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ABSTRACTS

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[1]

The Sterane Record of Precambrian Eukaryotes

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Molecular clock and microfossil evidence are basically in consistent with the concept that the origin and early diversification of eukaryotes occurred at least in the early Mesoproterozoic of ca. 1.6~1.5Ga. However, several new molecular fossil (biomarker sterane) research indicate that the origin of eukaryotes and the first eukaryotic diversification may have been postponed to 0.82Ga and 0.65Ga (after Sturtian glaciations), respectively. Clearly, these sterane evidence have been in a controversy with other lines of evidence.

Steranes are considered as the sole molecular fossil for the eukaryotes in geological history. However, the Precambrian sterane occurrence has never been systematically investigated, owing to the incompleteness of sedimentary record and the high thermal maturation of sedimentary organic matters that endured long-time and deep-bury history. Therefore, we still have a long way to go to establish a reliable history of steroid evolution.

In this study, we analyzed the sterane composition of the early Mesoproterozoic Gaoyuzhuang Formation (GYZF, 1.6~1.5Ga) in North China Craton. The syngeneity of the extractable hydrocarbons from the thick sequence of organic-rich dolomites are systematically evaluated. The syngeneity of steranes are confirmed to be reliable by referring the integrated chracteristics of the major series of biomarkers, their stratigraphic trends and maturity indexes. The ubiquitous occurrence of regular steranes in GYZF means that the eukaryotic algae may have become one of the primary production in the epicontinental sea. The normal C_{27}-C_{28}-C_{29} sterane composition, together with C_{30} steranes mainly composed of 4-me- and 3-me-isomers and dinosteranes in very low concentration, are all similar to that of the late Neoproterozoic sediments in South China Craton. These data may have provided the robust evidence for the early origin and divergence of eukaryotic algae in early Mesoproterozoic. Combined with other scenarios of sterane anomaly or sterane absence, the long-term Precambrian sterane record well explains the essence of environment-life co-evolution.

KEYWORDS: Sterane, eukaryotes, Precambrian.

[2]

Raman Spectroscopy of Proterozoic Organic-Walled Microfossils in North China Craton

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Raman spectroscopy, as a non-intrusive and non-destructive technique, has played an important role in analyzing Precambrian carbonaceous microfossils and microstructures. It was found that heterogeneities in structural order

of the constituent carbonaceous materials (CMs) revealed by Raman spectroscopy can be preserved within Proterozoic silicified cyanobacterial fossils. However, such heterogeneities have not been well characterized in Proterozoic eukaryotic microfossils. In this study, we investigated the structural characteristics of organic-walled microfossils, most of which are eukaryotes preserved as carbonaceous compressions from the Paleo-Mesoproterozoic Ruyang Group and the Tonian Liulaobei Formation in North China Craton using Raman spectroscopy. Raman-derived parameters and geothermometers indicate that the CMs of the Ruyang and Liulaobei microfossils have experienced advanced diagenesis or low-grade metamorphism with peak paleotemperatures of ~200 °C or lower. Under such a diagenetic and metamorphic history, heterogeneities in structural characteristics of constituent CMs in eukaryotic microfossils were found within different subcellular structures of *Shuiyoushaeridium macroreticulatum* or within different taxa of the same stratigraphic group. We suggest that these heterogeneities could be attributed to differences in organic precursor compounds. In particular, this study supports that the Ruyang microfossils *Dictyosphaera delicata* and *S. macroreticulatum* might be biologically conspecific taxa with vesicle walls similar in structural order and hence chemical composition, and that the Liulaobei microfossils *Leiosphaeridia jacutica* and *L. tenuissima* are distinct taxa, which only show variation in opacity under transmitted light microscopy. This study confirms that Raman spectroscopy of structural characteristics of constituent CMs provides an independent technique to test the biological affinity of early eukaryotes whose taxonomic classifications are usually based on morphological characters.

KEYWORDS: Raman spectroscopy, carbonaceous material, microfossils, Proterozoic, Ruyang Group, Liulaobei Formation.

[3]

Constraints on the Depositional Age of the Tongjiazhuang Formation by LA-ICP-MS Detrital Zircon U-Pb Age and Microfossil Assemblage

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As a result of lacking reliable age dating materials, the depositional age of the Proterozoic Tongjiazhuang Formation of the Tumen Group in western Shandong Province is still controversial. In this paper, we combined detrital zircon dating with microfossil assemblage to constrain the depositional age of the Tongjiazhuang Formation. The minimum detrital zircon $^{207}Pb/^{206}Pb$ age of a siltstone layer from the top of the Tongjiazhuang Formation at the Tangtou section is 1063±53 Ma, and at the Fulaishan section is 954±58Ma, which constrains the maximum depositional age of the Tongjiazhuang Formation. Organic-walled microfossils extracted from the yellow-greenish shales of the Tongjiazhuang Formation consist of 23 species belonging to 12 genera. It is important to note that some genera *Pellicularia*, *Navifusa*, *Chlorogloeaopsis*, *Ostina*, *Polytrichoides*, *Simia* and *Trachyhystrichosphaera* are reported in this region for the first time. Also present in the Tongjiazhuang Formation are Trachyhystrichosphaera aimika (a species widely present in pre-Cryogenian Neoproterozoic and latest Mesoproterozoic rocks). Biologically, the microfossil assemblage studied herein is similar to those from late Mesoproterozoic to early Neoproterozoic (pre-Cryogenian), especially resembling to Liulaobei Formation (Tonian) in Huainan area. Therefore, based on the minimum age of detrital zircon and the characteristics of microfossil assemblage, we suggest that the depositional age of the Tongjiazhuang Formation is early Neoproterozoic (Tonian).

KEYWORDS: Detrital zircon, microfossil, Tonian, western Shandong, Tongjiazhuang Formation.

[4]

New Findings of Organic-Walled Microfossils from the Neoproterozoic Shiwangzhuang Formation in Anqiu, Shandong Provence, North China

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A diversified organic-walled assemblage dominated by sphaeromorphic acritarchs and cyanobacteria filaments are found from the Neoproterozoic Shiwangzhuang Formation in Anqiu, Shandong Provence, north China. The assemblage include 11 taxa, such as *Chlorogloeaopsis kanshiensis*, *Jacutianema solubila*, *Leiosphaeridia minutissima*, *Navifusa actinomorpha*, *Ostiana microcystis*, *Pellicularia tenera*, *Polytrichoides lineatus*, *Simia annulare*, *Siphonophycus kestron*, *S. punctatum* and *Synsphaeridium* sp. Given the paucity of microfossil record in the Shiwangzhaung Formation, this new discovery of the assemblage significantly enriches the data for further research. Some forms mentioned herein, for example, *Jacutianema solubila*, have potential value for biostratigraphic correlation of Neoproterozoic strata. Whether acanthomorphic acritarchs and more taxa will be found in the Shiwangzhuang Formation still needs more research. Biologically, the microfossil assemblage is similar to those from late Mesoproterozoic to early Neoproterozoic (pre-Cryogenian).

KEYWORDS: Organic-walled microfossils, Shiwangzhuang Formation, Neoproterozoic, North China.

[5]

Organic-Walled Microfossils from the Early Neoproteorozoic Tongjiazhuang Formation in Western Shandong, North China and Their Biostratigraphic Significance

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Tongjiazhuang Formation of Tumen Group in western Shandong of North China containing fine-grained siliciclastic rocks, have the potential to preserve organic-walled microfossils. However, the abundance and diversity of organic-walled microfossils have long been overlooked and the depositional age of Tongjiazhuang Formation has also not been well constrained. Through systematically sample collection, using low-manipulation maceration techniques, a well-preserved and diversified microfossil assemblage is obtained from the Tongjiazhuang Formation, containing abundant smooth-walled sphaeromorphic acritarchs and cyanobacterium-like filamentous forms and relatively low abundance of more complex acritarchs. Most of which are described for the first time from the Tongjiazhuang Formation in western Shandong, including *Simia* sp.,

Trachyhystrichosphaera aimika, *T. botula*, *Germinosphaera bispinosa*, Unnamed sp. A, *Jacutianema solubila*, and *Pololeptus rugosus*. Particularly, the occurrence of *T. aimika*, *T. botula*, *G. bispinosa*, *J. solubila*, and *P. rugosus* indicates a late Mesoproterozoic to Tonian age for the Tongjiazhuang Formation. Simultaneously, *Tawuia* and *Sinosabellidites* are described newly from the Shiwangzhuang Formation of Tumen Group, as well as *Chuaria-Tawuia* assemblage from the Tongjiazhuang Formation, which are consistent with the youngest detrital zircon ages of 1063 Ma and a Rb-Sr whole rock isochron age of 910.2 Ma from Tongjiazhuang Formation, suggesting a Tonian age for the middle and upper Tumen Group (Tongjiazhuang, Fulaishan, and Shiwangzhuang formations). In addition, the Tonian age confirms the existence of the 'Great Unconformity' between Tumen Group and the Cambrian Liguan Formation in western Shandong.

KEYWORDS: Tonian, Tongjiazhuang Formation, organic-walled microfossil.

[6]

Descriptions and Taphonomy of a New Macroscopic Carbonaceous Compression Fossil from the Early Neoproterozoic Liulaobei Formation in the Huainan Region of North China

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Here, we describe a new primitive macroscopic compression fossil species collected from the early Neoproterozoic Liulaobei Formation in the Huainan region, North China. It has a relatively stable semicircular shape, with a thick anterior margin that has a strong curve and a flat posterior margin that probably is flexible, and is millimetric-to centimetric-sized. In addition, a certain filament structure which was preserved on carbonaceous surface of the fossil was visible under SEM. Based on morphology, these specimens were obviously distinct from those common carbonaceous compression fossils collected in the same layer, such as *Chuaria*, *Tawuia* etc. On the other hand, by electronic microscopy and element mapping, our data suggest that preservation of these specimens is remarkably similar to Burgess Shale-type fossils in that the exceptional preservation is closely associated with clay minerals. Furthermore, despite a great challenge, we try to reconstruct the three-dimensional morphology of the fossil as a hemispherical dome by identifying three potential morphotypes, which could appear when being compressed from different directions. But the phylogeny of this fossil still remains blurry because of its simple morphology, poorly preserved structure and lack of enough evidence showing recognizable complete life cycle. The new observation will dramatically aid the morphological, paleoecological interpretation and species diversity of these early Neoproterozoic carbonaceous compression fossils.

KEYWORDS: Neoproterozoic, North China, macroscopic, carbonaceous compression fossil.

[7]

Macrofossil Assemblages from the Early Neoproterozoic Jiuliqiao Formation in the Huainan Region and Their Environmental Significance

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The Neoproterozoic was one of the important periods in the history of the evolution of the earth's life. During this period, a series of complicated evolutionary activities such as the origin of multicellular form and epigenetic animals took place. The physical and chemical environment of the earth has also undergone tremendous changes. A large number of macroscopic carbonaceous fossils are preserved in the Jiuliqiao Formation, which is an ideal material for the study of early biological communities and their evolution. In the study, we identified the species of macroscopic fossils in the Jiuliqiao Formation by systematic paleontological methods. By taking account of the species richness, density, size, diversity, evenness and many other ecological indicators of different fossil communities, we can find the structure and evolution of the community. In combination with geochemical methods, we explored the evolutionary trends and causes of early eukaryotic ecological communities. The dominant species are *Chuaria circularis* and *Shouchiennia shouhsienensis*, with little intraspecific and interspecific competition pressure. There was periodic community prosperity rather than significant evolution of the community within the profile studied.

KEYWORDS: Neoproterozoic, Huainan area, macrofossil community, ecological structure, paleoenvironment.

[8]

Active H_2S-Reoxidation during the Melting of the Marinoan Glaciation

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Termination of the Marinoan snowball Earth glaciation at ~635 million years ago (Ma) is followed by rapid diversifications of eukaryotes and multicellular algae at the beginning of the Ediacaran Period (635-541 Ma). It is hypothesized that a significant rise in atmospheric oxygen level during the melting of Marinoan glaciation may trigger these evolutionary events. However, direct evidence of this hypothesis is lacking. Here, we carried out detailed analysis of pyrite sulfur isotopic compositions ($\delta^{34}S_{py}$) and pyrite content of the Doushantuo cap carbonate in the Yangtze Block, South China. The Doushantuo cap carbonate conformably overlies the Nantuo Formation (Marinoan glacial deposits), representing the rapid termination of the Marinoan glaciation. The Doushantuo cap carbonate displays significant spatial gradient in both δ34Spy and pyrite content. The $\delta^{34}S_{py}$ from deep water facies (basin facies: 13.22%; slope facies: 15.94%) are isotopically lighter than those from shallow water environment (33%), whereas pyrite content of shallow environment (0.08 wt.%) and slope facies (0.11wt.%) is lower than that of basin facies (1.89 wt.%). By using a numerical model (one dimensional

diffusion-advection-reaction model), we suggest that such spatial gradient of pyrite sulfur systematics are caused by differences in H_2S-reoxidation proportion. The modelling results show that ~90% (shallow environment) and ~10% (deep water facies) of H2S was oxidized after microbial sulfate reduction. Our study suggests active sulfide reoxidation during the deposition of Doushantuo cap carbonate and provides direct evidence for a basinal scale oxidation during the melting of the Marinoan snowball Earth.

KEYWORDS: Doushantuo cap carboante, pyrite sulfur isotope, oxidation, Marinoan glaciation.

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[9]

Iron Cycle in the Aftermath of Marinoan Snowball Earth: Implications for the Ediacaran Biological Evolution

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The terminal Cryogenian Marinoan snowball Earth glaciation (~650 – 635 Ma) was followed by the diversification of eukaryotes and oxygenation in the deep ocean in early Ediacaran. Previous studies indicate rapid recovery of marine primary productivity immediately after the Marinoan snowball Earth, resulting in the development of oceanic euxinia. In this scenario, the dissimilatory sulfate reduction (DSR) occurred in the water column, and diffusion of H_2S from euxinic seawater into sediment porewater resulted in the syndepositional pyrite precipitation near the top of glacial deposits. This argument explained the platform-wide distributions of pyrite aggregates in the top of Nantuo Formation in South China. On the other hand, pyrite precipitation consumed seawater H_2S, converting sulfidic seawater to ferruginous. However, pyrite formation involves with both DSR and dissimilatory iron reduction (DIR), and ferruginous seawater requires excessive supply of ferrous Fe (Fe^{2+}). Thus, in addition to the seawater euxinia, abundant pyrite aggregate formation also requires active DIR in sediment porewater. In this study, we analyzed Fe isotope composition ($\delta^{56}Fe$) of pyrite aggregates in the topmost Nantuo Formation. Samples were collected from three sections, spanning from shelf, slope, to basin environments. Pyrites from different sections have distinct $\delta^{34}S$ and $\delta^{56}Fe$ values. Pyrite from the slope section has the highest $\delta^{34}S$ and $\delta^{56}Fe$ of crustal composition, while the shelf samples have the lowest $\delta^{34}S$ but the highest $\delta^{56}Fe$ values. We proposed that the local productivity controls DSR and DIR rates. We developed a Rayleigh distillation model to simulate S and Fe isotopes of pyrite. The modeling results indicate that DIR in slope sediment was limited by insufficient supply of organic matter due to intense DSR in the water column. In contrast, limited DSR in the shelf seawater allows abundant organic matter supply into sediments, fueling active DIR. Unlike the canonical redox zonation in normal marine sediments, where DIR at shallower depth of sediment affects DSR by organic matter supply, our study indicates the extent of DSR in the water column placed the key constraint on the DIR in sediment, and the redox zonation in the postglacial ocean was reversed. Finally, we

speculate that, in order to generate sufficient Fe^{2+} to deplete seawater H_2S, the renewed primary productivity must be high, favoring oxygenation in atmosphere after the Marinoan snowball Earth.

KEYWORDS: Marinoan snowball earth, marine productivity, pyrite, iron cycle.

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[10]

Calibrating the Neoproterozoic Glaciations

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Multiple glaciation events occurred in the Neoproterozoic, among which the Cryogenian Sturtian and Marinoan global glaciations record the most severe paleoclimatic events in Earth history. U-Pb and Re-Os geochronological data suggest that both the onset and termination of Sturtian glaciation (~717 Ma and ~600 Ma, respectively), and the termination of Marinoan glaciation (~635 Ma) were globally synchronous.

There are several probably non-global glaciations occurred in the Neoproterozoic before and after the Cryogenian Period. The Kaigas Formation glaciogenic diamictite in southern Namibia and western South Africa may have been deposited between 771±6 Ma and 741±6 Ma, and the depositional age of Bayisi Formation diamictite in Quruqtagh area of northwestern China was roughly constrained by radiometric ages between 740±7 Ma and 725±10 Ma. They represent the pre-Cryogenian glaciations, however, whether they represent the same synchronous paleoclimatic event needs to be confirmed by future precise radiometric dating. The Ediacaran Gaskiers glaciation has been well constrained at ~580 Ma, its correlation with many other glaciogenic diamictite units from around the world remains uncertain. The Fengtai, Luoquan, and Zhengmuguan diamictites occur in southern and western margin of North China block may have been deposited later than the Gaskiers diamictite. A peri-Gondwanan ~565 Ma "Weesenstein-Orellana glaciation" reported in the northeastern Bohemian Massif and southwestern Iberia further supports that multiple glaciation events, likely of regional extension, occurred in the terminal Proterozoic Ediacaran Period.

KEYWORDS: Glaciation, geochronology, Cryogenian, Ediacaran.

[11]

First Occurrence of *Vendotaenia antiqua* from the Rungri Formation, Yonthan Group, Hwangju County, North Hwanghae Province, DPRK

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Tectonically Unsong-ri lies on the northern limb of the eastwest-trending Hwangju Syncline, and here the Rungri Formation is a tectonically stable and thick succession. Based on lithology, the Yonthan Group can be divided into two formal units-the Pirangdong and the Rungri Formations.

The fossiliferous unit lies in the upper part of the Rungri Formation and consists of dark and gray green shales. The specimens of *Vendotaenia antiqua* are commonly, smoothly curved and lie parallel to the bedding planes. Widths of the preserved fossils range from 0.5 mm to 2.0 mm, sometimes reaching 3.5mm and sometimes exhibit dichotomous branching of some individuals on a single bedding surface. After branching, the width does not change. Ribbon-like organisms reach lengths of up to 10 cm, sometimes up to 15cm, but, in life, were presumably longer. No complete fossils have been found. No clearly differentiated terminations were observed in the hundreds of specimens collected. In hand specimens, the majority of the fossils stand out clearly because of their strong color contrast to the surrounding matrix individuals are generally either rust or brown in color. The surrounding matrix of specimens is clayrich infill material differs from matrix predominantly in its elevated C and Fe abundances. SEM analyses of the specimens show distinctive longitudinal striations. *Vendotaenia antiqua* commonly occurs in dense populations. The high abundances and random orientations of these fossils suggest that benthic populations were preserved more or less in place. A striking feature of the preserved populations on almost all bedding planes of the upper Rungri Formation is that the specimens tend to be of near constant width on any single bedding plane-width varies between bedding planes, but rarely within them.

Morphologically similar *Vendotaenia*-like specimens occur in other Ediacaran, including localities in Namibia, the East European Platform, China, and Brazil.

Hence, the Rungri Formation of the Yonthan Group is likely correlatable to the upper Ediacaran strata globally (including Nama Group, Kotlinian Group, Doushantuo and Dengying Formations, and Tamengo Formation) on the basis of *Vendotaenia*.

The new finds from the Rungri Formation in the Yonthan Group epitomize an important paleontological discovery on the Korea-China Craton.

KEYWORDS: Ediacaran, Yontan County, *Vendotaenia*.

[12]

New Evidence from Ediacaran Sedimentary Sequence and Provenance for Cathaysia being an Interior Part of Rodinia

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As an essential part of South China, the Cathaysia Block has been more controversial than the Yangtze Block on its components, collision timing, tectonic location and other key geological issues, among which its relationship with the Neoproterozoic supercontinent Rodinia being significant. Here, we report the new evidence of sedimentary sequence and provenance from Ediacaran sedimentary strata in Dabu County of eastern Guangdong to improve that the Cathaysia Block had probably been a part of Rodinia, located relatively far from

the margin. Ediacaran sedimentary strata in research area has been composed of continuous sedimentation of Nanyan and Huanglian formations of turbidites of metasandstone-sericite phyllite series from the bottom to middle, phyllite interbedded with siliceous rock in upper middle part and the topmost chert, which could be corresponded to Ediacaran sedimentation in the Yangtze Block. Through the observation of the metasandstone rock slice from Nanyan formation, its component maturity is middle with 50% quartz and 15% felspar, meanwhile its textural maturity is high with about 10% cements and well-sorted fragments. Detrital zircon sample from metasandstone of middle part of Nanyan formation displays major U-Pb age populations of 964.6Ma and 601.9Ma indicating the regional Grenvillan provenance affected by assembly of Gondwana and this link South China with western Australia, eastern India and East Antarctica during late Neoproterozoic. Overall, the characteristics of intra-basin deposition and the Grenvillian provenance in eastern Guangdong provide new evidence for the Cathaysia Block being a part of Rodinia, probably not on the margin.

KEYWORDS: Cathaysia Block, Ediacaran, Sedimentary sequence, detrital zircon, provenance, Rodinia.

[13]

Constraining of the Ediacaran Atmospheric Oxygenation: Carbon and Nitrogen Isotope ---Evidence from the Doushantuo Formation, South China

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Geochemical and paleontological data indicate that the termination of the Marinoan global glaciation (635 Ma) might have directly triggered the diversification of eukaryotes and oxygenation of the atmosphere-ocean system in the early Ediacaran Period. The atmospheric pO_2 level is not straightforward, instead is inferred from the marine redox landscape. Here, we report high-resolution organic carbon ($\delta^{13}C_{org}$) and nitrogen ($\delta^{15}N$) isotopes of the Doushantuo Formation in the E-Shan section in the western margin of the Yangtze Block, South China. The Doushantuo Formation in the E-Shan section is composed of alternating deposition of sandstone and mudstone, and can be interpreted as deposited in near shore delta environment, suggesting the deposition in well ventilated seawater that might be in equilibrium with atmosphere. $\delta^{13}C_{org}$ profile displays two prominent negative excursions, which are coincident with two positive excursions in $\delta^{15}N$. In addition, there are negative correlations between $\delta^{15}N$ and TOC content and between $\delta^{15}N$ and $\delta^{13}C_{org}$. We suggest that the negative excursion in $\delta^{13}C_{org}$ may indicate an increase in organic matter production, resulting in a higher contribution from ^{12}C-enriched new organic carbon with respect to fossil kerogens from terrestrial inputs. With an increase input of fresh organic matter that is more prone to degradation, the seawater became suboxic, resulting in the enhanced denitrification. The high positive $\delta^{15}N$ values may suggest the surface water was sub-oxic, suggesting the maximum of 67 μM of dissolved O_2 in the ocean, equivalent to ~20% PAL O_2 in atmosphere.

KEYWORDS: nitrogen isotopes, carbon isotopes, oxygenation, Ediacaran.

[14]

Evidence of Bilaterian Occurrence from the Late Ediacaran: Their Contrasting Occurrence due to Climatic Differences

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Occurrence of U-shaped burrows assignable to *Arenicolites* sp. from the late Ediacaran Zuun-Arts Formation, western Mongolia[1], as well as recent discovery of trackways from the late Ediacaran Shibatan Member in the Yangtze Gorges area of South China[2], both strongly suggest that bilaterian animals with a high motility have already existed in the late Ediacaran. On the other hand, most of the fossil records from the Ediacaran lack occurrence of apparent bilaterials. Such contrasting occurrence with regards to bilaterian fossils might be attributed to the paleoclimatic difference between Mongolia plus South China and other areas in the late Ediacaran and in the early Cambrian.

Mongolia and South China were interpreted to be located near the equator near the Precambrian-Cambrian boundary. These two areas were therefore under the tropical environment in the late Ediacaran. Such tropical environment might enable rapid evolution of bilaterians prior to the other areas.

Presence of deep burrowing in the late Ediacaran also shows complex animal behavior related to predation or predator-avoidance, suggesting a different view from that of the "Garden of Ediacara".

KEYWORDS: Ediacaran, Mongolia, South China, bilaterians, predation.

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[15]

Terminal Ediacaran Microbial Mats Creates Sweet Spot for Early Animal Evolution

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Atmospheric oxygenation is considered as a prerequisite for animal evolution. However, fossil records suggest the earliest animals might live on or burrow into the seafloor, requiring oxidation of seafloor. The dilemma is atmospheric and seafloor oxygenation could be decoupled and existing geochemical proxies do not provide specific constraints on seafloor redox at local scales. Here, we employed a new proxy, the ferrous iron content in carbonate minerals (Fe_{carb}), to constrain the redox condition of seafloor during the deposition of shallow-marine fossiliferous limestone of the terminal Ediacaran Dengying Formation in the Yangtze Gorges area, South China. Fe_{carb} of the latest Ediacaran Shibantan limestone ranges from 2.27 to 85.43 ppm, corresponding to the seafloor O_2 fugacity of 162 μmol/L to 297 μmol/L. This result indicates that the Dengying limestone has extremely low Fe_{carb}, which is comparable to that of the shallow-marine carbonates in late Paleozoic, when atmospheric O_2 content reached or even exceeded the modern level. Our study suggests that the Dengying limestone precipitated in oxic seawater with limited benthic Fe^{2+} flux from sediment porewater, implying the shallow water seafloor was already oxygenated, although the atmospheric pO2 level was generally low. Despite the low atmospheric pO2 level, the seafloor oxygenation might be attributed to the development of microbial mats, which produced O_2 and resulted in the seafloor oxygenation and ventilation of the upper layer of sediment, providing oases for the radiation of benthic metazoans.

This model is supported by a modern analog: Los Roques lagoon in Venezuela has low O_2 concentration in water column but the O_2 concentration in the mat ground which was colonized by O_2-generating cyanobacteria mat, could be four times higher than that in the water column. Our new hypothesis implies that the O_2 barrier could be locally overcome in mat ground, generating “sweet spots” for the early evolution of animals, questioning the long-held belief that atmospheric oxygenation was the key control of animal evolution.

KEYWORDS: Ediacaran, seafloor, oxygen level, carbonate assoicated ferrous iron, microbial mat.

ACKNOWLEDGMENTS

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[16]

Ediacaran-Cambrian Boundary Assignment by Stable Carbon Isotope Profile in Khuvsgul Group, Northern Mongolia

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In the early Cambrian Period, multicellular animals have rapidly diversified - the event known as the “Cambrian Explosion”. Most of the phyla of extant animals are assumed to have appeared in this short period. However, evolutionary process of multicellular animals during and before early Cambrian is poorly understood because of

scarceness of fossil record. Recent studies suggest that the diversification had proceeded well before the Cambrian, and thus it is time to reevaluate the established theory of the "Cambrian Explosion."

Because well-studied Ediacaran or Cambrian fossil localities are limited, it is important to seek for a new site which give us clues to understand the early evolution of multicellular animals. This work focuses on Khuvsgul Group, northern Mongolia as a prospective research site for studying the early animal evolution. Khuvsgul Group consists of Ongoluk, Khesen and Erkhelnur formations in upward sequence, and includes Ediacaran and Cambrian strata. The youngest Doushantuo-Pertatataka-type microfossil assemblage was discovered from latest Ediacaran phosphorites of the Khesen Formation. Furthermore, in an adjacent Zavkhan terrane in western Mongolia, the Cambrian diversification of benthic animals is suggested to have occurred earlier than other regions in the world; thus, it is plausible to find another evidence of earlier occurrence of multicellular animals in the Khuvsgul Group. This makes the group unique and important strata for studying the early animal evolution.

However, the Khuvsgul Group is not well studied, and less information is available for reliable age estimates. In this context, this work estimated the ages of Ediacaran-Cambrian strata within the group by correlating stable carbon isotope profiles. Although a part of the profiles was available before, this work tried to estimate the ages more accurately and more in detail by sampling rocks in a finer interval and from wider stratigraphic horizons. The carbon isotope profile obtained in this study suggests the assignment of Ediacaran-Cambrian boundary either at the uppermost part of Ongoluk Formation or at the uppermost part of Khesen Formation. Further geochemical or paleontological studies will clarify the more reliable position.

KEYWORDS: Khuvsgul Group, age estimation, stable carbon isotope, early evolution of animals.

ACKNOWLEDGMENTS

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[17]

Migration of Cathaysia-Typed Sandbody between the Yangtze and Cathaysia Blocks during Late Neoproterozic-Early Paleozoic: Implications for Basin Evolution

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The basin between the Yangtze and Cathaysia blocks has been extensively filled during Late Neoproterozic-Early Paleozoic, but the filling process and their relationship of basin evolution is unclear. A part of sandbody that has monotonous lithology and lack of sedimentary structure and fossils played an important role in the filling process, they are different in rock assemblage, sedimentary characteristics, and the detrital zircon ages with the relevant strata in the Yangtze area, we call it "the Cathaysia-typed sandbody" here for they are mainly developed around the Cathaysia block.

Some new detrital zircon ages were obtained from these transitional sections, combined with previous studies and data, we trying to reconstruction the source supply and filling process of the basin through a

quantitative and "point-line-surface" way, and then constrain its tectonic-sedimentary evolution process. The results shows that, at least during the Cryogenian to Silurian, the Cathaysia-typed sandbody have a trend to migrate towards Yangtze block (NW): (1) In the Cryogenian, the front of sandbody reached Guiyang in Hunan, between Sizhoushan and Tianzidi Formation (Fm.); (2) In the Ediacaran, migrated to the north of Yongfu in Guangxi, between Hongjiang and Peidi Fm.; (3) during Cambrian, to the Xinning in Hunan between Niutitang and Chayuantou Fm.; (4) from Ordovician to Silurian, the sand travel across the Jiangnan discontinuous island and reached the Meitan Fm. in Youyang, Chongqing. In particular, it can be furtherly divided into three stages during Early Paleozoic: ①Cambrian-Early Ordovician, detrital sediments are derived from each shore side of the basin and exhibited a bilateral filling pattern; ②Late Ordovician, supply of detrital sediments are disturbed, different source of detritals mixed in some central basin areas (like Xinning, Hunan). ③Silurian saw an unidirectional filling pattern, which is overwhelmed by the Cathaysia-typed sandbody derived from southeast of the basin.

The detrital supply process implies that: (1) there is a source area becoming stronger in detrital supply during Late Neoproterozic-Early Paleozoic, implies a continuous land-uplift. (2) there is a process of shorten and steepen of basin floor and uplift of basin margin, which is linking to the uplift of Jiangnan Orogen, Wuyi-Yunkai Orogen, and Gondwana. (3) The migration process does not support the model of a broad and mature ocean between the Yangtze and Cathaysia blocks during the Cryogenian to Early Palaeozoic.

KEYWORDS: Detrital zircon, provenance, basin evolution, Wuyi-Yunkai Orogen, Gondwana.

[18]

The Fossil Record of Oscillatoriaceae from the Ediacaran-Lower Cambrian Liuchapo Formation in Central Guizhou, China

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Abundant filamentous cyanobacteria have been discovered from the Ediacaran-Cambrian Liuchapo chert at the Yangtiao section, Majiang County, Guizhou Province. Six Oscillatoriaceae species comprising of different genera are identified, including *Calyptothrix perfecta*, *Calyptothrix major*, *Megathrix longus*, *Obruchevella* sp., *Palaeolyngbya barghoorniana*, and *Palaeolyngbya* sp. In addition, an unnamed filamentous microfossil that is morphologically similar to the modern *Lyngbya* is also described. Based on its unique finely annulated sheath and coarsely annulated filaments, the unnamed fossil may represent a new species belonging to the genus *Lyngbya*. The systematic study of the Oscillatoriaceae adds new paleontological data to refine the biostratigraphic framework, and improves our understanding of the diversification of the primary producers during this time period transitioning from Proterozoic to Phanerozoic.

KEYWORDS: Oscillatoriaceae, chert, Liuchapo Formation, Yangtiao, Guizhou.

[19]

Clustered Vetulicolians from the Early Cambrian of South China

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Vetulicolians are a group of enigmatic Cambrian animals featured by their anterior section with gill slit-like pouches and segmented/annulated posterior section. A diverse mode of life has been suggested for different taxa of vetulicolians, varying from nektonic filter to midwater dweller. Recently, the gregarious behaviour in vetulicolian *Banffia* from the Burgess Shale was even argued as the evidence of benthic feeding. In this study we document slabs from the early Cambrian Chengjiang biota and Guanshan biota with dense aggregations of individuals in several vetulicolian taxa. We collected variety of taphonomic data from these slabs, such as orientation, density, preserved morphological characters and sizes of the individuals, to test different hypotheses that may explain the vetulicolian clusters. In most slabs, taphonomic data indicate an *in situ* origin for the assemblage, whilst others are more equivocal. We further evaluate possible explanations for the clusters, such as mass feeding, avoiding predators, mechanical aggregations, etc. Our observations reinforce the idea that insight into these clusters from different biotas can help elucidate the ecology and mode of life of vetulicolians.

KEYWORDS: Vetulicolian, Chengjiang biota, Guanshan biota, palaeoecology, taphonomy.

[20]

From Chengjiang to Qingjiang

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Our understanding of the Cambrian explosion and of the fundamental structure of the tree of animal life rests in large part on evidence from a dramatically enhanced fossil record, characterized by the preservation of entire assemblages of soft-bodied fossils. In the one hundred years since Walcott's original discovery of the Burgess Shale, exceptionally preserved fossil assemblages, i.e. Burgess Shale-type biotas, have been reported from Cambrian strata of almost every paleocontinent, which are particularly well represented in the Cambrian of South China and Laurentia. Nevertheless, only the early Cambrian Chengjiang biota of Yunnan Province has matched the Burgess Shale in total diversity of soft-bodied taxa and fidelity of exceptional preservation. Here we report a new Lagerstätte from South China, the Qingjiang biota (518 Ma), which is dominated by soft-bodied taxa from a distal shelf setting. The Qingjiang biota is remarkable for pristine carbonaceous preservation of labile organic features, an exceptionally high proportion of new taxa (ca. 53%), and preliminary taxonomic diversity that suggests it could rival the Chengjiang and Burgess Shale biotas. Novel aspects include high abundance of cnidarians, including both medusoid and polypoid forms, new taxa resembling extant kinorhynchs, and abundant larval or juvenile forms. The uniqueness in composition and preservation would provide new insights into the

evolution of Cambrian ecosystems across environmental gradients.

KEYWORDS: Cambrian explosion, origin of metazoans, Burgess Shale, Chengjiang, Qingjiang.

[21]

New Features Revealed with New Techniques – Recent Progress in the Studies of Chengjiang Arthropods

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More than 250 species have been reported from the early Cambrian Chengjiang biota, of which the arthropods represent the most abundant group. Although the fossils from the biota are usually exceptionally preserved – soft parts such as the eyes, the nervous system and the cardiovascular system have been reported from various arthropods and related groups, the phylogeny of these groups however still remains controversial. This is partly due to the incomplete knowledge of the animal's morphologies resulted from limited techniques in the last years. Our group is currently using advanced methods such as fluorescent microscopy, SEM to reveal previously unknown features from the surface of the fossils and more importantly micro-CT and related rendering techniques to extract 3D information from the inside of the fossils. Consequently, character matrix for phylogenetic studies will be largely improved, aiming to yield more reliable hypotheses.

KEYWORDS: Chengjiang biota, arthropods, fluorescent microscopy, SEM, Micro-CT.

[22]

The Early Evolution of Animals: Perspectives from the Chengjiang Problematic Fossils

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As the oldest Burgess Shale-type (BST) biota, the celebrated Chengjiang biota, which dates to Cambrian Epoch 2, Age 3, represents the first exceptionally preserved soft-bodied fossil record of the main burst of the metazoan radiation. Although most fossils from the Chengjiang biota can be identified as the earliest representatives of many extant animal phyla, including chordate, nearly half hundred species still remain as problematic, i.e. no consensus can be reached on their affinities. Over one-decade persistent investigations on the Chengjiang problematic fossils reveal that taphonomic alteration and biased homology assessment are the two main issues

that account for most controversies in their interpretations. After correcting these two biases, we here demonstrate that most Chengjiang problematic fossils, such as chancelloriids, 'dinomischids', radiodants *et al*., can be properly pinned in the stem group of some particular metazoan clades. Furthermore, integrating the Chengjiang problematic fossils into the tree of metazoan reveals some patterns unknown before in the early evolution of animal morphology. For example, altering the size proportion of different body parts might be a key pathway in the early evolution of several metazoan clades, such as in ctenophore. Morphological innovations in feeding structures, e.g. GLS of radiodonts, are widely revealed in the main clades of the Chengjiang metazoans, indicating that diversified feeding strategies might play a more important role in the early metazoan radiation.

[23]

Why is the Chengjiang Biota Exceptionally Well Preserved?

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Elected as a World Natural Heritage site in 2012, the Chengjiang Biota is renowned for its exceptional soft-tissue preservation, which provides crucial evidence for early metazoan evolution. However, it is not yet clear why the Chengjiang Biota is exceptionally well preserved. In recent years, this question has received greater scrutiny with the reporting of exceptionally preserved decay-prone tissues, namely neural, cardiovascular and visual structures. It has often been assumed that these labile tissues do not withstand fossilization and would decay away shortly after the animal's death. Yet mounting evidence supports the interpretation of these exceptionally preserved labile structures as true anatomical characters, further highlighting the gap in our understanding of exceptional preservation in Cambrian fossils. In this presentation, I will show how the latest developments in geochemical and experimental decay research shed new light on our understanding of the taphonomy and preservation of the Chengjiang fossils. The contrasting redox conditions in the event and background beds indicate that the Chengjiang Biota was flourishing in persistently oxic shallow marine environments, while the animals were buried and transported to an adjacent dysoxic deep-water depositional environment, which allows internal tissues to be organically preserved with fidelity. Polymerisation appears to be central to the long-term survival of normally decay-prone tissues.

KEYWORDS: Chengjiang Biota, exceptional preservation, geochemical research and experimental decay.

[24]

Pyritization of Sponge Spicules in the Early Cambrian Shuijingtuo Formation, South China

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As the basal clade metazoan, sponges were mostly preserved as dispersed spicules that were commonly replaced by pyrites in the early Cambrian rocks. It is unclear why sponge spicules are pervasively pyritized. In this study, we analyzed the sulfur ($\delta^{34}S$) and iron isotopes ($\delta^{56}Fe$) of pyritized sponge spicules in black shale of the Shuijingtuo formation in the Yangtze Platform, South China. The Shuijingtuo black shale yields abundant pyritized sponge spicules, which consists of subhedral pyrite crystals of 50~100 um in size. It is proposed that dissolution of siliceous spicules created voids in sediments, followed by pyrite precipitation before sediment compaction. In addition, the Shuijingtuo black shale also contains abundant disseminated anhedral pyrites of 10~30 in size, which may predate the precipitation of subhedral pyrites that replace the sponge spicules. Here, we make in situ sulfur and iron isotope analyses of individual pyrite crystals by using SHRIMP (Sensitive High Resolution Ion Micro Probe) and LA-ICP-MS, respectively. Disseminated pyrite and replacive pyrite have overlapping range of $\delta^{34}S$, ranging from 21~25‰, suggesting a homogeneous H_2S source. In contrast, disseminated pyrites are systematically enriched in ^{56}Fe as compared with the replacive pyrite. The invariant $\delta^{34}S$ data indicate inactive dissimilatory sulfate reduction (DSR) in sediment porewater, which would generate large variation in pyrite $\delta^{34}S$. Instead, we suggest that sulfidic seawater might be the major S source of pyrite. Higher $\delta^{56}Fe$ of the disseminated pyrites may indicate pyrites precipitated from a Fe^{2+} pool, because pyrite precipitation would associate with positive fractionation in iron isotope and early formed pyrite would have higher $\delta^{56}Fe$ values. Thus, the water column was sulfidic (H_2S-enriched), while the sediment porewater was ferruginous (Fe^{2+}-enriched). Our study indicates that pyritization of sponge spicules might have occurred in ferruginous porewater with H_2S supply from the overlying euxinic seawater. The pervasive pyritization of sponge spicules might be related to the widespread sulfidic condition in early Cambrian. Finally, the observed redox zonation is reversed to the canonical redox zonation in modern sediment, where the dissimilatory iron reduction (DIR) zone overlies the DSR zone.

KEYWORDS: Pyritization, pyrite, Cambian, sponge spicules, South China.

[25]

New Occurrence of Guanshan Lagerstätte (Cambrian Series 2, Stage 4) in Kunming Area, Yunnan, South China, with Records of New Taxa

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As a classic Burgess-Shale-Type (BST) Konservat Lagerstätte, Guanshan biota is well known for abundant soft-body fossils with high taxonomic diversity. Here we report a new locality of Guanshan Biota in Kunming area, Yunnan, South China, and briefly discuss its lithostratigraphy. In addition to all the known taxa of Guanshan biota, several new taxa are firstly documented from this locality. Particularly, a new euarthropod is assigned to genus *Emucaris*, based on the morphology of cephalic shield, thoracic segments and pigidium. A discoidal-shaped-animal, is identified as *Pararotadiscus*, a genus that was once known from the Emu Bay Lagerstätte of South Australia, which further strengths the biogeographic connection between early Cambrian biotas of South China and Australia. Our new discoveries not only expand the paleogeographic distribution of Guanshan biota, but reveal that the biodiversity of Guanshan is much higher, thus can be fairly regarded as an ecological community successor from the Chengjiang biota.

KEYWORDS: Guanshan Biota, early Cambrian, discoidal animal, biogeographic connection.

[26]

Calcified Coccoid from Cambrian Miaolingian: Revealing the Potential Cellular Structure of *Epiphyton*

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Epiphyton, *Renalcis*, and *Girvanella* are ubiquitous genera of calcified cyanobacteria/algae from Early Paleozoic shallow-marine limestones. One genus, *Epiphyton*, is characterized by a particular dendritic outline, and extensive research has revealed the morphology of calcified remains although little information on cellular structure is known. The mass occurrence of calcified *Epiphyton* in microbialites from Cambrian Miaolingian, the Mianchi area of North China is preserved as black clots within thrombolites and have dendritic and spherical outlines when viewed with a petrographic microscope. These remains, visible under scanning electron microscope (SEM), also comprise spherical or rectangle capsules. These capsules are made up from external envelopes and internal calcite with numerous pits, which closely resemble modern benthic coccoid cyanobacteria. These pits are between 2 μm and 4 μm in diameter and are interpreted here to represent the remnants of degraded coccoid cells, while the calcite that surrounds these pits is interpreted as calcified thin extracellular polymeric substances (EPS). In contrast, associated capsular envelopes represent thick EPS mineralized by calcium carbonate with an admixture of Al-Mg-Fe silicates. Dendritic 'thalli' are typically stacked apically because of the repeated growth and calcification of these capsules. Carbon and oxygen isotope results are interpreted to indicate that both photosynthesis and heterotrophic bacterial metabolism (especially sulfate reducing bacteria) contributed to carbonate precipitation by elevated alkalinity. *Epiphyton* are therefore here interpreted as colonies of calcified coccoid cyanobacteria, and the carbonate-oversaturated seawater during the Cambrian was conducive to their mineralization.

KEYWORDS: *Epiphyton*, Coccoid, calcification, Cambrian Wuliuan, North China.

[27]

Cambrian Fine-Grained Stromatolites within Oolite

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Kalkowsky's[1] Triassic stromatolites are fine-grained and embedded within oolite[2]. Fine-grained stromatolites are common throughout geologic history, but their origins are often unclear. Kalkowsky's stromatolites formed by precipitation[2]. What about other fine-grained stromatolites? Did they form by precipitation or by trapping and binding of fine-grained sediment?

