paleontological Expeditions played a main role in the study of the region. These studies commenced more than 40 years ago and are still in progress now partly.

Precambrian rock units mainly exposed within the north Mongolian region have been divided into three regional metacomplexes (baidrag, buteel, bumbuger) and four sedimentary formations (muren, khug, darkhad or zavkhan, khubsugul or tsagaanolom). Isotopic age determinations on rocks and minerals from Archean granulite-gneiss blocks demonstrate an evolution from ~3,1 to 2,6 Ga. The Paleoproterozoic sedimentary complex is good exposed in north and central Mongolia and distinguished by marbles, various calciphyres, amphibolites and iron quartzites. The age of the complex is 1600-2050 Ma. Detailed study of the Middle-Neoproterozoic and Early Cambrian faunal (comeosiliceous polyactinal sponge, ichnofossils, soft-bodied fauna, medusa, chiolite, anabarites, archaeocyathids, trilobites) and floral (stromatolites, microphytolite assemblages, cyanobacterial mats, microfossils, calcareous algae) fossils give possibility first regional stratigraphic subdivision of different facies sediments. Glaciogenic deposits are widely distributed in the Neoproterozoic successions around the world, but only few of them contain unequivocal macroscopic fossils. Precambrian glacial marine deposits (Ediacaran maikhanuul formation) were discovered in Zavkhan region of western Mongolia in 1990s; they discordantly overlie the volcanic rocks of zavkhan formation (732-777 Ma) and are conformably overlaid by the limestones of the tsagaanolom formation. Recent studies suggest that the discoidal macroscopic remains from the intertillite beds of maikhanuul formation, as well the assemblage of microfossils from the tsagaanolom formation are comparable to that from the Doushantuo formation of south China (600-550 Ma).

**Keywords:** Archean, Proterozoic, Cambrian, metacomplex, formation, sediments.

## Sea-level history during birth of a foreland basin – The Famennian-Visean of “Velbert 4”, westernmost Rhenish Massif, Germany

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The core “Velbert 4” (Velbert anticline, westernmost Rhenish Massif) records the development from a mixed carbonate-siliciclastic Late Famennian (“Strunian”) ramp to a Tournaisian carbonate platform, a Visean calciturbiditic platform slope and finally the installation of a deep, black alum shale filled foreland basin in the latest Visean. The long-term trend is controlled by the advancing Variscan orogeny. It is modulated by short-term sea-level fluctuations, which among others caused the Hangenberg crisis, the mid-Tournaisian deepening event, a major erosional unconformity in the late Tournaisian and a pronounced sequence boundary at the Asbian-Brigantian boundary.

**Keywords:** Devonian (Famennian), Carboniferous (Mississippian), sea-level changes, carbonate ramp, carbonate platform, platform slope, calciturbidites, sequence stratigraphy, Germany (Rhenish Massif).

## Presence of the callipterids in the Permian of northeastern Brazil: stratigraphic and phytogeographic implications

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This is the first record of callipterids *sensu stricto* in South America, Western Gondwana. Previously, they were known only from the paleoequatorial belt, e.g. the Euroamerican (North America, Europe), northernmost African and Cathaysian (northern China, Southeast Asia and the Malay Archipelago) regions or from northern of Pangaea (Siberia), during the latest latest Carboniferous-late Permian interval. Fossils were collected from sediments from the middle-upper Pedra de Fogo Formation, part of the Permian of the Parnaíba Basin, of eastern Maranhão State, northeastern Brazil. The material recovered can be attributed to the callipterid genus *Rhachiphyllum*, and specifically to the species *Rhachiphyllum schenkii* (Heyer) Kerp. In addition, we found an *Autunia*-like fructification, corroborating a peltasperm affinity. The presence of *R. schenkii* could be indicative of an early Permian age for the Pedra de Fogo Formation since this species has a short and well-determinate stratigraphic range in Europe. Paleogeographically, the above-mentioned species found in association with fern genus *Pecopteris* suggests a migration corridor running from middle Europe and north South America during Permian times.