Awramik and Riding[3] suggested that differential trapping and binding ability between algae and cyanobacteria might explain abundant fine-grained stromatolites in geologic history; algae could trap and bind coarse sediments and form stromatolites similar to those at Shark Bay and the Bahamas, whereas cyanobacteria could selectively trap fine sediment. Nonetheless, it can be difficult to confidently identify trapped and bound fine sediment in the geologic record.

We studied two Chinese examples of middle Cambrian (Miaolingian) fine-grained stromatolites surrounded by oolite to understand their formative processes. At Subeigo, Wuhai (Inner Mongolia), small domal stromatolites ~2 cm wide and high occur within oolitic packstone-grainstone. Low-relief micritic layers with cross-cutting relationships are present, with coarse sediment only occurring within small intramound pockets. At Xishan, near Beijing, meter-scale mounds with centimetric stromatolite columns occur within oolitic grainstone. Poorly laminated micritic layers with minor calcified microbes (e.g., *Epiphyton*, *Renalcis*) occur within the columns, whereas coarse ooid-bioclast-intraclast wackestone-packstone only occurs between columns.

The microfabrics suggest that these Cambrian stromatolites formed by fine-grained trapping/binding (Wuhai) plus precipitation (Beijing). In both cases, it appears that coarse sediment was selectively excluded by the mats and only accumulated in small pockets. We infer that coarse grains were excluded either because the mats were too firm or too thin to retain them.

KEYWORDS: Stromatoliinte, trapping and bindg, Cambrian, agglutinated stromatolite.

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[28]

The Progress and Some Aspects of Jianhe Biota of "Tingnsutung Formation" from Cambrian of Guizhou

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In 2010, Yuanlong Zhao and Jinlianyuan found many soft bodied fossils of the mud stone layer of the "Tingnsutung Formation" which named as Jianhe Biota. The Biota contain 52 genera: Porifera (6 genus), Cnidaria (3 genus), Brachiopoda (7 genus); Mollusa (2 genus), Echinodermes (1 genus), Pripulids (2 genus) and Arthropods (25 genus), in which 15 genera are Trilobites.

Besides the mud stone host fossils, we also found *Byronia* in the dolostone dominated Jialao Formation. The clade like Anomalocaris has much longer longevity than other clades and a case study comes from *Sphenothallus* which emerge in Niutitang Biota (Stage 3), the morph types diversification in Palang Biota (Stage 4), Jianhe Biota (Stage 4) and Kaili Biota (Miaolingian). The genus also found in Ordovician, Silurian, Devonian and Carboniferous. The evolution pattern of *Sphenothallus* is strongly support the gradualism. Gradualism and punctuated equilibrium, long considered as imcompatable theory. Faithfully, we can say both of which describe some aspects of the evolution.

[29]

Tsinania (Trilobita, Corynexochida) from the Cambrian Furongian in Northern Anhui and Its Intraspecific Variations

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The North China type Cambrian System is well developed in Anhui Province, especially the traditional middle and upper Cambrian series. Bi[1] divided the Cambrian in the Huaibei region of northern Anhui into 3 series and 7 stages with 7 formations and 17 trilobite zones, which include the "Changshanian" and "Fengshanian" stages. A large quantity of specimens of the trilobite *Tsinania* were collected from the Cambrian (Furongian Stage) at Fenghuangshan in northern Anhui, China, and are identified as *Tsinania canens* (Walcott, 1905) and *Tsinania dolichocephala* (Kobayashi, 1933). After making the characteristic comparisons between these two species and other species referred to *Tsinania*, various intraspecific variations in this two species are described and discussed (e.g. the shape and length of the anterior border, the shape of the pygidium, and the width of the pygidial border). Consequently, it is necessary to redefine these two species and discuss their intraspecific variations.

Various intraspecific variations are present in the biosphere, most of which are caused by geographic variation, sexual dimorphism, and different ontogenetic development stages. Intraspecfic variations also existed in fossils of different geological ages. In order to ensure the validity of classification during the fossil identification and study, it is very important to make a distinction between intraspecific variation and interspecific variation. However, such studies are relatively rare in paleontology[2-5].

The two species of *Tsinania* studied here have relatively short geological ranges and narrow geographic distributions mainly in North China, South China and Korean Peninsula. So they possibly had higher rates of morphological evolution because of more intraspecific variations. This may explain why previous studies mistook intraspecific variation as the interspecific variation and established many new species. According to the concept and criteria of species, each trilobite zone should host several morphologically transitional specimens representing intraspecific variation, but not indicate interspecific variation.

KEYWORDS: Trilobita, *Tsinania*, intraspecific variation, Furongian, Cambrian, northern Anhui.

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[30]

Bivalved Arthropods of the Cambrian Niutitang Formation in Zunyi, China

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The Niutitang Formation is a stratigraphical unit consisting of black carbargilite, carbonaceous shale, and multi-elemental 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. The study shows that there are 4 genus 6 species of bivalved arthropods from the Cambrian Niutitang Formation in Zunyi, including *Isoxys minor*, *I. paradoxus*, *I. curvirostratus*, *Perspicaris* sp., *Tsunyiella luna* and *Emeiella venusta*, and *T. luna* is the dominant species. The ontogeny of *T. luna* of the Cambrian Niutitang Formation, Zunyi, Guizhou province is studied preliminarily here by using geometric morphometric method. The result shows that the growth pattern of *T. luna* is allometric. And the ratio between the shell height and the shell length decrease during the ontogeny. And the ratio between the hinge-line length and shell length is decreasing with inverse proportional function during the ontogeny. The ventral margin is balanced growth. However, the molting stage is still not clear now. The ontogeny can be divided into three stages: early stage, middle stage and late stage. In the early stage, structure is from scratch, and the ratio of the height to length became larger as the shell become round. In the middle stage, the proportion of anterior node and dorsal margin ridge in the shell and the ratio of height to length gradually decreased, and the mid-dorsal area gradually increased on the contrary and the shell form gradually retral swing. In the late stage, the proportion of anterior node in the shell increased slightly, and the dorsal margin ridge decreased, and the mid-dorsal area is not obvious, and the ratio of height to length increased, and the shell form was more round. This study not only increases the composition of Niutitang Biota, but also provides more information for further study on taxonomy and phylogeny of *T. luna*, as well as the reconstruction of the paleoecology and paleoenvironment.

KEYWORDS: Bivalved arthropods, Niutitang Formation, Cambrian, Zunyi, China.

[31]

Evolutionary and Paleobiogeographic History of the Nisusiidae Based on Cladistic Analysis

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Cladistic and biogeographic analyses were conducted to reveal the evolutionary and paleobiogeographic history of the family Nisusiidae, a Cambrian rhynchonelliform brachiopod group. This primitive articulate brachiopod group shows a wide range of morphological variations in *Nisusia*, the only nisusiid genus with a spinose shell. This study aims 1) to reconstruct species-level phylogenetic relationships of the Nisusiidae and evaluate them with respect to current taxonomic scheme, 2) to examine character transformation patterns observed in phylogenetic tree, and 3) to investigate cladistic paleobiogeographic history of the group based on phylogenetic tree.

The data matrix shown in Holmer et al.[1] was revised and modified to construct a data matrix with 27 characters and 26 taxa including two species of Sino-Korean platform. The new data matrix was analyzed using parsimony methods with character reweighting based on consistency index. The analysis resulted in two most parsimonious trees with tree length of 50.765. Based on multiple stratigraphic congruence indices, a single tree was selected for evolutionary and paleobiogeographic interpretations.

The selected tree demonstrates that 1) the non-spinose nisusiids (*Bellistrophia*, *Narynella*, and *Eoconcha*) form the most derived clade including an undetermined Korean species and 2) *Nisusia* as a whole is paraphyletic, but a clade consisting eleven *Nisusia* species is recognized. Character state transformations of evolutionary significance are 1) spinose condition (from strongly spinose to non-spinose via finely spinose), 2) ventral interarea condition (from procline or catacline to apsacline), and 3) the position of the highest point of ventral valve (from at umbo to mid-valve position).

To trace paleobiogeographic history of the Nisusiidae, cladogram-based analyses were performed. Resulted Ancestral Area (AA) index and area cladogram optimized by Fitch[2] algorithm indicate that Laurentia is most likely to have been part of the ancestral area of nisusiids, and the spinose nisusiids subsequently diversified into Siberia, South China and Sino-Korea via peri-Gondwana, while the non-spinose nisusiids including the undetermined Korean species which were evolved from the spinose group were mainly confined to Laurentia. The modified Brooks Parsimony Analysis shows that Laurentia and peri-Gondwana were paleogeographically closer to each other relative to other areas.

KEYWORDS: Cambrian, Nisusiidae, cladistic analysis, paleobiogeography.

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[32]

New Organic-Walled Microfossils from the Cambrian Zhushadong Formation in Linyi, Shandong, China and Their Biostratigraphic Implication

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An organic-walled microfossil assemblage consisting of both cryptospores and acritarchs has been obtained by traditional palynological techniques from the shale samples of the Cambrian Zhushadong Formation in Linyi, southern Shandong, China. It significantly enriches the data of Cambrian microfossils in north China. According to their morphology, two genera of cryptospores and four genera of acritarchs are identified, such as cryptospores: *Adinosporus voluminosus*, *A.* cf. *bullatus*, *A.* sp., *Vidalgea maculate*; and acritarchs: *Asteridium tornatum*, *Heliosphaeridium obscurum*, *Leiosphaeridia* sp., *Leiosphaeridia* sp. A, and *Synsphaeridium* sp.

The character of the assemblage supports that there was an adlittoral tidal flat deposited environment of early-middle Cambrian in the research area. The situation of that cryptospores and acritarchs preserved together in the Zhushadong Formation might be interpreted as that cryptospore specimens were brought by terrestrial substances, otherwise it was of possibility that they were derived from parent plants which lived in nearshore environment.

KEYWORDS: Organic-walled microfossils, Zhushadong Formation, Cambrian, Shandong, north China.

[33]

Pentaradial Symmetry of Echinoderms as a Result of the Development of Ancestral Bilateral Asymmetry: Data from Paleontology and Embryology

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Five-radial symmetry (pentaradiality) is included in the echinoderm bodyplan along with a calcite stereomic skeleton and ambulacral system. Pentaradiate echinoderms appeared in the Early Cambrian at the same time, or a little earlier, with bilaterally asymmetric representatives. The five-radial Ediakaran *Arkarua* doesn't belong to echinoderms and it is a bursting oxygen bubble of a cyanobacterial mat. Pentaradiality occurs initially in the ambulacral system due to the growth of the left hydrocoele around the esophagus and the polymerization of the first single ambulacrum extending from it, first to two, and then up to three ambulacra. The following two ambulacra, necessary for the appearance of pentaradiate symmetry of ambulacral system, arise by the branching of two of the previous three ones resulting from the polymerization. This process is partially reflected in the ontogenesis of recent crinoids and in the morphology of the many fossil adult echinoderms. The symmetry of

the ambulacral system, as shown by paleontological data, extends to the symmetry of the skeleton, nervous and circulatory systems. Some key stages in the ontogenetic process of the development of pentaradiality (bilaterally asymmetric development of right and left coeloms, movement of the primordial mouth from the anterior to the posterior end of the settled larva (torsion), growth of the left hydrocoel around the esophagus) were absent in the ontogenesis of some "carpoid" echinoderms and therefore are not reflected in the morphology of their adult representatives. Stylophoran bodyplan reflect a bilaterally asymmetric pre-torsion developmental stage of the echinoderm symmetry. Adult morphology of the Solutans and Cinctans correspond to the developmental stage between torsion and pentaradiality[1]. Ctenocystoids and *Ctenoimbricata* can reflect the bilateral stage of the recent crinoid larva development, but it is possible that the bilateral skeleton symmetry (sometimes incomplete) of these fossils is secondary and does not reflect the symmetrical development of their coeloms, since they are not known as having the hydropores. Bilateral asymmetry of echinoderms could arise at the earliest stages of Bilateria diversification and reflect the features of bilateral symmetry emerging. Further development of asymmetry in echinoderms leads to the transformation of the left hydrocoele in the ring, the location of the posterior coeloms in stack and, ultimately, to the appearance of the pentaradiality. Five-radial symmetry is an improvement of the three-radial one, and three-radial symmetry is based on the morphogenetic mechanism of division of the bilaterally asymmetric ancestor body into the three initial metamers (anterior, middle and posterior). Findings of pre-skeletal fossils in Chinese and other Cambrian Lagerstätten are important for the study of the origin of echinoderm asymmetry and pentaradiality as well as the formation bilaterality in Bilateria.

KEYWORDS: Echinoderms, Bilateria, symmetry, pentaradiality, ontogeny, Palaeozoic.

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[34]

Conodonts from the Cambrian-Ordovician Boundary Strata of Hyesan Area, Rangrim Massif, DPRK

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The lower Paleozoic strata (lower Cambrian-middle Ordovician) of DPRK are orderly distributed at the Rangnim massif and many fossils including trilobites, brachiopods and conodonts are known until now. In Hyesan area situated in the northern part of the Rangnim massif, the upper Cambrian and the lower Ordovician strata are well developed and conodonts are also studied by several researchers long ago.

The upper Cambrian-lower Ordovician strata are mainly consisted of dark-grey limestones and grey argillaceous limestones including various conodonts.

At the upper Cambrian Kophung Formation, paraconodonts such as *Proscandodus delicatulus*, *Westergaardodina moessebergensissata*, *W.matsushitai*, *W.bicuspidata*, *W.tricuspidata*, *W.muelleri*, *Hertzina*?*bilibata*, *Furnishina triangulata*, *F.lingulata*, *F.*cf.*primitiva*, *Muellerodus erectus*, *M.oelandicus*, Prooneotodus *gallatini* and euconodonts such as *Cordylodus proavus*, *Teridontus reclinatus*, *T.nakamurai*, *T.erectus* are successfully known. And, at the lower Ordovician Singok Formation, many euconodonts including *Cordylodus intermedius*, *C.lenzi*, *C.lindstroemi*, *C.rotundatus*, *Teridontus reclinatus*, *T.erectus*, *T.nakamurai*, *Proconodontus cambricus*, *Prooneotodus rotundatus*, *Utahconus beimadaoensis*, *Monocostodus sevierensis*, *Drepanodus tangshanensis*, *D.parallelus*, *Acontiodus staufferi*, *Chosonodina herfurthi*, *Scolopodus quadraplicatus*, *S.opimus*, *S.nogamii*, *S.flexilis*, *S.manchordata*, *S.rex*, *S.restrictus*, *S.bassleri*, *S.primitivus*, *Bergstroemognathus* sp., *Serratognathus bilobatus* are known in rich amount.

Especially, the conodonts of genera such as *Westergaardodina*, *Hertzina*?, *Furnishina*, *Muellerodus*, *Prooneotodus*, *Cordylodus*, *Teridontus* from the upper Cambrian strata and genera such as *Cordylodus*, *Teridontus*, *Proconodontus*, *Prooneotodus*, *Utahconus*, *Monocostodus*, *Chosonodina*, *Scolopodus* from the lower Ordovician strata of this area are almost consistent with the conodonts of Dayangcha area, Jilin Province, China. Both Hyesan and Dayangcha areas, the boundary of *Cordylodus proavus* zone of the upper Cambrian and *Utahconus beimadaoensis-Monocostodus sevierensis* zone is the boundary of the Cambrian and Ordovician strata. But, until now, the fossils such as graptolites, acritarchs and trilobites from Dayangcha are unknown in Hyesan.

On the basis of these conodonts, we have confirmed the boundary of Cambrian and Ordovician strata in Hyesan area.

KEYWORDS: Cambrian, Ordovician, conodonts.

[35]

Konservat-Lagerstätten of Late Cambrian to Ordovician in South China: Facies, Preservation and Palaeoecology

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The recurrent shales of late Cambrian to Ordovician in South China yields diverse faunas and some Konservat-Lagerstätten. These shales occur intermittently and contain several exceptionally-preserved biota, including Guole Biota (Furongian), Fenghsiang Biota (Tremadocian), Tonggao Biota (Floian), Miaopo Formation Fauna (Sandbian) and Anji Biota (Hirnantian). These faunas recorded in South China are related to various facies, including intra-platform depression, marginal platform, upper slope, foreland basin with anoxic–dysoxic sea floor, etc. The Guole Biota is dominated by shelly faunas, including vagile trilobites and non-trilobite arthropods, benthic brachiopods and sessile early echinoderms, in association of a few benthic graptolites, cnidarians, hyoliths, palaeoscolecidan and algae, suggesting a marginal shelf setting. The Fenghsiang Biota is characterized by abundant bryozoans, brachiopods with pedicles, benthic graptolites, a few black corals with unmineralized skeletons, and possible agnathans, suggesting a platform facies. In the Tonggao Biota, palaeoscolecid worms, brachiopod with setae, arthropod appendages, algae and possible nematodes are exceptionally preserved, in addition to those common brachiopods, benthic and planktic graptolites, conulariids and echinoderms. The Miaopo Biota is well known for its diverse faunas of mixed benthos and planktons, especially those exquisite, pyritic graptolites and well-preserved chitinozoans and acritarches, suggesting a typical intra-platform

depression setting. The biota was preserved in black shale with intercalation of argillaceous limestones, which is indicative of anoxic and oxic alternations for the sea water. The post-mass extinction Anji Biota is unique in its predominance of highly diverse and exceptionally-preserved benthic sponges, in association of rich planktic graptolites. The exceptional preservation of the biota by rapid sedimentation was generated by post-glacial transgression over weathered land masses, and similar processes may have operated at other times in late Cambrian and Ordovician. The combined record of these faunas (and potential further faunas in the region) provides a key window for understanding the development of Ordovician ecology, beyond the normal shelly assemblages.

KEYWORDS: Konservat-Lagerstätten, facies, palaeoecology, Ordovician, Cambrian.

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[36]

Redefining the Global Cambrian–Ordovician Boundary: A Re-Study from the Xiaoyangqiao Section, Dayangcha in Jilin, China

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A new high-resolution integrated bio-, sequence-, chemo- and magneto-stratigraphic research of the Xiaoyangqiao section, Dayangcha, China and its precise comparison to the Green Point GSSP section, Newfoundland, Canada approved by 2000 (Cooper et al., 2001) demonstrate the GSSP has exposed a serious deficiencies for use as a GSSP. The current boundary biomark defined by *Iapetognathus fluctivagus* is not present in the specified boundary layer and point in unit 23/Bed 23, but in unit 26/Bed 26 above the beds with the graptolite *R.* "*praeparabola*"*-parabola* assemblage in the Section. The underlying rocks from the uppermost unit 24/Bed 24 to the lowest unit 25/Bed 25, ca 4 m above the GSSP horizon in the section is absent of the earliest planktonic graptolite *R. proparabola*, recorded from the Xiaoyangqiao section. The current "Golden Spiker", fixed in unit 23 of the GSSP section, represented in fact by the incoming of *Iapetognathus preaengensis* Landing in Fortey et al., 1982 (i.e. Bed 23 (Terfelt et al., 2012; Azmy et al., 2014), is situated in the *Acerocare* Lowstand, just above the prominent negative excursion and above the REE geochemical anomaly in the *Cordylodus intermedius* Zone. New research suggests that the Xiaoyangqiao section fully satisfies the requirements for a GSSP or ASSP. It shows the important 'missing link' between the faunal successions of shallow water carbonate deposits (Lawson Cove ASSP section) and the deep water lower slope deposits (Green Point GSSP section) and the deepest water basinal succession (Wa'ergang section) and solves the longstanding problem correlating shallow water facies with shelly fossils with deep water facies with graptolites. The current boundary horizon defined in the GSSP section is corresponding to the upper *C. intermedius* Zone, ca 1m below

the first planktic graptolite *R. proparabola* levels, that is at +20.9 m above the reference level of the Xiaoyangqiao section, and 0.5 m below the base of the *Cordylodus lindstromi* Zone in the Xiaoyangqiao section, along with the negative $\delta^{13}C_{carb}$-isotope and REE excursion identified at +19.9 m, and easy to be correlated globally. For the precision of global Cambrian-Ordovician boundary subdivision and comparison and also for establishment of a high-resolution Ordovician geological time scale present authors are strongly recommended the Xiaoyangqiao section as candidate as Auxiliary Boundary Stratigraphic Section and Point section (ASSP) for the base of the Ordovician System and accordingly, revising and redefining of the global Cambrian-Ordovician boundary.

KEYWORDS: Dayangcha ASSP section, Green Point GSSP section, Cambrian–Ordovician boundary, acritarchs, conodonts, graptolites.

[37]

A Review of the Ordovician Acritarch Genus *Orthosphaeridium* Eisenack 1968 nov. emend.

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Based on new investigations of palynological material from the Ghelli Formation in northeastern Iran and from the Dawan Formation in Hubei, South China, one of the easily recognizable acritarch genera in the Middle and Late Ordovician has been taxonomically revised. After its first description in the Ordovician strata from Baltica by Eisenack (1968), this genus has been found subsequently on most other palaeocontinents with more than 20 species, but many of them are apparently synonyms. The review indicates that the following four species can be easily differentiated: *Orthosphaeridium bispinosum* Turner, 1984, *Orthosphaeridium ternatum* (Burmann, 1970) Eisenack, Cramer and Díez 1976, *Orthosphaeridium rectangulare* (Eisenack, 1963) Eisenack, 1968 (type species) and *Orthosphaeridium octospinosum* Eisenack, 1968. The taxonomical ranks of *Orthosphaeridium rectangulare* var. *quadricornis* Burmann, 1970 and *Orthosphaeridium octospinosum* var. *insculptum* Loeblich, 1970 are changed from the species to the varietas level. The review indicates that *Orthosphaeridium* first appeared in South China in the *Expansograptus hirundo* graptolite biozone, i.e. in the early Dapingian (stage slice Dp1 and time slice 3a of the Middle Ordovician) and that it reached a global distribution during the Middle and Late Ordovician. The genus disappeared at the end of the Ordovician and has never been recorded from the Silurian. The genus is thus a stratigraphical index fossil for the Middle and Late Ordovician.

KEYWORDS: Phytoplankton, Lower Palaeozoic, Ordovician, biostratigraphy, taxonomy.

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[38]

The Early Devonian Transgression in South China and its Impact on the Evolution of Brachiopod Faunas

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After the Caledonian Orogeny in the Early Paleozoic, an extensive northward transgression took place during the Early Devonian in South China. The Lower Devonian brachiopod faunal replacement in South China shows close relationship with the transgression process and the consequent paleoenvironmental changes.

During the Pragian, the incipient stage of the transgression, epicontinental sea was widely distributed in Guangxi Province and adjacent regions, and the first widespread Devonian brachiopod fauna then appeared, which is called the *Orientospirifer* fauna and mainly composed of endemic taxa.

The *Orientospirifer* fauna was succeeded by the "*Spirifer*" *tonkinensis* Fauna", and the latter was one of the most diverse and most widespread Devonian brachiopod faunas in South China. According to recent study (Guo et al., 2019), appearance of the *"Spirifer" tonkinensis* Fauna in different areas of South China and adjacent areas is diachronous, showing an evident chronological trend from south to north. This trend is consistent with the northeastward transgression during the Early Devonian in South China. The disappearance of the "*Spirifer*" *tonkinensis* Fauna was also diachronous in different areas. Paleoecological study indicates the persistence of the Early Devonian transgression resulted in the disappearance of favourable biotopes of the "*Spirifer" tonkinensis* Fauna (i.e. the near-shore, shallow marine environment with muddy substratum and plentiful terrigenous input), due to either a deepening of seawater or the development of a carbonate platform. This might ultimately have triggered the extinction of the fauna.

After the "*Spirifer" tonkinensis* Fauna disappeared, the transgression, together with tectonic movements, led to the differentiation of basinal and platform sedimentary facies in South China. And as a result, divergent patterns of brachiopod faunal replacement were recorded in different facies of South China.

In Nandan area, where basinal facies developed since the late Early Emsian, the succeeding *Sinathyris* Fauna preserved in dark mudstone within the *P. nothoperbonus* Zone is of rather low diversity and dominated by the small-sized, double-spiral bearing *Sinathyris* Guo, Sun & Baliński, 2015 and accompanied by very rare orthids, atrypids and athyrids that together constitute 1% of the brachiopod fauna. Besides brachiopods, sporadic rugose corals, trilobites, nautiloids, and gastropods can also be recognized. Composition of the *Sinathyris* Fauna and the massive accompanying thin-shelled tetaculitids suggests a quiet, relatively deep marine environment.

While in central Guangxi Province, where carbonate platform facies developed since late Early Emsian, the "*Spirifer*" *tonkinensis* Fauna was succeeded by the *Howellella fecunda–Reticulariopsis ertangensis* assemblage, preserved in calcareous mudstone and marl and mainly comprised of spiriferids, athyrids, rhynchonellids, etc. (Chen, 1983). Accompanying taxon include tabulate corals, rugose corals, gastropods, bivalves, and conodont *P. perbonus* (Yu & Yin, 1978). This brachiopod fauna is approximately contemporary with the *Sinathyris* Fauna in Nandan, but is of much higher biodiversity and lived in a relatively shallow water environment.

After the Emsian, divergent patterns of brachiopod faunal replacement resulted from differentiation of basinal facies and carbonate platform facies in South China continued through the rest of Devonian.

KEYWORDS: Transgression, brachiopod faunas, Early Devonian, South China.

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[39]

Ontogenic and Phylogenic Studies of Lituitid Cephalopods: Based on New Materials from China

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The ontogeny of *Lituites* (Lituitida Starobogatov, 1974) is studied and discussed based on the measurements of the well-preserved specimens from the Middle Yangtze Platform, South China. Analytic geometry is adopted to explain ranging developmental stages using the polar coordinates method to describe different forms. Then three characteristic ontogenic stages in the species lifespan have been recognized, i.e., juvenile, rapid growth and mature stages. On this basis, a cladistic analysis was conducted for several significant species of Family Lituitidae and Sinoceridae, belonging to Order Lituitida, with the aim of elucidating the origin and phylogenic evolution of the group. Thirteen taxa, including lituitids and the related forms and outgroups, and 16 characters were selected for the analysis. The results suggest that the lituitids share a likely common ancestor, the orthocerids. The orthocerids gave rise to two lineages, one of which was the *Rhynchorthoceras* and *Ancistroceras* lineage, and the other was the Lituites, *Cyclolituites* and *Sinoceras* lineage. *Sinoceras* was the stem group from which *Lituites* and *Cyclolituites* were derived. Furthermore, weighted networks approach has been used to explain paleobiogeographic patterns of Lituitida near the northeastern peri-Gondwana region during the Middle to Late Ordovician.

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[40]

Middle Ordovician Camerate and Disparid Crinoids from the Jigunsan Formation, South Korea: Their First Record in Sino-Korean Platform

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Crinoid specimens with cups were found in two dark greenish gray, lenticular laminated shale slabs which are considered to have been derived from the Middle Ordovician Jigunsan Formation, South Korea. The slabs were collected near the outcrops of the formation and contain disarticulated sclerites of trilobites typical of the formation such as *Dolerobasilicus*. Most crinoid specimens have cup, arm and column preserved as external molds. Taxonomic study in progress indicates that one specimen belongs to the Diplobathrida of the Camerata and the remaining specimens which all occur in a single slab to the Disparida.

The diplobathrid specimen is characterized by a large-sized, subglobular cup with strong stellate median ray ridges, pentagonal structure at the cup base, uniserial and pinnulate arms, and circular stem with circular lumen. These morphological features are similar to those of *Pararchaeocrinus* or *Trochocrinites* (the family Rhodocrinitidae). The shape of the radial and interradial plates allows us to assign the specimen to *Pararchaeocrinus*. The Camerata is divided into two groups, the Diplobathrida and Monobathrida. It is the presence or absence of infrabasal plates that distinguishes one from the other; the diplobathrids have the infrabasal plates (dicyclic) whereas the monobathrids lack them (monocyclic). Like *Pararchaeocrinus* or *Trochocrinites*, the infrabasal plates are considered to be hidden by the pentagonal structure at the cup base.

Of the disparid specimens, four have a well preserved cup. The cup is small and monocyclic, and the arms are uniserial, which are typical of the Disparida. The two specimens have a spirally coiled anal tube and one specimen have the superradial and infraradial plate and the fused radial plate in between. These features allow us to assign these specimens to the Family Heterocrinidae. In other specimens without a poorly-preserved cup, these features are not well preserved, but the spirally coiled anal tube is observed in the two specimens.

The diplobathrids have been reported from the Middle Ordovician strata of North America, Spain, and Wales, and the disparids from those of North America, Oman, South China and Morocco. This is the first report of the Middle Ordovician diplobathrid and disparid crinoids from the Sino-Korean platform of North China Block.

KEYWORDS: Camerata, Diplobathrida, Disparida, systematics, Sino-Korean platform.

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[41]

A New Plant with Novel Leaves from the Upper Devonian of Zhejiang Province, China

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The evolution of vascular plants during the Devonian Period had great impacts on terrestrial ecosystems through innovations of key characters such as leaves, heterospory, seed reproduction, and secondary woods. Here we report a new plant, *Qianshouia mira* gen. et sp. nov., from the Upper Devonian Wutong (Wutung) Formation of Fanwan section, Changxing County, Zhejiang Province, China. This plant has slender axes which seldom branch. Its leaves are arranged in low helices, departing from axes with an acute angle. The leaves are strap-shaped and each can be subdivided into proximal, middle and distal portions. The proximal portion is characterized by a middle ridge on abaxial surface, while the middle portion has four to six abaxial ridges and grooves. The distal portion of leaves is adaxially curved, with no ridges but with forked tips. *Qianshouia* probably represents a small plant with a shrubby or herbaceous habit, while its exact phylogenetic position is difficult to evaluate due to its unique leaf morphology and the lack of fertile structures and anatomy. Nevertheless, the phyllotaxy in low helices on axes probably suggests a lycopsid affinity. *Qianshouia* adds to the diversity of leaf morphology among the Late Devonian plants.

KEYWORDS: *Qianshouia mira*; Late Devonian; Wutong Formation; leaf morphology; lycopsids.

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[42]

The Late Ordovician Graptolites from the Pingliang Area in Gansu Province, NW China

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The successions of the Upper Ordovician outcrops in a disused quarry, about 200m west of the well-known Guanzhuang section of Pingliang City in Gansu Province, namely the type locality of the Pingliang Formation. The middle part of the sequence is characterized by a set of dark shale of about 40cm thick which contains abundant graptolites. The graptolite fauna is represented by 17 species of 14 genus and 8 species indeterminate on the basis of a large collection of the specimens. It is dominated by *Dicranograptus brevicaulis* Elles and Wood, *Climacograptus bicornis* (Hall), *Archiclimacograptus meridionalis* (Ruedemann), *Dicellograptus rectus* (Ruedemann), *Archiclimacograptus arctus* (Ruedemann), *Ningxiagraptus yangtzensis* (Mu in Ge), *Nemagraptus delicatus* (Lin), *Jiangxigraptus sextans* (Hall) and *Normalograptus brevis* (Elles and Wood), and thus should be of the *Climacograptus bicornis* biozone. The fossil data supports that the sequence in the disused quarry are correlated with the upper part of the Pingliang Formation in the Guanzhuang locality.

KEYWORDS: New materials, graptolites, Shale, Upper Ordovician, Guanzhuang.

[43]

A Katian Acritarch Assemblage from Yongshan, East Yunnan Province, South China: Biostratigraphic and Palaeogeographic Implications

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The Wanhe section, located in the southwestern Yongshan County, northeast Yunnan Province, consists of the Pagoda, 'Linhsiang', Daduhe formations, Kuanyinchiao bed, Lungmachi and Huanggexi formations in ascending order, representing strata from the Upper Ordovician to the lower Silurian.

Thirty-eight samples are prepared for palynological analyses from the Wanhe section. A moderately well preserved acritarch assemblage, as well as chitinozoans was discovered from the 'Linhsiang' and Daduhe

formations. According to the graptolite biostratigraphic result, the acritarch assemblage was found in the *Dicellograptus complanatus*, *D. complexus*, and *Paraorthograptus pacificus* graptolite biozones.

The acritarch assemblage is consist of some typical Upper Ordovician taxa, such as *Baltisphaeridium adialstaltum, Buedingiisphaeridium balticum*, *Gyalorhethium granulispinuliferum, Navifusa ancepsipuncta* and *Ordovicium* sp., but some Silurian elements exist too, e. g. *Oppilatala* sp. *Hoegkintia* sp., *Likropalla adiazeta*, and *Evittia remota*.

The acritarch assemblage from the Wanhe section is quite differ from other acritarch assemblages described in the Katian from other parts of China, such as western Tarim and northwestern Zhejiang. The absence of *Dactylofusa cabottii* from the Wanhe section maybe indicates a deeper water environment during Katian.

South China was placed near the palaeoequator during the Late Ordovician in recent palaeogeographic reconstructions. Negative to brachiopods and graptolites, the diversity of acritarch assemblage from the Wanhe section is fairly low, and even lower than some acritarch assemblages in high latitudes, such as Libya and the Czech Republic. The acritarch assemblage from Wanhe section is differ from the Eastern Laurentian and Baltican assemblages (Delabroye) by low diversity and is differ from the peri-Gondwana assemblages (Delabroye) by lack of netromorph acritarch forms. The acritarch assemblage in Late Ordovician is still poorly understood and more researches are needed.

KEYWORDS: Ordovician, acritarchs, Yongshan, Katian, biostratigraphy, palaeogeography.

[44]

Katian (Late Ordovician) Conodonts from the Northwestern Margin of the North China Craton (NCC) and the Implications for Paleoceanography and Paleogeography

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Carbonate strata exposed continuously along the ridge of Baiyanhuashan Hill in Inner Mongolia, North China are the most representative Late Ordovician succession in the north western margin of the North China Craton (NCC). Thirty-nine limestone samples were collected from the Wulanhudong and Baiyanhuashan formations, and yielded 1215 conodont specimens after acid leaching. Forty-five species belonging to 17 genera, with a stratigraphic range spanning the early to the middle Katian, are present. Three successive conodont biozones have been recognized based on the Baiyanhuashan Hill material, i.e., in ascending order, the *Belodina confluens* Biozone, the *Yaoxianognathus neimengguensis* Biozone and the *Yaoxianognathus yaoxianensis* Biozone. The Baiyanhuashan Hill conodont fauna includes species both endemic to North China and widely distributed in cratonic blocks in the tropical zones, allowing a re-assessment of the regional and international correlations of the Katian conodont zonal successions of North China with those of the shallow-water carbonate platforms at low latitudes. Based on an analysis on the dispersal of both widely and restrictedly distributed conodont taxa regarding to the current fauna, early-mid Katian ocean surface circulation and continental configurations in the tropical zones are further studied, and some more detailed information with respect to the paleogeography of this time interval is provided.

KEYWORDS: Katian, conodonts, North China, paleoceanography, paleogeography.

[45]

Macroevolution of Graptolites During the End Ordovician Mass Extinction - Taking South China as an Example

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The end Ordovician mass extinction, one of the Big-five mass extinction events in geological history[1], results in not only the great loss of a large number of species, but also the evolutionary differentiation, ecological reconstruction and biogeographic reorganization. Graptolite, as an important marine plankton, suffered from the mass extinction, which was manifested by a sharp decline in diversity and abundance. However, it's still unclear about the variation in biogeography and ecology of graptolites during the mass extinction. A quantitative study on the ranges, patterns and dynamics of its distrinution, and the relationship between its distribution and environment will be helpful to understand the macroevolution of the late Ordovician graptolite fauna.

In our study, we took South China as an example, to examine the biogeographic and ecologic changes of graptolites during the end Ordovician mass extinction. Twenty-seven species of graptolites were chosen in this study, among which twenty-one belong to the Diplograptina and six belong to the Neograptina. Meanwhile, the study time interval (late Katian to Hirnantian, Ordovician) was divided into four time biozones: the *Dicellograptus complexus* Zone, the *Paraorthograptus pacificus* Zone, the *Metabolograptus extraordinarius* Zone and the *Metabolograptus persculptus* Zone. Species distribution models[2] (SDMs) was used to study the changes in biogeography and ecology of graptolite species through the end Ordovician mass extinction. This method can establish the link between the observed distributions of species with the environmental data, and then predict the potential geographic distribution in the uncertain regions, which can reduce the influence of the incompleteness of the fossil record. By investigating the modelled distributions of each graptolite species during the successive time slices, we got the following preliminary results: (1) Different clades of graptolites showed different evolutionary strategy during the extinction event: the geographical ranges of the Ordovician Diplograptina decreased, while those of the Neograptina increased, which became the major clade in Silurian. (2) Three different evolutionary types are recognized, i.e. background extinction units, mass extinction units and origination units. (3) Environmental factor analysis indicates that the hydrodynamic condition was the most important among the factors affecting the geographic distribution of graptolites.

KEYWORDS: graptolite, biogeography, niche, end Ordovician mass extinction.

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[46]

Paleoecological Interactions between Stromatoporoid *Clathrodictyon* and Tabulate Coral *Agetolites*: Evidence from the Upper Ordovician Xiazhen Formation of South China

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Syn-vivo interactions between stromatoporoid and other associated organisms provide valuable information to access growth behaviours of both stromatoporoid and the involved organisms. However, such fossil record is rarely known in the Ordovician but became common in the Silurian and Devonian. Here, we describe two types of syn-vivo interactions between clathrodictyid stromatoporoid *Clathrodictyon* and tabulate coral *Agetolites* from the Upper Ordovician Xiazhen Formation (middle to late Katian) at Zhuzhai section, Yushan, Jiangxi Province, China, which has not been reported before. Judging from their growth forms and modes, two types of paleoecological interactions have been recognized; mutualism (perhaps commensalism as well) and competition, and these associations were facultative for both organisms. The interactions are found from four horizons of the formation among all the 16 *Clathrodictyon*-bearing horizons. These four horizons are interpreted as reef environments with a high density of sessile organisms. Compared with other ten stromatoporoid genera from the formation, *Clathrodictyon* shows a variety of paleoecological association with other organisms including tabulate and rugose corals, *Rhabdotetradium* and *Eofletcheria*-like tubes, and stormatoporoid *Labechia* as well. The occurrence of these diverse relationships in South China indicates that ecological complexity had already been highly developed, as a result of the interactions between clathrodictyid stromatoporoids and corals that appeared during the Great Ordovician Diversification Event.

KEYWORDS: Late Ordovician, *Clathrodictyon*, *Agetolites*, paleoecological interaction.

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[47]

Two Paleozoic (Hirnantian and Guadalupian) Extinctions in Cosmoclimatological Context: Global Chilling by 'Non-Bolide' Extraterrestrial Causes

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The end-Paleozoic extinction that determined the fate of modern animals occurred in two steps: i.e., first around the Middle-Late Permian boundary (G-LB) and then at the Permian-Triassic boundary (P-TB). Biological and non-biological aspects unique to these two distinct events include changes in biodiversity, isotope ratios (C, Sr *etc.*) of seawater, sea level, ocean redox state, episodic volcanism, and geomagnetism. Multiple possible causes were proposed for the G-LB extinction that likely recorded the initial major global changes in the atmosphere, oceanograpahy, climate, and biodiversity. As the G-LB and end-Ordovician extinctions share multiple similar episodes, in particular, the appearance of global cooling, the same cause and processes for extinction probably have driven the major biodiversity crises (Isozaki & Servais, 2018). In addition to the currently most popular scenario of mantle plume-generated large igneous province (LIP) formation, emerging perspectives of cosmoclimatology may add alternative possible causes, which include 1) increased flux of galactic cosmic radiation (GCR) and solar/terrestrial responses in magnetism, and 2) encounter with dark nebula. Both can bring profound impacts on Earth's climate, in particular, global cooling by extensive cloud coverage and/or dust screen (irradiance shutdown) regardless of putative volcanogenic CO_2 input and relevant greenhouse effect. It is noteworthy that the past star-burst events detected in the Milky Way Galaxy apparently coincide in timing with the cooling-associated major extinctions of the Paleozoic (Ordovician, Devonian, and Permian) and also with the Neoproterozoic snowball Earth episode (Isozaki, 2019). Recently our research group detected for the first time the signature of increased flux of extraterrestrial ^{3}He from the slowly accumulated deep-sea P-TB beds immediately below the extinction horizon of Permian radiolarians (Onoue et al., 2019). Causes of extinction can be grouped into four categories in hierarchy, from small to large scale: i.e., Category 1 – direct kill mechanism for each local biota, Category 2 – background change in global environment, Category 3 – major geological phenomenon on the planet's surface, and Category 4 – ultimate cause from the interior and exterior of the planet (Isozaki, 2019). The study of mass extinctions on Earth is entering a new stage with a new astrobiological perspective.

KEYWORDS: Paleozoic, mass extinction, global cooling, Hirnantian, Guadalupian.

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[48]

Oldest Known Fossil of Rossellids (Hexactinellida, Porifera) from the Ordovician–Silurian Transition of Anhui, South China

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Rossellids are a popular and cosmopolitan group mainly found in the modern deep-water ecosystems. They are referred to Lyssacinosida, characterized by hypodermal pentactines and choanosomal megascleres of hexactines and diactines or the latter only. As a group of Lyssacinosida, which is an ultra-conservative group and known first from the Ordovician, there is no evidence showing that rossellids could trace back to the Paleozoic, let alone the Ordovician. The fossil records of rossellids are usually found in the Cenozoic, with the earliest existence known from the Upper Cretaceous, it is a problem of preservation of the earliest rossellids that they are composed of loose spicules, pentactines and diactines and normally not as articulated individuals. Accordingly, no genus has been erected on the basis of such isolated megascleres, which cannot be identified on a genus or family level but only as Hexactinellida indet. The only articulated specimen from the Upper Cretaceous shows hypodermal pentactines protruding the surface of the sponge body as prostalia. Recent molecular phylogenetic investigation illustrates the divergence time of the Rossellidae from its sistergroup (Leucopsacidae) at 294.7 Ma, roughly coeval to the Carboniferous–Permian boundary, and the crown-group of Rossellidae first appeared at 218.2 Ma, corresponding to the Late Triassic (Dohrmann et al. 2013). Until earlier fossils were discovered, this molecular data seemed to be congruent with the fossil record of the rossellids.

Recently, a new lyssacinosan hexactinellid, *Palaeorossella sinensis* gen. et sp. nov., is described from the uppermost Ordovician of Anhui, South China. The sponge shows a saccular, globular or oval form with relatively thick wall. The skeleton is lyssacine type mainly composed of hexactines and stauractines, with the outer margin reinforced by hypodermal pentactines, which usually protrude the periphery as prostalia lateralia. The new species is wellpreserved with typical hypodermal and prostalia pentactines as well as an articulated skeleton, giving some tentative insights into the affinity between the new species and other taxa in Rossellidae. It represents the oldest record of rossellids, providing new information for understanding the phylogeny of rossellids and on the evolution of modern Hexactinellida, which are considered as conservative in their morphology with some fairly crucial features appearing in the Paleozoic or even earlier.

KEYWORDS: Hexactinellida, Rossellids, Porifera, Ordovician–Silurian transition, Anhui, South China.

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[49]

The Upper Ordovician-Silurian Biota of DPRK: Peculiarity in Northeastern Asia

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The upper Ordovician and Silurian strata of the Korea-China craton are only distributed at the middle regions of DPRK. These strata are exposed at the Koksan, Suan and Singye counties of North Hwanghae Province, and Popdong county of Kangwon Province, and they are distributed with almost 60 km^2 in area. In here, the upper Ordovician strata are named as the Sangso Formation and the Silurian strata are divided into the Koksan Formation and Wolyang Formation from lower to upper. Furthermore, the upper Ordovician and Silurian fossil remains are also known at the basal conglomerate of the Songnimsan Formation(the lower Jurassic) of developing at Songnim City, North Hwanghae Province. Until now, the upper Ordovician fossils known at the Sangso Formation are as follows; corals: *Agetolites multitabulataus*, *A. regularis*, *Agetolites oculiporoides*, *A. huangi*, *A. crassus*, *A. multiseptatus*, *A. tenuis*, *Agetolitella gracilis*, *Agetolitella longseptatai*, *A. multiseplatus*, *A. crassiseptata*, *A. maxima*, *A. raritabulata*, *Favistella alveolata*, *F. intermediata*, *F. irregularis*, *F. grandiformis*, *F. crassa*, *Catenipora zheiangensis*, *Holocatenipora orientala*, *Rhabdotetradium nobile*, *Heliolites giyangensis*, *H.* sp., crinoids: *Cyclocyclicus* sp., *Pentagonopentagonalis* sp., gastropods: *Hormotoma longiformis*, conodonts: *Panderodus unicostatus*, *Trichonodella nitida*, *T. asymmetrica*, *Spathognathodus dolboricus*, *Neocoelodus dutchtownensis*, *Trichonodella illustris*, *T.undulata* etc.

And the Silurian fossils known at the Koksan Formation are as follows; corals: *Favosites forvesi*, *F.* cf. *gothlandicus*, *F. kennihoensis*, *F. nanshanensis*, *F. malungensis*, *Palaeofavosites balticus*, *P. balticus* var. *chuannanensis*, *P. balticus* var. *amisanensis*, *P. paulus* var. *kogsanensis*, *Mesofavosites shimizui*, *M. chalfini*, *M. shigianensis*, *M. zoniformis*, *M. kogsanensis*, *M. gansnenis*, *M. baemsanensis*, *M. gungulsanensis*, *M. meruensis*, *Quepora ozakii*, *Q. sindoensis*, *Q. sapporiensis*, *Sapporipora wolyangensis*, *S. miruensis*, *Triplasma kaolingpoense*, *Syringopora* cf. *bifurcata*, *Fletcherine* sp., *Halysites elongatus*, *Streptelasma* sp., *Elcatenipora rectusformis*, *Catenipora* sp., *Kenophyllum* sp., brachiopods: *Lepidocycloides nana*, *Camarotoechia ubsuensis*, *C.* cf. *tonkinensis*, *Nalivkina elongata*, *Clintonella*? *kueichouensis*, *Nikiforovaena calliensis*, *Striispirifer shigianensis*, *S. acumitiplicatus*, *Howellella tingi*, *Zygospira* cf. *kueichouensis*, *Atrypa* cf. *reticularis*, *Acrospirifer* sp., cepalopods: *Virgoceras sichuanensis*, bivalvia: *Modiolopsis* cf. *rypta*, crinoids: *Pentagonocyclicus borealis*, *Pentagonopentagonalis kokajgyrensis*, *Compositocrinus compositus*, *Bystrowicrinus guinguelobatus*, *B. augustilobatus*, *Obuticrinus bullosus*, *Ramosocrinus ramosus*, *Dintiferocrinus dividus*, *D. tinuis*, *Cyclocyclicus* sp., conodonts: *Neoprioniodus unicostatus*, *N. plonus*, *Ozarkodina* aff. *rhodes*, *O. adiutricis*, *Neospathognathodus celloni*, *Spathognathodus celloni*, *Trichondella inopinatus* etc.

At the Wolyang Formation, corals: *Sapporipora favositoides*, *Mesofavosites shimizui*, *Favosites forbesi*, *F.* cf. *malungensis*, *Cystiphyllum ompymiforme*, *Halysites* sp., *Haliolites* sp., *Brachyelasma* sp., *Tryplasma* cf. *kaolingpoense*, gastropods: *Hormotoma* cf. *kutsingensis*, crinoids: *Obuticrinus bilobatus*, *Pentagonopentagonalis probus*, *Pentagonocyclicus monocostatus* etc. are known until now.

Generally, the marine invertebrate animals of the upper Ordovician and Silurian in DPRK are mainly characterized by coral-shell biota. But the upper Ordovician and Silurian in south China are characterized by coral-graptolite biota.

KEYWORDS: Northeastern Asia, Ordovician, Silurian.

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[50]

The Graptolite Biostratigraphy Constraint on the Distribution Pattern of the Black Shale in Yangtze Platform, South China

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The recent study on the graptolite faunas in the Yangtze Platform, South China demonstrated a considerable gap between the *Cystograptus vesiculosus* Biozone (Ruddanian) and the *Lituigraptus convolutus* Biozone (Aeronian). The interval of the upper Rhuddanian *Coronograptus cyphus* Biozone to the Lower Aeronian *Coronograptus gregarius* Biozone is missing. The gap was recognized for the first time in the drill core YD-1 in Yichang area for shale gas exploration. Then it was proved again in the black shale in the Dingjiapo section in Yichang area. The base of the gap may be diachronous from the base to the top of *Cystograptus vesiculosus* Biozone by the investigation of the graptolite faunas in this region. And the top of the gap may be from upper part of the *Pribylograptus leptotheca* Biozone to the lower part of *Lituigraptus convolutus* Biozone. Consequently, the graptolite zonations provide well constraint for the gap and for the distribution pattern of the black shale form the end of Ordovician (Katian) to early Silurian (Llandovery).

The sea level drops dramatically due to the evolution of the foreland basin by the Kwangxi Orogeny in South China, during the end Ordovician-early Silurian period. There are two gaps at least during the process of the forming of the foreland basin, the gap at Ruddanian/Aeronian (Early Silurian) boundary interval (upper gap) and the gap at the Ordovician/Silurian boundary interval (lower gap). The two gaps reveal that the fore bulge immigration is northward gradually form the end of Ordovician to the early Aeronian. The process doubtlessly controlled the temporal and spatial distribution of the black shale, although this process may be more complicated because of the superimposed effect of the expansion of the Gongwana icesheet. It is various from place to place for the thickness and the richness of organic material of the black shale. The most favorable zone for shale gas exploration is at the depression of the inner Yangtze Platform, i.e., the 'Yichang Slope' area, where is the depocenter for organic rich black shale. The black shale is intercalated with siltstone in the foredeep at the early Silurian. There are gaps in the fore bulge where the thickness and the richness of the organic materials of the black shale are in between the foredeep and the depression of the Yangtze Platform.

KEYWORDS: Raptolite, gap, drill-core, black shale, shale gas.

[51]

Early Palaeozoic Marine Diversifications and Extinctions: A Continuum of Change

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A new analysis of global biodiversity curves of individual groups of marine organisms indicates that, despite fluctuations in amplitude, a single, continuous, large-scale, long-term radiation of life occurred during the Early Palaeozoic, consisting of regionalised events in terms geography and on phylogenies. The results were summative and along this cumulative biodiversity trajectory both organisms and their communities evolved complexity. This major biodiversification was initiated in the late Precambrian and was only finally concluded in the Devonian. The curve captures both the high-profile Cambrian 'Explosion' and the Great Ordovician Biodiversification 'Event' coincident with the establishment of modern climate and marine ecosystems. Both occurred during the continuous establishment of organisms and their ecological communities, developed during the 'Cambrian substrate revolution', the 'Ordovician plankton revolution', the 'Ordovician substrate revolution' the 'Ordovician bioerosion revolution' and the 'Devonian nekton revolution.' At a lesser scale, different regional radiations have been identified and named (e.g. the 'Richmondian Invasion' during the Late Ordovician in Laurentia and the contemporaneous 'Boda Event' in parts of Europe and North Africa), particularly from areas that were in or moved towards lower latitudes encouraging high levels of speciation in epicontintental seas.

Datasets remain incomplete for many parts of the globe, but also for key time intervals (e.g. during the late Cambrian 'Furongian Gap'). The trajectory of Early Palaeozoic biodiversification appears thus to be a long-term, process where its progressive character will be better exposed and understood by more complete datasets and better analytical techniques.

KEYWORDS: Cambrian Explosion, Great Ordovician Biodiversification, palaeoecosystems, palaeoclimate, palaeoenvironments, single trajectory.

[52]

Devonian Strata and Biota of DPRK

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There are peculiarly distributed from the middle Devonian to lower Carboniferous strata in Cholwon-Kumchon and Kangryong areas of DPRK. These strata are named as Rimjin Group, and consist of Anhyop, Puap and Saknyong Formations. Among them, Anhyop and Puap Formation are middle and upper Devonian, and Saknyong Formation is lower Carboniferous.

In DPRK, research of Devonian strata began to 1960s, after that, many fossils including brachiopods, crinoids, bryozoans were found.

Especially, in the end of 1980s, many plant fossils that reflect appearance and development of land organisms were found, therefore, they contributed in resolving evolution history and in deciding geologic time of Rimjin Group.

Typical fossils founding in Rimjin Group until now are as follows; brachiopods: *Atrypa douvilii var. lungkouchungensis*, *Spirifer tersiensis*, *Spirifer* sp., *Cyrtospirifer sinensis*, *C.* cf. *pekinensis*, *Hananospirifer* cf. *ninghsiangensis*, *Tentioospirifer tenticulum*, *Ptycnomaletoechia setienchiaoensis*, *Spimatrypina lungkouchungensis*, *Pleuropugnoides* cf. *kilingensis*, *Actospirifer cyrtiopsifornis*, *Atrypa hunanensis*, *A. richtofeni*, *Spinatrypa semilukiana*, *Camartocchia panderi*, *Punctospirifer kusbassicus*, *Plicochonetes*(?) *transversus*, *Shizophoria* cf. *serra*, *Retzia* sp.; corals: *Stringophyidinm* cf. *isaticum*, *Peneckiella* sp.; ammonites: *Kosnoclimenia* sp.; bryozoans: *Monotrypa hsui*; crinoids: *Pentagonocyclicus levidensis*, *P. glaber*, *P. jucundus*, *Cyclocyclicus* sp., *Antinocrinus* aff. *fiolens*, *Hexacrinites*(?) *detadus*; green algae: *Litanaia* sp.; plant fossils: *Taeniocrada decheniana*, *Psilophyton* cf. *princeps*, *Protooteridium hostimensi*, *P. minutum*, *Protocephclopteris praccox*, *Archaeopteris arachetipus*, *A. sibirice*, *Lepidodendrogsis guangzhaegensis*, *L.*(?) *dzungariensis*, *Leptophloenum rhombicum*, *Hyenia eiegans*, *Archaeocalamites scrobicalatus*, *Lycopodites oesiensis*, *Aneurophyton germanicum*, *Hostimella hostimensis* etc.

The Devonian strata of DPRK consist of many marine invertebrate fossils and land plant fossils, species are very abundant, therefore, it have very important significance in comparing and researching the Devonian-Carboniferous strata between DPRK and adjacent areas.

KEYWORDS: Devonian, Paleozoic, biota.

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[53]

Givetian Miospore Zonation of the Central Devonian Field (Voronezhanteclise, Russia)

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The comprehensive biostratigraphic studies of the Middle Devonian sediments were carried out by the authors as part of the work on the GDP-200 in the territory of the Central Devonian Field. Based on the study of new core material, it became possible to expand and detail the palynological characteristic of Givetian deposits of the studied territory. The reliability of the results is confirmed by the significant amount of core material studied and carried out by palinological studies (185 samples from 14 wells).According to the Regional Stratigraphic Scheme (Decision..., 1990) the Givetian Stage in the Central Devonian Field (CDF) includes Vorobiev, Ardatov and Mullin Horizons, which are united into the Starooskol Superhorizon. This Overhorizon is characterized by conodonts of the hemiansatus and varcus Zone and by miospores of the Geminospora extensa (EX) Zone. According to the decisions of the Stratigraphic Committee of Russia (Sobolev&Evdokimova, 2008) the (EX) miospore Zone corresponds to the Lower and Middle Givetian. The (EX) Zone is divided into three Subzones:

Cymbosporites magnificus–Ancyrospora tichonovitschi (=Hymenozonotriletes tichonovitsch) tichonovitschi (MT) (Vorobiev RS), Vallatisporites celeber–Kraeuselisporites violabilis (=Cristatisporites? violabilis) (CV) (Ardatov RS), Samarisporites triangulatus (=Cristatisporites triangulatus) – Corystisporites serratus (TS) (Mullin RS) (Avkhimovich et al., 1993). As a result of the palynological studies of the CDF Givetian deposits, we identified five miospore assemblages corresponding to one palynological Zone and three Subzones. The palinological marker of Early Givetian became the cavatemiospores of the genus Geminospora and the dominant speciesinclude *G. extensa*, *G. tuberculata*, *G. decora* and miospores belonging to the morphon Geminospora lemurata, which gradually become more numerous further up the zone. At the upper boundary of the Mullin Horizon, the index species Geminospora extensa and its associated species are disappeared. Palynological studies carried out by the authors made it possible to clarify the miospore zonation of the Lower and Middle parts of Givetian Stage of the Voronezh anteclise. The leading role in the establishment of the biostratons was played the index species of zones and subzones, as well as taxa with a narrow stratigraphic distribution and clear morphological characteristic. The percentage of miospores were played a secondary role. The results of the research allow us to update the taxonomy of dispersed miospores and provide more substantiated results of the biostratigraphic studies. The obtained palynological data were used for mapping GDP-200, and also used for correlation of local and regional stratigraphic units of the Givetian deposits of the East European platform.

KEYWORDS: Biostratigraphy, miospores, Vorobiev, Ardatov, Mullin Horizons, Voronezh anteclise.

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[54]

Biotic Interactions between Corals and Stromatoporoids from the Upper-Uppermost Famennian (Devonian) Etoucun Formation, Huilong, South China: Implications for the Recovery of Metazoan Reefal Community after the F-F Crisis

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Biotic interactions between corals and stromatoporoids are important to understand the Paleozoic reef structure and evolution through time. Extensive reef complexes occurred globally in the Givetian and Frasnian, characterized by various forms of coral-stromatoporoid associations. However, the metazoan reefs suffered greatly in the global Frasnian/Famennian biotic crisis and little is known about the coral-stromatoporoid relationships in the Famennian. In this study, we document biotic interactions between corals and stromatoporoids from the upper-uppermost Famennian (Devonian) Etoucun Formation, Huilong, South China,

which indicates the recovery of metazoan reefal community in the latest Famennian, approximately 13 Ma after the F-F crisis.

The upper-uppermost Famennian Etoucun Formation at Huilong, which is the stratotype section for the regional Shaodongian stage of South China, is characterized by thick-bedded to massive peloidal limestone containing abundant stromatoporoids, syringoporoid tabulates, rugose corals, gastropods, and oncolites, indicating open to restricted carbonate platform environments. Two foraminifer biozones, corresponding to DFZ4-DFZ6 and DFZ7, respectively, are recognized in the formation, and each contains different stromatoporoid and syringoporoid tabulate coral assemblages. In the former foraminifer zone, biotic interactions are relatively rare and include: stromatoporoid *Labechia* and *Gerronostroma* encrusting *Cystophrentis* rugose corals; endobionts auloporids embedded in the skeleton of stromatoporoid *Gerronostroma*, indicating a syn-vivo interaction; syringoporoid tabulate coral *Chia* settling on the growth surface of stromatoporoid *Platiferostroma*. In the latter foraminifer zone, biotic interactions are much more frequent and include: syringoporoid *Fuchungopora* settling on the growth surface of stromatoporoid *Gerronostroma* and conversely, fouled by the latter genus; stromatoporoid *Labechia* encrusting syringoporoids; overgrowth between stromatoporoids *Gerronostroma* and *Stylostroma*. These associations, combining with the development of stromatoporoid biostromes in the DFZ7, indicate an obvious recovery of metazoan reefs in the uppermost Famennian, although the scale and complexity is much less than those of the Givetian and Frasnian ones.

KEYWORDS: Biotic interactions, coral-stromatoporoid association, metazoan reefs.

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[55]

Seafloor Oxygenation in the Late Devonian Frasnian-Famennian Boundary Event

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The Frasnian-Famennian (F-F) boundary (~372 Ma) event represents one of the 'big five' mass extinction events in Phanerozoic, and is characterized by a positive excursion in carbonate carbon isotope ($\delta^{13}C_{carb}$). The F-F boundary event is also coincident with the global deposition of two layers of black shale, i.e. the lower and upper

Kellwasser Events, and various lines of geochemical evidence suggests the development of oceanic anoxia or euxinia, suggesting the possible linkage between marine redox condition and biological evolution. In order to further explore the environmental background of the F-F boundary event, we measured the elemental and isotopic compositions of carbonate samples collected from two sections, the Panlong and Baisha sections, which were deposited in a shallow marine carbonate platform and an intrashelf basin in South China. (1) $\delta^{13}C_{carb}$ shows a positive excursion by +3‰ in the Baisha section, while $\delta^{13}C_{carb}$ of the Panlong section decreases by 1.6‰ followed by a 3‰ increase in the F-F boundary. (2) The Panlong section has more consistent and higher CAS sulfur isotopes (i.e. carbonate associated sulfate, $\delta^{34}S_{CAS}$, Panlong: +22‰~+29‰, Baisha: +6‰~+26‰) and pyrite sulfur isotopes ($\delta^{34}S_{pyrite}$, Panlong: +6‰~+26‰, Baisha: -30‰~+30‰). (3) There is a significant decrease of Fe content in carbonate (Fe_{carb}) in the Baisha section, while Fe_{carb} remains at low values in the Panlong section. (4) $\delta^{13}C_{carb}$ shows a negative correlation with Fe_{carb} in the Baisha section. Because of predominant deposition in seafloor in late Paleozoic, benthic carbonate would be influenced by benthic flux from sediment porewater, which normally enriches in Fe^{2+}, ^{13}C-depleted HCO_3^- that derives from organic carbon remineralization, and ^{34}S-depleted sulfate sourced from H_2S oxidation. Thus, higher $\delta^{34}S_{CAS}$ and $\delta^{34}S_{pyrite}$ values of the Panlong section may indicate lower benthic flux, probably due to higher sedimentation rate and more oxygenated seafloor in shallow water platform, while the positive excursion of $\delta^{13}C_{carb}$ as well as negative correlation between $\delta^{13}C_{carb}$ and Fe_{carb} may indicate seafloor oxygenation near the F-F boundary. We further use the Diffusion-Advection-Reaction (DAR) model to simulate the pyrite formation in sediment in the F-F boundary of the Panlong section in the shelf and the Fuhe section in the intrashelf basin. The modelling results indicate that the Panlong section was always deposited in oxic condition, while there was an oxygenation event occurring during the F-F boundary in the Fuhe section. Thus, instead of oceanic anoxia, our study indicates the seafloor oxygenation in the F-F boundary, which is consistent with emergence of diverse brachiopods fauna in the shelf sections.

KEYWORDS: Oxygenation, F-F Boundary, mass extinction, South China.

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[56]

Carboniferous Brachiopod Giants, Shell Fabric and Biomineral Organic Fraction: Implications for Their Lifestyle and Diet

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Well known as giants within the Palaeozoic sedentary marine benthos, the species of *Gigantoproductus* attain a shell area which is 20 times larger than that of coeval species. Not only their size, but also their thickness is impressive, reaching over 1 cm. This is surprising as brachiopods are known – and have been known - to have a low-energy lifestyle (low metabolism, low growth, feeding and reproduction rates), but this has never been investigated in detail nor satisfactorily explained. Angiolini et al. (2019) offer an explanation for this gigantism, starting from the study of their shell microstructure and inferring their possible diet.

The shell fabric of these giants, deemed to be pristine based on multiple screening techniques [cathodoluminescence, Scanning Electron Microscopy, Electron Backscatter Diffraction (EBSD), Transmission Electron Microscopy (TEM), geochemistry], comprises a thin pseudopunctate laminar secondary layer and a very thick columnar tertiary layer. Local alterations by chalcedony and microquartz spherulites occurred during an early diagenetic phase, but they did not affect the main shell as shown by EBSD analyses. TEM analyses also showed a pristine columnar layer containing nanometres inclusions, forming trails between calcite grain borders similar to those observed in Recent brachiopod shells. These inclusions were analysed by Nuclear Magnetic Resonance and Gas Chromatography Mass Spectrometry, which showed that an occluded organic fraction is preserved with an amino acid composition comparable to that observed in Recent brachiopods. Carbon- and nitrogen-isotopes analyses of the occluded organic matrix allowed to fingerprint their feeding strategy and to detect the biogeochemical signatures that identify symbioses vs. a normal suspension feeding strategy.

The gigantic size and thick carbonate skeleton of these Carboniferous brachiopods is interpreted as the result of a mixotroph lifestyle, by which they could rely on the energy and nutrients derived both from photosymbiotic microbes and from filtered particulate food.

KEYWORDS: Gigantism, Carboniferous, brachiopods, biominerals, symbiosis.

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[57]

Late Carboniferous to Early Permian of Cathaysian Flora from Paya Peda, East Peninsular Malaysia

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The Cathaysian Floral Province has been recognized and studied for over 100 years. The Cathaysia flora is mainly distributed in present-day China, Korea, Japan, Laos, Thailand, Indonesia and Malaysia. Cathaysia was the name used on Grabau's paleogeographic maps for an ancient landmass. The Cathaysia flora is one of the four prominent floras of the Late Carboniferous and Permian world. The Cathaysia flora is composed mainly of lycopods, sphenopsids, ferns, pteridosperms and cordaitean gymnosperms, suggesting tropical climatic conditions during the Late arboniferous and Permian, similar to the climatic conditions of modern tropical rainforests. These plant fossils outcrops are exposed during excavation works at the Paya Peda Dam project at Northern Terengganu, East Peninsular Malaysia in 2013. The Telemong bed of the Paya Peda tuffaceous shale

has yielded fragmentary remains of in situ fossil plants in several localities at along the road cutting of the right abutment of Paya Peda Dam. These plants remain believed to be Late Carboniferous to early Permian in ages and related to pantropical Cathaysian floras member Among others are *Pecopteris* sp., *Lepidodendron* sp., *Stigmaria* sp., *Cordaites* sp., *Sigillaria* sp., *Sphenophyllum* sp., and *Neurotepris* sp. the sedimentary rock sequence in this area was deposited in fluvial, lacustrine, and paludal environments. These plant fossil bearing beds form and important Malaysian geological record of national or regional significance, hence it's should be conserved and later on developed to become an educational as well as a geotourism site.

KEYWORDS: Paya Peda, Cathaysian Floral, Telemong Bed.

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[58]

A 298-Million-Year Old Gleicheniaceous Fern from China

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The late Palaeozoic genera *Chansitheca*, *Oligocarpia* and *Szea* are small ferns that represent putative early members of the Gleicheniaceae based on their morphology as well as anatomy of their fertile organs. However, their rachis and cauline anatomy are unknown, rendering their systematic affinity controversial. Here we document a rachis with partly preserved anatomical structure associated with compression/impression specimens of *Chansitheca wudaensis* from the Wuda Tuff Flora. The rachis has a C-shaped vascular bundle with strongly inrolled ends, with multiple protoxylem strands occurring at the internal side of the xylem. Protoxylem tracheids

possess spiral thickening and metaxylem tracheids possess uniseriate and multiseriate scalariform thickening. Phloem is present at the internal side of the xylem, and is differentiated into parenchymatous cells and a sclerotic fibrous layer. Intercellular space is well-developed in the phloem. Comparisons justify the creation of *Protogleichenia permica* gen. et sp. nov. within the Gleicheniaceae, with our evaluation considering it to belong to the same plant that produced fertile fronds of *Chansitheca wudaensis* and *Sphenotperis*-type vegetative fronds from the flora. As the Wuda Tuff Flora has been dated to 298 million years ago, during the Asselian Stage of the Permian, this represent the oldest unequivocal evidence for the gleicheniaceous ferns. Our results demonstrate that the Gleicheniaceae had diverged from other ferns families including the Osmundaceae by 298 Ma.

KEYWORDS: Gleicheniaceae, *Chansitheca wudaensis*, rachial anatomy, Permian, Asselian, molecular clade dating.

[59]

A Left-Handed Fern Twiner in a Permian Swamp Forest

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The origin of homochirality in nature was one of 125 great unanswered questions suggested by *Science*. Chirality is present at all scales from molecule to galaxy, and plants are no exception. Plants with twisted axes are usually climbing "twiners". Most extant twiners (>90%) possess fixed right-handed helices. In geological history, direct preservation of a fossil twiner has only been documented in the Miocene Shanwang Formation of Eastern China (*ca.* 16 Ma), albeit with the identity of the twiner difficult to establish and likely to be a self-twiner. Here, we report the second fossil twiner from the Permian Wuda Tuff fossil Lagerstätte of Inner Mongolia China (*ca.* 298 Ma), rooting the twining habit all the way back to the Paleozoic. According to the rachis anatomy, attached and associated plant fragments, the twiner is likely to be an anachoropterid fern. It engaged around the host by persistent left-handed helices. In addition, the host plant is classified as Callistophytales on account of its anatomy. It's likely to also be a climber indicating by the prickles on the stem surface and terminal swollen structures interpreted from similar material as adhesive pads. Such a climber-climbing-a-climber phenomenon signals the potential ecological complexity of late Paleozoic forests.

KEYWORDS: Plant chirality, fossil twiner, anachoropterid, Callistophytales, dual-climbing phenomenon.

[60]

A New Species of Eoangiopteris from Permian "Vegetational Pompeii"

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Eoangiopteris is a late Palaeozoic fossil genus with free bilateral synangia held together by a common pad of tissue, thus hypothesized as the ancestor of extant *Angiopteris* and descendant of *Scolecopteris*. The primitive material of type species *Eoangiopteris andrewsii* was questioned as the terminal pinnule of a *Scolecopteris* frond. Subsequently a new species *Eoangiopteris goodii* was described from the upper Pennsylvanian of Ohio. The research confirmed the generic distinctness between *Eoangiopteris* and *Scolecopteris*, but on the other hand suggested that they were in the same evolutionary level rather than one derived from the other. Overall, the fossil records of *Eoangiopteris* are scarce, thus limited our knowledge of the diversity of the genus and its phylogenetic relationship with *Scolecopteris*.

Here we present a new *Eoangiopteris* species from the well-known "Vegetational Pompeii", a Permian tropical swampy forest preserved *in situ* by a catastrophic ash-fall event. Frond is at least tripinnate. Penultimate pinna is linear and at least 23 cm long; penultimate rachis is dotted and 4.4 mm in wide. Ultimate pinna is linear with 6 - 7 pairs of alternating pinnules, attached to penultimate rachis at an angle of 60°. Sterile pinnules are oblong- ovoid in outline, 6.8 - 7.3 mm long and 3.8 - 4.4 mm wide. Pinnule apex is obtuse, whereas pinnule base is acroscopically constricted and basiscopically decurrent. The base would be somewhat confluent when the ultimate pinnae are still undivided. Midvein is strong and slightly sinuous, decurrent, dissolves before reaching the apex. Lateral viens divide once at a short distance from midvein or occasionally undivided, and the first basiscopic lateral vein usually arises from the decurrency of midvien. In gross morphology, the sterile pinnules are assignable to the group of *P. oreopteridia*.

Numerous fertile pinnules are detected on the ultimate pinnae from the lower part of a penultimate pinna. Fertile pinnules appear smaller than those sterile ones in size due to the strongly recurved margin. Synangia are borne on each side of the midvien, along with lateral veins, and arranged considerably closely. Most synangia are bilaterally symmetric and composed of 6 - 8 sporangia arranged in two rows and connected to pinnule lamina by a receptacle. Usually the receptacle is not vascularized and composed of undifferentiated isodiametric cells, which make it distinguishable from similar genera *Millaya* and *Grandeuryella*. Sporangia are elongate and exannulate. The outer walls of the sporangia are 2 or 3 cells thick, whereas the inner walls are uniseriate. Sporangia are closely appressed but free from each other after dehisence. Spores are oval, trilete, 41 - 51 μm in greatest dimension, and bear an ornamentation of little spins.

KEYWORDS: Marattiales, Bilaterally symmetric synangia, Micro-CT.

[61]

A New Species of *Scolecopteris* (Marattiales) from the Asselian (Permian) of Inner Mongolia, China

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Scolecopteris Zenker 1837 was described based on petrified materials from the Permian of Saxony (SE

Germany), characterized by radially symmetrical and pedicellate synangia. *Scolecopteris* is one of the most common genera in Marattiales, and widespread during late Carboniferous and Permian. About forty-eight species of *Scolecopteris* have been recorded, but they are all only described based on fertile organs, without sterile part or organically connected sterile part.

Scolecopteris sp. nov. is established with partial three-dimensionally preserved materials containing both sterile and fertile fronds collected from the volcanic tuff at the top of the Taiyuan Formation in the Wuda Coalfield, Inner Mongolia, China. Fronds are tripinnate, with rachises over 200 mm in diameter, long lanceolate or falciform pinnules with thick veins. Pinnules are of the pecopterid-type, with those at the base of the ultimate pinnae usually divided into small lobes. Eight to twelve circular synangia are arranged in two rows along midvein. Synangia are borne on a short pedicel attached to the middle of lateral veins. A synangium is composed of 7–10 fusiform exannulate sporangia with pointed apices. Sporangia are free among each other beyond the base of synangia. *In situ* microspores are trilete, and 10–20 μm in diameter, which belong to *Cyclogranisporites leopoldii*. The anatomy characteristics of rachises are accordant with *Stewartiopteris*.

The majority of the species of *Scolecopteris* have been divided into five groups: Minor, Latifolia, Oliveri, Altus and Shanxiensis. The lack of anatomical features on the outer facing sporangial walls of *Scolecopteris* sp. nov., hinders to assign it into any of the five groups. However, in the lights of the features of the spores, synangia, and pinnules, the new species might be a member of the Minor group. Fertile pinnules are strongly deformed to enclose and protect the synangia in Latifolia and Shanxiensis groups. In contrast, the fertile pinnules of *Scolecopteris* sp. nov. are flatten, rather than deformed. *In situ* spores of Oliveri Group are commonly 40–115 μm in diameter, which are bigger than those of *Scolecopteris* sp. nov. The small spores in Altus Group are monolete, different from *Scolecopteris* sp. nov. Over all, the synangia of In *Scolecopteris* sp. nov., are composed of 7–10 sporangia, significantly more than those of most *Scolecopteris* species.

KEYWORDS: *Scolecopteris*, Marattiales, Synangium, Permian, Wuda.

[62]

A Palaeostachya Guanglongii Plant from the Asselian (Permian) Taiyuan Formation in the Wuda Coalfield, Inner Mongolia, China

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Calamitaleans commonly occur in late Palaeozoic terrestrial rocks. They first appear in late Devonian and reached its highest diversity in earliest Permian. However, most species so far known are based on disarticulated organs. Materials presented herein were collected from Wuda Coalfield, Inner Mongolia, China, well-known as an autochthonous burial locality of early Permian forest. A *Palaeostachya guanglongii* plant is reconstructed based on materials showing organic connection and morphological similarity.

The *Palaeostachya guanglongii* plant is 2 m in height. Crown consists of two major branches resulted from a bifurcation of the stem. Each branch bears numerous ultimate subordinate branches, which bear both strobili and leaves. There are two types of ultimate subordinate branches: Sterile branchs with *Asterophyllites longifolius* leaves and, fertile branches composed of lower sterile nodes and upper fertile nodes with *P. guanglongii* strobili. Stem and major branches of the crown are attributed to *Calamites* cf. *schützeiformis*, with anatomy of *Arthropitys* type. *Calamariophyllum* leaves cover the surface of the stem and major branches. *Palaeostachya guanglongii* strobili are well-preserved representing a new *Palaeostachya* species. Bract whorls and sporangiophore whorls arrange alternately in strobili, sporangiophores insert slightly above bract whorl. Four sporangiophores form one whorl and each sporangiophore bears four sporangia. Sporangia are heterosporous and yielded micro- and megaspores of the *Calamospora* type.

Our research systematically investigates *Palaeostachya guanglongii* plant and introduces a new branching mode of calamites. It is defined as an authentic calamite with whole plant reconstructed. Combination of organ species included in this plant will provides future studies a most powerful template for taxonomic assignment of separated organ species.

KEYWORDS: *Calamites*, *Arthropitys*, *in situ* spores, whole-plant concept.

[63]

Lycopsid Roots from the Lowermost Permian of Wuda Coalfield, Inner Mongolia

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Stigmaria Brongniart represents the underground rooting system of arborescent lycopsids，which lived mostly in wetlands during the Carboniferous and Permian(Taylor, 2009). Their primary axes, each of which dichotomizes once or twice, are commonly given off from the base of the trunk and extend horizontally (Williamsown, 1887; Thomas and Sefyullah, 2015). Rootlets attached spirally to the axes，with rootlet scars well visible on axis surface(Taylor, 2009; Stewart, 1947).

A different compound arborescent lycopsid rooting system has been reported from the lower Permian of Cathaysia. They can go deeper into the soil and could potentially adjust the depth by bending at different depths. This type of rooting system has been identified as *Stigmaria asiatica* Jongmans et Gothan, and proposed as the underground part of the *Sigillaria branrdii-ichthyolepis* (Pfefferkorn and Wang, 2009). This unique function made *S. brardii-ichthyolepis* group survived and flourished in the Cathaysia during the Permian (Pfefferkorn and Wang, 2009). Here, for the first time, we describe the anatomical characteristics of *Stigmaria asiatica* from the 60 cm thick volcanic tuff layer between Nos. 6 and 7 coals in Wuda Coalfield, Inner Mongolia, North China. In transverse section, the diameter of *S. asiatica* ranges from 1 to 5 cm. A thin ring of stele surrounding pith in the transverse section of axes. Medullary rays and rootlet bundles dissect the secondary xylem into multiple wedge-shaped areas. Surface of the axes is smooth with some round and oval rootlet scars. Rootlet scars are commonly irregular, rarely spirally distributed. Rootlets attached to *S. asiatica* axes are 3-6 mm in diameter. Vascular bundle of the free rootlet is triangular and monarch. In the free rootlet, there is a three-layered cortex. The middle cortex is commonly not fully preserved, with some bridge-like tissues connecting the inner and outer cortices.

KEYWORDS: *Stigmaria*, *Sigillaria*, Anatomy, Systematic, Wuda Tuff Flora.

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[64]

Sigillarian Strobili from the Asselian Wuda Tuff Flora, Inner Mongolia

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Sigillarian strobili are the reproductive organs correlated with *Sigillaria* Brongniart, a fossil genus of arborescent lycophyte that dominated the Permo-Carboniferous Euramerican and Cathaysian swamps. On the bases of various types of preservation or different type of megaspores they produced, these strobili have been attributed to three genera, namely, *Sigillariostrobus*, *Mazocarpon* and *Nudasporestrobus*, which all are monosporangiate.

Here we present a preliminary study of biosporangiate sigillarian strobili from the Asselian Wuda Tuff Flora in the Wuda Coalfield of Inner Mongolia. A whole crown of *Sigillaria* cf. *S. ichytholepis* was found within an area of two square meters, consisting of broken stem, linear leaves and a dozen of strobili radially spread out. Cylindrical bisporangiate strobilus with a slender peduncle, sporophylls arranged in a narrow spiral pattern, and often appearing as an alternatingly whorled pattern. Megasporangia located on the lower part of strobilus whereas microsporangia present on the upper part. Dozens of laevigate megaspores 500 um in diameter, fully filled megasporangia. Subcircular microspores are trilete, spinose, 30-50 um in diameter.

The current specimens show great differences from our conventional knowledge about Sigillarian strobili by the bisexual nature of strobili and quantity of megaspores. It enlightens us a further investigation on reproductive strategy of this new type of strobili and the systematics of *Sigillaria*.

KEYWORDS: Sigillarian strobili, bisporangiate, reproductive, Wuda.

[65]

Tingia unita Wang: A Whole Noeggerathialean Plant from the Earliest Permian Coal Swamp Forest of Wuda Coalfield, Inner Mongolia

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Adapted to tropical climate and needed nutrient rich soil, but could withstand wet–dry seasonality, Noeggerathiales are a plant group of Carboniferous and Permian fossil floras rare in the Euramerican floral realm (Europe and North America), where most floras do not even contain a single specimen, but more common in the Cathaysian floral realm (China), where some fossil floras contain Noeggerathiales in substantial or even large numbers (Pfefferkorn and Wang, 2016). The genus *Tingia* Halle (1925) is one of the major typical taxa of the Cathaysia Flora, whereas its affinity, along with the whole order Noeggerathiales (Nemejc, 1931), has long been uncertain. *Tingia unita* Wang (2006) was named based on the discovery of a crown of the tree, which illustrates the organic connection of the once compound leaf and strobilus, and it is among the very few species of Noeggerathiles that have both known fertile and sterile parts for certainty. A large collection of *T. unita* since its discovery has been accumulated, including various parts of the whole plant from the Early Permian peat-forming flora in the Wuda Coalfield of Inner Mongolia (Chinese "vegetational Pompeii") (Wang et al., 2012), and therefore, a fully on-depth investigation appears feasible and would certainly promote our understanding of the systematic position of the enigmatic group Noeggerathiales. Here we present a full documentation of this species on the basis of these materials, which, as a result of the present research represents the best known taxon in the genus. The gross morphology, heterospory and *in situ* spore morphology, homology of leaf and strobilus, anatomy of leaf rachis and strobilus axis, and sporophyll arrangement are all basically known, and conforms its close affinity to progymnosperms. It is an understory tree in the coal swampy forest, approaching the height of tree ferns, with *Sigillaria* Brongn. or *Cordaites* Ung. forming the upper storey, contributing considerably to the biomass of the coal swampy vegetation.

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[66]

280-m.y.-Old Fossil Starch Reveals Early Plant-Animal Mutulism

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Starch is a major component in the human diet, and the acquisition of starch-rich food sources is considered a pivotal step in the biological and cultural evolution of humankind. However, the potential role of starch as an energy vector in paleo-ecosystems has never been addressed, obviously due to the lack of tangible records of pre-Quaternary starch grains. Here we describe ~280-m.y.-old lycopsid megaspores from Permian forest-swamp deposits in north China that bear caps of granular material. Size, shape, and surface structures as well as chemical and optical properties of these grains show that these caps are masses of compound storage starch. This is by far the oldest unequivocal record of fossil starch known to date. Deposition outside the actual megaspore container makes it unlikely that these starches were used for embryo nutrition; moreover, ultrathin sections of the megaspores indicate that they may have been produced after the megaspores were fertilized. By analogy to the elaiosomes on seeds of zoochorous plants today, we suggest that these starch caps were used to attract and reward animals, possibly land arthropods or snails, for megaspore dispersal. This study offers a rare glimpse into early stages of plant–animal co-evolution in Permian swamp-forest ecosystems.

KEYWORDS: Fossil starch, megaspore, Ealy Permian, plant-animal mutulism, swamp-forest ecosystem.

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[67]

The Paleontological and Stratigraphical Constraints on the Opening Time of the Bangong-Nujiang Ocean in Tibet

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The formation of the Qinghai-Tibet Plateau involves a complex history of the opening of many Tethyan oceans, drifting of many blocks and amalgamation of many tectonic blocks accompanied by the closure of oceans. The uncertainties in the reconstruction of the tectonic history of the Qinghai-Tibet Plateau is the Bangong-Nujiang suture zone in northern Tibet. Especially for the opening time of this ocean, it has been a contentious issue in past decades. Some scholars considered that this ocean has a long history that formed as early as Cambrian time, whereas other scholars claimed that this ocean is a short-lived ocean that opened during Early Jurassic and closed

during Cretaceous.

The strata and faunas from the Qinghai-Tibet Plateau are important to constrain the opening time of an ocean because both paleobiogeography and sedimentary facies would change if one block rifted away from another block. In the past decades, we have done some paleontological work in both the Lhasa Block and the South Qiangtang Block in order to constrain the opening time of the Bangong-Nujian Ocean between them. We found the following evidence. Firstly, both South Qiangtang and Lhasa blocks have glacio-marine deposits during the Early Permian indicating their proximal position in Gondwanan margin. Secondly, from the viewpoint of Permian sequence, the whole Lhasa Block is very stable that changes from glacio-marine deposits to carbonates with warm-water faunas. By contrast, the South Qiangtang Block has various facies change from the stable sequence in west and seamounts in east. Thirdly, the typical warm-water fusuline *Palaeofusulina* is present in the South Qiangtang Block but absent in the whole Lhasa Block. Fourthly, the middle Permian fusuline *Nankinella-Chesenella* fauna is widespread in the Lhasa Block, but this assemblage is not present in the South Qiangtang Block according to current knowledge. Furthermore, our recent studies on the fusulines from the Shan Plateau of Myanmar also proves that the Middle Permian fusuline faunas of the Sibumasu, Baoshan and South Qiangtang blocks are different from those of the Lhasa and Tengchong blocks.

Conclusively, the Bangong-Nujiang Ocean may have opened after early Permian but prior to Wordian age.

[68]

Constrain the Amalgamation Times of the Blocks on the Eastern Margin of Pangea Using Non-Marine Tetrapod Records

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Paleogeographic maps are reconstructed by the methods such as paleomagnetism, basin analysis, biogeography, geochemistry, but the time of collision of plates is mainly deduced from tectonics, paleomagnetism combining with dating. Due to some fundamental data are absent and some are conflict, different team proposed different time for the time of collisions, and produced different maps for the same ages. The migration of the tetrapods was controlled by the movement of plates, and the terrestrial tetrpods can provide direct evidence for the connection of lands. The early terrestrial tetrapods of China (Carboniferous—Triassic) can be used to constrain the time of collisions on the eastern margin of Pangea.

The oldest tetrapod record is *Urumqia liudaowanensis* from Lucaogou Formation of Xinjiang, Cisuralian (291–284 Ma) in age. It confirmed the presence of the land bridge between the Kazakstan collage system and the North China block (NCB), same as the current reconstructions. The Dashankou Fauna from Yumen, Gansu is regarded as Roadian or Wordian in age. So this area had connected to the Baltica craton via Kazakhstan block and became part of Pangea at least by early Guadalupian (~270Ma).

Recent years, the tetrapods were reported from the Purple Claystone Formation of Laos and are the latest Permian or earliest Triassic in age. Our work shows they are closely related to the tetrapods from China, and should be late Permian in age. It shows the NCB was connected to the Indo-China Block in land by that time, so the collision of NCB and South China Block is in Permian rather than Triassic.

KEYWORDS: Permian, North China Block, South Chinese Block, Indo-China Block.

[69]

Late Permian Bennettitalean and Cycadalean Foliage on Jiamusi-Mongolia Block and Their Paleoclimatic Implication

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The Jiamusi-Mongolia Block was located in the middle latitude area in the northern hemisphere during Carboniferous and Permian. It is situated between the Sibirian and the North China plates (Wang et al., 2008, 2009), and is bounded by the Solonker - Xar Moron River suture to the south, and the Mongolia – Okhotsk suture to the north, and by the Mesozoic accretionary prism to the east. Recent research indicate that the eastward termination of the Solonker–Xar Moron River suture situate along the Wangqing – Hunchun region, eastern Jilin Province, China (Sun et al., 2013). To the west, the Beishan Block of the Altaides is isolated from the Jiamusi – Mongolia Block by the Engerwusu Suture in the western Inner Mongolia, China. During most time of Permian, the Jiamusi-Mongolia block had been vegetated by temperate Angaran floras. The famous well-studied localities include the Sitsa of Primorye, Far East of Russia (Zimina, 1997), Hongshan and Sanjiaoshan in southeast Lesser Hinggan Range, Heilongjiang Province, China (Huang, 1977), Soron of Inner Mongolia (Zhang et al., 2014), and Tabun Tologoy, Mongolia (Durante, 1976). They are all Lopingian in age. There are only several localities of Early and Middle Permian age due to the Jiamusi-Mongolia block was dominated by marine deposits during that time. The floras on the block were thoroughly different from those Early and Middle Permian floras on the North China Plate where the Cathaysian flora occupied the subtropical continent. It is the Palaeo-Asian Ocean performed as a bio-geographical barrier divided the floras on the two continents. However, during the Lopingian (Late Permian) the Jiamusi-Mongolia Block was collided with the North China plate, mixed floras were formed in the transition zone between the Cathaysian and Angaran floristic realms.