**Keywords:** callipterids, Permian, Western Gondwana, Pedra de Fogo Formation, northeastern Brazil.

## Pridolian to early Eifelian brachiopod zonation of the Rhenish Massif (Germany)

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A twofold brachiopod zonation is presented for the Pridolian to early Eifelian succession of the Rhenish Massif (Germany). It consists of 24 spiriferid taxon range zones and 18 brachiopod "faunal zones". The biostratigraphic subdivision is mainly applicable to successions developed in siliciclastic, shallow-marine or, respectively, rhenotypic facies. Supraregional correlations especially with sections in W and SW Europe and North Africa are possible. Due to still existing problems of neritic-pelagic correlation, the classic subdivision into Gedinnian, Siegenian and Emsian stages is still preferred on a regional scale.

**Keywords:** Brachiopoda, biostratigraphy, Lower Devonian, Germany.

## **Miospore zonation of the Givetian Stage and its upper boundary in the Southeast of the Russian Plate**

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The results of palynological studies of the Givetian and the overlying boundary Frasnian deposits in the South-East of the Russian Plate are represented. There are the five palynological assemblages corresponding to the five biostratigraphic zones. The upper boundary of the Givetian Stage in sections of the Russian Plate is discussed.

**Keywords:** Miospores, Zone, Givetian, Regional Stage, Russian Plate.

## **The Fezouata Biota (Central Anti-Atlas, Morocco): biostratigraphy and associated environmental conditions of an Ordovician Burgess Shale**

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The Lower Ordovician Fezouata Biota (Central Anti-Atlas, Morocco) is the sole exceptionally preserved marine fossil assemblage of Burgess Shale type, so far known from post-Cambrian rocks. It offers a unique opportunity to document the transition between the Cambrian and Palaeozoic Evolutionary Faunas. Recent fieldwork in the

area north of Zagora has yielded critical new information both on the precise stratigraphic position of, and palaeoenvironmental conditions associated with exceptionally preserved assemblages of the Fezouata Biota.

**Keywords:** Biostratigraphy, Lagerstätte, Morocco, Ordovician, Palaeoenvironment.

## **On the way to correlate Paleozoic French strata with the International Stratigraphic Chart**

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Paleozoic rocks occur in France in geographically and geologically independent regions. They are mostly deformed during the Hercynian Orogeny. This work presents the first step of a larger project, which attempts to propose biostratigraphic correlations between the Phanerozoic formations of the different French regions and the International Stratigraphic Scale. This preliminary outcome focuses on four regions containing Cambrian-Silurian strata: the Eastern Pyrenees, the Montagne Noire, and the Mid and North Armorican Domains.

**Keywords:** France, Stratigraphy, Palaeozoic.

## **The Austrian Stratigraphic Chart 2004 (sedimentary successions) and its lithostratigraphic units – the Paleozoic era(them)**

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A description of all Paleozoic lithostratigraphic units depicted in the Austrian Stratigraphic Chart 2004 (sedimentary successions) is presented in a consistent manner. These include 191 units which belong to several major tectonic units irregularly scattered over Austrian territory and covering only less than 10% of the surface area. The tectonic units are: Greywacke Zone, Gurktal Nappe System, the Graz Paleozoic, Carnic Alps and Karavanke Mountains.

**Keywords:** Paleozoic, lithostratigraphy, Austria.

## **Application of Wavelets in cyclostratigraphy of the Gėluva regional stage (Upper Hommerian: Silurian) in the Viduklė-61 deep well (Western Lithuania)**

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Gêluva age (Latter Homeric: Silurian) is important interval of time during which occurred one of the major episodes of mass extinction, when many clades of marine organisms were affected. In this study we investigated stratigraphic series of gamma log in Viduklê-61 well. In order to test the possibility of presence of sedimentary cycles we applied Wavelet and other time series analysis techniques. As a result we revealed two cyclicities with different periods – one 16.7 and other 6.7 m long cycles. Based on our calculations, those cyclicities are best explained as caused by two Milankovitch eccentricity cycles (400 and 100 ka). If this interpretation is true, then it gives us a good tool, to understand tempo of *lundgreni* extinction event and subsequent biotic recovery.