Meanwhile, some of the cycadalean and Bennettitalean leaves were discovered in this transition zone. The present discovery of these leaves in the Soron locality is one case. They are belonging to *Nilssonia hongshanensis* Huang, *N. permica* Yang, *Taeniopteris* cf. *macrospatulata* Kawasaki, *T. szei* Chow. Besides the *Nilssonia hongshanensis* Huang which was recorded in the Hongshan of Heilongjiang Province, China, the other three species were reported from the Yuzhou Cathaysian flora in western Henan Province, China (Yang et al., 2006). The age of these four species is Late Permian. Some of the leaves assigned to *Nilssonia hongshanensis* Huang are preserved together with *Iniopteris* or *Rachyphyllum* in the same horizon on one specimen. Some leaves of *Taeniopteris* are preserved together with *Lobatannularia lingulate* on the same specimen. This indicates that the Cathaysian plants lived together with the Angaran plants. Thus, the climate during Late Permian might be warmer than the Early and Middle Permian climate on the Jiamusi-Mongolia Block. We infer that the climate might be warm-temperate or even subtropical, and the Late Permian climate might be global warming.

KEYWORDS: Palaeoclimate, Jiamusi-Mongolia block, Late Permian, global warming, Soron of Inner Mongolia, China.

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[70]

A New Changhsingian (Lopingian) Brachiopod Fauna of Shallow-Water Clastic-Shelf Facies from Fujian Province, Southeastern China

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Although many attentions have been paid on Changhsingian brachiopod in South China, there are only two Chinese studies respectively published in 1979 and 1990 on Changhsingian brachiopod from the southeastern part of South China so far. Based on systematically collected fossil materials, this paper describes and quantitatively analyses a Changhsingian brachiopod fauna from the southeastern part of South China for the first time. The brachiopods were collected from the Luokeng Formation in the Hongtian section, Fujian Province, Southeastern China. There are 30 species in 18 genera yielded in the Luokeng Formation. Among the brachiopods described and illustrated, *Cathaysia yongdingensis* Liao, 1982 and an endemic genus of South China (*Qinglongia*) are firstly reported in English. Two new species *Neochonetes* (*Sommeriella*) *longa* and *Neochonetes* (*Sommeriella*) *transversa* are proposed. After comparing the width/length ratio data of the two new species with data of all previously reported specimens of *Neochonetes* (*Sommeriella*) in Lopingian, it was found that the two species have consistent width/length ratios which are distinguished from other contemporaneous species. The Hongtian fauna is mainly composed of *Cathaysia* (29.4%), *Neochonetes* (19.3%), *Linoproductus* (13.5%), *Orthothetina* (11.7%), and is correlated with brachiopod fauna from the lower part of the Luokeng Formation in Fujian Province. According to our quantitative data and results from literatures, we suggest *Cathaysia–Neochonetes–Orthothetina* Assemblage to represent the lower part Changhsingian brachiopod fauna in the shallow-water clastic-shelf of Fujian Province. The Hongtian fauna differs from Changhsingian brachiopod faunas in the Upper Yangtze area in its different fauna composition, having no absolute dominant species and larger body-size. In addition, species *Cathaysia spiriferoides* Xu & Grant, 1994 was found to be unique in not only morphology which is shown in the PCA result, but also in its distribution. It has only been found in the southeastern part of South China in Lopingian and northeast Thailand in the Middle Permian so far. It might indicate the species was originated from the northern Thailand and migrated to South China in Lopingian. The distribution of *C. spiriferoides* and comparison of fauna composition in the Hongtian section with fauna in northeast Thailand indicate that there is a strong faunal affinity between the two regions.

KEYWORDS: Taxonomy, Hongtian section, Fujian province, PCA, Thailand.

[71]

The Latitudinal Gradient of Shell Ornament – a Case Study from Changhsingian (Late Permian) Brachiopods

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Changhsingian brachiopods provided ideal materials for investigating the latitudinal gradients in marine organism ornament because they were dominant in the benthic palaeoecosystem in the Palaeozoic ocean and highly diversified and widely distributed in the late Palaeozoic. Based on a newly designed set of four quantitative metrics of shell ornaments and the measurement and quantification of shell ornaments from 2654 Changhsingian (Late Permian) brachiopods (representing 702 species) spanning 80° south to 30° north in paleolatitude, we found that both single ornament frequency and the total ornament frequency index showed increasing trends towards equatorial area in both coarse and thin latitude gradients. Three alternative scenarios are offered to account for the latitudinal gradients of Changhsingian brachiopod shell ornaments. First, shell ornaments are regarded as defence apparatuses against predation, and shell ornament of Changhsingian brachiopods is interpreted to have become stronger and more elaborate in lower paleolatitudes as an adaptive response to the progressively increased predation pressure towards the paleotropics. Secondly, the latitudinal gradient pattern of Changhsingian brachiopod shell ornaments could also be explained by the latitudinal temperature gradient. The CaCO3 solubility increases in colder high latitude area, thus makes it difficult for marine organism to extract calcium carbonate to generate their shells so that results in the less developed ornament. Last but not least, substrate might be one of the reason leading to the pattern. The more records of our data from muddy substrate might be the reason that more Productida, which developed spines and could be better adapted to muddy substrate than other brachiopods, was found in lower latitude area. The more occurrence of Productida could be one of the reason that a higher proportion of brachiopod with complex and dense ornament was found in lower latitude area.

[72]

Late Palaeozoic Qinfang Basin: A Small-Scale Oceanic Basin

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The Qinfang Basin is located in the south margin of South China. The upper Palaeozoic sedimentary sequences in Qinfang mainly comprise grayish red or grey thin-bedded chert and siliceous mudstone. In the sequences, the

radiolarian assemblage is similar to the Japan pelagic counterpart, abundantly consisting of bathyal to abysmal Albaillellarian forms.

The upper Devonian to Permian radiolarian zones in Qinfang can be well correlated with that of Panthalassa and PaleoTethys Ocean, e.g., Janpan, north Thailand or Changning-Menglian of Yunnan in China. It indicates that the Qinfang Basin was probably an oceanic basin and lasted for about 130 million years. Such a long-time deep-water basin was most likely to be an oceanic basin (e.g., Changning-Menglian Ocean), instead of an interplatform basin in South China.

The upper Palaeozoic strata in Qinfang consist of numerous rock slices divided by a series of high-angle, imbricate faults all of which thrust to northeast in the section. This imbricate structure was possibly formed by off-scrape accretion at a toe of an accretionary complex and indicates a specific horizon of Permian pelagic sequences acted as a décollement zone.

Consequently, the sedimentary feature, biotic assemblage and age of strata, as well as the structure style, suggest the Qinfang Basin was most probably a small-scale oceanic basin. And the deposition of the basin was related to the active arc in the process of Paleo-Tethys Ocean subduction in the Permian. Additionally, along the Pinxiang-Chongzuo area (northwest and close to Qinfang area), the Permian basalt, tuffaceous mudstone, radiolarian siliceous mudstone and bioclastic carbonate, as well as the coexisted ultrabasic rock were deposited, indicating the south margin of South China is a complex area in an orogenic setting.

KEYWORDS: Late Palaeozoic, Qinfang Oceanic Basin, South China.

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[73]

A Brief Introduction to the Book "Brachiopods around the Permian–Triassic Boundary of South China"

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The Permian–Triassic mass extinction was the most severe biodiversity crisis and over 90% brachiopod species were killed globally. The mass extinction was turned out to have taken place with a complex process, varied with

respect to different depositional settings. Therefore, the research on brachiopods in varied settings is particularly important for us to understand the crisis. Most of the published brachiopods in China were mainly collected from shallow-water carbonate facies. By comparison, brachiopods usually are sparse in deep-water facies and thus far less attention has been paid to them. Consequently, systematic knowledge of the Late Permian deep-water brachiopods is very limited throughout the world.

Aiming to advance the research on biodiversity evolution across varied depositional settings, authors began to collect brachiopods since 2002. Totally, over 10000 specimens have been collected mainly from the Changhsingian to lowermost Triassic rocks of 15 sections in South China. Most of these specimens were collected from deep-water facies, with nice information about ornamentation and structures.

The book systematically describes 66 species in 34 genera, clarifies the morphological differences among some similar genera or species and corrects species names with synonymum or homonimum problems, based on their collections with well preservation and careful comparison with the published specimens.

The book summarizes the spatio-temporal differences of brachiopod body sizes and diversity evolution across varied paleogeographic settings, based on the well-constrained age correlation. Also, this book discusses the morphological features and why those brachiopods survived the end-Permian mass extinction.

The book timely provides a robust complement for the study on the latest Permian–earliest Triassic brachiopod taxonomy and biodiversity in different facies, especially from the deep-water facies, and will innovatively advance the understanding of the process and dynamics for the Great Dying.

KEYWORDS: Brachiopods, diversity evolution, body size, Permian–Triassic mass extinction.

[74]

Changes in Silicate Weathering Conditions Across the Permian-Triassic Transition and Implications on the Mass Extinction and Its Recovery

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The Permian-Triassic transition witnessed the most catastrophic biotic crisis in the Phanerozoic which is recognized not only by the wipeout of almost all life on land and in the sea (Benton & Twitchett, 2003), but also by a notably protracted recovery process that did not achieve completion until several million years later in the latest Early Triassic or Middle Triassic (Grauvogel-Stamm & Ash, 2005; Galfetti et al., 2007; Bottjer et al., 2008; Song et al., 2011; Algeo et al., 2019). Environmental consequences of intense volcanisms during this critical time interval, including greenhouse gas-induced global warming (e.g., Joachimski et al., 2012; Sun et al., 2012), acidification (e.g., Black et al., 2013; Clarkson et al., 2015; Septon et al., 2015), hypoxia/anoxia (e.g., Wignall et al., 2002; Huey & Ward, 2005; Winguth & Winguth et al., 2014; Penn et al., 2018; Zhang et al., 2018; Sun et al., 2019), ozone depletion (e.g., Beerling et al., 2007; Benca et al., 2018), wildfires (e.g., Shen et al., 2011; Jasper et al., 2013), aridification (e.g., Newell et al., 1999; Smith & Botha-Brink, 2014; MacLeod et al., 2017), heavy metal poisoning (e.g., Rampino et al., 2017; Wang et al., 2018; Shen et al., 2019) etc., have all been invoked as killing agents for this profound biotic crisis and/or as environmental perturbations causing the long-duration of the subsequent recovery. Amongst all these above, greenhouse conditions that persisted into the Early Triassic is considered to have played a central role. As encouraging as the major progresses that have been made in the understanding of environmental perturbations and their links to the Permian-Triassic biotic crises and

prolonged recovery process, geological evidences, however, are far from adequate to depicting a comprehensive picture of the complex and interlinked Earth surface system at that time. One of the major problems that needs to be tackled with is the depiction of the silicate weathering conditions which may provide critical insight into the interactions between climatic, biotic and sedimentological evolutions.

In this study, geochemical and mineralogical characterizations were conducted at two terrestrial Permian-Triassic sections, respectively from the middle paleolatitude Southern Junggar Basin and low-middle paleolatitude North China. The results show generally decreasing silicate weathering intensity across the Permian-Triassic transitional interval and persisting well into the Early Triassic in both studied regions. Although detailed time framework is currently impossible for either section as is a common problem for terrestrial sections, the lowest silicate weathering intensity is constrained to the Induan stage. Subsequent recovery of weathering intensity appears to be rapid and a return to the pre-PTTB levels was probably achieved within the Smithian. Cross-correlations with other indicators suggest climatic drying followed by amelioration as a major controlling factor while vegetational changes may also have played a part (likely, the dieback of forests could also have been for a large part driven by climatic drying). Although global warming could have contributed in some degree, the causes of climatic drying and its amelioration, in turn, are yet to be determined. Regardless, dwarfed silicate weathering conditions during the earliest Triassic resulted in inefficient atmospheric CO_2 drawdown which further contributed to the continued global warming as more volcanic CO_2 was released in the atmosphere during the earliest Triassic. Subsequent acceleration of silicate weathering as a result of wetter climate in the early Olenekian led to the lowering of Earth surface temperatures, which combined together led to the rapid biotic recovery during the latest Early Triassic-Middle Triassic. Our study also stands as a supporting evidence for an important role of climatic humidity, other than temperatures in regulating silicate weathering conditions.

[75]

Marine Anoxic Event from the Latest Changhsingian to Induan: Evidence from Pyrite Framboids at Liuzhi Section, Guizhou Province

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The most drastic biotic event in the whole Phanerozoic, which occurred in the transitional period between latest Permian and Early Triassic, caused the biggest mass extinction and the most profound ecosystem reconstruction process in the geological age. As for the potential reasons, the couple of secondary disasters (e.g., global warming, anoxic) leaded by the volcanic events were considered as the main trigger mechanism.

Recently, pyrite framboids is a widely used to indicate the redox condition of oceanic environments, especially to track how anoxic event caused the extinction and delayed the reconstruction process in the Permian–Triassic transitional period. This study analyzed the size distribution of pyrite framboids from the uppermost Permian to Lower Triassic at Liuzhi section, Guizhou Province, and revealed the marine anoxic event from the latest Changhsingian to Induan in this region. Significantly, this new study case shows that the redox condition of marine environment is fluctuant in the Lower Triassic, and abundant benthic fossils occur in the certain layers where possess higher oxygen content at Liuzhi section.

KEYWORDS: Mass extinction, reconstruction, marine environment, pyrite framboids, Liuzhi section.

[76]

Ostracods (Crustacea) through Permian–Triassic Events

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Through geological times, the main turnover of marine ostracod group occurred at the Permian–Triassic boundary (PTB) when the Palaeozoic world gave way to Meso-Cainozoic world. As quite all the groups, ostracods intensively suffered of the end Palaeozoic events but they have the particularity to pass the PTB and to be present in quite all marine environments. We have studied the ostracod assemblages from the best preserved marine Permian–Triassic sections through the world. These sections are, for most of them, located along the Palaeo-Tethys margins: South China Block and Tibet (P.R. China), Bükk Mountains (Hungary), Dolomites (Italy), Taurus Mountains (Turkey) and Elbourz Mountains (Iran). These areas present different environmental settings from very shallow water to deep shelf. The biostratigraphy is well constrained by the presence of conodont index.

In deep environment from external shelf to slope, all the Permian ostracods disappear slightly before the PTB and are absent from the Early Triassic. The last representatives of palaeopsychrospheric forms occur in the Early Anisian.

On the platforms, during the Late Permian, the ostracods are abundant and highly diversified everywhere along Peri-Tethyan margins. The typical Palaeozoic forms are mixed with the very first Meso-Cainozoic representatives. The specific extinction rates, in the latest Permian, vary from 74% to 100%. During the earliest Triassic, two different settings have to be considered: with or without microbialitic deposits. The development of microbialites gives favorable ecological conditions to ostracods. During the Griesbachian, the fauna is composed of both new comers and surviving Palaeozoic forms. The reduction of size is frequently observed. This interval is called "survival stage". During the Dienerian and the Smithian the fauna are very scarce and poor. These two substages represent the maximum of poverty for the ostracod fauna, may be due to the development of anoxia on the platforms. During the Spathian, occurs the beginning of the true recovery. The very last Palaeozoic representatives are found in the Earliest Anisian which is the radiation stage of ostracod fauna with typical new comers. The interval of Palaeozoic–Meso–Cainozoic ostracod turnover is quite long (about 15My).

KEYWORDS: Ostracods, Crustacea, Permian–Triassic boundary, extinctions, recovery.

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[77]

Stromatolite-Dominated Microbialites and Sedimentary Facies across a Permian–Triassic Boundary from South Qinling Block, China

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Permian–Triassic boundary microbialites (PTBMs) are organosedimentary carbonates formed immediately after the end-Permian mass extinction. All those reported PTBMs constrained by convincing conodont biozones are present stratigraphycally not higher than the *Hindeodus parvus* zone and mostly dominated by thrombolites. Here we provide the first record of a brief, but spectacular development of stromatolite-dominated PTBMs within the basal *Isarcicella isarcica* conodont zone of the earliest Triassic from the Xikou section of South Qinling Block, China. The Late Permian sequence of the Xikou section is composed of reef sponge framestones and inter-reef crinoid grainstones. Capping them is a set of oolites, with the thickness increasing from 0.25 m on the reef top to 2.1 m on the inter-reef sequence. Overlying the oolitic layer is a micritic dolostone bed with a thickness of 0.2 to 1.2 m. A stromatolite-dominated microbialite unit lies on the dolostone, capped by thin-bedded lime mudstones. The microbialites developed on inter-reef sequence have smaller thicknesses and contain mudstone intercalations, while those on reefs have greater thicknesses and bear no mudstone interbeddings. These microbialites mainly consist of columnar, domical or wavy stromatolites, with minor thrombolites on the topmost in inter-reef facies. At the microscopic scale, laminoid structures in stromatolites comprise wavy, millimetric-domical and tangled laminae.The increased grain and fossil contents and/or bioturbation in the domical and tangled laminae indicate that the formation of these laminae is likely related to an increase in the populations and the disruptions by benthic metazoans, as well as an influx of sediment grains. The stratigraphic succession from stromatolites to thrombolites of the PTBMs may represent a transgressive succession and/or a transient ecosystem recovery immediately after the end-Permian mass extinction. The thrombolite-dominated PTBMs mainly developed in near-equator shallow marine geographic locations, and stromatolite-dominated PTBMs mainly developed in higher latitude settings, which probably indicates that a relatively lower diversity and abundance of marine benthic metazoans existed at higher latitudes after the end-Permian mass extinction.

KEYWORDS: Stromatolites, sedimentary facies, Permian–Triassic boundary, Xikou section, South Qinling Block, China.

[78]

Cranial Morphology of the Lower Triassic Ichthyosauriform *Chaohusaurus brevifemoralis* (Reptilia: Ichthyosauromorpha) Based on Digital Reconstructions

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Chaohusaurus is one of the most basal ichthyosauriforms. However, its cranial morphological information is still limited or equivocal, especially in braincase, palate and cheek region. In this study, we redescribe a three-dimensionally preserved skull of *C. brevifemoralis* (GMPKU-P-3086) comprised of most of the cranium, partial mandibles and four articulated cervical vertebrae, with the assistance of CT scan.

New anatomic information of *C. brevifemoralis* is revealed. A single row of teeth is on the palatine, as in Placodontia. The proatlas is present. The basioccipital peg is absent. The internal carotid canal has two openings. To our knowledge, the former two characters are firstly reported in ichthyosauromorphs.

In addition, previously misidentified and uncertain characters of *C. brevifemoralis* are rectified and further identified, respectively. The suborbital fenestra is absent due to the enlargement of the palatine. The retroarticular process is present. Medial to the surangular, the coronoid is anterior to the prearticular. The jugal is uncontacted with the strut-like quadratojugal both internally and externally, and it contacts the squamosal dorsally and excludes the postorbital from the infratemporal fenestra, as in Sauropterygia, Saurosphargidae and *Hupesuchus*.

Specifically, the squamosal of *Chaohusaurus* is firstly definitively identified, providing key evidence to understand the evolution of the temporal region of ichthyosauromorphs. Dorsally, it partly participates in the formation of the lateral margin of the supratemporal fenestra, but is nearly laterally excluded from the supratemporal fenestra by the enlarged supratemporal. This character explains the squamosal is excluded from the lateral margin of the supratemporal fenestra by both the dorsal enlargement of the supratemporal and the dorsal reduction of the squamosal in Ichthyosauria.

KEYWORDS: *Chaohusaurus brevifemoralis*, Ichthyosauromorpha, Lower Triassic, CT scan.

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[79]

Early Triassic Trace Fossils from South China Marginal-marine Settings: Implications for Biotic Recovery Following the End-Permian Mass Extinction

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The Longmendong section is one of the few Early Triassic sections containing fluvial to marine deposits in South China. No trace fossils have been recorded in the fluvial deposits, but a total of 26 ichnospecies are reported from the Lower Triassic Dongchuan, Feixianguan and Jialingjiang formations in this section. This ichnofauna represents brackish-water conditions during the late Dienerian to Smithian, and fully shallow-marine settings in the Spathian. Several ichnologic metrics, such as ichnodiversity, ichnodisparity, ichnoabundance, bioturbation intensity, burrow size, and depth of bioturbation, have been analyzed in order to evaluate the role of environmental and evolutionary factors. Although the upward increases in ichnodiversity, ichnodisparity, burrow size and bioturbation intensity may be linked to the biotic recovery after the end-Permian mass extinction,

environmental controls also play an important role in this case. Transgressive-estuarine successions typically show a vertical decrease in the salinity stress, showing the passage of brackish-water ichnofaunas to more diverse associations showing more marine affinities. However, the vertical increase in depth of bioturbation cannot be explained by environmental controls alone, instead most likely reflecting the phase of biotic recovery. Overall, ichnologic data suggest that the brackish-water ecosystem was less impacted by the end-Permian mass extinction than the fully marine realm. The shallow, fully marine benthos completely recovered in the Spathian as is the case for other areas in South China. This study underscores the importance of a careful evaluation of sedimentary facies and environmental conditions as a pre-requisite for interpreting evolutionary mechanisms of biotic recovery.

KEYWRODS: Ichnology, Ichnodisparity, Ichnodiversity, biotic recovery, Longmendong Section.

[80]

Early Triassic Marine Reptile Representing the Oldest Record of Unusually Small Eyes in Reptiles Indicating Non-Visual Prey Detection

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The end-Permian mass extinction (EPME) led to reorganization of marine predatory communities, through introduction of air-breathing top predators, such as marine reptiles. We report two new specimens of one such marine reptile, *Eretmorhipis carrolldongi*, from the Lower Triassic of Hubei, China, revealing superfcial convergence with the modern duckbilled platypus (*Ornithorhynchus anatinus*), a monotreme mammal. Apparent similarities include exceptionally small eyes relative to the body, snout ending with crura with a large internasal space, housing a bone reminiscent of os paradoxum, a mysterious bone of platypus, and external grooves along the crura. The specimens also have a rigid body with triangular bony blades protruding from the back. The small eyes likely played reduced roles during foraging in this animal, as with extant amniotes (group containing mammals and reptiles) with similarly small eyes. Mechanoreceptors on the bill of the animal were probably used for prey detection instead. The specimens represent the oldest record of amniotes with extremely reduced visual capacity, utilizing non-visual cues for prey detection. The discovery reveals that the ecological diversity of marine predators was already high in the late Early Triassic, and challenges the traditional view that the ecological diversifcation of marine reptiles was delayed following the EPME.

KEYWORDS: Hupehsuchia, Early Triassic, prey detection, recovery.

[81]

No Short of Firewood and Oxygen for Early-Triassic Wildfires

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Fires are an integral part of modern and ancient ecosystems, serving as friends for renewal or foe for complete destruction and extinction. Indicators of paleo-wildfire were absent from the Early Triassic. Lack of firewood in the Early Triassic due to the end-Permian mass extinction event and low atmospheric oxygen levels were proposed for the major reasons of the scarcity of wildfires. We present macroscopic charcoals from the Lower Triassic in northwestern China, showing smoldering fires occurred on landscapes in mid-latitudes of northeastern Pangea. Atmospheric oxygen concentration during the Early Triassic would be above 18.5%. These findings demonstrate that wildfire was still a significant source of disturbance of the terrestrial ecosystems on earth after the end-Permian biotic crisis. Vertebrate extinctions in the end of the Permian and the delayed recovery of terrestrial ecosystem in the Early Triassic may not be forced by hypoxia.

KEYWORDS: Wildfire, Induan, charcoal, oxygen level, extinction.

[82]

A New Chondrichthyan Fauna from the Zhuganpo Member of the Falang Formation at Nimaigu Section, Guizhou Province, South China

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The Middle-Late Triassic succession of the Nimaigu Section (Wusha area, Xingyi City, Guizhou Province, South China) has yielded two exceptionally well-preserved marine vertebrate faunas, i.e. the Middle-Late Ladinian Xingyi Fauna and the overlying younger Carnian Guanling Biota, of which the former shows turnover of marine reptiles from coastal to oceanic environments. Herein, we report a newly discovered chondrichthyan fauna strata intermediate between the above mentioned vertebrate faunas. This chondrichthyan assemblage consists of one new genus of 'pre-Jurassic *Synechodus*' (neoselachian), one new genus closed to *Omanoselache* (hybodont shark), Aff. *Arctacanthus* (chimaeroids?), and some shark genera showing Palaeozoic affinities.

The new genus of 'pre-Jurassic *Synechodus*' possesses a double-layered enameloid made of Single Crystallite Enameloid (SCE) and Parallel-Bundled Enameloid (PBE) and represents the first definitive record of a neoselachian shark from the Chinese Mesozoic so far. Another species is similar to *Acrodus* aff. *spitzbergensis* that was previously recorded from the Triassic of Japan, and which is certainly related to *Omanoselache*. The classification of *Arctacanthus* is still problematic because of its peculiar morphology. Several teeth display

intermediate lateral cusplets, a basolabial depression and labial accessory cusplets, which would suggest affinities with Palaeozoic genera although this needs further investigation.

KEYWORDS: Chondrichthyes, Triassic, Zhuganpo Member, Guizhou Province, China.

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[83]

New Inspection of the Lower Xingyi Fauna: Paleoenvironment Comparison and New Fossil Material

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Xingyi Fauna is one of the important Triassic marine reptile faunas in south China. It was found in Zhuganpo Member of Falang Formation, in age of Ladinian (Middle Triassic). Since the discovery of *Keichousaurus hui* Young, 1958, thousands of marine reptile fossils were excavated from Xingyi, Anlong and nearby counties and 28 species were erected. Differs from other marine reptile faunas in south China, the diversity of Xingyi Fauna is the highest, which shad lights on that the marine ecosystem had already fully recovered from Permian-Triassic Mass Extinction and the radiation of marine reptiles had come to the later scene. Recent study shows that Xingyi Fauna can be subdivided into two assemblages. The lower assemblage is composed of nearshore taxa, and the upper assemblage of pelagic taxa. As some of the stratigraphic records were not exact enough, high resolution excavations have been carried out in Xingyi. The lower assemblage is well-preserved in two sections, namely Nimaigu section and Langmushan Section. The study based on the detail field investigation, section measurements and microfacial analysis revealed more information about the paleoenvironment. According to the deposit sequence and the fossil distribution, these two sections can be corelated. Nine types of microfacies have been recognized, indicates that the fossils deposited in different environment between the two localities, as Langmushan was deeper in the basin and Nimaigu was shallower at subtidal in a restricted sea. Both of these two localities were in the same intraplatform basin. Langmushan was closer to the center of the basin, as while as to the margin of the carbonate platform. New fossil materials were found and prepared during the excavation

as well. A new specimen, XNGM WS-22-R5, was found in Nimaigu section. It's a bizarre nostrum of thalattosaurs. It differs from other thalattosaurs by its strongly down turned rostrum and blunt and bulbous marginal teeth. Phylogenetic analysis shows that it is the sister group of *Xinpusaurus*, a typical thalattosaur in south China. According to current phylogenetic tree, the strongly downed turned rostrum among thalattosaurs had emerged multiple times. This feature should be corelated to environmental adaption.

KEYWORDS: Lower Xingyi Fauna, Middle Triassic, microfacies, paleoenvironment, thalattosaur.

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[84]

New Materials of Annalepis Fliche (Lycopsid) from Middle Triassic of Ordos Basin, North China, with a Brief Review of the Genus

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The genus *Annalepis* Fliche is one of the most important lycophytes in the Early-Middle Triassic, which went extinct in the Middle Mesozoic. Due to having relatively narrower historical ranges and stringenter requirements of living conditions, the fossils of *Annalepis* are of important significance for stratigraphical and palaeoenvironmental studies. It has been widely recorded in the Northern Hemisphere, and particularly from the Lower and Middle Triassic sediments of North China and the Yangtze River areas of South China previously. Recently numerous specimens of lycophyte fossils were collected from the Middle Triassic Tongchuan Formation of the Ordos basin by the authors. Among them, two species, namely *Annalepis zeilleri* Fliche and *A. ordosensis* sp. nov. are recognized and described in detail, especially the *in situ* megaspores of the former species. Precise dating of zircons from tuff beds indicating the age of the strata bearing the lycophyte fossils are early Ladinian of Middle Triassic. Additionally, a brief review of study on *Annalepis* has been presented, including emendation of generic diagnosis, discussions on the origin and evolution, spatial and temporal distributions, and habitats of the genus.

KEYWORDS: Middle Triassic, *Annalepis*, ecology, Ordos Basin, North China.

[85]

Pleuromeia with the Relic Cathaysian Elements from the Middle Triassic Linjia Flora in Benxi, Northeast China

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Pleuromeia is an index fossil of the Early-Middle Triassic. However, its diversity and paleogeoraphical pattern in China are unclear. Recently, a new species *Pleuromeia shaolinii* Zhang et Wang sp. nov., represented by 8 specimens was discovered from the Middle Triassic Linjia Formation in Benxi of East Liaoning, Northeast China. The stem is erect, with a diameter of 1.6 cm. Leaves are linear, at least 7.5 mm in length. The basal part of the stem is the same as the middle of the stem, also attaining a diameter of 1.6 cm. A rhizophore with four lobes is developed below the basal part of the stem. The adventitious roots are attached to the rhizophore in an approximately helical order, with a diameter of 0.5 – 2 mm. An ovate heterosporous cone bears on the apical part of the stem, attaining a length of 5.8 cm, and a width of 4 cm. The basal part of the cone is attenuated to 1.6 cm in width. The upper to middle part of the cone yields microsporophylls, while the lower part develops megasporophylls. Sporophylls dispose in a spiral order on the cone axis. Both microsporophylls and megasporophylls are obovate, attaining to the length of 15 mm, and the width of 7.5 mm, bearing an obovate sporangium with a similar size, about 9 mm in length, and 5 mm in width. Leaf ligule is located at the upper part of sporophylls, whereas sporophyll scar is positioned at the lower part of sporophylls. Megaspores and microspores are trilete, up to 300 – 400 μm and 60 – 70 μm in diameter, respectively.

The Middle Triassic Linjia Formation can be compared with the Middle Triassic Ermaying Formation in Shaanxi, North China, yielding the typical Middle-Late Triassic elements, such as *Danaeopsis*, *Symopteris*, and *Sinozamites*, inferring that the age of the Linjia Formation is the Middle Triassic. Interestingly, Cathaysian elements, such as *Lobatannularia linjiaensis* sp. nov., *Pecopteris lativenosa*, *Gigantopteris* sp. and *Taeniopteris* spp. are also found in the Linjia Formation. In these elements, *Lobatannularia linjiaensis* sp. nov. is an interesting taxon found in the Linjia Formation, characterized by leaf-whorls small, each leaf-whorl forming two marked lobes, generally composed of 10 leaves; leaves linear to oblanceolate, with different sizes in length, united for 2/3 to 3/4 of their length. *Pleuromeia* discovered in the Middle Triassic Linjia flora associated with relic Cathaysian elements indicates a more complicated pattern for the process of the mass extinction through the Permian—Triassic transition and its subsequent recovery.

[86]

Restudy of Lower to Middle Triassic Conodont Biostratigraphy at Tulong Section, Tibet

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The Permian–Triassic boundary mass extinction event eliminated more than 90% of marine animals and 70% of terrestrial animals in the end of Paleozoic. Subsequently, marine ecosystem began to enter a long pulsatile reconstruction process along with the continuous turbulence of the marine environment in the beginning of Mesozoic. The whole reconstruction process showed temporal and spatial differences and lasted for about 5 million years (the whole Early Triassic), and completed until the Middle Triassic. In this paper, we restudied the conodont biostratigraphy to improve the accuracy of Lower–Upper Triassic recovery time frame at the Tulong section, Tibet.

The Lower–Upper Triassic strata of Tulong section is mainly formed by the Tulong Group and Qvlonggongba Formation. Tulong Group is mainly characterized by bioclastic and sandy limestone, and Qvlonggongba Formation is mainly characterized by shales, bioclastic and sandy limestone. As for the conodont biostratigraphy, nine conodont zones are recognized including: *Novispathodus waageni* Zone, *Novispathodus abruptus* Zone, *Triassospathodus homeri* Zone, *Triassospathodus symmetricus* Zone, *Neogondolella jubata* Zone, *Chiosella gondolelloids* Zone, *Chiosella timorensis* Zone, *Quadralella polygnathiformis* Zone and *Quadralella intermedius* Zone in ascending order.

KEYWORDS: Lower Triassic, Middle Triassic, conodont biostratigraphy, Tulong, Tibet.

[87]

Diversity and Tempo-spatial Distributions of Genus *Thaumatopteris* in China

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Thaumatopteris (Goeppert) Nathorst is an extinct leptosporangiate fern genus of Dipteridaceae which was initially established based on the plant fossils from the Upper Triassic (Rhaetian) of Bayreuth, Germany. It is not only a sensitive paleoclimate indicator, but also an important biostratigraphic indicator for the beginning of the Jurassic in Europe. There are 21 species of *Thaumatopteris* have been reported from 45 localities in China, including species with comparisons (cf.) to *Thaumatopteris* taxa. Among them, T. fujianensis and T. muensteri have been revised as Dictyophyllum muensteri and T. xiangchengensis should be merged into T. contracta. So, there are 18 species of *Thaumatopteris* in china. The fossil record of *Thaumatopteris* are concentrated from the Late Triassic to the Early Jurassic. The genus reached its highest species diversity and differentiation Late Triassic. Although, there were 2 new species (T. hissarica and T. pusilla) first appeared in the Early Jurassic, the genus suffered a severe loss of species diversity across the Triassic-Jurassic transition.

KEYWORDS: *Thaumatopteris*, late Triassic, early Jurassic, China.

[88]

Megamonsoon in Late Triassic Xujiahe Formation: Evidence from in situ Trunk Fossils at Guangyuan Zilanba Area

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The climate of Late Triassic was controlled by strongly monsoonal system, megamonsoon, which caused by a seasonal reversal of circulation and large-scale migration of the Inter-Tropical Convergence Zone (ITCZ) over Pangaea supercontinent. Currently, the megamonsoon activity was recorded in Upper Triassic at North America, the lower Jurassic-Upper Cretaceous at South America, and the Upper Triassic in Europe. As a series of dissociative block outside the main Pangaea, there is rare research about megamonsoon activity in Chinese blocks. Here, we report a series of in situ trunk fossils from the 5th member of Late Triassic Xujiahe Formation in Guangyuan, Sichuan Province, China. And these in situ trunk fossils may indicate the megamonsoon activity at east Tethyan Sichuan basin.

The 5th member of Xujiahe Formation consists mainly of coarse-grained sandstones, mudstones and coal with abundant plant fossils. At the lower part paleosol-swamp facies, there are residual in situ circular holes of collapse trees at the silty mudstone surface, notably, the direction of fall down trees indicated by the wood fossils and the trunk impression on the same surface is opposite to the source supply direction. Up to the top part of 5th member, plant branch fragments and trunk fossil began to appear in large number, channel-filled with branch-support coarse-grained sandstones.

One-way direction fall down of trees in still water within successive formation is rare in geological history. One of the mechanisms may related to the strongly wind. During Late Triassic period, the monsoonal circulation is predicted to have been at maximum. Megamonsoon not only make inner Pangea arid gradually, but also brought a lot of precipitation to the Tethyan costal realm. Meanwhile, megamonsoon activity may cause heavy damage to the forests on the northern Sichuan Basin. Evidence of in situ trunk fossils orientation at 5th member of Xujiahe formation in Guangyuan may record the megamonsoon activity in Sichuan Basin, although there is rare data for comparison from the interior of the basin.

KEYWORDS: Late Triassic, Megamonsoon, in situ trunk fossils, Guangyuan.

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[89]

Preliminary Discussion on Regional Differentiation of Xingyi Fauna in Guizhou Province

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There are abundant reptile fossils in the Triassic marine strata of Guizhou Province. Among them, the Xingyi fauna is an important representative of early Mesozoic marine reptiles in South China, widely distributed in the Zhuganpo Member of Falang Formation of the Late Triassic in southwestern Guizhou and Eastern Yunnan. Recently, our field geological survey in Xingyi and its adjacent Guanling area in Guizhou Province shows that there is a big difference between the two fossil combinations. Through further study, it is considered that biological groups may be restricted by paleogeographic environment, resulting in regional differentiation.

The analysis of the field of Guanling, Xingyi and Zhenfeng which the area between them in Guizhou shows that in the early stage of the sedimentation of the Zhuganpo Member, the Guanling area is dominated by the containing bioclastic micrite deposits in the open platform, while the mud content is higher in the Xingyi area, and the main part is micrite with shale interlayer. At the same time, in the area of Zhenfeng-Longchang, several stages of karst breccia were developed at the bottom of the Zhuganpo Member, showing a high point in palaeogeomorphology, which was conducive to the formation of barrier system. This kind of system may hindered the connection of seawater between the two areas, leading to the environmental limitations in Xingyi area, which prevented the migration of small marine reptiles such as Guizhou dragon in Xingyi area to Guanling area, thus the marine reptiles were not found in Guanling area. As the transgression continues, the sea level continues to rise, to the late stage of the Zhuganpo Member and the early stage of the Wa Yao Member of Falang Formation, the sea submerged the highland and connected with the wide sea. The two areas tend to be identical, showing the open platform facies. Large marine reptiles, such as ichthyosaurs and sea dragons from the wild sea entered the two palce, while small marine reptiles such as Guizhou Dragon gradually decreased, the species of organisms tend to be identical and the differentiation disappeared.

KEYWORDS: Xingyi fauna, Zhuganpo Member, paleogeographic environment, open platform, confined sea.

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[90]

Sedimentary Facies and Environment Evolution of the 1st Member of the Xujiahe Formation in Guangyuan Area, Northern Sichuan

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The late Triassic Norian stage was an important transitional from the marine to terrestrial environment in the Sichuan Basin. The mass extinction events during the turn of Triassic-Jurassic period made the paleoenvironment and paleoclimate of the late Triassic more complex and had a more significant impact on terrestrial ecosystems. The well developed and exposed Triassic-Jurassic strata in the northern Sichuan Basin, covering the continuous deposits of the Upper Triassic Xujiahe Formation and the Lower Jurassic Zhenzhuchong Formation, represents an excellent record for the paleoclimate and paleoenvironment changes. In particular, the Norian and Rhaetian are crucial transition for the marine and terrestrial environmental changes in the Sichuan Basin. In this paper, the the 1st member of the Xujiahe Formation in Guangyuan, North Sichuan Basin is investigated focusing on the analysis of the sedimentary facies and environment evolution. The results show that: The lagoon marshes, delta plains and braided rivers facies are developed in the section in Guangyuan region, which is a remarkable continental transitional — continental facies sedimentary system. Through the influences of the formation and development of Ganzi - Aba back-arc basin, the transgression began in Carnian age affected the Guangyuan region during the later Norian. Due to the uplift of the Qinling orogenic belt and Longmen mountain, marine facies ended in Guangyuan area, and changed to terrestrial facies in the 1st member of Xujiahe Formation. We have reconstructed the paleoclimate in the later Norian of late Triassic in Guangyuan area by analyzing the fossils assemblage combined with sedimentary cycle and sedimentary facies characteristics. We suggest that Guangyuan area is the subtropical coastal humid climate in the deposition period of the 1st member of Xujiahe Formation, and this coastal humid climate has continued from the time of the 1st member of Xujiahe Formation to the late Norian stage.

KEYWORDS: 1st member of the Xujiahe Formation, sedimentary facies, sedimentary environment, Guangyuan City, Sichuan Province.

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[91]

Systematics and Phytogeographical Implications of Genus *Staurosaccites* Dolby, 1976

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Staurosaccites Dolby, 1976 is a group of bisaccate pollen grains with distinct "cross" morphological characteristic (Dolby and Balme, 1976). This genus is stratigraphical marker for Middle-Upper Triassic sediments in Australia and India in the South Hemisphere (e.g., Helby et al., 1987), and in the Europe and the Boreal areas in the North Hemisphere (e.g., Vigran et al., 2014). Moreover, this genus is regarded as key taxon characterizing the Middle-Late Triassic Onslow Microflora on Gondwana Land (e.g., Foster et al., 1994).

To date, six species were assigned to *Staurosaccites* since 1976, among which species could not be easily differentiated from each other; and specimens attributed to other genera bear distinct "cross" feature, which should be synonymized within this genus. Meanwhile, the palynofloral provincialism of Middle Triassic is poorly understood than the phytogeography of Late Triassic (e.g., Césari and Colombi, 2013).

Here we reexamine the original illustrations and descriptions of these morphologically similar species, suggest to classify them into three distinguished species, i.e. *S. quadrifidus* Dolby, 1976, *S. tharipatharensis* Kumaran, 1979 and *S. densus* Kumaran and Maheshwari, 1980 emend. Tripathi, Tiwari and Kumar, 1990. Based on the systematic amendments, we update the palaeogeographical distribution of this genus to investigate the palynofloral provincialism. The palynofloral provinces of the South Hemisphere generally continued from Middle Triassic to Late Triassic, although the Onslow Microflora occupied broader latitudes in Middle Triassic. The palynofloral provincialism in the North Hemisphere is still ambiguous possibly due to the ignorance of this taxon in coeval palynofloras, or, if the distribution of this taxon is reliable, a palaeogeographical reconstruction is thus required to get accord with the phytogeographical map.

KEYWORDS: *Staurosaccites* Dolby, 1976, systmatics, palynofloral provinces, palaeogeography.

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[92]

The Records of the Late Triassic Tetrapoda Tracks in China

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Triassic, a period of flourishing reptiles, is of great significance in the evolutionary history of Tetrapoda. However, no Late Triassic dinosaur skeleton fossil has been found in China so far, leaving a gap in the evolutionary history. From 1986 to 2005, Chinese researcher found some dinosaur tracks in Late Triassic Xujiahe Formation but did not research in any detail. Such evidence raise a question that whether Late Triassic Tetrapoda tracks including dinosaurs tracks can help us understand the early evolution of China's Triassic dinosaur fauna? Since 2009, the author and his team have been carefully investigating Sichuan Basin and surrounding Permian-Triassic strata, and obtained following new findings:

(1). Relatively diverse theropod track. By sorting old specimens, *Pengxianpus* (Yang and Yang, 1987), which was classified as Sauropodomorpha, is reclassified as theropod track. It is morphologically similar to Late Triassic-Early Jurassic *Kayantapus* in North America (Xing et al., 2013a). Tianquan tracks (Wang et al., 2005) is similar in size to *Grallator*, and is classified as theropod tracks indet. (Xing et al., 2013a). These findings suggest that as early as Late Triassic, theropods were already relatively diverse in southwestern China.

(2). Early evolution of Sauropodomorpha. The author found Sauropodomorpha tracks in Fushun, Zigong, Sichuan Basin and Bingtu Township, Meigu County, Xiichuang Basin, which are referred to original Sauropodomorpha track *Eosauropus* (Xing et al., 2014a) and cf. *Eosauropus* (Xing et al., 2018). These new records indicate that primitive Sauropodomorpha had appeared in southwestern China as early as Late Triassic, and coexisted with the basal sauropods in Early Jurassic.

(3). New records of mammal-like tetrapods and Pseudosuchia tracks. The newly discovered very small-sized tracks in Pengxian County present the first record of mammal-like tetrapods in East Asia. New *Chirotherium–Grallator* track assemblage has been discovered in Panzhihua-Xichang area (Xing et al., 2014b). The former is more common in European Triassic strata, and Late Triassic *Chirotherium* would provide important information on early evolution and diversity of Triassic archosaurs. In addition, the author also discovered *Chirotherium* in Guizhou Province and the Guanling Formation (Middle Triassic) of Yunnan Province (Xing et al., 2013b). The latter also yields the first Asian *Rhynchosauroides* (Xing and Klein, 2019).

In summary, the author has surveyed six dinosaur and other Tetrapoda track sites in Southwest China and established a preliminary Permian-Triassic track database. In this area, there are tracks of eight morphological types left by diverse theropods, Sauropodomorpha, Pseudosuchia, mammal-like tetrapods and prolacertiform. These are the earliest fossil records of Tetrapoda in China, filling the gap in the evolution history of Chinese Tetrapoda.

KEYWORDS: Permian–Triassic, theropod, Sauropodomorpha, Pseudosuchia, prolacertiform.

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[93]

Dental Microwear Texture Analyses of Extant Ruminants and Triassic Tetrapods

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Dental microwear texture analysis (DMTA), which quantitatively analyzes microscopic use wear on tooth surface, has been applied to various extant and extinct vertebrates to elucidate their diets and foraging ecology. Here we present several case studies we have conducted: 1) testing the reliability of DMTA using samples of extant Japanese ruminant (sika deer, *Cervus nippon*, and Japanese serow, *Capricornis crispus*) with known ecology, 2) reconstructing jaw movement of Triassic cynodont (*Exaeretodon*), and 3) estimating the diet of Triassic placodontids (*Cyamodus* and *Placodus*). For these analyses, we collected 3D surface texture data from occlusal surface of teeth by a confocal laser microscope, VK-9700. From these surface data, we calculated surface roughness parameters defined by ISO 25178.

For the first case, we compared DMTA parameters between the sika deer and Japanese serow from the same locality. We found significant differences in the parameters between deer and serow. The tooth surfaces of the deer were more undulated with parallel scratches (linear microwear features), whereas those of the serow were smoother with pits. These results indicate that the deer consumed abrasive graminoids, such as dwarf bamboo, more frequently than the serow, which is in accordance with previous dietary analyses using stomach contents of culled animals or field observation. In DMTA parameters, the two species did not segregate

dichotomously but showed a huge overlap, implying dietary overlap. This case study shows the potential of DMTA to clarify the foraging ecology of sympatric ruminants from skeletal remains.

For the second case, direction of scratches were investigated in order to reconsturuct the jaw movements of *Exaeretodon*. Scratches of their cheek teeth were well aligned and mostly directed to the antero-posterior direction in all teeth examined. This finding indicates the palinal masticatory jaw movement in *Exaeretodon* that corroborate the inference of previous studies based on the gross morphology of wear facets. Further, the lack of lateral scratches denied the existence of the lateral jaw movement proposed in the previous study.

For the third case, dental microwear of placodontids were compared with that of sea-plants eater (*Dugong dugon*) and various modern durophagous fishes: eagle rays (*Aetobatus narinari* and *Aetomylaeus vespertilio*), guitar fishes (*Rhina ancylostoma* and *Rhynchobatus djiddensis*), Japanese bullhead shark (*Heterodontus japonicas*), humphead wrasse (*Cheilinus undulates*), and Singapore parrotfish (*Scarus prasiognathos*). Dugong and eagle rays showed flat dental surface. Other fishes exhibited undulated and rough tooth surface. These differences in surface textures may reflect differences in feeding habitats (sandy bottom vs. reef) and/or gross morphology of tooth (with or without denticles). The dental surface texture of placodontids were intermediate between these two groups and differ from both dugong and durophagous fishes. Analysing additional dental microwear of placodontids with better preservation and comparisons with extant durophagous marine tetrapod, such as sea ottar, may help resolving diet of placodontids in the future.

KEYWORDS: Dental microwear, diet, Ruminants, Triassic, Cynodon, Placodont.

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[94]

A New Tritylodontid from China and Its Mode of Tooth Replacement

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The family tritylodontidae is a derived clade of non-mammalian cynodonts which is often considered to be more closely related to mammals than probainognathia. It has a global distribution, with the reports from the Upper Triassic-Lower Cretaceous of Europe, Southern Africa, North America, Antarctica and Asia. Known genus of tritylodontidae from China includes *Bienotherium*, *Lufengia*, *Yunnanodon*, *Dianzhongia* and *Oligokyphus* from Lufeng, Yunnan, *Bienotherides* and *Polistodon* from Sichuan and *Yuanotherium* from Xinjiang. Here, we report a new genus and species, based on a nearly complete skull associated with lower jaws from the Lower Jurassic of Lufeng, Yunnan. The fossil is characterized by a strongly squeezed skull with the upper teeth and jaws well preserved. There are three upper incisors preserved on the right premaxilla and five postcanine teeth on each row

of dentition. Phylogenetic analysis based on 18 taxa and 35 characters has generated 5 most parsimonious trees and the majority rule consensus tree supports that new fossil occupies a basal position within the clade containing *Dianzhongia*, *Lufengia* and *Kayentatherium*. The clade is supported by the following synapomorphies, the absence of upper cheek tooth B0, M0 and L0 cusp, and with two lower postcanine tooth roots. The fossil, coupled with micro-CT images, shed light on the tooth occlusion and replacement of tritylodontid. As in *Bienotherium*, the new fossil shows a polyphyodont-horizontal mode of postcanine replacement that the postcanine teeth grow posteriorly and shed anteriorly. In addition, there are two vestigial teeth mesial to lower functional postcanine teeth on the left row and one on the right, and upper functional teeth PC1-4 occlude with the lower pc2-5, indicating that lower postcanine teeth have a faster replacement rate than upper postcanine teeth.

KEYWORDS: Tritylodontid, tooth replacement, Early Jurassic, Lufeng Formation, Yunnan.

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[95]

Palynological Data from the Middle Jurassic Deposits in the Western Margin of Longjiang Basin

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Palynological fossils collected from the coal-bearing strata of the Middle Jurassic Wanbao Formation in the Longjiang Basin were systematic analysized. In total, 73 species of 45 genera were recognized, including 16 species of 15 genera in pteridophyte spores and 57 species of 30 genera in gymnosperm pollen from the Wanbao Formation in Longjiang Basin, and also *Alisporites-Chasmatosporites- Cyclogranisporites*, *Chasmatosporites - Piceites - Cyclogranisporites* and *Cyclogranisporites - Baculatisporites - Protopinus* assemblages were established in the ascending order.

The palynological data (in the ascending order) showed a trend of gradual increase of ferns spores and a gradual decrease of gymnosperms pollen, among which the filicales spores were dominate in pteridophytes, and bisaccate and monosulcate pollen were primary in gymnosperms. With high diversity, gymnosperms were mainly composed of conifers, cycads, bennettitales and ginkgophytes, in accord with the flora features reflected by the megafossils. Based on the palynological data, the Wanbao Formation should be assigned to early Middle Jurassic.

Referring to the ecological and environmental characteristics of living plants and the quantitative analysis of palynological data from the Wanbao Formation, the vegetation, dry humidity and the temperature zone type revealed that the palynological flora in the lower part of Wanbao Formation dominated by coniferous forest, the middle part mainly composed of mixed coniferous forest and shrubs, while the upper part were preponderant by shrubs with coniferous forest. In addition, coniferous forest and shrubs usually grow on a low mountain with slope hilled environment, combined with the ecological features, the Wanbao flora could live in the humid to semi-humid with warm temperate-temperate climate during this period.

KEYWORDS: Wanbao Formation, palynological data, Middle Jurassic, Longjiang Basin.

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[96]

The Middle Jurassic Dinosaur Fauna of Qinglongshan in Zigong

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Sichuan is great province in resources of dinosaur fossils. Since the first discovery of the dinosaur fossils in 1915, there is a history of more than one hundred years in discovery and study. Remarkable research results have been obtained in dinosaur faunal assemblages, systematic evolution, causes of mass death and buried environments, life habit and behavioral patterns, bone histology and paleopathology etc. Up to now, there are 34 genera, 47 species of dinosaur bones have been identified, which count for respectively one-fifth of all dinosaur bone species (more than 240 species) in China. Among them, includes the most typical Middle Jurassic *Shunosaurus*-Fauna and Late Jurassic *Mamenchisaurus*-Fauna. This also shows that Sichuan is indeed one of the areas where dinosaur bones are most abundant.

Qinglongshan dinosaur fauna site is located in fuxing township, northwest of rongxian county, Zigong city. The fauna is buried in the lower shaximiao formation of the middle Jurassic. Its geological age is roughly equivalent to the dinosaur fauna of Dashanpu.Dinosaur fossils of this fauna are very concentrated. More 600 fossils have been found in the excavated area, including teeth, cervical vertebra, dorsal vertebra, caudal vertebra, appendicular skeleton and other parts. The significance of the discovery of this fauna is to fill in the blank of the early and middle Jurassic dinosaur fossils in the world.

KEYWORDS: Sichuan, Qinglongshan dinosaur fauna, history, Middle Jurassic.

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[97]

The Middle Jurassic Swamp Plant Communities of Asia

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The coal formation in the geological past was linked with the development of plant communities which produced a large biomass at the same time possessed relatively simple structure. A considerable part of phytomass was removed from swamp ecosystems and became mortmass. The coal formation involving rapid burial of plant remains has paleoecological and taphonomical significance. The coal seams are particularly subject of paleobotanical research. The study of plant material has great importance for knowledge of the composition of swamp vegetation, genesis and quality of coal. Many elements of the coal-forming plant community can still be identified in the coal. At the time of the mire formation and growth, climatic conditions were not suitable for sediment transport into the basin particularly biogenic components, with almost complete absence of clastic sediments. Therefore, it is possible to assume that plants that gave rise to the coal deposits were autochthonous and provided the first elements of peat accumulation. Since the clastic deposits represent the material transported from the provenance area, fossil plants assemblages from the terrigenous deposits between the coal layers are often mixed, consisting of elements from both the slope and lowland communities.

We have studied the Middle Jurassic coal-bearing deposits of the Kansk-Achinsk and Irkutsk basins of Eastern Siberia (Russia) and Ordos Basin (China). The coals from thick productive and thin coal seams of these basins were processed. After chemical maceration of coals, the dispersed cuticles were revealed, their taxonomic position was determined, and coal-forming plants were identified.

The coals were sampled in Pereyaslovskoe and Nazarovskoe coal mines in the Kansk-Achinsk Basin. In the former mine the productive seams are associated with the Middle Jurassic Upper Kamala Formation. Total thickness of all seams is 22 m. We revealed abundant dispersed cuticles of czekanowskialeans. In the latter mine the thick coal seams occur in the Lower Itat Formation. The thickness of the productive seam is 13.8 m. Numerous cuticles of *Phoenicopsis gracilis* Samylina, *Czekanowskia* spp. and rare conifers were found in the coal seams.

The taphocoenoses of Kamala Formation are dominated by czekanowskialeans – genera *Phoenicopsis* and *Czekanowskia*. The ferns are represented by *Coniopteris, Cladophlebis*, *Phlebopteris*, and *Raphaelia*, the cycadaleans – by *Nilssonia* (1 species). The ginkgoaleans and conifers played in this flora significant role (Kostina, 2004).

The burials of plant remains in the Itat Formation are dominated by *Czekanowskia* and *Pityophyllum.* Next in significance are horsetails, ferns *Coniopteris* and *Cladophlebis*, ginkgoaleans *Ginkgo* and *Sphenobaiera*. Rarer *Phoenicopsis* occurs. Other plants are single (Samylina and Markovich, 1991).

The Middle Jurassic flora of the Irkutsk Basin comes from Prisayanskaya and Kuda formations. The remains of ferns *Raphaelia*, *Coniopteris* and *Cladophlebis*, ginkgoalean *Ginkgo sibirica* Heer, czekanowskialeans *Czekanowskia* and *Phoenicopsis*, conifers are widely distributed (Frolov, Mashchuk, 2018). The maceration of coals revealed the dispersed cuticles of *Pseudotorellia*, *Phoenicopsis*, and conifers.

The coals were sampled in Wulanhada coal mine in the Ordos Basin. In this mine the Yan'an Formation (the Middle Jurassic) has productive seams; the thickness of all seams is about 16 m. The burials of Yan'an Formation are dominated by ferns *Coniopteris* and *Cladophlebis*, czekanowskialeans *Czekanowskia* and *Phoenicopsis*, ginkgoaleans *Ginkgo* and *Baiera*. Cycadaleans, horsetails, and conifers played important role in this flora. The coals mainly consist of leaves of *Pseudotorellia* and ferns. The conifers are rare.

Thus, we have paleobotanical evidence, that the czekanowskialeans and somewhat *Pseudotorellia* gave rise to the dominant Middle Jurassic groups of swamp plant community in the Siberian basins, while in Ordos Basin the czekanowskialeans grew on the slopes and they did not enter the swamp plant community. We can outline the main trends in the vegetation zonation during the Middle Jurassic – the abundance of the czekanowskialeans to north and loss of their significance to the southern region.

KEYWORDS: Coal-forming plants, swamp plant communities, Middle Jurassic, Siberia, Ordos Basin.

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[98]

Recent Advances in the Study of the Jurassic Feathered Dinosaur *Anchiornis* and Its Kin

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Anchiornithinae is a group of small maniraptoran dinosaurs from the Late Jurassic of northeast China and Germany. As one of the earliest known feathered animals and "four-winged" dinosaurs, they are at least 10 million years earlier than *Archaeopteryx*, which is widely regarded as the earliest known bird, and bear a closer morphological resemblance to *Archaeopteryx* than to any other known dinosaurs.

Although the anchiornithines are very similar in morphology to *Archaeopteryx*, they bear some plesiomorphic features such as relatively short forelimbs, straight ulna, small and not reversed hallux, and slender and symmetrical flight feathers, so some scholars think that they lacked flight capability and their long pennaceous feathers were for display rather than flight. However, a recent study shows that *Anchiornis* has patagia-bearing arms as in modern flight birds, hinting that the arms with the long pennaceous feathers have an aerodynamic benefit.

Recently, a new member of Anchiornithinae, *Caihong juji*, was discovered in Qinglong, northern Hebei, which also produced the fossil of the bizarre scansoriopterygid *Yi qi*. An investigation suggests the fossil-bearing

bed should be assigned to the upper part of the Tiaojishan Formation. *Caihong* is significantly different from the other known anchiornithines in having a long and shallow-snouted skull with a bony crest and proportionally much longer ulnae. More significantly, it shows more derived integumental features such as proportionally longer arm and leg feathers, presence of alula, and tail feathers with asymmetrical vanes forming a tail surface area even larger than that in *Archaeopteryx*, suggesting the presence of some aerodynamic capabilities in this animal. Some platelet-shaped melanosomes that produce bright iridescent colors in extant birds are present in the feathers of *Caihong*'s head, neck and chest, implying a rapid diversification of feather colors in early evolution of feathers.

The discoveries of *Caihong juji* and other anchiornithines demonstrate a rapid evolution and significant diversity in morphology, signaling and locomotor strategies prior to the genesis of birds.

KEYWORDS: Anchiornithinae, morphology, locomotor, signaling, Late Jurassic, northeast China.

[99]

Palaeobiology of the 165 Ma Lobster Voulteryon parvulus (Polychelida) from La Voulte-sur-Rhône Lagerstätte (France)

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Decapod crustaceans (most shrimps, all lobsters and crabs) are ecologically, economically and culturally important. It is therefore important to understand how changing environmental conditions affected them in the past. Unfortunately, these animals are rarely preserved, especially with enough details for in-depth palaeoecological studies. Yet, in the case of *Voulteryon parvulus*, a small polychelidan lobster, the exceptional preservation of fossilised organs, surfaces of the eyes and epibiotic branchiopods allows an in-depth study its palaeoecology. *V. parvulus* possesses eyes with hexagonal facets (apposition optics?), more likely poorly adapted to deep-water environment. It was, however, found in an outcrop deposited in relatively deep waters (low light intensity), and bear epibiotic thecididean branchiopod which prefer dark environments (crevices or deep waters). We suggest that *V. parvulus* actually lived in crevices in shallow water and migrated, perhaps for reproduction, to the depths where it was fossilized. A less parsimonious hypothesis is that *V. parvulus* evolved superposition eyes well adapted to dim light. This study also shows us the pitfall of relying on a single line of evidence: a small difference in preservation might have led to the conclusion that *V. parvulus* was a true deep-water animal, or on the contrary, a true shallow water animal.

KEYWORDS: Jurassic; La Voulte-sur-Rhône, Crustacea, Brachiopoda, eyes, epibionts.

[100]

Evolutionary Stages of Ornithischian Dinosaurs in the Khorat Group of Thailand

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So far most of the southeast Asian dinosaur fossils have been found in the Khorat Group, a stratigraphic unit of continental formations ranging from the Late Jurassic with the lower part of the Phu Kradung to the Aptian-Albian with the Khok Kruat Formation of Thailand.

Ornithischian dinosaurs in Khorat Group of Thailand were known from two formations the lowest Phu Kradung and the top-most Khok Kruat. The latter formation presents a highly abundant neornithischian dinosaurs comprises 4 taxa of iguanodonts plus one taxon of basal ceratopsian whereas a stegosaur remain was a presence in the Phu Kradung Formation. Recently, the nearly complete skeleton except the cranial of small-bodied ornithischian remains has yielded together with various size of femurs and a few isolated cranial parts from the extraordinary site of Phu Noi located in Kalasin province. Although these remains are un-publish the distinct characters such as asymmetrically distributed enamel on the lingual surface of fan-shaped dentary teeth, narrowing, along with a perfectly rounded termination of the preacetabular process of the ilium, including short and high postacetabular process suggesting that it is the oldest neornithischian in southeast Asia. Both stegosaurs and small neornithischians illustrate an early stage in the evolution of this group, which resemble those Chinese ornithischians from the Middle to Late Jurassic Dashanpu Formation.

The principal purpose of this study is to illustrate the diversity of ornithischian assemblages in Thailand, providing an updated review and a discussion about their particular history and their role in the palaeoecology during crucial periods of the Mesozoic as no evidence of them occurring in the Early Cretaceous Sao Khua Formation (Barremian). Although Barremian ornithischians of Japanese Kitadani Formation or English Wealden Group are abundant, does not mean that the Sao Khua ornithischians were completely absent, but reflected niche overlap and competition between herbivores considerably.

KEYWORD: Jurassic, Cretaceous, neornithischia, ornithopod, ceratopsia.

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[101]

The Palaeogeographic Distribution of Elatocladus Morphogenus in the Mesozoic: New Record from Iran

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We present newly discovered conifer fossils from the Middle Jurassic of the Tabas Block, Iran. Impression/compression specimens are assigned to *Elatocladus laxus* (Phillips) Harris. This is the first record of *E. laxus* from Iran and one of only very few Laurasian occurrences of this taxon. In addition, *E. laxus* has never been discovered from the Southern Hemisphere. Statistical data based on the paleobotanical distribution of the genus *Elatocladus* from 334 localities suggests that this conifer mostly appeared at mid- to high-latitudinal (>30° N and >45° S) belts from the Middle Triassic to the Late Cretaceous. Despite this latitudinal restriction, *Elatocladus* is usually not considered as a strict indicator of climatic condition but it is assumed that it generally grew on river or lake banks under a warm and dry or moderately humid climate. Maximum relative frequency of this genus was restricted to paleo-latitudes of 45° N to 60° N from the Middle Triassic up to the Late Cretaceous in Laurasia (62.6% concentrated) and paleo-latitudes of 45°S to 60° S in the Late Triassic up to the Late Cretaceous of Gondwana (69.31% concentrated). The Middle Triassic to the Late Cretaceous coincide with increasing mean annual temperature (greenhouse climate) as well as absence of icecaps in the poles, with forest ecosystems extending into the high-latitudes during this interval *Elatocladus* gradually declined in low paleo-latitudes and become more abundant at high paleo-latitudes. In addition, diversity of this genus appears to have reached its peak in the Middle Jurassic (37 species; North Hemisphere) and in the Early Cretaceous (13 species; South Hemisphere). A statistical meta-analysis of the global distribution of *Elatocladus* records shows that the genus was largely restricted to warm regions during the Mesozoic.

KEYWORDS: First record, *Elatocladus laxus*, Middle Jurassic, Mesozoic, Iran, paleogeographical distribution.

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[102]

Ammonoid Stratigraphy of the Gucuo Formation in Tibet, China

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The Jurassic-Cretaceous boundary is a major topic of the international stratigraphic study, and it is a difficult point in the study of the Phanerozoic stratigraphy boundary, which seriously restricts the improvement of the

geological chronological sequence of the Mesozoic era. In the early years, the debate over the Jurassic-Cretaceous marine stratigraphy boundary mainly focused on the existence of the Berriasian and its attribution. At present, the existence of this stage has been recognized, and it is agreed that it should be subsumed into the Lower Cretaceous, and its bottom boundary should be regarded as the boundary between Jurassic and Cretaceous.

Ammonoid biostratigraphy of the Gucuo Formation is being discussed in light of new data. Their systematics supported by stratigraphic details of the collected ammonoids have resulted in the organization of a set of successive ammonoid assemblages ranging may in age from Tithonian to Berriasian, including: *Blanfordiceras*, *Malagasites*, *Haplophylloceras*, *Aulacosphinctes*, *Himalayites*, *Spiticeras*. The chronostratigraphically significant Jurassic/Cretaceous System boundary may be identified, but need more ammonoid material to confirm.

KEYWORDS: Ammonoid, biostratigraphy, Tithonian, Berriasian.

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[103]

Fossil Liverworts from the Jurassic-Cretaceous of Xinjiang and Inner Mongolia and Paleoenvironment Reconstruction

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The liverwort is considered one of the earliest divergent land plants. Fossil liverworts are important in shaping the paleo-ecosystem in earth's history, and are significant in understanding the origin and evolutionary history of land plants and terrestrial ecosystems. They are widespread around the world during the Phanerozoic and have been reported to record the paleo-CO_2 levels and climate change. We collected some fossil liverworts from the Middle Jurassic Xishanyao Formation of Sandaoling open-cast coal mine in Hami, Xinjiang and the Lower Cretaceous Huolinhe Formation of Huolinhe Basin, Inner Mongolia. The fossil liverworts were classified and identified according to the general morphology and the anatomical features. They were assigned to 7 genera including 1 new genus, with 13 species including 6 new species.

Stable carbon isotope composition ($\delta^{13}C$) of three fossil species were measured. The paleo-CO_2 concentration were calculated using the BRYOCARB. The results of the early Middle Jurassic and the early Early Cretaceous are 641 ppm ($BRYOCARB_{NP}$) or 608 ppm ($BRYOCARB_{P}$) and 567 ppm ($BRYOCARB_{NP}$). All the results are in the error range of the GEOCARB II. According to the distribution of the related extant species of the fossil liverworts and other fossils from the same fossil-bearing layer, the paleoclimate of the Sandaoling open-cast coal mine at the Middle Jurassic and the Huolinhe Basin at the Early Cretaceous is humid and warm. This is accordant with the previous study. The fossil liverwort can be considered as a proxy of paleoclimate.

Regression analysis of $\delta^{13}C$ and elevation were made in Matlab. At different elevation, their relationship can be expressed by a section function,

$$y = \begin{cases} -0.007896 \cdot x - 25.54 (x \le 1270) \\ 0.005289 \cdot x - 40.03 (1270 < x \le 2000) \\ 0.00723 \cdot x - 48.82 (2000 < x \le 2690) \end{cases} \cdot$$

The paleoelevation was reconstructed using this function. The paleoelevation of the Sandaoling open-cast coal mine at the early Middle Jurassic is 173 meters above the sealevel, and the paleoelevation of the Huolinhe Basin at the early Early Cretaceous is 28 meters above the sealevel. The results are accordant with the paleogeographical and tectonic background of the two fossil sites. So the fossil liverwort can also be considered as a proxy of paleoelevation.

KEYWORDS: Fossil liverwort, paleoclimate, Middle Jurassic, Early Cretaceous, Xishanyao Formation, Huolinhe Formation.

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[104]

Preservation of Radiolarians Across the Jurassic-Cretaceous (J/K) Boundary in the Bosso Valley Section, Northern Apennines, Central Italy

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The Global Boundary Stratotype Section and Point (GSSP) of the Jurassic–Cretaceous boundary (JKB) is the last among the GSSPs in the Phanerozoic. 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 pronounced increase in abundance of *Calpionella alpina* documented at the base of Calpionella zone was accepted as the Jurassic–Cretaceous boundary (JKB) indicator in the Bosso Valley section. The magnetostratigraphical record of the JKB has been correlated with the Calpionella zone (Houša et al., 2004). The Maiolica Formation, which includes the JKB, is characterized by whitish, beige to gray colored, well-bedded limestones with abundant black to gray chert layers and chert nodules and marly intervals. Certain horizons in the Bosso Valley section yield well-preserved radiolarians, significant for the correlation of deep marine sediments. In order to establish radiolarian biostratigraphy across the JKB, detailed study was conducted to elucidate relationship between lithology and preservation of radiolarians in the Bosso Valley section. In this study, after the field-etching selection, we conducted carefully observation of the etched surface under a SEM in the laboratory. The limestone samples were immersed in 10% hydrochloric acid for 30 to 60 minutes, then washed, dried and examined under a binocular microscope. Two samples were examined under a scanning electron microscope. Other three samples were immersed in 5% hydrofluoric acid for 24 hours, then washed, dried and examined under a binocular microscope. Well-preserved radiolarians are located inside the lime part near the chert bands or nodules. Primary results of radiolarian assemblages near the JKB are proposed. Limestones near chert layers or nodules in the Bosso Valley section enable radiolarian biostratigraphic study across the JKB.

KEYWORDS: Jurassic, Creataceous, radiolarian, preservation, GSSP.

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[105]

Preliminary Study on Mamenchisaurid-like Sauropods from the Phu Kradung Formation, Northeastern Thailand

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The Late Jurassic - Early Cretaceous Phu Kradung Formation of Northeastern Thailand preserves a rich fossil vertebrate assemblage, including amphibians, crocodiles, fish, turtles, pterosaurs and dinosaurs, especially sauropods which are the most abundant fossils known from the formation. Numerous cranial and postcranial

remains, consisting of articulated partial skeletons and isolated bones, were found at Phu Noi locality and some vertebrae were found at Phu Dan Ma locality, Kalasin province. Several specific characters of this material, i.e., shape of occipital part of the braincase; spatulashaped teeth; bifurcate neural spines of cervical vertebrae, as well as small pneumatic camellate structure inside the cervical vertebrae and procoelous shape of anterior caudal vertebrae, are reminiscent of the sauropod family Mamenchisauridae which is commonly found in the Late Jurassic of China.

KEYWORDS: Late Jurassic–Early Cretaceous, Mamenchisauridae, Phu Kradung Formation, pneumatic camellae, procoelous vertebrae.

[106]

The Discovery and Potential Areas of Dinosaur Fossils in Malaysia

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Since the last five years, the Department of Mineral and Geoscience Malaysia (JMG) has carried out several scientific expeditions to search for dinosaur fossils in Malaysia. The first discovery of dinosaur remains by JMG was in October 2014 where fossils of dinosaur footprints and tooth has been discovered at Chichir River of Hulu Terengganu, in Terengganu State, Malaysia. The fossils have been discovered within the sandstone of the Jurassic-Cretaceous Gagau Group. The Gagau Group composed of pyroclastic rocks, conglomerates, sandstones and shales deposited in fluvial, lacustrine and deltaic environments. The tooth has been identified as belong to Iguanodon ornithopods dinosaur and the footprints most probably belong to theropods, Iguanodon and sauropods. Earlier, in early 2014, a team of palaeontology researchers from the Department of Geology, Faculty of Science, University of Malaya and Japanese universities (Waseda University and Kumamoto University) has announced the discovery of spinosauridae dinosaur fossil teeth in the rural interiors of Pahang state. In the same year, a team of paleontogists from the University of Malaya has reported the discovery of Cretaceous fish fossils in Pahang composed of isolated teeth with less of noncranial remains. A total of more than 100 teeth were examined with confirmation of nine taxa. Entrusted with the developing and adding value to the study of dinosaurs in Malaysia, the National Dinosaur Research Group has been established in 2015 and consists of representatives from JMG, local universities, and the Malaysian Geological Heritage Group. There are several potential areas of Jurassic-Cretaceous sequence in Peninsular Malaysia such as Saiong and Kayu Hitam Formations in Kedah, Berapit and Tan Hain Formation in Perak, Panau and Koh Formation in Kelantan, Gagau and Tembeling Group in Terengganu-Pahang border areas, as well as Ma'Okil, Paloh, Tebak and Panti Formations in Johor. The discovery of the dinosaur teeth and footprints are strong evidence for the existence of other dinosaur fossils in Malaysia.

KEYWORDS: Teeth, footprint, dinosaur fossils, Jurassic-Cretaceous rocks, potential areas in Malaysia.

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[107]

Allometry between Suture-Line Length and Phragmocone Volume in Some Cretaceous Ammonoids

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The margin of the ammonoid septum commonly shows a frilled structure forming a fractal-like suture line. The complex septa sometimes have been thought to have enhanced a metabolic function and some authors have focused on the relation of suture perimeter or septal surface area to shell volume in terms of allometric scaling [1, 2]. However, ontogenetic allometry between them has not yet sufficiently been studied. The present study aims to explore allometric scaling of ammonoid suture line within a species. In this study, the allometric relationship between suture perimeter and phragmocone volume was examined in a total of 28 specimens belonging to six ammonoid species recovered from the Upper Cretaceous Yezo Group. A sutural perimeter was calculated by summing the distances between a series of digitized points along the suture line on its photographic image. Phragmocone volume was calculated using a theoretical morphologic model. The relationship between suture perimeter and phragmocone volume in each species was expressed as an allometric equation in logarithmic scale. As a result, the exponent of allometric scaling estimated for each species (0.333 for isometry) ranges from 0.459 to 0.623 and was much larger than previously reported in a study of interspecific allometry [1]. This result indicates that suture perimeter grows much rapidly with respect to body size and suggests a strong positive allometry of septal surface area. Although the present study did not deal with biomechanics, it provides new and essential data on ontogenetic allometry of ammonoid suture lines that will constrain possible hypotheses on functional morphology of fluted ammonoid septa.

KEYWORDS: Ammonoid, suture line, allometry.

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[108]

The Anatomy of Petrified Wood from the Phu Kradung Formation, Phu Po, Kham Muang District, Kalasin Province, Thailand

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The four petrified wood samples were collected from the Phu Kradung Formation of the Korat Group (late Jurassic - early Cretaceous). The rock unit is located in Phu Po, Kham Muang District, Kalasin Province, Thailand. The three-dimensional thin sections (transverse, radial and tangential sections) were operated and photographed. The samples were described and identified. The results suggest that the two petrified wood samples belong to the genus *Ginkgoxylon* Saporta and they have visible growth rings by 2-3 cells of latewood. Meanwhile, the *Lhassoxylon* Vozenin-Serra et Pons and the unidentified sample express very faint growth rings by 1-2 cell of latewood. Although the plant growths are disturbed by the semi-arid condition in a short time, but it is unsuitable to estimate the palaeo-environment of the region by using the small number of samples.

KEYWORDS: Petrified wood, Phu Kradung Formation, Thailand.

[109]

Conchostracans from the Lower Cretaceous of Sinuiju Region, DPRK

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The Sinuiju Formation in Sinuiju region, North Phyongan Province, DPRK is situated in Sinuiju basin. It is distributed long in a northeast-southwest direction and 50 km long, 5kms wide.

The Sinuiju Formation comprises, in ascending order, the first to eighth member.

The first member consists of purple-green siltstones, fine-grained sandstones and mudstones including nonmarine invertebrate and plant fossils, overlying the precambrian basement unconformably.

The second member is composed of andesites and tuffceous siltstones with sedimentary intercalations, conformably overlying the lower unit.

The third member is situated in Paekto-dong and Tosong-ri, and consists of grey-green sandstones, grey to black mudstones and siltstones and yields vertebrate fossils, insects, conchostracans, bivalves, gastropods, ostracodes and plant fossils. This member is 200~300 m in thickness, which conformably overlies the second member.

The lower part of the fourth member is distributed in Paekto-dong and consists of volcanic sandstones and siltstones, claystones and shales.

The fifth member to the eighth member has no fossils.

The most of conchostracan fossils are discovered from the third member of the Sinuiju Formation.

The typical fossils are as follows; *Eosestheria chii*, *E. elongata*, *E. fuxinensis*, *E. intermedia*, *E. jingangshanensis*, *E. lingyuanensis*, *E. middendorfii*, *E. ovaliformis*, *E. semiorbita*, *E. subelongata*, *Yanjiestheria bellula*, *Y. endoi*, *Y. longa*, *Y. jiaoheensis*, *Y. proamurensis*, *Y. kyongsangensis*, *Y. saitoi*, *Y. sinensis*, *Diestheria jeholensis*, *D. longinqua*, *D. shangyuanensis*, *D. yixianensis*, *Liaoningestheria jiufotangensis*, *L. oblong*, *L. ovata*, *L. riufotangensis*, *Pseudograpta yuzhongensis* etc.

Jehol biota of northeast China bordering on DPRK is represented by "*Eosestheria-Ephemeropsis-Lycoptera*"(*E-E-L*), where *Eosestheria middendorfii* is very much.

The conchostracan fossils from the Sinuiju Formation are well comparable with ones from the Jehol biota. So we can prove that the Sinuiju Formation is the lower Cretaceous.

It is same as the age by insect and bivalve fossils.

KEYWORDS: Lower Cretaceous, conchostracan, Sinuiju Formation.

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[110]

Fossil Green Lacewings (Insect, Neuroptera, Chrysopidae) from Cretaceous in China

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The family Chrysopidae, commonly known as green lacewings, are a worldwide distributed insect group, belonging to Neuroptera. They are one of the largest families among the extant lacewings, including about 1200 extant species assigned to 80 genera. The family are divided into four subfamilies: one extinct subfamily Limaiinae and three extant subfamilies Nothochrysinae, Apochrysinae and Chrysopinae, although the phylogenetic relationships among the subfamilies are still controversial. Chrysopidae have abundant fossil records, extended as far back as Middle Jurassic. Up to date, twenty six genera with about 60 species have been reported, but several genera are still debatable in regard of their monophyletic and subfamilial assignment. Most of the Mesozoic green lacewings were assigned to Limaiinae, whereas others were considered to be subfamily *incertae sedis*, i.e. no chrysopids belonging to the extant subfamilies were recorded from Mesozoic. Fossil representatives of Nothochrysinae and Chrysopinae have been found since Paleogene, and gradually succeeded lamaiines during Neogene.

Lamaiinae were diverse during Mesozoic, and widely distributed in Eurasia and South America. Five genera of the subfamily have been established hitherto, of which, *Mesypochrysa* was the dominated genus. About twenty species of *Mesypochrysa* have been described from seven localities across Eurasia and one locality in South America. Although the monophyletic of Limaiinae have not been thoroughly analyzed and evidently verified, the subfamily status is extensively accepted based on stable wing venation characters.

Herein new fossil chrysopids from the Early Cretaceous Jehol Biota in China are studied, with description of new taxa of Limaiinae. Based on the new taxa, along with published fossil and extant chrysopids, the venational transformation among the four subfamilies along their evolutionary history are discussed.

[111]

Key Fossils in Reconstructing the Early History of Flowering Plants

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Palaeobotanical data document a major floristic transition during the Cretaceous associated with the emergence and initial diversification of flowering plants (angiosperms). Following the first scattered occurrences of angiosperms in the Valanginian and Hauterivian the role of angiosperms in the Cretaceous vegetation rapidly changed from subordinate in the Early Cretaceous to dominant in many Late Cretaceous floras. Mesofossil floras and the application of synchrotron X-ray tomographic microscopy (SRXTM) have been particularly crucial for unravelling patterns of phylogenetic diversification and tracing reproductive biology through the early phases of angiosperm history. The fossils clearly demonstrate an orderly appearance of successively more derived angiosperm groups with Early Cretaceous forms related to basal lineages and more advanced angiosperms only appearing in the Late Cretaceous. This pattern largely corroborates results from phylogenetic studies of extant plants, but in other respects, the fossils reveal patterns that could not be have been detected based on analyses of extant plants alone. Many fossils show combinations of characters that is unknown among extant angiosperms, but that may help bridging morphological splits among extant taxa and help understanding character evolution in lineages with unusual floral traits. We will illustrate this with examples from Early Cretaceous flowers, fruits and seeds from Portugal and eastern North America with particularly focus on the extraordinary diversity of early angiosperms related to lineages that today are extremely species-poor such as the Austrobaileyales, Nymphaeales, Chloranthaceae and some eumagnoliids. Unusual reproductive features recognized in Early Cretaceous seeds using SRXTM also illustrate unanticipated changes in angiosperms over time.

KEYWORDS: Angiosperms, Early Cretaceous, fossil flowers, fossil seeds, synchrotron x-ray tomographic microscopy (SRXTM).

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[112]

Boreal Molluscan Records in the Late Mesozoic Strata in East Asia Provide Clues for the Paleobiogeographical Reconstruction in the Mid-Latitudes of the Northwest Pacific

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Studying marine paleobiogeographical conditions in the mid-latitudes of the Northwest Pacific probably contributes to better understandings of the paleoclimatic and/or paleoenvironmental background of the evolution of the Late Mesozoic terrestrial ecosystem in East Asia. In this context, southern distribution of the Boreal faunal elements, and the position of the biogeographical ecotone between the Boreal and Tethys realms in the mid-latitudes have been discussed. However, the uncertainty of paleogeography of the eastern margin of the Asian Continent has caused the difficulties for the paleobiogeographical discussion.

Although the Mesozoic shallow marine strata in Japan usually contain abundant Tethyan faunal elements, the occurrences of Boreal faunal elements have also been reported from the Upper Mesozoic strata in the Inner Zone of Southwest Japan. Some typical Boreal molluscs (ammonoids, belemnites and bivalves) were recovered in the Tetori Region, northern Central Japan. They are *Kepplerites*, *Cylindroteuthis* and *Retroceramus* from the Kaizara and "Yambarazaka" formations (Late Bathonian–Callovian) of the Kuzuryu Group, and *Cylindroteuthis* and *Arctoteuthis* from the Mitarai and Otaniyama formations (late Tithonian?–Berriasian) of the Tetori Group. These Boreal molluscs co-occur with the Tethyan–Pacific ammonoids, and Tetori bivalve fauna, showing some similarities with those in the Boreal Realm and Early Cretaceous strata in Heilongjiang, Northeast China. The Kuzuryu and Tetori groups deposited in the Hida Belt, which is located in the eastern margin of the North China Block. Thus the fossil record in the Tetori Region provides evidence that the Boreal faunal elements reached the mid-latitudes of the Northwest Pacific, and this region was probably located within the ecotone of molluscs between the Boreal and Tethys realms, at least in the Middle Jurassic and around Jurassic–Cretaceous boundary.

Considering the tectonic setting of the localities of Boreal faunal elements of the Jurassic age in the eastern margin of the Asian Continent, the Bureya (Russian Far East) and Suibin (Heilongjiang) regions are located in the Bureya and Jamusi blocks, respectively. Other regions, where Boreal faunal elements occur, are probably located in the tectonic belt or Jurassic accretionary complex, whose paleo-position in the Jurassic is highly debated. Since the final amalgamation of the Khanka/Jamusi/Bureya Block with the Songliao and North China blocks probably occurred by the Early Jurassic, the north–south oriented geographical relationship among the Bureya, Suibin and Tetori regions was probably almost the same as the present relationship, and they can be considered the “fixed points for paleobiogeographical reconstruction.”

Further studies of the records of Tethyan and Boreal taxa in the “fixed points” and other localities in East Asia could provide clues to reveal the paleobiogeographical reconstruction in the mid-latitudes of the Northwest Pacific in the Late Mesozoic, and also the paleoclimatic and/or paleoenvironmental background of the evolution of the terrestrial ecosystems at that time.

KEYWORDS: Boreal Realm, central Japan, Jurassic, Kuzuryu Group, paleobiogeography, Tetori Group.

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[113]

New Eupolypod Fossils from the Mid-Cretaceous Myanmar Amber and Their Significance

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In the recently revised classification for ferns[1], Eupolypods, composed of two clades: Eupolypods I and Eupolypods II, include nearly 6000 species—more than half of extant fern diversity. However, the evolutionary history of this lineages remains incompletely understood, especially on its diversification scenarios. So far, there are two diffent hypothes on Eupolypods divergence time based on molecular dating: A Cretaceous diversification or a Jurassic one? most DNA-based divergence-time studies indicate that Eupolypods diversification occurred in the Late Cretaceous, but a more recent study[2] demonstrated that Eupolypods originated as early as in the Early Jurassic. On the other hand, although a range of molecular dating methods is now available, they all share a vital dependence on fossils as one of important age calibrations. It is therefore of prime importance to thoroughly document and critically evaluate new and informative fern fossils, especially those fossils from those periods of geologic time that are believed to represent important phases in the establishment and/or radiation of new fern lineages. However, so far, no single study based on fossils from stratigraphic depositions has provided unequivocal evidence for a Cretaceous or pre-Cretaceous occurrence for Eupolypods[3], the molecular dating of a Jurassic diversification for Eupolypods needs further evidence.

In recent years, it has been found that approximately 100 million-year-old Myanmar amber provides a unique source of eupolypod fossils. Different eupolypods and numerous eupolypod spores and scales have been found in the mid-Cretaceous Myanmar amber[4]. These discoveries are nevertheless important because they provided the first unequivocal fossil evidences that a diversity of eupolypod ferns was present already in the mid-Cretaceous Myanmar amber forests, clearly showing that Eupolypods originated before mid-Cretaceous, probably as early as the Early Jurassic, and the Jurassic diversification for Eupolypods is also consistent with the recent divergence time estimates based on molecular dating[2].

KEYWORDS: Eupolypods, mid-Cretaceous, Myanmar amber, fossils, molecular dating.

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[114]

A New Record of Brachyoxylon Wood from South China and its Palaeoclimatic Implications

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A new species of conifer wood—*Brachyoxylon zhouii* sp. nov.—is described from the Lower Cretaceous of Zhejiang Province, southeastern China. The new species is characterized by mixed type of radial pitting, araucarioid cross-fields, high uniseriate rays, and the presence of traumatic resin ducts. The new finding represents the second species of *Brachyoxylon* from the Guantou Formation in Zhejiang Province, and contributes to further understanding the forest composition of the Early Cretaceous flora in southeastern China. The CSDM curves of deciduous conifers are dominantly left-skewed or symmetrical, whilst evergreen conifers have dominantly right-skewed CSDM curves. The magnitude of right-skewedness in evergreen conifers appears to be positively related to leaf longevity (Falcon-Lang, 2000b). The skew of CSDM curves of *Brachyoxylon zhouii* are from 0% to +80% (mean percentage of skew of CSDM curves +34.83%), which indicate the new species was evergreen. The Ring Markedness Index of the new species is from 8.45% to 21.03% (mean RMI 14.28). Compared with the leaf longevity and growth ring markedness analysed for five conifer trees from southern England, the Leaf Rentention Times (LRTs) of the *Brachyoxylon zhouii* is 3-15 years.

It is deduced that Zhejiang Province is dominated by a subtropical to tropical hot and relatively semiarid climate during the Early Cretaceous interval.

KEYWORDS: Conifer wood, South China, palaeoclimate, *Brachyoxylon.*

[115]

Aquatic Angiosperms from the Upper Cretaceous Yong'ancun Formation in Jiayin, China.

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The Upper Cretaceous terrigenous deposits in Jiayin area have been divided into the Yong'ancun, Taipinglinchang, Yuliangzi and Furao formations in ascending order. The Yong'ancun Formation is mainly composed of alternating yellow-brown cross-bedded sandstones, greyish-brown siltstones and mudstones, intercalated with pebbly sandstone, representing a basin dominated by alluvial-lacustrine, which yields ostracods, bivalves, conchostracans, dinosaur footprints and abundant plant fossils. On the basis of palynological data, the age of the Yong'ancun Formation should be assigned to Santonian, additionally the palynological assemblages are comparable to those from the upper Yaojia Formation and the lowest Nenjiang Formation in Songliao Basin, which have been studied in high resolution with radiometric dating method by Wan et al., 2013. During these years, numerous impressions of plant-fossil leaves and fruits were found in the Yong'ancun Formation, mainly including horsetails (*Equisetum*), ferns (*Gleichenites*, *Asplenium*, *Cladophlebis*), ginkgoales (*Ginkgo*), conifers (*Cupressinocladus*, *Taxodium*, *Metasequoia*, *Sequoia*) and angiosperms (*Trochodendroides*, *Nyssidium*, *Dalembia*, *Platanus*, *Nelumbo*, *Quereuxia*, and *Cobbania*).