**Keywords:** wavelet, gamma log, Gêluva Regional stage, Silurian, Lithuania.

## **A revised correlation of Lower Ordovician sedimentary rocks in the Central Iberian Zone (Portugal and Spain)**

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Widespread Lower Ordovician sandstones (Armorican Quartzite facies) initiated a passive margin sedimentation in the late Floian over a huge area of SW Europe. Their deposition ended during Dapingian to early Darriwilian times. Precursors of the Armorican Quartzite were deposited behind the border of a rift system, leading to the formation of conglomeratic fans associated to the fault planes of tilted blocks generated during the rifting on the Cadomian basement. Tremadocian deposits, coeval with volcanic events, were also recorded across this extensional basin. A general scarcity of sedimentological studies or other elements aiding the correlation and a more accurate reconstruction of the basin architecture is also emphasized.

**Keywords:** Lower Ordovician, Central Iberian Zone, Lithostratigraphic correlation, Armorican Quartzite, Toledanian Unconformity.

## **Progress of the Permian Timescale**

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The Permian Period ranged from 298.9 Ma to 252.2 Ma based on latest radiometric ages in southern Urals and south China and comprises three series and nine stages. Among the three undefined GSSPs, a vote for the Kungurian-base GSSP candidate is ongoing and proposals for the Sakmarian-base and Artinskian-base GSSPs are expected to be completed within one year. The Permian timescale has been greatly improved in resolution recently.

**Keywords:** Permian, GSSP, timescale, correlation, biostratigraphy, chemostratigraphy.

## **Sedimentological causes of some problems in Cambrian Stratigraphy of the Siberian Platform**

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A comprehensive approach to the study of the sedimentary cover of the Siberian Platform, or the North-Asian Craton, including analysis of drilling logs, seismic profiles, and natural outcrop data enables widespread revision of the understanding about the extensive shallow-water sedimentation that existed in early Paleozoic intra-pericratonic seas of this region. The model, indicating development of giant carbonate platforms and starved basins in the Cambrian, solves numerous controversies in the sphere of stratigraphy. In particular, it helps in the problem of paradoxical combination of “structural unconformities” with biostratigraphical continuity of sections, revealed in the course of geological mapping. This fact is well explained by progradation of primary dipping carbonate slopes for many tens of kilometres and their overlapping by horizontal shelf sediments.

The model also explains reasons for the strong facies differences within this region as well as evolution of the deposition environments through the Cambrian. Besides, it accounts for the different lithostratigraphic sequences and sediment thicknesses, on the one hand, identified in composite sections from outcrops along the progradation direction, and on the other hand, the stratigraphy intersected in wells drilled within the same territories.

For the correct reproduction of stratigraphic data this model requires several modifications of traditional format in stratigraphic charts and completeness of accompanying documentation, including validation of biostratigraphical scales for separate environmental regions, while putting aside the unified scale for all facies, introduction of sedimentation reconstructions as addition, etc.

**Keywords:** Cambrian stratigraphy, stratal architecture, Siberian Platform, carbonate sedimentation, palaeogeography.

## **Carbon and sulfur isotopes from the Cambrian Series 2–Series 3 boundary: Potential proxies for a global correlation?**

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The Cambrian Series 2–Series 3 boundary interval of five investigated mixed carbonate-siliciclastic successions of Gondwana, Laurentia, and Siberia was analyzed for their carbonate carbon isotopes ( $\delta^{13}\text{C}_{\text{carb}}$ ) and sulfur isotopes from carbonate-associated sulfate ( $\delta^{34}\text{S}_{\text{CAS}}$ ). For all sections the boundary interval is characterized by distinct positive  $\delta^{13}\text{C}_{\text{carb}}$  excursions, flanking the first appearance datum (FAD) of trilobite species applied for the definition of (regional) bases of Cambrian Series 3. If the positive  $\delta^{13}\text{C}_{\text{carb}}$  shifts could be used as an additional proxy for an intercontinental correlation of the base of Cambrian Series 3 has to evaluate.

No distinct positive and/or negative  $\delta^{34}\text{S}_{\text{CAS}}$  excursions are discernible for the investigated successions. However,  $\delta^{34}\text{S}_{\text{CAS}}$  data provide important information for the characterization of paleo-environmental conditions, but probably no additional detail for a global correlation of the Cambrian Series 2–Series 3 boundary interval.

**Keywords:** Cambrian Series 2–Series 3 boundary, correlation, sulfur, carbon.