The fossil record of aquatic flowering plants from the Upper Cretaceous sediments of the Yong'ancun Formation broadens our understanding their former diversity and origins. Up to now, three taxa of aquatic angiosperms, *Cobbania corrugata* (Lesq.) Stockey et al., *Queruexia angulata* (Newb.) Krysht. and *Nelumbo jiayinensis* sp. nov. Liang et al. were described from the Yong'ancun Formation, which are common components of Cretaceous deposits in Eurasia and North America, and imply a warm temperate seasonal climate with an alluvial-lacustrine environment during Late Cretaceous in Jiayin area.

KEYWORDS: Upper Cretaceous, Yong'ancun Formation, aquatic angiosperms.

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[116]

A Nearly Complete Skeleton of a Hadrosaurine Dinosaur (Dinosauria: Hadrosauridae) from the Marine Deposits of the Late Cretaceous Hakobuchi Formation, Yezo Group, Japan

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A nearly complete skeleton of a hadrosaurid dinosaur was discovered from the outer shelf deposits of the Upper Cretaceous Hakobuchi Formation (early Maastrichtian) of the Yezo Group in the Hobetsu area of Mukawa town in Hokkaido, Japan. This hadrosaurid was named as *Kamuysaurus japonicus* in September, 2019, and is important for understanding the diversity of hadrosaurids in marine-influenced environments because hadrosaurid materials from marine deposits are rarely reported. Given the completeness of this skeleton, this dinosaur also sheds light on understandings of the diversity of hadrosaurids in the Far East as well as spatial and environmental significance for the hadrosaurid evolution during the Late Cretaceous. *Kamuysaurus* has some unique characters (the midpoint of the quadratojugal notch positioned at roughly three-quarters of the total length of the quadrate from the dorsal end, short ascending process of the surangular, high average height/width ratio of dentary tooth over 3.30, anterior inclination of neural spines of sixth to twelfth dorsal vertebrae). Our phylogenetic analysis shows that *Kamuysaurus* belongs to Edmontosaurini (a sub-clade of Hadrosaurinae) and forms a clade with *Laiyangosaurus* and *Kerberosaurus* from the northern Far East. *Kamuysaurus* has a long frontal platform for the nasofrontal sutural surface, indicative of the presence of a moderate-sized supracranial crest, similar to a sub-adult form of *Brachylophosaurus* based on the extension of the nasofrontal sutural surface. The histological section of the mid-shaft of the tibia of *Kamuysaurus* exhibits at least nine lines of arrested growth (LAGs). The last few LAGs of the outermost circumference are closely apposed, and the growth curve reconstruction indicates that this individual had virtually reached its asymptotic body size. The Dispersal Extinction Cladogenesis analysis with the 50% Majority Rule consensus tree suggests that the clade of *Kamuysaurus*, *Laiyangosaurus*, and *Kerberosaurus* may have separated from the hadrosaurines in the rest of Asia prior to the late Campanian and that the clade was endemic during the late Campanian and early Maastrichtian in the northern Far East. The results of both Dispersal Extinction Cladogenesis analysis and ancestral state reconstruction on depositional environments imply that the marine-influenced environments in North America during the Campanian may have played an important role for the hadrosaurid diversification in its early evolutionary history.

KEYWORDS: Japan, Hokkaido, dinosaur, Hadrosauridae, Hadrosaurinae, Yezo Group, Hakobuchi Formation, Upper Cretaceous, Maastrichtian, marine depositis.

[117]

A new sauropod remains from Kyushu Island, western Japan

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In these decades, several dinosaur remains have been recovered from the Lower and Upper Cretaceous sediments in Japan (e.g., Shibata et al., 2017), but the skeletal specimens of Japanese sauropods have been rare. Here we report a new sauropod remain (GCM-VP568) from the Early Cretaceous Eboshi Formation (late Albian), Goshoura Group, Amakusa City, southwestern Japan. GCM-VP568 is referred as a proximal part of a dorsal rib (42 cm in long) with main shaft of a sauropod dinosaur, based on the following features: a gently curved medial edge suggesting the transversely huge body cavity; deep curvature between the capitalum and tuberclum; a triangular transverse cross section of the shaft; and an anteroposteriorly expanded distal shaft. The direction of a concavity on the anterior surface of shaft supports that GCM-VP568 is a right dorsal rib. Ornithopod dinosaurs have achieved relatively large body size since the mid-Cretaceous; thus, large ornithopod ribs are also similar in size but their body cavities are not as wide as in sauropods.

Referring to closely related sauropod species, the whole length of the dorsal rib is estimated as about 1.4 m. Accepting that the partial preservation of skeletal element is available, the skeletal length would be 10 to 20 meters in long. Most sauropod remains in Japan are isolated teeth, but from the Lower Cretaceous in Fukui, Hyogo, Iwate, and Mie prefectures, some postcranial elements are limitedly known. GCM-VP568 is the first record of sauropod remains from the Goshoura Group, and is a new evidence showing a further dinosaur diversity in mid Cretaceous of Kyushu island.

KEYWORDS: Sauropoda, dorsal rib, Late Cretaceous, Goshoura Island.

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[118]

Colonial Nesting Ground from Late Cretaceous Mongolia Reveals Nest Attendance Behavior in a Non-Avian Theropod

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Colonial nesting is a common behavior found in many extant archosaur species (i.e., crocodylians and birds), where multiple individuals nest communally in an area during a single nesting season. This behavior has been inferred for various dinosaur groups (e.g., hadrosaurs, sauropodomorphs, and non-avian theropods), but sedimentologic and taphonomic evidence demonstrating that multiple nests were built during a single nesting season is often lacking. Here, we report on a new nesting site discovered in the Upper Cretaceous Javkhlant Formation of the eastern Gobi Desert, Mongolia, which provides strong evidence for colonial nesting of a non-avian dinosaur during a single nesting season. The Javkhlant nesting site preserves at least 15 egg clutches that contain 3–30 eggs each. The eggs are spherical in shape (10–15 cm in diameter) and exhibit dendroolithid eggshell microstructure, suggesting a probable therizinosaur affinity. The highly porous eggshell indicates the eggs were incubated in fully covered nests, similar to mound nests of extant crocodylians and megapode birds. Taphonomic and sedimentologic evidence of the Javkhlant eggs and clutches, such as the occurrence of the clutches at the top of a common paleosurface, the distribution of eggshell fragments within clutches, the presence of a consistent two-layer sediment infill within eggs, and a thin marker lithologic unit blanketing all the clutches, indicates the clutches were laid and hatched during a single nesting season. Out of 15 nests, nine clutches showed evidence that at least one egg successfully hatched. This high nesting success rate (60%) is comparable to that of extant crocodylian populations and bird species that attend and/or protect their nests, suggesting that the Javkhlant theropods attended the nests during incubation. This study indicates that colonial nesting with parental attendance, widespread in extant birds, likely evolved initially among non-brooding, non-avian dinosaurs to increase nesting success.

KEYWORDS: Colony, dinosaur, Javkhlant Formation, nest attendance, therizinosaurs, Upper Cretaceous.

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[119]

Establishment of Upper Cretaceous Bio- and Carbon Isotope Stratigraphy in the Northwest Pacific Ocean and Radiometric Ages around Several Stage Boundaries

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The Yezo Group has continuously recorded Cretaceous paleoenvironmental changes in the Northwest Pacific

Ocean. This group contains many well-preserved microfossils fossils in addition with various macrofossils. In recent years, we success to add the carbon isotope stratigraphy with this biostratigraphy. Based on this study, the proposed integrated bio- and carbon isotope stratigraphy of the Yezo Group enables high-resolution international stratigraphic correlation in the Europe and United State regions spanning from Upper Albian to Lower Campanian. The correlation of the present study represents the stratigraphic horizons of the Albian/Cenomanian, Cenomanian/Turonian, Turonian/Coniacian, Coniacian/Santonian, and Santonian/Campanian boundaries, as well as the Late Cretaceous paleo-environmental events in the Yezo Group.

The Yezo Group is also important for calibration of the chronometric age of the Cretaceous geologic time scale because of inter-calculations of numerous felsic tuff beds. The U-Pb zircon ages of some of these tuffs are interbedded near the Albian/Cenomanian, Coniacian/Santonian and the Santonian/Campanian boundaries in the Yezo Group. They are dated at 99.7±0.3 Ma (Quidelleur et al. 2011), 86.87±0.60/0.67 (internal/total error) Ma and 84.7±0.7/1.8 (internal/total error) Ma, respectively. These radiometric ages are consistent with the latest age model of the Cretaceous time scale.

KEYWORDS: Cretaceous, carbon isotope stratigraphy, Yezo Group, U-Pb age, planktic foraminifera.

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[120]

Evolution and Geographic Distribution of Chemosynthetic Bivalves in Japan

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Numerous Cretaceous and Cenozoic chemosynthetic communities have been found in Japan (Majima et al., 2005; Amano, 2014; Amano et al., 2018; Jenkins et al., 2018). These communities include members of characteristic families or subfamilies of chemosynthetic bivalves such as solemyids, lucinids, nucinellids, thyasirids, vesicomyids, and bathymodiolins. The first four families are found from the mid-Cretaceous onward, the latter two appeared in the late Eocene and the late Eocene to early Oligocene, respectively (Amano, 2014). The families Thyasiridae, Lucinidae, and Vesicomyidae show remarkable changes in their generic composition through time, while solemyids, nucinellids, and bathymodiolins do not. Lucinidae were diverse during the Cretaceous, are absent during the Eocene, and *Lucinoma* is the dominant genus from the early Miocene onward. Within the Thyasiridae, *Conchocele* replaced *Thyasira* as the dominant genus in the late Eocene. The vesicomyids show two occasions of turnovers of the dominant genera: during the Oligocene and at the end of the middle Miocene. *Hubertschenckia* is as-yet the only known vesicomyid genus in Japan in late Eocene to early Oligocene time. It was replaced by *Pleurophopsis* in the late Oligocene, which lasted as dominant genus until the middle Miocene. From the late Miocene onward *Archivesica* and *Calyptogena* are the most diverse and widespread genera. An interesting paleobiogeographic pattern can be observed among the Neogene vesicomyids, when they show marked differences in diversity and species composition between the Japan Sea side and the

Pacific side of Japan. The Japan Sea hosts mainly species of *Calyptogena*, with an increase in species diversity since the early Miocene, attributed to the semi-enclosed geographic situation with an open strait to the north, likely allowing the influx of cold northern waters. In contrast, only *Archivesica* has been recorded from the Pacific side with its presumably warmer waters since the Pliocene. No such paleobiogeographic trends have been observed in other families of chemosymbiotic bivalves.

KEYWORDS: Evolution, paleogeography, chemosynthesis, Bivalvia.

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[121]

Lower Cretaceous Lebanese Amber: An Exceptional Window to the Past

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Amber is a material that fascinated so much and forever will not cease doing it. It constitutes a wonderful 'natural time capsule' as termed by Ross (1998, 2010), and an original material that not only preserves superb biological inclusions in their pristine three-dimensional details, but also aspects of their mode of life and their ecology. Life forms' preservation in amber increases significantly our knowledge of the palaeobiodiversity, the palaeoenvironment, and the palaeoecology, and gives the amber its attribute of exceptional 'window to the past' given by Grimaldi (2003).

Amber in Lebanon is found in more than 450 outcrops. It constitutes the oldest amber with intensive biological inclusions and is considered among the most important material enabling the knowledge of the continental palaeobiodiversity from the very important Lower Cretaceous, a crucial period for the coevolution between flowering plants and insects. This period is largely admitted to witness the first occurrence and radiation of angiosperms. Most of the times biological inclusions in Lebanese amber represent records of the earliest representatives of modern living insect families or the youngest ones for extinct families. Lebanese inclusions constitute most of the time the "missing links" between the old fauna and the modern one. The study of the Lebanese amber inclusions is to date the only one that gives a clue in determining the North-East Gondwanian biodiversity and environment of the extremely significant Lower Cretaceous period. Latest geological data give an Early Barremian age for the Lebanese amber (Granier et al., 2016; Maksoud et al., 2017). To date 232 taxa

(mainly insects) were described and named from the Lebanese amber, other inclusions are still waiting their identification. The recent discoveries of new and very diverse outcrops of fossiliferous amber in Lebanon help to increase the possibility to realize the challenge of improving considerably our knowledge of the past.

Efforts are done to categorize this natural treasure on the list of Heritage of Humanity. The different Lebanese outcrops are not yet officially protected against vandalism. Their destruction or pillaging would be a great loss to the Human Heritage, and to the scientific knowledge.

KEYWORDS: Lebanon, fossil insects, Lower Barremian, palaeoenvironment, palaeobiodiversity.

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[122]

The Early Cretaceous Swamp Plant Communities of Transbaikalia

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We have studied the Lower Cretaceous coal-bearing deposits of the Tugnuy, Tarbagatai, Bada, Chita-Ingoda, Chikoy, Bukachacha and Turga-Kharanor basins of Transbaikalia and sampled the coals from thick productive and thin coal seams. After chemical maceration of coals, the dispersed cuticles were revealed, their taxonomic position was determined, and coal-forming plants were identified. The spores and pollen obtained from both clastic layers and coals made it possible to determine the vegetation of the basin.

The palynospectra of the Olon-Sibir coal mine (Tugnuy Basin) are dominated by spores having affinity with Cyatheaceae and pollen having affinity with Pinaceae. Next in importance are close to Osmundaceae and *Ginkgocycadophytus*. In coals the cuticle *Pseudotorellia* was found. Coal accumulation occurred in swampy lakes of a wide river floodplain. Ferns, *Pseudotorellia* and pine trees formed swamp vegetation.

Numerous cuticles of *Pseudotorellia* sp., *Ginkgo* cf. *insolita* Samylina, *G.* cf. *coriacea* Florin, *Pityophyllum* sp. 1. and rare *Anomozamites* sp., Czekanowskiales sp. indet., *Pagiophyllum* sp. were found in the coal seams of the Tarbagatai Basin The territory of this basin was occupied by lake surrounded by a ginkgo-coniferous forest

with an understory of club-mosses, ferns, and cycadophytes. At higher places, araucariaceous and cheirolepidiaceous conifers grew. Phytoplankton and green algae existed in the lake water.

The coals of the Khalyarta coal mine in the Bada Basin are composed of the remains of plants *Arctopitys* sp. A, *Tarphyderma* sp. nov.

The coals from the Chernovskoye and Tataurovo coal mines were studied in the Chita-Ingoda Basin. The following coal-forming plants were revealed: Bennettitales sp. indet., *Czekanowskia vachrameevii* Kiritchkova et Samylina, *Phoenicopsis parva* Vassilevskaja, *Phoenicopsis* sp., *Sphenobaiera* sp., *Ginkgo* sp., *Pseudotorellia palustris* Shi, Herrera, Herendeen, Leslie, Ichinnorov, Takahashi et Crane, *Ps. resinosa* Shi, Herrera, Herendeen, Leslie, Ichinnorov, Takahashi et Crane, *Pseudotorellia* sp., *Elatides* cf. *zhoui* Shi, Leslie, Herendeen, Ichinnorov, Takahashi, Knopf et Crane, *Pagiophyllum* sp.

The cuticles of *Pseudotorellia* sp. were received from the coals of the Zashulan and Krasnochikoysky coal mines of the Chikoy Basin. The palynospectra are dominated by those having affinity with Cyatheaceae and Dicksoniaceae, Pinaceae, as well as *Ginkgocycadophytus* and lower plants. It was a stagnant lake on this territory; its swampy banks were overgrown with ferns, ginkgophytes and conifers.

From the coals of the Bukachacha Basin these plants were revealed: *Pseudotorellia transbaikalica* Bugdaeva, *Elatides asiatica* (Yokoyama) Krassilov, *Pagiophyllum* sp., *Pityophyllum* sp.1, cf. *Farndalea* cf. *fragilis* Bose. The palynospectra are dominated by those close to Cyatheaceae, Araucariaceae, Pinaceae, as well as *Ginkgocycadophytus*.

The main coal producers of the Kharanor coal mine of the Turga-Kharanor Basin are bennettite *Nilssoniopteris* aff. *prynadae* Samylina, ginkgophyte *Pseudotorellia kharanorica* Bugdaeva, conifers *Elatides* sp. A, *E*. cf. *zhoui*, *Holkopitys* sp. A, *Pagiophyllum* sp., ginkgoalean *Ginkgo manchurica* (Yabe et Oishi) Meng et Chen, plants having affinity with Taxaceae (*Tomharrisia* sp.A), and also with Pinaceae, constituted a slope vegetation.

Thus, the basis of the Early Cretaceous swamp plant communities of Transbaikalia were ginkgophytes, conifers and ferns, to a lesser extent czekanowskialeans and bennettites. The well-studied Aptian-Albian flora of the central Mongolia (Tevshiin Govi and Tugrug localities) also is dominated by conifers and ginkgophytes (Herrera et al., 2017). These plants inhabited permanently flooded systems (e.g., forest-moor swamps).

KEYWORDS: Coal-forming plants, swamp plant communities, Early Cretaceous, Transbaikalia.

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[123]

The Diet of Therizinosaur Dinosaurs

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Therizinosaurs are distinctive theropods mostly diversified in the mid-Cretaceous, with multiple sympatric taxa reported in several localities in the Gobi Desert, Middle Asia and North America. Various features, such as an edentulus premaxilla with a rhamphotheca, small, closely spaced teeth with lanceolate crowns, the presence of "cheeks", a long neck, and wide pelvic, strongly suggest berbivorous habits. However, what could be their candidate food sources? and what was the potential use of their unique enlarged sickle-like claws relating to this? No certain answers yet. Considering their "sudden" abundance in the mid-Cretaceous and the huge body masses some of them achieved, a new food link could have been established in therizinosaur-abundant land ecosystem. Here a hypothesis is proposed: the radiation of herbivorous therizinosaurs were closely related to the rising of tall monocot angiosperms, probably bamboo-like basal grassess. This is largely based on evidences of recent studies, espcially new progress on the study of late Early Cretaceous Mazongshan Dinosaur Fauna in northwestern China.

Bite force estimation analysis shows that their low bite performance was mainly used for leaf-stripping and plant cropping, and therizinosauroids (e.g., *Erlikosaurus andrewsi*) would be able to process only thin (4–8 mm diameter) branches and plant matter. Recent quantitative analyses infer most therizinosauroids used their manus in a hook-and-pull fashion to pull vegetation within reach. Noticing that their neck is nearly equal to or longer than the forelimbs; thus, pulling vegetation makes sense only if large units of the plant were pulled down, in order to get at parts that were out of reach (e.g., long branches pulled down by a basal part).

Monocot leaves are typitally narrow and linear, basally ensheathing the stem, in contrast to the typital dicot leaves which have a well-defined petiole and elliptical blade. Tall monocots occur in the later diverging clade of commelinids, including tree-like Arecales (palms) and Dasypogonaccae, reeds in several lineages of Poales, and bamboos in Poaceae. Although few commelinid fossils have been reported before Campanian except for palms, numerous molecular analyses suggest the presence of many monocot groups in mid-Cretaceous. Recent phytolith analysis shows the existence of basal grassess in the late Early Cretaceous Mazongshan Dinosaur Fauna in northwestern China, where large-bodied therizinosaur (*Suzhousaurus*) is a key component in it. Therizinosaurs might have dealled with these newly evolving tall monocoets with their unique sickle-like claws and horny rhamphotheca, and convergently evolved leaf-like cheek teeth, long necks and large body size as in basal sauropodomorphs.

KEY WORDS: Therizinosaur, diet, monocots, grassess.

[124]

Aquatic Angiosperms from the Upper Cretaceous Yong'ancun Formation in Jiayin, Heilongjiang, Northeast China

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The Upper Cretaceous terrigenous deposits in Jiayin area are divided into the Yong'ancun, Taipinglinchang, Yuliangzi and Furao Formations (in ascending order). The Yong'ancun Formation is mainly composed of alternating yellow-brown cross-bedded sandstones, greyish-brown siltstones and mudstones, intercalated with pebbly sandstone, representing a basin dominated by alluvial-lacustrine, which yields ostracods, bivalves, conchostracans, dinosaur footprints and abundant plant fossils. On the basis of palynological data, the age of the Yong'ancun Formation should be assigned to Santonian, additionally the palynological assemblages are comparable to those from the upper Yaojia Formation and the lowest Nenjiang Formation in Songliao Basin, which has been studied in high resolution with radiometric dating in recent years. During these years, numerous impressions of plant-fossil leaves and fruits were found in the Yong'ancun Formation, mainly including horsetails (*Equisetum*), ferns (*Osmunda*, *Asplenium*, *Cladophlebis*), ginkgoales (*Ginkgo*), conifers (*Cupressinocladus*, *Taxodium*, *Metasequoia*, *Sequoia*) and angiosperms (*Trochodendroides*, *Nyssidium*, *Dalembia*, *Platanus*, *Nelumbo*, *Quereuxia*, and *Cobbania*).

The fossil record of aquatic flowering plants from the Upper Cretaceous sediments of the Yong'ancun Formation broadens our understanding their former diversity and origins. Up to now, three taxa of aquatic angiosperms, *Cobbania corrugata* (Lesq.) Stockey et al., *Queruexia angulata* (Newb.) Krysht. and *Nelumbo jiayinensis* sp. nov. Liang et al. were described from the Yong'ancun Formation, which are common components of Cretaceous deposits in Eurasia and North America, and imply a warm temperate seasonal climate with an alluvial-lacustrine environment during Late Cretaceous in Jiayin area.

KEYWORDS: Upper Cretaceous, Yong'ancun Formation, aquatic angiosperms.

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[125]

A New Lambeosaurine Hadrosaurid Braincase Discovered from Upper Cretaceous Yuliangzi Formation of Jiayin, Heilongjiang, Northeast China

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Jiayin is most famous in the palaeontological community because it is the first place where dinosaurs have been discovered in Asia. Since the first hadrosaurid dinosaur bone discovered in 1902, which was named as *Mandschurosaurus amurensis*, numerous dinosaur fossil bones have been excavated from the Late Cretaceous Yuliangzi Formation in both Jiayin and Wulaga fossil sites in Heilongjiang Province. More than 90% of the bones discovered in the Yuliangzi Formation belong to hollow-crested lambeosaurine hadrosaurids in the

previous studies. However, the fossils discovered during the latest excavation organized by Jiayin Dinosaur National Geopark in 2010-2011 are dominated by an unnamed new taxon of flat-headed saurolophine hadrosaurid, with only several lambeosaurine bones have been found. Among them, an incomplete lambeosaurine hadrosaurid braincase (JSDM-00152) has been studied recently. This is the third lambeosaurine braincase reported from the Yuliangzi Formation. For investigating the osteological and neuroanatomical information, the new discovered lambeosaurine braincase was CT-scanned, and a 3D endocast was virtually reconstructed.

The lambeosaurine braincase (JSDM-00152) differs from all other Cretaceous hadrosaurid dinosaurs on the following combination of osteological and neuroanatomical characters: the posterior process strongly extending laterally, forming a 90° angle with the anterior process of the lateral sphenoid; the paired rostrolateral processes of the parietal extend laterally with tipped ends, with an obvious spherical depression behind the cerebral hemisphere; a particularly large midbrain depression and cerebellar bulge; and a small angle between the anterior and posterior semicircular canals of the inner ear.

Although incompletely preserved, the new discovered lambeosaurine braincase (JSDM-00152) displays several unique characters, which suggest it represents a new taxon of lambeosaurine hadrosaurid dinosaur in the Yuliangzi Formation. This not only increases the diversity of hadrosaur assemblage in the Heilongjiang area but also provides new information of the osteology, neuroanatomy and paleogeographic distribution of the Late Cretaceous hadrosaurid dinosaurs.

KEYWORDS: Late Cretaceous, lambeosaurine, hadrosaurid, Yuliangzi Formation, Jiayin.

[126]

Carbon Sequestration of Post OAE2 Record in Cretaceous Paleolake Sediments from the Songliao Basin, North China: Indication of Long Duration of Greenhouse Climate

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The Cretaceous is recognized as a period of long-term climate stability with warm equable climates resulting from a higher atmospheric greenhouse gas content, punctuated by rapid climate and carbon cycle perturbations such as ocean anoxic events (OAEs). The role of the Cretaceous terrestrial deposit corresponding to theses rapid climate events and further to the global carbon cycle perturbations, is still ambiguous. In this study, TOC-rich deposits from the Qingshankou Formation (K_2qn^1, ~91.0-91.9 Ma) of the Songliao Basin, one of the largest Cretaceous continental sedimentary basins developed post OAE2 (~93.9 Ma), were collected. Using molecular isotopic geochemistry methods, our objectives are to probe the mechanisms controlling the organic matter deposit dynamics and to evaluate the long-lasting impact of greenhouse climate in the post OAE2 Formation of the Songliao Basin.

The molecular and stable carbon isotopic results suggest three distinct stages corresponding the organic matter accumulation and paleoenvironmental evolution. Stage III (oldest) and Stage I (youngest) are characterized by high Total Organic Carbon contents with relatively high Pr/Ph ratios and low Gammacerane Index values, implying that high primary productivity, rather than redox condition, accounted for organic matter accumulation. The high primary productivity in paleolake system was most likely induced by a large amount input of land-based nutrients due to strengthened weathering, and further resulted in the strong methane cycle at the water bottom (methanogens and methanotrophs). The weak water stratification enabled a large amount of

^{12}C-rich CO_2 and CH_4 to enter the upper water body, which was reutilized by the primary productivity. On the other hand, Stage II is characterized by relatively low Total Organic Carbon contents, low Pr/Ph ratios and high Gammacerane Index values, indicating that good preservation condition and strong water stratification played a key role on organic matter accumulation. Water stratification could be induced by higher water level and salinity at this stage. Compared to Stages III and I, relatively weak methane cycle occurred at Stage II as evidenced by ^{13}C-enriched hopanes, also favored the organic matter accumulation at the water/sediment interface. Therefore, the long-lasting impact of greenhouse climate post OAE2 induced a large amount of carbon burial in the Songliao Basin, by accelerating surface erosion and thus the nutrient supply into terrestrial lake ecosystem. The terrestrial system could be one of the main factors accounting for atmospheric CO_2 concentration in the Late Cretaceous, asking for further studies other Cretaceous terrestrial sedimentary basins to address this issue.

KEYWORDS: Post OAE2, paleolake sediments, the Songliao Basin, organic matter accumulation, paleoenvironmental evolution, methane cycle.

[127]

Marine Vertebrates of Japanese Upper Cretaceous: A Review

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Marine sediments of the Upper Cretaceous in Japan are well known for the rich macroinvertebrate fossils and have been subject to intensive stratigraphic studies since the late 19th century. The same sequence also yields vertebrate fossils such as reptiles and fish, but their through study started much later in late 20th century. In this presentation, I will summarize the taxonomy and stratigraphic distribution of major vertebrate taxa in Japanese Upper Cretaceous with updated information since our review of reptilian fossil records in 2012, and their significance in our understanding of marine vertebrate fauna of the northwestern Pacific during the last 40 million years of the Mesozoic.

Remains of plesiosaurs (Sauropterygia; Elasmosauridae, Polycotylidae, and Pliosauroidea), mosasaurs (Squamates; Mosasauroidea) and sea turtles (Chelonioidea) have been documented from Hokkaido, Pacific side of Tohoku region, and along a belt of Upper Cretaceous stretched from western Kinki region to southern Kyushu via Shikoku. Plesiosaurs are known from all stages of the Upper Cretaceous but rather rare in the uppermost Cretaceous, whereas confirmed stratigraphic ranges of mosasaurs and chelonioids are narrower but fairly common in the Campanian-Maastrichtian. There is a single specimen of diving bird (Hesperornithiformes) described from the Coniacian-Santonian. In addition to these truly marine forms, remains of terrestrial dinosaurs are very rarely mixed in the same marine strata. There are no confirmed occurrences of other taxa marine reptiles known in other parts of the worlds, such as marine crcodiles and marine squamates (e.g., dolichosaurs, marine snakes).

An increasing number of recent publications are revealing the presence of diverse chondorichthyan taxa represented by several orders, i.e. Hybodontiformes, Hexanchiformes, Echinorhiniformes, Squaliformes, Lamniformes, Carcharhiniformes, and Rajiformes. Their occurrences are most extensively documented in the Santonian, but as a whole they range from the Cenomanian to the Maastrichtian In contrast, our knowledge on bony fish is very limited: well-preserved specimens of a Cenomanian pachycormiform, a Turonian crossognathiform and Maastrichtian indeterminate myctophids have been reported, but the rest are represented by fragmentary teeth.

KEYWORDS: Cretaceous, Japan, marine reptiles, Chondorichthyes, Osteichthyes.

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[128]

Recent Discoveries on Cretaceous Floristic Changes in Japan

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Japan Archipelago or Island arc holds unique present biota with high diversity including many local endemics. Recent human activities, particularly since the end of Tokugawa Dynasty in 1867, have allowed rapid increase of unfavorable impacts to the domestic biota of Japan from various directions. Rapid and intense decrease of domestic biodiversity is still continuing even after the designation of Japan as one of the world biodiversity hotspots. In order to promote public awareness to conserve biodiversity, creating an ethical base to respect present biota and surrounding nature in each personality is important to create a sustainable nation. General understanding that the present biota has its origin in deep history of the earth and organisms could help constructing such ethical basis in the present and future generations. Only science, particularly paleontology, could provide concrete evidence to visualize the “paleoworld” realistically for the public.

The Cretaceous had been a key period toward construction of the present biota, because rapid shift to the angiosperm-dominated world occurred during this long time interval. Global biota change was influenced by the breakup of supercontinent, and further accelerated by a terminal K/T (Pg) mass extinction event. In Japan Mesozoic floristic changes have been well documented since Geiler (1877), and the Cretaceous flora is most fruitfully reported because of relative abundance of fossil sites of that period. This presentation summarizes recent advances in revealing and reconstructing Cretaceous floristic components and paleofloristic changes in Japan in relation to the angiosperm spread. New taxa are still being described based on permineralized plants preserved in carbonate concretions. Palynological data from major Early Cretaceous sites in Japan make it

possible to illustrate overall patterns of floristic changes during the key period. The present results show patterns well comparable to those reported in the Potomac Group of North America as well as in Eastern Asia. Cretaceous biota being reconstructed provides scientific resources for wide range of biological and geo-historical studies, as well as for future educational purposes.

KEYWORDS: Concretion, Cretaceous, flora, palynology.

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[129]

Seawater Incursion History of Cretaceous Songliao Paleo-lake Revealed by Specific Molecular Fossil

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Many large lakes have been formed since Triassic in Northern China. Seawater incursion events (SWIEs) in those lakes were well discussed in the past but lack solid evidence to confirm and methodology to reconstruct the detail processes. We employed specific molecular fossils, 24-*n*-propyl cholestanes, 24-*iso*-propyl cholestanes, to trace the SWIEs in the Songliao Basin (SLB).

The temporal distributions of 24-*n* -propyl cholestanes, 24-*iso*-propyl cholestanes in the well dated SK1 core indicate that the SWIEs mainly occurred in the Upper Cretaceous Qingshankou and Nenjiang formations. SWIEs in Qingshankou stage started from 91.37 Ma and terminated in 89.00 Ma, with time span of 1.37 Ma. While, SWIEs in Nenjiang stage was triggered in 84.72 and ended in 83.72 Ma, with narrower time span of 1.00 Ma. The detailed temporal distributions of these molecular fossils in the Houjingou and Yuewangcheng Section show that the SWIEs was frequent and episodic in the lower Nenjiang Formation.

High total organic carbon (TOC) and negative $\delta^{13}C_{org}$ excursion in sediments during seawater incursion are interpreted by high productivity in the lake as enhancement of nutrient supplies, and high aqueous CO_2 due to the mixing of alkalic seawater and acidic lake water. The SWIEs in SLB were controlled by regional tectonic activity and eustatic variation. Movement direction changes of Izanagi/Kula plate in 90 and 84 Ma created sinistral slip faults and triggered SWIEs. High sea level from 90 to 84 Ma also facilitated the occurrence of SWIEs in Songliao Lake.

KEYWORDS: Cretaceous, molecular fossil, seawater incursion.

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[130]

The Discovery of the Shallow Marine CORBs in Southern Himalayan Tethys and Its Paleogeographic Significance

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The "Cretaceous Oceanic Red Beds (CORBs)" associated with "Oceanic Oxic Events" has become a hot topic for geologists around the world. CORBs are widespread in the northern Tethyan Himalaya. These CORBs consist of reddish to pink limestone, marlstones, shale, siltstone, and radiolarian cherts that are commonly assigned to the Chuangde Formation. Previous studies generally suggested that the CORBs in the Tethyan Himalaya are restricted to the slope and basinal environments (northern Tethys Himalayas sub-belt, NTH) and are entirely missing in the shelf depositional environments (southern Tethys Himalayas sub-belt, STH). However, in our recent field geological survey, a set of shallow-marine red beds were found to occur in the Cretaceous Jiubao Formation in the Gyabuqing section, Guru, Yadong, where locates in STH (shelf depositional environments), which challenges the previous views/understanding on the distribution range of the CORBs in south Tibet. The shallow-sea red beds in the Gyabuqing section are characterized by "monotonous color (light purple red), single lithology (wackestone), small thickness (about 5 m), and with an age of Late Campanian (equivalent to the upper *R. calcarata* zone of planktonic foraminifera). A total of 19 genera and 69 species of planktonic foraminifera have been identified from the Gangbacunkou and Jiubao formations in the Gyabuqing section. Four fossil zones of planktonic foraminifera have been recognized in ascending order as *Dicarinella asymetrica, Globotruncanita elevata, Globotruncana ventricosa* and *Radotruncana calcarata*, which give an age of late Santonian to Late Campanian of late Cretaceous. During Cretaceous, the Tethys Himalayas were generally characterized by a paleogeographic pattern of "deep north and shallow south": The NTH was generally in a continental slope-oceanic basin environment with relatively deep water bodies and characterized by the prosperity of such skotoplankton as radiolarians and belemnites and the widespread development of the oceanic red beds. Conversely, the STH was generally in a relatively shallow continental shelf environment with almost no such skotoplankton as radiolarians and belemnites and oceanic red beds. The discovery of shallow-sea red beds in the Jiabuqing section is the first report of Cretaceous oceanic red beds in the STH, which is of great significance to the study of the genetic mechanism of Cretaceous oceanic red beds in southern Tibet.

KEYWORDS: Shallow marine CORBs, foraminiferal biostratigraphy, Jiubao Formation, palaeography, Tethyan Himalaya.

[131]

Research of Palaeovegetation and Palynostratigraphy in Sanjiang Basin-Borehole Dongji 3

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The research of the Pomology and pollen palaeoclimatology in the Borehole DongJi 3 was developed to establish the stratigraphic sequence of the Late Cretaceous in Sanjiang Basin, which can be compared with the standard section of outcrop area, besides to recovery depositional environment of the Upper Cretaceous .With the method of anhydrofluoric-sulphuric acid cold-treating process to analysis the spore and pollen fossils of samples from the layer of the well depth 1226.0-1538.0 m in Borehole DongJi 3, sporo-pollen assemblage of Borehole DongJi 3 was established by sporopollen spectrum, which is the ensemble of *Cyathidites-Taxodiaceaepolleni-Aquilapollenites*. Compared with the Nenjiang Formation in the Songliao Basin,the sporo-pollen assemblage indicate the geological periods was Santonian- Campanian. Considering that the conchostracans fossils, such as *Estherites mitsuishii*, *E. liuxinensisi*, *Tylestheria* cf. *Shanhoensis*, *Halysestheria yui*, *Calestherites* and *Brachygrapta* sp. and so on which were origin from the Hailang Formation in the outcrop at Nantuanshanzi and Gaojia villages in Ningan City, eastern Heilongjiang Province,was the common molecule of Nenjiang Formation in the Songliao Basin,can be compared with the Nenjiang Formation. Therefore, the layer of the well depth 1226.0-1538.0 m in Borehole DongJi 3 is classified as the Hailang Formation, and the former "Qixinghe Formation" is abandoned. The characteristic of the revised palynological assemblages of the Hailang Formation, Formation by quantity persent: 48.10-78.58 of Gymnosperm pollen, 2.44-34.18 of Pteridophyte spores, and 0-28.26 of angiosperm pollen. *Cyathidites* were the most abundant in Pteridophyte spores (0.79-37.50%). The important molecules were *Appendicisporites*, *Schizaeoisporites*, *Lygodium sporites* and *Lygodioisporites.* The percentage of *Inaperturopllenites* in Gymnosperm pollen was the highest (11.29-38.83%). The important molecules were *Tsugaepollenites*, *Parcisporites*, *Parvisaccites*, *Ephedripites* and *Classsopollis*. The percentage of *Tricolpites* in angiosperm pollen was the highest (0-16.46%). The important molecules were *Aquilapollenites*, *Fibulapollis*, *Proteacidites* and *Quercoidites.* According to the Borehole DongJi 3 sporopollen spectrum, the ancient times vegetation is dominated by evergreen coniferous forest in Depositional stage of the Hailang Formation. The ancient times climate was subtropical temperate humid climate.

KEYWORDS: The Sanjiang Basin, Borehole DongJi 3, spore-pollen assemblage, Hailang Formation, paleovegetationl, paleoclimate.

[132]

New Species of Embolemidae (Hymenoptera: Chrysidoidea) from Cretaceous Burmese Amber

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Embolemidae (Hymenoptera: Chrysidoidea) are parasitoid wasps whose biology is particularly unknown. These insects, present in the fossil record since the Lower Cretaceous, today have a cosmopolitan distribution. The current species are divided into 3 genera: *Embolemus* Westwood, 1833; *Ampulicomorpha* Ashmead, 1893 and *Trogloembolemus* Olmi et al., 2014. Three new species of *Embolemus* and two new species of *Ampulicomorpha* are described from Cretaceous Burmese amber (ca. -99 Ma). The specimens of the genus *Embolemus* constitute the first occurrence outside Europe and more particularly in Asia. One female and five males of this genus were found within the same fragment, which would hypothetically be the first observation of a reproductive behaviour in Embolemidae. *Ampulicomorpha* females, considered as macropterous in the descriptions, can also be brachypterous according to *A* sp. nov. 1, at least in the Upper Cretaceous. In addition, interspecific variability generally seems to be restricted to continuous traits such as antenna, scape or eye size. Intraspecific variability seems to be reduced or absent, which has notably been observed in the specimens of *Embolemus ruddii Westwood, 1833* preserved at the National Museum of Natural History in Paris. Finally, it seems that *Embolemus* and *Ampulicomorpha* already coexisted in the Cretaceous Myanmar's tropical forests.

KEYWORDS: Embolemidae, *Embolemus*, *Ampulicomorpha*, amber, Cretaceous, Myanmar, taxonomy.

[133]

Dinosaur Footprints from the Cretaceous Ponghwasan Formation of DPRK

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The upper Cretaceous Ponghwasan Formation is distributed mainly in the Hanpho basin (including Ryonggung-ri and Sansong-ri), which covers the area of 8 km^2. In Ryonggung-ri, the Ponghwasan Formation is composed of grey to black siltstones, sandstones, and mudstones containing invertebrate and plant fossils (e.g. bivalves: *Limnocyrena buriatica*, *L. obalis*, *L. selenginensis*, *L. rotunda*, *Leptesthes coreanica*, gastropods: *Baica elongata*, *B. asiatica*, *Valratactropidins pusilla*, plant fossils: *Abies* sp., *Platanus* sp., *Cladophlehis* sp., *Onycniopsis elongate* (?), *Populus* sp., *Pseudoplatanoides* sp., charophytes: *Euaclistochara mundula*, *E. obesa*, *Mesochara symmetrica*, *M. stipitata*, *Atopochara restricta*, *Aclistochara caii*) , overlying the lower Cretaceous Sansong Formation conformably.

Dinosaur tracks were also discovered in the upper Cretaceous Ponghwasan Formation of Ryonggung-ri, Phyongsan County, North Hwanghae Province in 1989. These footprints were shown as Anchisauripodidae (?), Tyrannosauridae, and Iguanodontidae, respectively.

Recently we have reexamined some (the second type) of these trackways, and undertaken a systematic review of them.

About 16 dinosaur tracks of the second type were studied and measured in Ryonggung-ri. But only one well defined trackway consisting of three consecutive large and deep footprints have been identified.

The tracks show very short pace and stride values (stride length: 95-100 cm), with an inward rotation of about 5°. The specimen represents a small-sized ornithopod and consists of impressions of three broad digits and a U-shaped heel. The length is 21-22 cm, and the width 22-23 cm. The digits are broad, short, and distally rounded, and the third digit (central) is clearly U-shaped. Digits gently become slightly narrow distally but are quite blunt. The divarication angle is 60°.

Some of the footprints are very deep suggesting that the animals stepped on waterlogged mud. The footprints are characterized by a wide and broad heel surface, and they have symmetrical indentations on both medial and lateral sides.

These morphological features suggest that these dinosaur tracks were made by ornithopods. No manus prints or tail drags have been discovered in Ryonggung-ri.

Well-preserved and abundant tracks in Ryonggung-ri site yield data for potential behavioral studies.

The potential for further research in the region could lead to new discoveries in the near future that may improve our understanding of the dinosaur tracks from DPRK.

KEYWORDS: Cretaceous, footprints, dinosaur.

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[134]

Dinosaurs, Birds, and Pterosaurs of Korea: Past, Present and Future

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Republic of Korea is one of the richest and most exciting regions on earth for the study of vertebrate ichnology. It is the global epicenter for the study of Cretaceous bird tracks and sites are aptly named as an avian paradise. So far many of the Korean ichnogenera appear indigenous to Korea, and on present evidence there is nowhere else in the world were such densities and diversity of bird tracks have been reported. Many sites reveal the highest density of bird and dinosaur track levels anywhere in the world. The 2000s decade saw further significant advances in Cretaceous Vertebrate ichnology and dinosaur remains in Korea. Several dinosaur fossilsites were excavated, and very unique vertebrate fossils including dinosaurs, pterosaurs were discovered from more important sites. New finds of dinosaur skeletal remains have increased the number and diversity of known Korean dinosaur species. These include *Pukyongosaurus millennium*, *Koreanosaurus boseongensis* and *Koreaceratops hwaseongensis.* Other fossils including dinosaur tooth and skin impressions, pterosaur bones and

tooth, turtle bones and eggs, crocodile skull and tooth, lizard bone, wood fossils, and trace fossils have been discovered during the last decade in Korea. This landslide of discovery has resulted in a proliferation of papers on vertebrate tracks and remains from the Cretaceous of South Korea and the growing recognition that as a region it reveals multiple track rich sequences of unique quality and scientific utility. Because of the outstanding ichnological resources in this region it has been dubbed the Korean Cretaceous Dinosaur Coast (KCDC). Many sites of national and international significance have been designated as national Natural Landmarks, and the best of these have been nominated for World Heritage Inscription and inscribed as Global Geopark of UNESCO. Thus, Korea led the way in raising global awareness of the rich potential of vertebrate ichnology.

A striking feature of the dinosaur sites is the intense interest in utilizing the sites for school and community education. These sites span the whole Cretaceous to the end of the 'Age of Dinosaurs' and provide considerable insight into the ecology and behavior of dinosaurs in contrast to the more abundant. Although protection, development and promotion of these sites for scientific, geotourism and public education purposes has only taken place within the last decade they have already became very heavily used. Nearly all sites are protected as National Monuments and have been developed for public education associated with its adjacent cultural and historical heritages, geographical and scenic sites. Among the geological heritage sites in South Korea, the Cretaceous sites are the most abundant. The Cretaceous sites consist of fossil sites including dinosaurs, pterosaurs, birds, invertebrates, and plants, inorganic sedimentary structure sites, unique geological feature sites, and geologically scenic view sites. The most Natural Monuments are designated for their unique preservation of dinosaur footprints and they are world-class scale in preservation. A large dinosaur museum at Haenam, three exhibition halls protecting different sets of trackways, outdoor dinosaur models and interpretive features have been provided. Many hundreds of thousands of visitors use the site annually. The representative dinosaur egg site is Bibongri site at Boseong County, in which dinosaur egg clutches are repeatedly preserved in several horizons and lizard and dinosaur bones (*Koreanosaurus*) are associated. Facilities to support geotourism at Boseong include a very large and modern museum. It will supplement an outdoor exhibition plaza containing models of dinosaur egg clutches, a very large dinosaur sculpture, boardwalks and interpretive signage. The other fossil sites also have an outdoor dinosaur education parks as well as a pathway with interpretive signs.

KEYWORDS: Dinosaurs, birds, pterosaurs, Cretaceous, South Korea.

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[135]

A Review of the Mesozoic Amphibians in Thailand

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The non-marine Mesozoic sedimentary rocks of Thailand consist of Indochina and Sibumasu terranes. These Thai sedimentary rocks preserve both temnospondyl and anuran from the Late Triassic to the Early Cretaceous periods. In Indochina terrane, numerous amphibian fossils were discovered from three Formations i.e., 1) Huai Hin Lat Formation 2) Phu Kradung Formation and 3) Sao Khu Formation. Three different taxa of amphibians were discovered in Huai Hin Lat Formation, that is, a partial skull of the specimen referred to *Cyclotosaurus* cf. *posthumus* (Ingavat and Janvier, 1981); a dermal bone of a plagiosauroid (Suteethorn, *et al*., 1988); intercentrum and dermal bone fragments which is reminiscent of the family metoposauridae. The younger Phu Kradung Formation (Late Jurassic), an intercentrum of temnospondyl (Buffetaut *et al*., 1994) and an undescribed posterior skull were found. Lastly, the Sao Khu Formation (Early Cretaceous) a pelvic girdle and two humeri of anuran amphibian were found (Srisuk, 2002 and 2005). In Sibumasu terrane, two intercentra of temnospondyl were discovered at Khlong Min formation (Middle Jurassic) (Buffetaut *et al*., 1994). The discovery of these fossil remains represent at least five taxa of amphibian occurred in Thailand during the Mesozoic and, at the meantime, also indicate the most diverse Mesozoic amphibian record in Southeast Asia.

KEYWORD: Triassic, Jurassic, Cretaceous, temnospondyl, Anuran, Southeast Asia.

[136]

On Tendencies in Evolution of the Late Carnivorous Dinosaurs (Theropoda), Mongolian Gobi

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Late carnivorous dinosaurs of the Cretaceous and, especially, Late Cretaceous show the diverse structural modifications referable to the particular and general aspects of their morphology, both equally illustrating the tendencies in their evolution. The modified features are considered below, as follows: transformation of the predatory habit revealed by the change of manual structure, also, increasing of the brain inversely proportional to the body weight, then, similarity with the birds, or, an ornithization (Barsbold 1983), widely spread in the theropod evolution, and, finally, a combination of the generalized and specialized characters predetermined with the respectively close relationship of the late theropod branches.

The grasping ability of the tridactyl manus in theropods is an actual indicator of their predatory (Osborn 1905; Romer 1956). Didactyl manus in tyrannosaurids, manus with the single digit in alvarezsaurid, as well as, the gigantic claw (0.7 m long) in therizinosaurid and twice lesser, but much massive claws of deinocheirid represent the scale of the radical manual modifications in the late theropods. Modified manus and gastroliths (no direct correspondence with diet) in ornithomimids, deinocheirus (Kobayashi et al. 1999; Lee et al. 2014) and tarbosaur (Lee, personal communication) indicate the possible transformation of diet preference from the predatory to herbivory (vegetarianism). Transformation also means a change of the behavioral strategy of the late theropods predisposed to the diet change, that, in turn, might disturb an established force balance within the dinosaur communities and even ecosystems, causing unpredicted consequences in evolution of the dinosaur faunas (Barsbold 2018). Increased brain in some oviraptorids (Barsbold 1983), two orders lesser in weight by comparison with giant tarbosaur (Maleev 1955), made its bearer much more “intellectual” (Barsbold 2018), because of more perfect sensor organs (Russel 1969; Hopson 1977), what was an advantage of the light-weighed dinosaur category against giant. On the ways of ornithization oviraptorosaurs are considered, as the probable competitors of dromaeosaurids, or, actual birds secondarily lost an ability to the flight. Oviraptorids with a pygostyle (Barsbold et al. 2000), formerly the classic bird character, were the first theropods susceptible to the graduated shortening of the tail, sometimes decorated with this feature. Manus of dromaeosaurids and some

oviraptorids reached to the highest grasping ability among the late theropods, also revealing the modified carpus at least of two types (Barsbold 1983). Dromaeosaurid pes is also accepted, as adapted to the climbing on trees, representing an exaptation to the recent bird pes (Fowler 2009) prepared to the free flight. Ornithization was one of the prevailed tendencies in evolution of the late theropods, maintaining a stabilizing selection and defining an exit to "the main road" of their last rising. Dromaeosaurids and oviraptorids with their mosaic combination of relatively generalized and inimitably specialized features, frequently contrast and even opposite, outline the parallel evolution of the late theropods, distinctly, but often closely related (Barsbold 2019).

KEYWORDS: generalized, specialized, predatory, grasping ability, ornithization, diet, manus, dromaeosaurids, oviraptorids, evolution.

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On the Dinosaur Research in Mongolia

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Dinosaurs from Mongolia are presented as one of the biggest kin of origin and development of ancient world in Central Asia among the world wide inhabitants as dinosaurs. Although they were own particularty of evolution,

they had close relationship within the groups distributed other continents and their ancesteral origin of some groups.

Prior to the Cretaceous period, representative dinosaurs are relatively few in Mongolia. In contrast, Cretaceous dinosaur fossils compare well with other continents, and in fact by the end of last century a quarter of all known dinosaurs had been found in Mongolia. A total of more than 230 well characterized dinosaur and Mesozoic bird genera come from Asia, with more than 80 genera from Mongolia.

Paleontological research in Mongolia was pioneered by the American Museum of Natural History (AMNH) with its expeditions in the 1920's led by Roy Chapman Andrews, and one of the most famous locations, known as the Flaming Cliffs, was discovered in 1922. This extremely rich fossil location has provided not only the first definite dinosaur eggs and nests, but also the complete skeletons of *Protoceratops* and *Pinacosaurus* and remains of *Oviraptor*, *Velociraptor* and *Saurornithoides.*

After World War II the Academy of Sciences of USSR was sent several expeditions for paleontological research in the Gobi Desert (1946, 1948-1949). The expedition discovered in southwestern Gobi Desert the first giant dinosaur *Tarbosaurus* and *Saurolophus,* armored dinosaurs (ankylosaurs), also the strange Paleogene primitive mammals. The discovery of the Nemegt area with the greatest badlands of mostly Late Cretaceous age is one of the main achievements of the expedition.

The Mongolian-Polish paleontological expedition was the first one in Mongolia organized by the academies of sciences of both sides on a joint basis. Having visited all of the well-known localities of the south and southwestern Gobi Desert, the expedition concentrated its main excavation work at Nemegt and Altan Ula localities. Here were discovered the groups of dinosaur quite new for Central Asia, referred to Sauropoda, Pachycephalosauria, and Theropoda. The discovery of *Deinocheirus*, a never before known theropod dinosaur with the biggest forelimbs, was one of the remarkable achievements of the expedition.

Since 1969, the MSJPE of academic institutions of both countries carried out its researches most intensively until the late 1980s. This expedition was the first in Mongolia and Central Asia, that built its scientific activity on the realization of the widest possible research program that embraced about 700 million years of organic evolution on the Earth. In dinosaur research, many new groups, especially of carnivorous branches, among them oviraptorosaurs, ornithomimosaurs, other small theropods, and some gigantic groups, have been discovered. New divisions of Early Cretaceous birds, as well as the later genera of the group, and fresh water turtles, Paleogene and Neogene mammals, fishes, and also the groups of invertebrates, insects, had been studied on the base of large collections.

The most fruitful series of recent expeditions have been established by the American Museum of Natural History (AMNH), and these run since 1991, which concentrated first on previously known sites in southern Mongolia. A key discovery on the 1993 AMNH expedition was the new locality Ukhaa Tolgod, in the Nemegt Basin, where huge numbers of fossils were found in sediments that combine evidence for equivalence of age Djadokhta Formation and the Barungoyot Formation. The fossils from Ukhaa Tolgod include over 400 specimens of dinosaur (ankylosaur, *Bagaceratops*, carnosaur, troodontid, oviraptorids, *Velociraptor*), lizards (five species), a turtle (?*Basilemys*), birds (*Mononykus*), and mammals (14-15 species). The putative flightless bird Mononykus and the discovery of the so-called 'egg thief' Oviraptor apparently incubating a nest of eggs, rather than stealing them, have attracted a great deal of attention.

Since 1993, the joint field works with the Hayashibara Museum of Natural Sciences in Japan examined all of the main fossil localities, and during a short time reached good results. The expedition carried out hard excavations at many localities in the remote parts of the Gobi Desert having obtained original material not only the best of preservation but of the greatest scientific importance as well. Among them are the discovery of

hadrosauroids from the early and successive stages of evolution, *Tarbosaurus* including individuals of different growing stages, a mass-burial of armoured dinosaur-*Pinacosaurus* and other reptiles, and the best samples of protoceratopsids. The discovery of the flock of *Protoceratops* babies consisting of 15 individuals that are mostly of the best state of preservation is one of the unique fossil samples found anywhere in the world.

Joint expedition with KIGAM (2006-2010). This expedition discovered the skeletal material expected in the dinosaur study during almost 50 years. Deinocheirus after its initial discovery (in 1965 and publication in 1970) was one of the most unusual and mysterious dinosaurs of Mongolia (after terizinosaur preserved till now its enigma during 70 years). Discovery of almost complete skeleton of deinocheirus became possible in consequence of efforts of the joint researcher`s team and high ranked administration of Mongolia (first in the history of paleontological research) had led to "the happy end".

Spreading in time of the Mongolian dinosaurs is limited with the Cretaceous, the longest interval in Phanerozoic, and the longest final period in the global evolution of dinosaurs, as well. Mongolian dinosaurs clearly demonstrated the close ties with the Chinese (Early Cretaceous) and North American (Late Cretaceous) branches. Difference of two Cretaceous intervals in Mongolia in many aspects of paleoclimate, environment, geochemistry of landscapes, sedimentation and burial are considerable, contrast and often opposite. Late Cretaceous Mongolian dinosaur species take about 90 per cent from the total number of all species discovered in the country. They possessed with the widest divergency and high extent of innovations in their morphology, being united on the base of ornithization (development of bird-like features), a prevailed tendency especially in their late evolution. Some carnivorous dinosaurs were developed with transformation of their diet from a predatory to vegetarianism, what represents a new phenomenon, early not known in dinosaur study, and, probably, the forceful factor in their evolution. Transformation of diet preference may be connected with the changeable conditions of their inhabitance, and, in turn, changing a behavioral strategy of the dinosaurs. The chain effect of these phenomena opens the new perspectives in study of the Mongolian dinosaurs and dinosaur kingdom, as a whole, in the global scale.

The history of paleontological and geological investigations in the Gobi Desert, Mongolia will continue every year with fruitful, accomplishing a comprehensive understanding of the ancient world of organisms.

KEYWORDS: Dinosaur, biostratigraphy, chronology of dinosaur study in Mongolia.

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Plant-fungal Interactions in Mesozoic Terrestrial Ecosystem----Evidences from China

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In extant terrestrial ecosystem, fungi as saprotrophs, mutualistic symbionts, parasites and pathogens, establish series of ecological and co-evolutional interactions with other organisms. Among those complicated interactions, plant-fungal interactions occur at multiple levels and contribute to shape plant communities and the ecosystems they comprise . As a large group of extant biological world, fungi have a remarkably long evolutionary history. Interestingly, many of the fungal fossil records are associated with permineralized plant remains . Structurally preserved petrified woods not only play roles in understanding the floristic composition and evolution of plant kingdom in geological history, but also contribute to revealing the complex interactions between plant and other organisms in terrestrial ecosystems, including fungi. Abundant and diverse Mesozoic petrified woods have been described in China. Most of these previous studies on Chinese Mesozoic petrified woods mainly focused on their anatomy and systematics; whereas, rare attentions have paid the fungal remains associated with them and their interactions with the host.

In the past few years, numerous well-preserved fungal remains represented fungal mycelia were found within the Mesozoic petrified woods from series of horizons throughout China, including the Lower Triassic of Inner Mongolia, the Middle Jurassic of west Liaoning Province, Chongqing City and Tibet, the Lower Cretaceous of west Liaoning, Heilongjiang and Zhejiang Provinces. Besides fungal hyphae, some fungal mycelia bear also delicate asexual spores (e.g., intercalary/terminal chlamydospores and conidiospores), which contribute to understanding the evolution of asexual reproduction of the fungi. Taxonomically, some of these fungal remains are referable the Basidiomycota, since they bear typical clamp-connections; while some other are difficult to determine their affinity. Palaeoecologically, most of them are interpreted as saprobes of the forest ecosystem, since typical wood decay characters can be recognized in the wood tissues of their host. Judging from wood-rotting characteristics, some of them are white-rot fungi, while some others are brown-rot fungi. Of interest, in an Early Cretaceous coniferous wood from western Liaoning Province which was infected by fungal hyphae, numerous tyloses at different developmental stages were found. The formation of these tyloses is presumed to be triggered by fungal infection as a physiological restraint to the invasion of the fungus. In other words, such a fungus might be a pathogen.

In conclusion, the current new findings of fungal remains in China contribute to understanding the diversity and asexual reproductive behaviors of Mesozoic fungi, and shed light on revealing complex plant-fungal interactions in Mesozoic forest ecosystem.

KEYWORDS: Fungal hyphae, wood rotting, asexual reproduction, Mesozoic, China.

[139]

Prominent Mesozoic – Cenozoic petrified wood sites and museums in Thailand: past, present, and further collaboration in Asia

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Prominent Mesozoic – Cenozic fossil wood sites have been found in North and Northeastern Thailand. The renowned sites include Tak, Phichit, Kampaeng Phet, Nakhon Ratchasima, Khon Kaen, and Kalasin provinces. Records of petrified wood in Thailand date back to the 1913. One of the earliest research publications on dicot

fossil Leguminosae - Combretaceae wood in Thailand was by Prakash, an Indian paleobotanist, in 1979. During the 1989s and 2001, fossil wood of Araucariaceae, Combretaceae, Dipterocarpaceae, and Leguminosae was studied by French colleagues. In 1994, the first petrified wood museum was established in Nakhon Ratchasima Province as an on-site museum with an initial research collaboration on Mesozoic – Cenozoic petrified wood with Nanjing Institute of Geology and Palaeontology and Shenyang Institute of Geology and Mineral Resources, China, during 2004 – 2006, resulting in an interesting discovery of antler embedded petrified wood. This collaboration has led us to other important collaborations on vertebrate paleontological research with other institutes in China and Japan, including the initial Thailand – Japan Dinosaur Excavation and Asia Dinosaur Continent exhibition. Petrified wood has great influence not only in scientific research, but also the local economy from geotourism. The other petrified wood museum in Thailand is in Sukhothai Airport, Sawankhalok District, Sukhothai Province, where petrified wood from around the world is exhibited. While the number of visitors at the petrified wood museums have increased, the number of visitors at Doi Soi Malai national park (former petrified forest park), Tak Province, where the giant 72 m long fossil tree was found, has greatly declined due to the fossil deteroriation and insufficient conservation. Therefore, in addition to research, we tried to develop geoeducation, geoconservation, and geotourism following the Lesvos Island UNESCO Global Geopark as a model. In 2017, we expanded collaboration to visit the petrified wood site in Myanmar's Mount Popa Aspiring Geopark for research and conservation. Our current research includes study of fossil gymnosperm wood from Phichit Province and palm wood from Nakhon Ratchasima Province, and we welcome collaboration with Asian researchers on these and other projects.

KEYWORDS: Southeast Asia, fossil wood, conservation, Tak, Khorat, Sukhothai.

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[140]

The Rise of Meso-Cenozoic Ostracods: From the Surviving of Ghost Lineages to the Emergence of Modern Marine Ostracods

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In marine environments, ostracods have been severely affected by the end-Permian extinction, about 252 Ma, and it is considered that this crisis prompted a deep restructuration of their assemblages: the transition from the Palaeozoic Fauna, dominated by Palaeocopida, to the Meso–Cenozoic or 'Modern' Fauna. However, this shift becomes observable only at the very end of the Late Triassic and mainly in the Jurassic, so that Triassic marine

assemblages can be considered neither really Palaeozoic anymore, nor truly 'Modern' yet. The Triassic period is consequently pivotal to unravel the evolutive history of these organisms and how marine ecosystems were restructured in the long term.

During the Early Triassic, marine ostracod assemblages were chiefly composed of survivors of the end-Permian extinction that document two very distinct survival strategies corresponding to different groups. The first one is the results of the exploitation of 'oases' provided by microbial mats widespread after the extinction. The second one corresponds to the local survival of taxa in association with high sediment influx. The Middle and Late Triassic taxa have been extensively studied during the 1970's and 1980's: most of what we know today of ostracods during this period and during the Jurassic derives from European localities and this has led to consider that Modern ostracods radiated in western Tethys. However, new data lay the groundwork for a revolution of how we conceive the origin of modern marine ostracods. Increasing evidence document drilling predation on ostracods during the Triassic: this observation not only confirms the Mesozoic aspect of this ecosystem, but also the establishment of drilling predation on ostracods as early as Carnian. Several assemblages from South China evidence the oldest records of a genus known to be typical of the Norian–Rhaetian interval of the western Tethys and a family characteristic of the European marine Jurassic. These observations are the very first tangible evidences of the hypothesis already being proposed in the 1980's that the eastern portion of the Tethys might have played a major role in the radiation of 'Modern' marine ostracods during the Triassic, which then might have colonized the western Tethys owing to the Late Triassic transgression.

KEYWORDS: Ostracods, Crustacea, Triassic, survival, radiation.

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New Progress in the Study of Cretaceous-Paleogene Micropaleontology in Southern Tibet

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The late evolution of Neo-Tethys, Creceous major geologic events (i.e. OAEs, CORBs, LIPs), and the initial collision between India and Asia plates have always been the focus of attention of many geoscientists. A series of Marine cretaceous - paleogene stratigraphic sequences developed in southern Tibet, which provides a good stratigraphic foundation for us to study the above problems. In the past few years, important advances have have been made in the K-Pg micropaleobiostratigraphy in southern Tibet as follows: (1) Evolution of mid-Cretaceous radiolarians (93 species from 43 genera) in response to oceanic anoxic events in the eastern Tethys. (2) Planktic foraminiferal biostratigraphy of the CORBs in Gyangze (18 species of 9 foraminferal genera). (3) Late Cretaceous foraminiferal biostratigraphy in Gongza (22 species of 8 foraminferal genera). (4) Late Cretaceous-Early Paleogene foraminiferal biostratigraphy in Xishan, Gamba (112 species of 48 genera). (5) The discovery of Eocene 12 species of 11 radiolarian genera from Tüna, Yadong. (6) First report of Early Eocene marine microgastropods in Yadong. (7) Eocene dinoflagellate biostratigraphy (88 species of 63 genera) in Tüna. (8) Eocene sporopollen biostratigraphy in Tüna. (9) Eocene planktonic foraminifera biostratigraphy (119 species of 24 genera) in Tüna. (10) Eocene ostracods (34 species from 15 genera) from Yadong.

KEYWORDS: Neo-Tethys, Cretaceous-Palegene, micropaleontology, southern Tibet.

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[142]

The diversity of Cupressaceae (Conifer) in the Paleocene of Jiayin, Heilongjiang, China and its environmental significance

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During the Cretaceous-Paleogene (K-Pg) transition, a series of obvious global climate fluctuations occurred, which in turn resulted in dramatic changes in terrestrial ecosystems and organisms. Cupressaceae *sensu lato* (*s.l.*) is one of the most important components of global forests since the Mesozoic, and the diversity changes of this family across this boundary could reflected how the environment changes across the K-Pg Boundary. Fossil records of Cupressaceae have been reported from both the Late Cretaceous and Paleocene formations in Jiayin County, Heilongjiang Province, Northeastern China. Macrofossil records of *Glyptostrobus*, *Metasequoia*, *Taxodium*, *Sequoia* and *Cupressinocladus* were reported in the Yongancun Formation and Taipinglinchang Formation from the Late Cretaceous Jiayin Area. Besides the above components, records of *Cupressus* and *Thuja* were also appeared in the Paleocene Wuyun flora of Jiayin Area. However, studies on how plants of Cupressaceae *s.l.* reflecting the climate changes during this period are still limited.

Here, we discovered new fossil materials of branchlets and seed cones in Cupressaceae *s.l.* in the upper part of the Paleocene Wuyun Formation, at Wuyun coalmine (49°14′N, 129°28′E) in Jiayin. These branchlet records contain taxa of *Metasequoia*, *Mesocyparis* sp., *Juniperus* sp., *Cupressus* sp., *Calocedrus* sp., and Cupressoideae. The cones are of *Mesocyparis* and *Metasequoia*. Our findings exhibit that the Cupressaceae plants of Jiayin experienced diversification in the early Paleocene, especially in the clade of Cupressoideae. Moreover, the newly found taxa could also provide new insights into how plants response to the environmental changes across the K-Pg transition.

KEYWORDS: Cupressaceae, diversity, Jiayin, Paleocene, environmental change

[143]

Fossil Leaves of Berhamniphyllum (Rhamnaceae) from Markam, Tibet and Its Biogeographic Implications

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A new occurrence of buckthorn fossil leaves is reported from the upper Eocene strata of Markam Basin, SE Tibet. The leaf margin is either entire or slightly sinuous. Secondary veins are regularly spaced, forming eucamptodromous venation. These secondaries exist as straight lines from midvein to near margin and then arch abruptly upward and enter into a margin vein. The tertiary veins are densely spaced and parallel, and are percurrent to secondary veins. This leaf architecture conforms with *Berhamniphyllum* Jones and Dilcher, an extinct fossil genus reported in America. Our fossils are characterized by their dense secondaries, with secondary veins on the upper half portion of the blade accounting for over 40% of all secondaries. A new species, *Berhamniphyllum junrongii* Z. K. Zhou, T. X. Wang et J. Huang sp. nov., is proposed. Further analysis shows that confident assignment among *Rhamnidium*, *Berchemia*, and *Karwinskia* can not be made based on leaf characters alone. *Berhamniphyllum* might represent an extinct common ancestor of these genera. In this study, several fossil *Berchemia* from Yunnan and Shandong are emended and reassigned to *Berhamniphyllum*. A new complex, namely the *Berchemia* Complex, is proposed based on morphology, molecular evidence, and fossil record. This complex contains the fossil leaves of *Rhamnidium*, *Karwinskia*, *Berchemia*, and *Berhamniphyllum*. Historical biogeography of the *Berchemia* Complex is also discussed in this paper. This complex might have originated in the late Cretaceous in Colombia, South America, and dispersed to North America via Central America in the Eocene. Subsequently, the complex moved from North America to East Asia via the Bering Land Bridge no later than the late Eocene. Besides, the complex migrated from North America to Europe via the North

Atlantic Land Bridge and then migrated further to Africa. In East Asia, it first appeared in Markam, the Qinghai-Tibetan Plateau, and then dispersed to other regions of Asia.

KEYWORDS: The *Berchemia* complex, *Berhamniphyllum*, Cenozoic, Qinghai-Tibetan Plateau, biogeography.

[144]

Marine Sediments in the Micropaleontology Collections of the Muséum National d'Histoire Naturelle: Overview and Potentials

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The Muséum national d'Histoire naturelle (MNHN) of Paris, France, houses collections of major importance in the history of palaeontology and particularly of micropalaeontology. The contributors of these collections are diverse, from MNHN researchers to institutions as the French Oil Institute, scientists and explorers as Jean-Baptiste Charcot, Jacques-Yves Cousteau. They gather major historical collections such as the foraminifera's of Alcide d'Orbigny, bought by the MNHN in 1858, which led the groundwork for micropalaeontology and biostratigraphy. Others paved the way to modern micropalaeontology such as George Deflandre's collection, who pioneered in the fields of algology, protistology and palaeoprotistology, or Nicolas Grekoff's material, which is a key contribution to modern ostracodology.

Besides these central collections, the MNHN also stores numerous modern marine sediments that are still not documented. Following the recent demonstration on material collected during the HMS Challenger voyage around the globe from 1872 to 1876, the sea-bottom sediments stored in the MNHN might provide snapshots to describe the changes related to anthropic influence through time and space. The MNHN preserves material collected by the Travailleur and Talisman cruises from 1880 to 1882, Pourquoi-Pas? in Rockall and Jan Mayen in 1921, Lapérouse, Astrolabe and Octant along Indochina shores in 1926, La Calypso voyage in the Red Sea in 1952, to cite only a few of them. A large project of documentation of these important collections has begun and here I propose an overview of the sea-bottom sediments stored in the micropalaeontology collections of the MNHN and their potentials for ostracodologists.

KEYWORDS: Micropalaeontology collections, Muséum national d'Histoire naturelle, marine sediments.

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A significant Discovery of Alveolina Vredenburgi from in-situ Beds across P/E Interval, Nammal Gorge, Pakistan

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The first discovery of the *Alveolina vredenburgi* from the in-situ beds of late Palaeocene-early Eocene Patala Formation, Nammal Gorge, western Salt Range, Pakistan made a significant contribution to the biostratigraphy pertaining to the Paleocene-Eocene Boundary (PEB) interval. This was confirmed by its co-occurrence within a negative shift of 1.61‰ in $\delta^{13}C$ along with the presence of the cosmopolitan dinoflagellate species *Axiodinium augustum* in Unit-2 (dominantly composed of dark grey shales). This Unit-2 overlies on unit-1 (composed of creamy and light grey thick bedded to nodular limestone interbedded with dark grey and greenish shales) and underlies to Unit-3 (yellowish, thick bedded larger foraminifera rich limestone interbedded with greenish to yellowish brown shale along with three closely spaced unconformities demarcated as U1, U2 and U3 at the top), and Unit-4 (dominantly composed of greenish grey shale), respectively. The concurrent existence of CIE along with *Axiodinium agustum* also suggests the location of topotype, which is in ≤50cm limestone bed lying 13m below the top of the Patala Formation for *Alveolina vredenburgi*, a marker species of the Larger Foraminiferal Turnover (LFT) associated to the Paleocene Eocene Thermal Maximum and PEB Tethys wide. This study also suggests that the endemic larger benthic foraminiferal species *Discocyclina ranikotensis* first appears in the earliest Eocene SBZ5.

KEYWORDS: Paleocene-Eocene Boundary, Patala Formation, Nammal Gorge, Indus Basin, Pakistan.

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[146]

Evolution of Late Paleocene-Early Eocene Larger Benthic Foraminifera and Implications for Biostratigraphy and Paleobiogeography in Eastern Neo-Tethys, Lower Indus Basin, Pakistan

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From Late-Paleocene-Early Eocene succession in the Eastern Neo-Tethys, Indus Basin, Pakistan, more than 30000 individual specimens of larger benthic foraminifera (LBF) were examined, and more than 1200 oriented thin-sections were prepared. The thin-sections were described for biometrics-based taxonomy, and five LBF families were recognized, including Orthophragminids, Alveolinidae, Nummulitidae, Miscellaneidae, and Rotaliidae. Fifty-four species of the mentioned LBF families were identified and described for biometrics-based taxonomy, biostratigraphy, and paleobiogeography. Within a single-family and genera, the species and sub-species show polygenetic and ontogenetic variations, which reveal the response of LBF to environmental changes and self-modification to adopt new environment. The identified LBF assemblages represent eleven Shallow Benthic (SB) zones (SB-3 to SB-13 zones). The SB zones of this study were correlated with central and western Neo-Tethys, and the range of many species are recalibrated.

The LBF species show a massive turnover across the Paleocene-Eocene Boundary interval. Integration of isotopes curve, biostratigraphic ages and the paleogeographic distribution indicates that the LBFs were present across the Neo-Tethys during SB 3-4 zones but restricted to low latitudes (33˚ N and 33˚ S), while across Paleocene-Eocene Boundary interval (SB 5-7 zones), LBFs extended to both hemispheres 43˚ N and 43˚ S. The lowest temperature requirement for the living LBFs is 18˚C which is hardly possible up to 34˚N and 34˚ S in the existing oceans. As a result, the habitat of extant foraminifera of similar LBF's is restricted to tropics. Therefore, the widespread occurrences of LBF's in the Early Eocene times reaching to relatively higher latitudes (i.e. 43˚ N and 43˚ S) in both hemispheres is contributed to Early Eocene warming due to which the oceans at even higher latitudes became warmer and favorable for the survival of LBFs. During SB 13, the isotopes curves show relatively cold climate and the LBF's distribution is again restricted to lower latitudes.

KEYWORDS: Larger Benthic Foraminifera, Taxonomy, Biometrics, Biostratigraphy, Paleobiogeography.

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[147]

Eocene Larger Benthic Foraminifera of the Indus Basin, Pakistan: New Developments

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The larger benthic foraminifera (LBF) of the Patala and Drazinda formations Indus Basin, Pakistan have been revaluated in the three significant localities of the Indus Basin, Pakistan including the famous Thal Section of Davies 1927 in Kohat, Nammal Gorge Section in Salt Range and Zinda Pir and Rakhi Nala sections in Sulaiman Range. Three different groups of LBF were the focus of this study, these included orthophragminids of the type-locality of *Discocyclina ranikotensis* Thal, *Heterostegina* of Sulaiman Range and alveolinids of Salt Range.

New associations of the genera *Discocyclina* Gümbel and *Orbitoclypeus* Silvestri, not yet reported from Eastern Tethys, have been found in the Patala Formation at Thal. This work validates the controversial *D. ranikotensis* as the endemic species at least to the Indo-Pakistan region. The key taxa for orthophragminids zonation in peri-Mediterranean Tethys i.e. *Discocyclina archiaci* (Schlumberger) and *Orbitoclypeus schopeni* (Checchia-Rispoli) have been found in association with *D. ranikotensis*. A few other discocyclinid specimens showing affinity to *D. dispansa* and *D. fortisi* suggesting a possible connection to western Tethys were also noted. According to the Western Tethys orthophragminids zonation, this assemblage represent orthophgragminid zone (OZ) 3. The typical western Tethyan taxa first appearing at or around the Paleocene/Eocene boundary (OZ1B/2, SBZ4/5) (e.g. assemblage of asterocyclinids, nemkovellids and ribbed orbitoclypeids) have not been identified. The occurrence of *D. archiaci* extends the geographical distribution of this taxon to Eastern Tethys, which hitherto was only known from peri-Mediterranean region.

The stratigraphic utility of Eocene *Heterostegina* in Western Tethys prompts an interest in the Eastern Tethyan domain, where virtually no information exists on this group. The classical Eocene sections, Zinda Pir and Rakhi Nala, in West Pakistan offer a unique opportunity to fill the information gap. The genus here is confined only to the upper part of the Drazinda Formation ('*Pellatispira* beds' of the obsolete Kirthar series) associating with *Pellatispira*, *Silvestriella*, reticulate *Nummulites*, rare orthophragminids and other less significant LBF. *Heterostegina* specimens are characterized by a notably small, nearly flat, to flat test, a small proloculus and tight early spirals. The early operculinid chambers, few in number, are followed by the heterosteginid stage consisting of rectangular chamberlets, developed only in the median part of the test, but not in alar prolongations. A combination of these features permits their differentiation from the Western Tethyan *Heterostegina*, also demonstrated morphometrically, and a new species, *H. indusensis* n. sp., is erected. Our data, along with the recent records of genus in tropics of Indian Ocean, show the differentiation of the Eastern and Western Tethyan heterostegines in Priabonian times and do not support a previous hypothesis that the genus was confined to the high-latitudes during this time.

The Patala Formation at Nammal Gorge was revisited with the aim to re-evaluate the larger benthic foraminiferal (LBF) assemblage. During this attempt, *Alveolina vredenburgi* Davies and Pinfold (1937) was encountered in ≤50cm limestone bed lying 13m below the top of the Patala Formation. Therefore, this study also deals with the diagnosis, age and stratigraphic significance of *Alveolina vredenburgi* Davies and Pinfold (1937) recovered from Nammal Gorge and its comparison with the specimens reported by Hottinger et al. (1998).

KEYWORDS: Larger Benthic Foraminifera, Indus Basin, Pakistan, Patala Formation, Drazinda Formation, Eocene.

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[148]

Factors Controlling Reservoir Properties of the Paleogene Lacustrine Bioclastic Mixing Deposits, Bohai Sea, China

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Lithologic reservoirs of lacustrine bioclastic mixing deposits with burial depth over 4000m are important exploration targets in the Paleogene of Bohai Sea and account for more than 300 million tons of reserves. Bioclastic dolomite and clastic rock interbedded with volcanics are the main lithologic compositions of the lacustrine bioclastic mixing deposits. Research on reservoir characteristics and sedimentary characteristics of the mixed stratum are of great significance for the lithologic reservoir exploration in Bohai Sea, China.

The study reveals that distribution of bioclastic, dolomitization of carbonate rocks and fracture development are the main controlling factors on reservoir quality of bioclastic mixing deposits. High content of bioclast is favorable to the formation of dissolved pore, organism pore and framework pore, which typically accounts for a large contribution to improving reservoir quality. Significant positive relationships exist between both the porosity and permeability and the content of bioclast. In Well QHD36-3 the average content of bioclastic of the mixed stratum is 36% during 3762-3770m，and the porosity of it is 32.66% and permeability is $489.68*10^{-3}\mu m^2$.

The interaction between bioclastic dolomite, clastic rock and volcanics makes effective effect on the prosperity of organisms and dolomitization of carbonate rocks. Multiple mafic magmatic activities brought abundant elements for prosperous of organisms and sufficient Mg^{2+} for dolomitization. The volcanic activities also provided favorable conditions for rapid biological burial. Moderate terrigenous clastic rocks mixed in carbonate rocks increased the content of silicious in dolostone, which enhanced the brittleness of rocks. The reservoir will be more easily to develop fractures when it is imposed by external force.

The Paleogene lacustrine bioclastic mixing deposits mainly distributed in carbonate beach-bar and fan delta front. As wind is the main driving force of waves and longshore currents, which play a major role on the formation of beach-bar and the enrichment of bioclast of the fan delta front. The Bohai Sea was located in the coincided zone of the western belt of the planetary wind system and subtropical high belt during the Paleogene

period. The northwest wind and north wind were dominant. On account of a large number of organisms, frequent volcanic activities and suitable climate, the Paleogene lacustrine bioclastic mixing deposits are more developed in the central and southern parts of Bohai Sea.

KEYWORDS: Bohai Bay Basin, Eocene, bioclastic, Lacustrine Mixing Deposits.

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[149]

The Early Eocene Jianglang Flora from Central Tibetan Plateau: A Missing Linkage of Paleogene Floristic Exchange in the North Hemisphere

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We reported the early Eocene Jianglang flora from Bangoin County, central QTP, which shows quite high plant diversity. In Jianglang flora, there are totally 71 fossil morphotypes in varieties of preservation forms such as leaf, fruit, seed, flower, branch and tuber. All these taxa have no longer existed in central Tibetan Plateau nowadays. Many taxa in the flora are found on the plateau for the first time, e.g., *Ceratophyllum*, *Illigera*, *Lagokarpos*, Apocynaceae and Vitaceae, giving us an opportunity to explore the plant diversity scenario at the early stage of the Tibetan Plateau. Meanwhile, some taxa also occurred in the adjacent younger flora of the Lunpola Basin, such as *Ailanthus*, *Cedrelospermum*, *Limnobiophyllum*, and *Koelreuteria*, indicating that some taxa in the community had survived in the core area of the Tibetan Plateau for at least ~25 million years. Besides, many taxa in Jianglang flora are the oldest fossil records in Asia, e.g., Apocynaceae, *Lagokarpos*, *Limnobiophyllum*, and *Cedrelospermum*, significantly improving their implications for understanding the origin and evolution of plants in the North Hemisphere. Generally, the species assemblage in the Jianglang flora is quite similar to the early-middle Eocene Green River flora in western interior USA and the early Eocene Messel flora in Germany. The floristic assemblage of Jianglang flora resembles that of the contemporaneous biota in both western North America and Europe, attesting to the significant species exchange before plateau formation, and the importance of Tibet in global biodiversity evolution.

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[150]

Variability in Sea Surface Water Temperatures and Planktic Foraminiferal Paleoecology in the Late Eocene with Individual Isotope Analyses

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Carbon and Oxygen isotopes ($\delta^{13}C$ and $\delta^{18}O$) of planktic foraminiferal calcite are widely used to estimate paleoecology. One of those examples is to infer the relative depth of habitat of each species within a water column. According to the segregation in $\delta^{13}C$ and $\delta^{18}O$, each species has been identified as a mixed layer, thermocline, or sub-thermocline dweller in the late Eocene. However, there are still some arguments about the depth of habitat since those isotope results are slightly different each other from site to site even at the same age. Those isotope analyses on foraminiferal tests have been typically conducted with 10–30 individuals for a single analysis to obtain average isotope values. However, if one mixed layer dwelling species is more abundant in summer or winter, their isotope temperatures would be skewed toward higher or lower temperatures, respectively. As a result, depth of habitat of those species would be artificially segregated. Therefore, to make paleoecological analyses more accurate, we need to identify frequency distribution of $\delta^{13}C$ and $\delta^{18}O$ of each species within a population.

Here, we present $\delta^{13}C$ and $\delta^{18}O$ of a single planktic foraminiferal test to show frequency distribution of $\delta^{13}C$ and $\delta^{18}O$ of a given species. The late Eocene 15 species within 11 genera, recovered by Integrated Ocean Drilling Program Expedition 342, Site U1411 at the Newfoundland margin, have been used for this analysis. 3 out of those 15 species (*Globoturborotalita ouachitaensis*, *Turborotalia ampliapertura*, *Subbotina angiporoides*), were selected for individual isotope analyses. For other 12 species, we conducted conventional isotope analyses, hence, approximately 10 individuals were mingled for a single isotope analysis. Average $\delta^{18}O$ of *G. ouachitaensis* and *T. ampliapertura* are comparable and show the most negative value within a community, indicating their mixed layer dwelling nature. *S. angiporoides* shows more positive $\delta^{18}O$, implying they were deep dweller. This depth segregation among these three species is consistent with previous studies. The range of individual $\delta^{18}O$, i.e., difference between the maximum and minimum $\delta^{18}O$, of *S. angiporoides* is 0.6‰, which corresponds to approximately 2˚C. This narrow range in temperature implies that *S. angiporoides* inhabited sub-thermocline depth. On the other hand, the ranges of *G. ouachitaensis*, and *T. ampliapertura* are 1.7‰, and 1.1‰, respectively, which correspond to approximately 7˚C and 4˚C, respectively. Considering these two species should be mixed layer dwellers, these temperature ranges should suggest seasonal sea surface water temperature ranges. Nevertheless, *G. ouachitaensis* and *T. ampliapertura* give different temperature ranges. We interpret this inconsistency in "apparent" seasonal sea surface water temperature ranges as a result of skewed seasonal population dynamics of *T. ampliapertura*. If we assume that the isotopic temperature ranges of *G. ouachitaensis* capture the seasonal sea surface water temperature range, the highest temperature in summer and the lowest

temperature in winter may not be recorded on the tests of *T. ampliapertura*, because they were less abundant in those seasons.

KEYWORDS: Planktic foraminifers, carbon and oxygen isotopes, Eocene, population dynamics.

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Late Oligocene Fruits and Seeds from the Nanning Basin, South China

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More than 1500 three-dimensionally preserved mummified fruits and seeds were collected from the Yongning Formation, Nanning Basin, Guangxi Province, South China. The geological age of the Yongning Formation is considered to be the late Oligocene based on the occurrence of representatives of fossil ostracods and mammals. Most of the fruit and seed specimens are clearly visualized by the use of micro-CT-scanning and tomographic reconstruction. Based on these techniques, 21 genera of 18 families were recognized so far. Fruits and seeds provide additional insights on floral composition. This flora was mainly dominated by Fagaceae which account for the largest proportion in terms of specimen quantity. The floristic component of vegetation distinctly consists of the large part of tropical and subtropical elements, including *Mastixia* (Cornaceae), *Nyssa* (Nyssaceae), *Pterospermum* (Sterculiaceae), *Symplocos* (Symplocaceae), *Vernicia* (Euphorbiaceae), *Ziziphus* (Rhamnaceae), *Annamocarya* (Juglandaceae), *Schima* (Theaceae), and *Choerospondias* (Anacardiaceae). The fossil assemblage correspond to the modern plant community in Guangxi, supporting the presence of subtropical evergreen and deciduous broad-leaved mixed forest during the late Oligocene.

KEYWORDS: Mummified, fruits and seeds, late Oligocene, Nanning Basin, subtropical forest.

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[152]

The New Early Oligocene Micromammal Record in Central Nei Mongol, China

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Middle Cenozoic terrestrial deposits with rich fossil record are widely distributed in Nei Mongol (Inner Mongolia). A series of investigations, attempted to fossil collection and biostratigraphic study, were carried out in the last 30 years or so in the central Nei Mongol. As a result, quite a number of localities with fossiliferous deposits were found, a Neogene mammal succession has been developed by faunal seriation in the central Nei Mongol, and a preliminary framework of Neogene biostratigraphy and biochronology has been established for this region. Nevertheless, Oligocene fossiliferous sediments in these campaigns in the area were only known from one locality Xiaohongshan.

Xiaohongshan Locality, discovered in 2005, is close to Aoerban, an Early Miocene locality, situated about 200 km southwest of Xilinhot. After two surface collections in 2011 and 2015, and screen washing in 2018, a number of micromammal specimens were obtained, as well as some remains of larger-sized mammals. The assemblage contains more than a dozen of isolated teeth of peradectid, the first record of marsupials in Nei Mongol. Associated with the marsupial are, Erinaceidae and Soricidae of Eulipotyphla, *Zaraalestes* (taxonomic position disputed), *Prosciurus* of Aplodontidae, *Eomys* or *Asianemys* of Eomyidae, *Heosminthus* or *Sinosminthus* of Dipodidae, *Karakoromys decessus* of Ctenodactylidae, Cylindrodontidae indet., *Tsaganomys altaicus* of Tsaganomyidae, *Eucircetodon* of Cricetidae, *Desmatolagus* of Ochotonidae, *Palaeogale* of Palaeogalidae, nearly 20 taxa in total.

The Xiaohongshan Fauna is most similar to the B assemblage of the Hsanda Gol Fauna in the Lake Valley area of Mongolia. It is correlated to the Early Oligocene micormammalian faunas reported in China, including the assemblages from the Upper Naogangdai Formation in Erlian Basin, the lower part of the Ulantatal Formation in Alxa Zuoqi, and the Wulanbulage (Ulan Prague) Formation in Haggin Qi of Nei Mongol, the lower part of the Xianshuihe Formaiton in Lanzhou Basin, and the lower part of the Paoniuquan Formation in Aksay of Gansu, the Qingshuiying Formation in Haiyuan of Ningxia, the Ulunguhe Formation in Fuyun of Xinjiang, and the upper part of the Caijiachong Formation in Qujing of Yunnan. The discovery with rich material at Xiaohongshan will not only be conducive to the study of micromammal faunas of the Early Oligocene age in China, but also supplement important information on the evolution and communication of relative taxa in Asia.

KEYWORDS: Early Oligocene, Nei Mongol, micromammals.

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Mummified Fuits of Fagaceae from the Late Oligocene of Guangxi, South China

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Fagaceae having nearly 927 living species is widely distributed in temperate, subtropical and tropical regions of both the Northern and Southern hemispheres. The fossil records suggest that the fagaceous fossils have been reported throughout the Eocene strata of East Asia, North America and Europe. In China, those from the northeastern, eastern and southwestern areas were well studied. However, the corresponding report on Fagaceae fossils from the lowest latitude of South China is limited. In addition, previous fossil records are mainly compressions. Three-dimensional preserved mummified fossil fruits are rare. In this study, we investigated abundant mummified fruits of Fagaceae from the late Oligocene of Nanning Basin, Guangxi Province, South China, including *Quercus* L. (subgenus *Cyclobalanopsis*), *Lithocarpus* Bl., *Castanopsis* (D. Don) Spach. We use CT scanning studied and reconstructed three-dimensional inner and outer characters of the fruits of *Quercus* and *Lithocarpus*. Such abundant mummified fagaceous fruits provide significant evidence for the palaeogeography of the family and implications for the reconstruction of paleoclimate and paleoenvironment.

KEYWORDS: Guangxi, Nanning Basin, Oligocene, Fagaceae, Mummified fruits.

[154]

Araucarioid Wood from the Late Oligocene–early Miocene of Hainan Island: First Fossil Evidence for the Genus *Agathis* in the Northern Hemisphere

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Although many fossil and molecular data suggest migrations from Malesia and Asia to Australia appear to dominate floristic exchange between Australian and Asian rainforests, evidence is emerging that demonstrate dispersal of plant groups from Australia to Asia. In this paper, a new species *Agathis ledongensis* sp. nov. is described on the basis of silicified wood from the late Oligocene – early Miocene of the Qiutangling Formation in Ledong, Hainan Island, South China. It is the first fossil record of *Agathis* in the Northern Hemisphere, and the only known fossil evidence of its dispersal outside of Gondwana. The close affinity of the fossil wood from Ledong with the genus *Agathis* was confirmed by comparing quantitative traits in 31 wood samples of 20 species representing all three extant genera of the Araucariaceae. The percentage of tracheids with uniseriate pitting on radial walls is shown as an additional diagnostic trait for separating *Agathis* and *Wollemia* from *Araucaria*. The wood of *Agathis ledongensis* provides evidence for the dispersal of this important plant group from Australia, or another Gondwanan terrane, to eastern Asia based on reliable fossil data. It records the occurrence of this genus in Hainan Island by the early Miocene, i.e. at the beginning of the formation of the island chains between Australia and the South-East Asia and thus the provision of a land migration route. As the land routes between these continents were restricted at that time, the migration of *Agathis* to Malesia and Asia was presumably facilitated by long-distance dispersal of its winged seeds by wind.

KEYWORDS: *Agathis*, Araucariaceae, wood identification, fossil wood, biogeography, South China.

[155]

Late Oligocene to Early Miocene Diatoms from Surface Sediments in the Central Pacific

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Since the first occurrence of the fossil record by the earliest Cretaceous, diatoms have developed to be the most abundant and diverse group of phytoplankton in the ocean. They were widely used in biostratigraphy and paleoclimatic reconstructions due to their sensitivity to environmental changes. In recent decades, there is renewed interest in global diversity patterns over the Cenozoic attributed to the establishment of the marine plankton databases, e.g., Neptune Database and World Register of Marine Species Database. Despite the existence of the two major conflicting quantitative reconstructions of total diversity using different "packed" units (e.g., morphotaxon assemblages, molecular groups, new separate catalog, clade-specific concepts, etc.), the sample size biases could never be neglected and always considered to be the challenge point owing to the nature of the sedimentary preservation of the siliceous fossils.

According to the studies of diatom diversification over geological time, a remarkable decline trend in the late Oligocene to the earliest Miocene can be told, e.g., the Rabosky-Sorhannus curve and the Spencer-Cervato curve. This trend drew less attention in comparison to the two major expansion took place at the Eocene/Oligocene boundary and during middle to late Miocene, however, more evidences suggested that a major shift in diversity like species replacement took place in the Oligocene. To refine the diatom diversity in the late Oligocene to earliest Miocene, more than 45 short column sediments from surface Paleogene-Neogene outcrops in the central Pacific Ocean were reexamined focusing on the diatom taxonomy as the first step.

Diatoms were extracted from the sediments using a special "heavy liquid + centrifugation" method to minimize the loss of diatom valves. Both light and scanning electron microscopic observations were taken for careful identification. Based on the co-occurrence of key members of diatom (e.g., *Coscinodiscus lewisianus* Greville, *C. lewisianus* var. *rhomboides* Barron, *C. lewisianus* f. *concavus* Gombos, *C. oligocenicus* Jousé, *Rocella vigilans* (Kolbe) Fenner, *Lisitzinia ornata* Jousé, *Macrora stella* (Azpeitia) Hanna, etc.) and biozone maker of silicoflagellate, *Naviculopsis biapiculata* (Lemmermann) Frenguelli, 7 of total 45 columns may be assigned to late Oligocene to early Miocene. At least one new *Actinocyclus* species was defined so far, associated with the description of its special hyaline rays (stripes). Furthermore, it provided information of the early type of pseudonodulus, and the relationship among valve diameter, number of rays and areolae density was tentatively discussed using a small dataset based quantitative analysis. The renewed investigations of the Paleogene-Neogene diatom from surface sediments could be not only the supplement of traditional deep-sea material from DSDP and ODP sites, but more available cases to expand our knowledge of the morphotaxonomy and diversity in the late Oligocene to early Miocene.

KEYWORDS: Diatom, diversity, Oligocene, central Pacific, *Actinocyclus.*

[156]

A New species of *Ormosia* (Leguminosae) from the middle Miocene of Fujian, Southeast China and its biogeography

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The Leguminosae are the third–largest angiosperm family with crucial floristic and ecological importance in major biomes, especially in tropical rainforests. However, reliable fossils of the family are not common in East Asia, rendering a poor understanding of the diversification and biogeographic history of the Leguminosae in this region. In this paper we described a new species of *Ormosia* (Leguminosae: Papilionoideae) based on compressed fruits (legumes) from the middle Miocene of Fujian in southeastern China. *Ormosia* zhangpuensis sp. nov. is an obovate to broadly elliptical fruit with acuminate apex, and constricted, neck–like base. Each fruit contains one single seed. External cuticle of pericarp has trichome bases and randomly oriented, anomocytic stomata. The studied fossils provide a new evidence for the diversity of the Leguminosae in East Asia during the Neogene. Fossil records also indicate that *Ormosia* had expanded its distribution southwards, probably in response to the global climatic cooling during the Cenozoic.

KEYWORDS: *Ormosia*, middle Miocene, Fujian, pod, biogeography.

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[157]

Unlocking the Mystery of Tibetan Orographic Evolution: Palaeontology is the Golden Key!

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There was no such thing as the 'uplift of the Tibetan Plateau'. Plateau uplift is a false concept born of simplistic Earth systems modelling, but is often invoked to explain Miocene monsoon intensification and phylogenetic diversification. The Tibetan region grew piecemeal in elevation and extent through several successive accretions of Gondwanan terranes beginning in the early Mesozoic. By the time the India-Eurasia collision began at ~55 ±10 Ma Tibet already exhibited complex relief with high (> 4.5 km) Gangdese mountains across its southern margin, separated from northern Qiangtang Terrane highlands by a wide (~ 600km) forested lowland ≤ 2 km above sea level. Late Paleogene South-North compression from the India-Asia collision narrowed the enclosed central Tibetan valley and, together with infilling of sediment from the bounding mountain ranges, raised the valley floor by several kilometres. Compression also extruded the Qiangtang Terrane eastward raising eastern Tibet and the Hengduan mountains, where near-modern elevations were attained by the late Eocene. This extrusion also created numerous pull-apart basins across Yunnan whose fossils record Eocene to Present climate and biotic change. Neogene infilling of Tibetan intermontane basins formed today's high plateau, while the Himalaya rose against Tibet's southern margin. To understand Tibetan orographic development has required new approaches to analysing palaeontological data. Here we show why many existing isotopic palaeoaltimetry results for central Tibet are misleading and how radiometrically-dated fossil finds, coupled with isotope and vegetation-enabled climate models, are transforming our knowledge of the links between orography, climate and biodiversity.

ACKNOWLEDGMENTS

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[158]

Fossil Fruits and Seeds from the Cenozoic of Northeastern Thailand

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A series of commercial sandpits in Chaloem Phra Kiat District, Nakhon Ratchasima Province, Northeastern Thailand, have yielded numerous fossils from middle Miocene to late Pleistocene in age. Most of the fossils studied have been vertebrates, especially mammals, with publication of 3 new species, an orangutan, hornless rhinoceros, and anthracothere, and reports of ten genera of proboscideans. However, little study has been made of plant macrofosssils. Recently fruits and seeds were collected from a lower level of Phra Phut sandpit in Phra Phut Subdistrict of Chaloem Phra Kiat District, a deposit thought to be late Miocene or younger in age based on the presence of an elephant jaw. A combination of approaches has been used to investigate these fossils, including synchrotron radiation X-ray microtomography and scanning electron microscopy. Five endocarps with 2 locules and 2 basal plugs could be identified as *Parinari* (Chrysobalanaceae), a species occurring today in tropical Asia, Africa, and the Americas. Isolated vitaceous seeds are similar to *Tetrastigma* (Vitaceae), a genus found at present in Asia and Australia. A single endocap with an elongate valve may have affinity to Icacinaceae. Attempts at identifying additional specimens are in progress. In addition to fruits and seeds, bamboo stems and

rhizomes are common. Study of plant macrofossils in coordination with study of vertebrates and pollen will enable a more complete reconstruction of past environments and climates.

KEYWORDS: Fruits, seeds, Chaleom Phra Kiat, *Parinari*, *Tetrastigma*, Thailand.

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This research was supported by the Northeastern Research Institute of Petrified Wood and Mineral Resources, Nakhon Ratchasima Rajabhat University, and the Synchrotron Light Research Institute.

[159]

Planktonic Foraminiferal Biostratigraphic Correlation on the Brownish Claystone in Three Sites from the Deep Basin of the Northern South China Sea

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The IODP have executed 3+1 expeditions (IODP349, 367/368/368X) in the deep basin of the South China Sea, and have all encountered brownish claystone during the Miocene stratum. Are these brownish claystone have the same cause of formation? Are they belong to the same age is still unknown. Here we try to make a correlation of these brownish claystone deposits using planktonic foraminiferal and benthic foraminiferal comparison on three sites (U1500, U1502, U1503) from the northern South China Sea. We found the brownish claystone deposits show a very good correlation in foraminiferal composition changes in the three sites. It can be generally divided into two layers: the upper part is barren of planktonic foraminifera, only with few sporadic deep water agglutinated benthic foraminifera; while the abundance of planktonic foraminifera is relatively high in the lower layer. Apart from deep water agglutinated benthic foraminifera, all the planktonic foraminifera are allochthonous supported by the common appeared upper slope benthic foraminifera, make the planktonic foraminiferal biostratigraphy more uncertainty. The thickness of these brownish claystone deposits thinning from the north to the south, indicating the main sediment source possibly come from the north direction. The young sand claystone deposits (<15 Ma) below the brownish deposits in the 54R and 56R of Site U1500 may possibly suggest the brownish claystone deposits are mainly formed during the middle Miocene.

[160]

The Oldest Known Bovid from China and Reappraisal of the Chinese "*Eotragus*"

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The bovid material from Xishuigou, Tabenbuluk Area, Gansu Province, China, is described here. The type material of "*Eotragus*" *halamagaiensis* from the Halamagai Formation, Junggar Basin, Xinjiang Uygur autonomous region, China is reviewed as well. Both should be attributed to *Turcocerus halamagaiensis* comb. nov. The short and almost straight horncores with concave anterior margins and convex posterior margins are similar to the morphology of the genus *Eotragus*. However, the slight homonymous twisting (visible in the course of the anterior rib) and well-developed posterior and posterolateral grooves on the horncores, as well as a weaker inclination than in *Eotragus*, indicate a closer affiliation to the genus *Turcocerus*. The short lower cheek teeth with a considerably shortened premolar row further infer the assignation of the material from Xishuigou to *Turcocerus*. Thus, there is no reliable representative of *Eotragus* in China. The record of *Turcocerus* from Xishuigou, dated to the late early Miocene, might be the oldest known and indicates that the genus *Turcocerus* could originate from China. The biostratigraphic position of *Turcocerus* also demonstrates that the dispersal events from China to Turkey and from China to Mongolia may have taken place in the late Shanwangian and the late Tunggurian, respectively.

KEYWORDS: China, late early Miocene, Xishuigou, *Turcocerus*, horncore.

[161]

Variation in Middle-late Miocene Sedimentation Rates in the Northern South China Sea and Its Regional Environmental Implications

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Three International Ocean Discovery Program (IODP) expeditions (349, 367 & 368) were dispatched during 2014-2017 to the South China Sea (SCS). Though the main objective focuses on the complex patterns of continental margin breakup and basin formation, the thick sediment sequences fueled by high sedimentation rates provide excellent materials for further advancing our knowledge of the paleoceanographic and environmental evolution of the SCS and southeast Asia during the Cenozoic.

Calcareous nannofossils were used to establish a detailed biostratigraphic framework for sediments at Site U1501 (water depth: 2845.8 m) drilled during IODP Expedition 368. All samples contain abundant, well- to moderately well-preserved calcareous nannofossil assemblages, with 89 taxa and 32 datums observed. The plot of age vs. depth of nannofossil datums reveals a dramatic variation in sedimentation rates during the middle-late Miocene (ca. 15~5 Ma). The sedimentation rate was 27.3 mm/kyr during 15-13.3 Ma, dropped to 10.9 mm/kyr during 13.3-10.6 Ma, essentially ceased during 10.6-9.2 Ma, but resumed to 4.2 mm/kyr during 9.2-5.5 Ma and then increased drastically to 26.7 mm/kyr afterward. Most interesting is the apparent 1.4-Ma-long hiatus during 10.6-9.2 Ma, which coincidently corresponds to the regional tectonic uplift named Dongsha Movement and the globally distributed "carbonate crash". *Discoaster hamatus* had a full range of 10.6-9.5 Ma. Its occurrences in the hiatus interval implicate that the Dongsha Movement occurred at 9.2 Ma instead of 10.6 Ma, which appears to have caused massive erosion removing the sediments along with *D. hamatus* specimens deposited during 10.6-9.5 Ma, while uplifting at 10.6 Ma would have resulted in nondeposition and consequently no occurrence of *D. hamatus*.

KEYWORDS: Calcareous nannofossil; Dongsha Movement; South China Sea; International Ocean Discovery Program (IODP).

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[162]

Stratigraphy of IODP Site U1505 in the Northern South China Sea based on Planktonic foraminiferal Bio-events and Benthic Foraminiferal Oxygen Isotope since the Late Miocene

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Site U1505 during the IODP Cruise 368 in the northern margin of the South China Sea disclosed relatively continuous Cenozoic sedimentary sequences since the Early Oligocene (Jian et al., 2018). In addition to the shipboard bio-stratigraphic results, this study chooses the well-preserved upper 143 m (CCSF) core samples with a high-resolution of 10 cm interval to refine the stratigraphy based on the benthic foraminiferal oxygen isotope analyses.

~1500 samples were washes and benthic foraminiferal specimens (*Cibicides wuellenstorfi* or *Cibicides* spp.) were picked up to perform the stable oxygen isotope measurement at Nanjing institute of Geology, Chinese Academy of Sciences. We select specimens large than 300 μm, if possible. The precious ~1400 benthic foraminiferal Oxygen isotopes provide accurate stratigraphy subdivision together with the close-check of the planktonic foraminiferal bio-event. A higher resolution data (2 cm) of the magnetic susceptibility were adopted as the supplement to the oxygen isotope stage subdivision. Based on planktonic foraminiferal bio-events and benthic foraminiferal Oxygen isotope, the 143 m-core of upper U1505 disclosed a high-resolution sedimentary history of the northern South China Sea over the last 6 Ma, which provides a reliable chronological frame of the climatic and paleoceanographic evolution.

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[163]

The Neogene Marine Biota in Kilju-Myongchon Area of DPRK

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Kilju-Myongchon area of DPRK contains the marine strata of Neogene, Cenozoic, and these strata have abundant marine organisms. In this area, it is distributed from lower Miocene to Pliocene strata, especially, since they consist of the Miocene marine strata, marine organisms are very abundant. In this area, most of the Miocene strata are mainly distributed in the Kilju-Myongchon rift valley, some are distributed in Mt. Chilbo horst valley. The Miocene marine strata of this area is named as Kilju Group, it consists of Phyongryuk, Hamjin and Kumso Formations, and these formations consist of clastic rocks, including sandstones, siltstones, conglomerates. And, these formations contain many marine organisms including bivalves, gastropods, fishes, foraminifers and so on. Especially, *Ostrea* of above 10cm in length are very extensive.

Main fossils found in this area until now, are as follows; Bivalves: *Acila submiravilis*, *A. miravilis*, *A.* sp., *Arca(Anadara) abdita*, *A.(Anadara) daidokudoensis*, *Anadara ogawai*, *Glycimeris yessoensis*, *Chlamys swiffi*, *C.* sp., *Venus* sp., *Cardita ferruginea*, *Cyrtodaria kurriana*, *Nemocardium rasmylovae*, *N. karaftoensis*, *Nucula aralensis*, *Nuculana* sp., *Panope generosa*, *P. japonica*, *P.* sp., *Macoma optiva*, *M. truncatoides*, *M. lacumensis*, *Martesia striata*, *Laevicardium shinjense*, *Phacoides acutilineata*, *Thyasira crassiusola*, *Genota crtptoconoides*, *Mya truncata*, *M.* sp., *Taras kavranesis* , *Pecten akitanus*, *Prototheca* sp., *Lima goliath*, *Tellina* sp., *Solen krusensterni*, *Ostrea gracitesta*, Gastropoda: *Batilaria yamanarry*, *B. tateiwai*, *Cerithium meisense*, *Trochoceritium* sp., *Potamides kampokuensis*, *Nassarius simizui*, *Vicarya callosa*, *Jonnisisella meisensis*, *Monilea* sp., *Lineardia* sp., *Antalis* sp., *Polimices meisensis*, *Natica meisensis*, *Searlesia kurodai*, *Genota cryptogomnoides*, *Cannceuaria kovayashii*, *C.* sp., *Dentalium conlexum*, *D. corocinum*, *Melania* sp, *Viviparus marharyacformis*, foraminifers: *Globobulimina pacifica*, *G. ovata*, *Haplophragmoides inaentatus*, *Martinottiella communis*, *M. bradyana*, *Plectina nipponica*, *Bathysiphon edurus*, *Cyclammina japonica*, *C. ezoensis*, *C. pilvoensis*, *C. pyonglukriensis*, *C. girchunica* , *Budashevella desertus*, *B. laevigata*, *Dorothia paupercula*, *Glandulina laevigata*, *Sphaeroiaina bulloides* etc.

Since marine organisms of this area are very diverse, productive, and various fossils are concentrated into definite zone, these fossils have very important significance in studying Miocene marine organisms and in resolving distribution feature of them.

KEYWORDS: Neogene, marine biota, Kilju-Myongchon.

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[164]

Early Pleistocene Oceanographic Changes around the Pacific Side of Japan based on Oxygen Isotope Analysis and Calcareous Nannofossil Assemblages

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The Mid-Pleistocene Transition (MPT) is the well-known interval (approximately 1250–700 ka) that Earth's climate cycles changed from 41 ky to quasi-100 ky rhythms (e.g., Elderfield et al., 2012). Asymmetrical climate fluctuations between the glacial and interglacial times established during this interval (Head and Gibbard, 2015). The Kazusa Group, distributed in the central part of the Pacific side of the Japanese archipelago, is the Lower–Middle Pleistocene forearc basin-fill sediments. The Group is suitable for high-resolution paleoceanographic researches because its sedimentation rate is very high (ca. 1–2 m/ky on average) (Kazaoka et al., 2015). This study will discuss sea-surface environmental changes during the Early Pleistocene around the central part of the Pacific side of Japan based on calcareous nannofossil assemblages and oxygen isotope analysis. We analyzed stable oxygen isotopes of a planktonic foraminifera *Globorotalia inflata* and benthic foraminifera *Uvigerina* spp., *Bulimina* spp., and *Bolivinita quadrilatera*. Oxygen isotopic measurements were conducted using MAT253 with a Kiel IV carbonate. At the same time, relative abundances of calcareous nannofossils were examined based on the usual counting method, and also separate counts for subordinate taxa, except for *Gephyrocapsa, Reticlofenestra, Florisphaera,* and *Pseudoemiliania*, were applied to obtain data for environmental changes.

The average value of benthic $\delta^{18}O$ is approximately 0.6 ‰ smaller than those of the LR04 stack. Based on the graphic correlation with the standard stack curve by LR04 (Lisiecki and Raymo, 2005), Marine Isotope Stages (MIS) 41 to 36 were recognized in the examined section. Sequential fluctuations of planktonic $\delta^{18}O$ and relative abundances of *Florisphaera profunda* (stratified, warm, and offshore index) resembles to those of benthic $\delta^{18}O$. It means that the glacial-interglacial climatic changes controlled the movement of the past Kuroshio front. Sudden change in calcareous nannofossils, dominances from a cold-water taxon, *Coccolithus pelagicus*, to a warm water taxon, *Umbilicosphaera sibogae,* was observed within ten ky immediately after MIS 38/37 boundary. Because planktonic $\delta^{18}O$ values concordantly became the largest in this interval, the rapid warming of the surface to subsurface ocean environments was suggested. In the lower MIS 36, subsurface and bottom water masses may be slightly warm due to smaller values of planktonic and benthic $\delta^{18}O$ profiles.

KEYWORDS: Calcareous nannofossils, Oxygen isotope analysis, Paleoceanography, Kuroshio.

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[165]

The Transition Zone between Palearctic and Oriental Realms in China: the Most Important Source Area for Human and Other Mammalian Fossils

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The eastern part of the boundary between Palearctic and Oriental realms occurs in China, which corresponds approximately with the physical topography along the Qinling Mountain and Huaihe River; whereas the boundary is not always a clear-cut; most of the time, it was a transition zone instead. During the past decades in China, most of the important finds of ancient human remains associated with rich mammalian fossils were from the Transition Zone, such as the Bailongdong, Hexian, Yunxian, Longyadong, Tangshan at Nanjing and Hualongdong. Concerning the question why the Transition Zone concentrated so many ancient human remains, there should be two answers: it can be attributed to the suitable environment for human inhabitation during Pleistocene or it's just because of a good post-mortem condition for fossil preservation.

KEYWORDS: Transition Zone, ancient human sites, mammalian fossils, Pleistocene, China.

[166]

High-Resolution Sea Surface Temperature and Salinity Dynamics in the Northern Okinawa Trough over the Last 24 kyr

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Based on the high-resolution Mg/Ca and oxygen isotope ratio ($\delta^{18}O$) of planktonic foraminifera *Globigerinoides ruber*, sea surface temperature (SST) and salinity (SSS) were reconstructed in Core PC-1 from the northern Okinawa Trough during the last 24 kyr. From the last glacial maximum to Holocene, SST varied from 20.2 to 24.6 °C. Millennial-scale climatic events of the SST during the last glacial, such as the Heinrich events, Bølling-Allerød warming and Younger Dryas, have been identified, which are synchronous with the climate changes in the North Atlantic, suggesting a teleconnection between the northwestern Pacific and the North Atlantic. During the last 24 kyr, the SSS variation can be divided into three parts: (1) during 21-15.5 ka, there was a significantly low SSS; (2) during 15.5-11.7 ka, the SSS increased obviously; (3) since 11.7 ka, the SSS is relatively stable. In

order to discuss the main factors influencing the SSS in the northern Okinawa Trough, the relative abundance of *Pulleniatina obliquiloculata* and the oxygen isotope difference between the northern and middle Okinawa Trough ($\Delta\delta^{18}O_{sw}$) have been used to indicate the intensity of the Kuroshio Current and Changjiang freshwater discharge, respectively. The $\Delta\delta^{18}O_{sw}$ result shows that there is a large amount of Changjiang freshwater emptied into the northern Okinawa Trough during 18-15.5 ka, which is caused by the subtropical monsoon rain band lingering in the lower reaches of the Changjiang River drainage, supporting the Jet Transition Hypothesis. As the Kuroshio Current strengthened since 15.5 ka which is indicated by the increased relative abundance of *P. obliquiloculata*, the variation of Kuroshio Current became the more important contribution to the SSS in the study region. The results of our study indicated that the key factor influencing the SSS in the northern Okinawa Trough is variable during the last 24 kyr.

KEYWORDS: Planktonic foraminifera, Kuroshio Current, East China Sea, Millennial-scale climatic events, East Asian summer monsoon.

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Paleoecology of the Late Cenozoic Giant Scallop Collected from the Seafloor of the Western Coast of Kyusyu Island, Japan

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A giant scallop, *Mizuhopecten kamagai* (Nagasawa, 1965), was dredged by fisherman's coral net from the seafloor of the western coast of Kyushu Island in the East China Sea. Surprising thing is that the scallops were huge enough to have never seen in Japan. Shell size of the holotype specimen shows 280 mm in length and 270 mm in height. Then, the scallop was described as a new species of the genus of *Mizuhopecten* by Dr. Joji Nagasawa in 1965. However, because exact location, water depth and its occurrence age are not apparent, this giant scallop has not been examined for a long time. In this study, we tried to reconstruct the paleoecology of the giant scallop on the basis of the stable oxygen isotope analysis, the radiocarbon dating, and identification of the bryozoa attached to the shell.

Radiocarbon age of the holotype and paratype specimens are 25,080-24,750 calBP and 18,010-17,820 calBP, respectively. Their geologic ages are around Last Glacial Maximum (LGM) in the latest Pleistocene. The sea-level in this stage was 120 m lower than the present. Results of the oxygen isotope analysis show that the paratype shell records seven seasonal fluctuations which are ranging from 1.38 to 4.31 per mil. This result indicates that the age of the specimen is only seven despite huge shell size. Though other fossil and recent species of Mizuhopecten group around Japan reach about 150 mm in shell height in seven years, the giant species reach that size in 1-2 years. In fact, the hugeness of the shell is not dependent on the longevity but on the extreme shell growth rate. On the composition of bryozoan species, 13 species are identified (Arakawa, 2014), and it shows that water depth was 100 to 150 m. Considering the sea-level in the LGM, the habitat of the giant scallops was estimated to be a shallow marine of subtidal to 30 m in depth.

Such a huge scallop is not known in the late Cenozoic in the East China Sea. However, considering paleobiogeography of *Mizuhopecten* group in this area, there is a possibility that *M. tokyoensis* have evoloved into the giant species. Most of the continental shelf of the East China Sea became land due to regression in the LGM, and it seems that the low salinity environment spread into the near Kyushu Island by the Cangjiang River

from the Asian continent. This environmental change may be one of the factors for this enlargement of this scallop.

KEYWORDS: Paleoecology, late Cenozoic, Pleistocene, scallop, Bivalvia, off Kyushu Island, East China Sea.

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[168]

Microbial Lipids Indicative of Quaternary Hydroclimate Change in China

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Microbial communities show sensitive responses to the changes of Earth environments and climate, and microbial lipids are thus widely used to reconstruct the environmental conditions in Earth history. Significant progress was made in the reconstruction of paleo-temperature on the basis of microbial lipids, such as the well-known algal unsaturated ketones, the archaeal glycerol dialkyl glycerol tetraethers (GDGTs), and the bacterial GDGTs. However, it remains unknown if the microbial lipids could be used as proxies of hydroclimate or hydrological conditions in ancient times. Hydroclimate exerts an important impact on the terrestrial ecosystems, and thus it is of significance to deciphering the evolution history of hydroclimate change or to identifying the extreme hydroclimate events such as the regional drought or flooding, in particular in China dominated by the monsoonal climate in modern days and in ancient times.

For years, we tried to develop a series of microbial proxies of hydroclimate which could be applied in terrestrial archives including loess-paleosol sequences, peat deposits, lacustrine sediments, as well as stalagmites (Xie et al., 2013; Tang et al., 2017; Wang et al., 2018). Here two examples from loess-paleosol sequences and peat deposits will be presented to show the potential of microbial lipids proposed in the identification of both the megadrought events in Northwest China and the hydroclimate changes in the last deglaciation in East China. The reconstruction of hydroclimate condition by the microbial lipids, together with some other records (Zhu et al., 2017), enables to identify the new dynamic processes driving the water cycle in the terrestrial settings of both Northwest and East China (Tang et al., 2017; Zhang et al., 2018). These microbial lipid records greatly help decipher water cycling in Earth surface system.

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[169]

Quaternary Vegetation Changes in Southern China

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In order to reveal the changes of vegetation in southern China since the Last Glacial Maximum, we have established palynological sequences of borehole profiles in high-resolution time by drilling cores in some weak areas of the research to reconstruct vegetation changes over the past 20,000 years. This paper focuses on the vegetation zoning maps of 18, 9 and 6kaBP respectively in southern China, and describes the distribution characteristics of plants in different zones/subzones. The results show that the vegetation zonations around 18kaBP were significantly different from that at present. It appeared in turn with Cold-temperate coniferous forest and alpine meadow steppe zone, and Temperate mixed coniferous and broad-leaved forest zone/warm temperate deciduous broad-leaved forest zone from northwest to southeast in the west, and Temperate mixed coniferous and broad-leaved forest zone, Warm temperate deciduous broad-leaved forest zone, and Northern subtropical mixed evergreen and deciduous broad-leaved forest zone from north to south in the central and east. The vegetation distribution around 9 kaBP changed distinctively. Except that the northwest part was located in Mountain temperate mixed coniferous and broad-leaved forest zone, the vegetation in other areas occurred in turn with North subtropical mixed evergreen and deciduous broad-leaved forest subzone, Mid-subtropical typical evergreen broad-leaved forest subzone, and South subtropical monsoon evergreen broad-leaved forest subzone/Tropical seasonal rainforest and rainforest zone from north to south. There was little change in the appearance of vegetation zonations between 6 and 9kaBP, but the northern edge of each vegetation belt moved a little northward, reflecting that the overall climate became warmer around 6 kaBP. The vegetation changes in southern China over the past 20,000 years were largely driven by environmental changes. Climate change was the main factor affecting the vegetation distribution. The impact of human activities became more and more remarkable in the later period. In the lower reaches of the Yangtze River and the delta region, sea level changes also influenced the vegetation distribution.

KEYWORDS: Vegetation changes, 18 ka BP, 9 ka BP, 6 ka BP, Environmental change, Southern China.

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BrGDGTs in Deep See Sediments: Potential for Reconstructing Changes in Deep Ocean Carbon Reservoir?

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Branched glycerol dialkylglycerol tetraethers (brGDGTs) are ubiquitous in marine environments. However, whether they are derived from terrestrial soils or produced in situ is unclear. Here, we report data of brGDGTs in sediments and suspended particulate materials (SPM) in surface waters in the East China Sea (ECS) and the South China Sea (SCS). $\#Rings_{tetra}$ values of brGDGTs in SPM increase offshore, suggesting increasing marine produced brGDGTs offshore. The offshore increasing trend of $\#Rings_{tetra}$ occurs also in shelf surface sediments. However, the offshore increasing trend in core-top sediments of SCS ceases at water depth ca. 100 m and turns to constantly low $\#Rings_{tetra}$ values at sites deeper than 780 m. Instead of interpreting the low $\#Rings_{tetra}$ values in deep-sea sediments as results of more contributions of terrestrial derived brGDGTs, we propose brGDGTsin deep-sea sediments are in situ produced. Lower pH values in deep-sea bottom water and sediment porewater than in seawater column could be the reason for the low $\#Rings_{tetra}$ values. We thus propose that reconstructed pH in deep-sea sediments cores (e.g., >1000 m water depth) with little terrestrial influences should reflect pH changes in marine bottom environments. Such pH changes are valuable for understanding changes in deep ocean circulation carbon reservoir, and hence global carbon cycle in the past.

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Case Studies on Late Paleolithic Vegetation and Climate in Yunnan, SW China

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Late Paleolithic sites are well documented in Yunnan Province, SW China, which give us opportunity to reconstruct vegetational and climatic background for the early human beings before the occurrence of agriculture. In the paper, we will give two case studies, including Xiangbidong site and Naminan site. The Xiangbidong site is located in Hengduan Mountains, the first cave relic found in Jianchuan County. The Naminan Site is located in the west of Luoguo Mountain, Xishuangbanna Dai Autonomous Prefecture.

Pollen study on the Xiangbidong site recovers abundant palynomorphs in two stages, indicating a changing process of vegetation and climate. It reveals that during 100-75 Ka BP the site was under a warm and humid climate condition represented by abundant *Nyssa* and *Pinus* at first, and followed with a short dry period indicated by a distinct occurrence of Chenopodiaceae. The warm and humid climate condition mostly recognizable by *Nyssa* and *Fagus* was then resumed again. It is in consistent with the climate condition in the last interglacial period (MIS 5). At about 11 Ka BP, *Nyssa* and *Fagus* became the maximum which is accompanied by *Cyclobalanopsis*, representing a much warmer climate condition in the postglacial period.

The Nanminan site is located in a karst cave, and pollen are not well preserved. Instead, rich phytoliths are found from the archaeological layers with six recognizable phytolith zones. According to the warm index and humid index of the phytoliths, it infers that the Namini site experienced a process of climate changes with warm and humid at first, and followed by cold and dry, cool and humid, cool and dry, cold and dry, and warm and humid conditions during 23 Ka BP-10 Ka BP, which is more or less comparable with the global changes at that time.

Taking into the account of high woody pollen value on the whole at the Xiangbidong site, the signal for human activities during the two separated stages was still weak. Meanwhile, both sites show no evidence for cultivated plant in the fossil assemblages, gathering, hunting and fishing are considered as the human being's main approaches for living. Palm-type phytoliths are very rich in most of the phytolith assemblages at the Nanminan site which might indicate an enhanced human activity.

KEYWORDS: Vegetation and climate, Xiangbidong site, Naminan site, Late Paleolithic, Yunnan.

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[172]

Modern Shallow Water Radiolarians with Photosynthetic Microbiota in the Western North Pacific

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We analyzed plankton samples from waters shallower than 200 m at 30 stations in the western North Pacific. A total of 328 taxa, including morphotypes, were identified from 2,091 specimens. The fluorescence patterns were mainly classified into five groups: R&D, R-G, Y-B, Periph-R; and Pale-R. There were 37 species/morphotypes with the R & D pattern in the orders Collodaria, Entactinaria, Nassellaria, and Spumellaria. The R-G and Y-B patterns were confirmed in only four species (*Dictyocoryne profunda*, *D. truncata*, *Spongaster tetras tetras*, *S. tetras irregularis*) of our identified 328 taxa, suggesting a strong species-specific effect on the presence of PE-

containing *Synechococcus*-type cyanobacteria. In the Periph-R pattern, red fluorescence is emitted from the peripheral part inside flat spumellarians, suggesting that the source of this pale red fluorescence is photosynthetic organisms digested by radiolarians. Many taxa belonging to Acanthodesmiidae and *Lophospyris* have a great number of symbiotic dinoflagellates outside the central capsule. However, Acanthodesmiidae include non-photosynthetic holobionts (*Amphispyris* and *Ceratobotrys borealis*), suggesting different environmental adaptability to some acanthodesmiid species. In contrast with the obligate symbiosis tendency in Acanthodesmiidae, Lophophaenidae tend to have non-photosynthetic holobionts. In Spumellaria, one significant tendency was recognized in *Tetrapyle* and *Phorticium* as obligate dinoflagellate holobionts. Thus, *Tetrapyle* and *Phorticium* are useful for tracing oceanographic conditions in the euphotic zone. *D. truncata* and *D. profunda* are classified into the R-G pattern, whereas *D. muelleri* was grouped into the R&D pattern, indicating that the difference in the photosynthetic association may be closely related to the floating depth. The Q-mode cluster analysis showed that the 30 stations were classified into four clusters: A1, A2, B, and C. The geographical distributions of the four cluster groups are consistent with the climate zone and water masses, suggesting that the species composition of these shallow taxa is influenced by the distribution of water masses. In particular, the Kuroshio Current may play an important role in the migration of shallow living radiolarian species from the subtropical climatic zone to the subarctic climatic zone.

KEYWORDS: Living Radiolaria, fluorescence, latitudinal distribution, water masses, western North Pacific.

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An Indian Geoheritage Site: Siwalik Fossil Park, Saketi (Himachal Pradesh)

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The Siwalik rocks forming the foothills are low hill ranges lying between the high Himalayas and the plains in the Indian subcontinent. These hills are made up of clays, silts, sandstones and conglomerates brought down between 16 and about 0.6 million years ago, by numerous fast flowing rivers coming from the then rapidly rising mountain mass to the north. The Siwaliks represent about 6000 m of sedimentary sequence deposited in the flood plains of the area now occupied by the foot-hills of Himalaya. Siwalik rocks of Indian subcontinent are famous worldwide among the geoscientists for the large variety and number of vertebrate fossils mainly mammals entombed in these sediments. In addition to mammalian fossils, fossils of fish, few amphibian, snakes & birds, crocodiles, tortoises, molluscan shells, leaf impressions & fossil wood have also been recovered from Siwalik rocks. Certain sections are richly fossiliferous than the others.

The Markanda valley with its natural grandeur, richness of fossil vertebrates and unique geological set up is a mini representative of the vast Siwalik region where rocks from Middle Miocene to Lower Pleistocene are exposed.

Geological Survey of India declared a geosite (covering an area of about 1.5 sq.km.) in Siwaliks exposed in Markanda valley at Saketi in Sirmaur district of Himachal Pradesh as geological monument in 1974. Siwalik Fossil Park, Saketi has been developed by the Geological Survey of India, in collaboration with the Himachal

Pradesh Government. It is a significant step towards preservation of prehistoric animal sites, restoration of their natural environment and utilisation of the same for scientific, educational and recreational purposes. The park displays life-size fibreglass models of six of the vertebrates that thrived in the area about 1 to 1.5 million years ago; their fossilized remains were recovered from Saketi and neighbouring areas. Many spectacular fossil specimens of fossil vertebrates have been exhibited in a museum within the park. These fossils include skulls, jaws, teeth, horn cores, limb bones, vertebrae, scutes, etc. of elephants, hippopotamus, rhinoceros, giraffes, camels, suids, horses, bovids, rodents, fish, crocodiles, tortoises, etc.

KEYWORDS: Geoheritage, Siwalik Fossil Park, Museum.

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[174]

Biological Differentiations of Foraminifera by Test Types in Response to Temperature Rise Using Modern Techniques

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Sea water warming is an important environmental pressure faced by the current marine ecosystem. Foraminifera is known as the thermometer of the ancient ocean. However, what are the biological characteristics and mechanism of the responses of foraminifera to the temperature change are still unknown. A series of laboratorial (6-30 °C) and on-board (24-33 °C) culture experiments were designed by using the new techniques of in vivo culture and molecular biology. The results show that: 1) the increase of temperature can lead to the change of the whole community structure of planktonic and benthic foraminifera, but there are adaptability differences for the critical value of temperature: the shipboard culture experiment of planktonic foraminifera shows that the community parameters As the temperature increased to 27 °C, it increased, and then began to decline; as for benthic groups, community parameters kept increasing with the temperature increased from 6 °C to 18 °C/24 °C, and continued to rise, and finally porcelain shells increased, transparent shells decreased. 2) the growth rate of each type of foraminifera was significantly increased by the increase of temperature ($P<0.05$), which showed that the length to width ratio of single species increased, but the length to width ratio decreased, and the mortality

increased. The maximum feeding rate (~ 18 °C) of porcelain shell was higher than that of transparent shell (~ 12 °C). Our results suggest that the number of foraminifera of various types will decrease under global warming, but the benthic group is more tolerant to temperature than the planktonic group. In the range of temperature tolerance, foraminifera may gradually increase their body shape and reduce the aspect ratio. The sensitivity to temperature is plankton > benthic transparent shell > benthic porcelain shell. When the temperature is higher than the tolerance temperature, the ability of resistance to temperature of benthic porcelain crusts is stronger, transparent crusts will be less and less, and planktonic groups may evolve or disappear rapidly.

KEYWORDS: Global warming, Planktonic foraminifera, Benthic foraminifera, Temperature.

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Chemical Composition of N-Alkanes and Microbially Mediated N-Alkane Degradation Potential Differ in the Sediments of Qinghai-Tibetan Lakes with Different Salinity

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N-alkane-based proxies are widely employed to reconstruct paleoclimate and paleoenvironment in lacustrine environments. However, little is known about the influence of microbially mediated alkane-degradation on *n*-alkane-derived proxies. In this study, the chemical composition of *n*-alkanes and microbially mediated *n*-alkane degradation potential were investigated in the surface sediment samples collected from seven lakes with a range of salinity from freshwater to salt saturation on the northern Qinghai-Tibetan Plateau (QTP). The results showed that the chemical composition of *n*-alkanes differed among the studied QTP lakes. Significant correlations were observed between salinity and some *n*-alkane-based paleoclimate and paleoenvironment proxies, such as ratio of C_{21}^{-}/C_{22}^{+}, average chain length (ACL) and carbon preference index (CPI). This suggested that salinity may affect the validity of some *n*-alkane-based paleoclimate and paleoenvironment proxies. Alkane-degrading bacteria were abundant and widespread in the studied freshwater and saline/hypersaline lakes but were minor or absent in salt-saturation lakes. The obtained alkane-degrading bacterial strains showed active ability to degrade *n*-hexadecane. This suggested that the salinity influence on the *n*-alkane distribution may be partially related to microbial degradation, which awaits further *in-situ* investigation. So salinity variation should be taken into account when using *n*-alkane-based proxies for reconstructing paleoclimate and paleoenvironment in lakes.

[176]

Characteristics of Popularization of Palaeontology in Popular Science Journals

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Palaeontology is an interdisciplinary subject of life sciences and earth sciences, providing intuitive evidences and theoretical support for the basic theory of life science. Meanwhile, palaeontology can also satisfy human curiosity about the mysteries of the Earth and its life. So that both palaeontology and fossils always draw special attention especially in popular science journals. Therefore, it is of great significance to analyze the characteristics and regularity of popular palaeontological articles (PPA) in medium of popular science and to further promote the science communication in the field of palaeontology.

Generally speaking, main carriers of PPA are popular science periodicals (PSJ), a traditional and important media of science communication. Comparing and analyzing PPA published on PSJ and the academic papers of palaeontology in academic journals during a certain time, could show the popularization of palaeontological achievements and could reflect the social attention to the subject and public understanding about the subject also.

At present, there are two kinds of PSJ related to palaeontology. The one is professional PSJ, primarily sponsored by the palaeontological research institutes, called the “specialty stores” of popular palaeontology. The other is comprehensive PSJ which more or less publishing PPA, called the “supermarket” PSJ. These journals have three characteristics. The first one is “more”, meaning more PPA published. The second one is “early”, meaning most of them starting early. The third one is “complex”, it means that they often have various host organizations, with diverting topics and subjects and diversiform readers. As a result, comprehensive PSJ have extensive and profound influence with important popularization. Among which, the ones focusing on and reporting the progress in palaeontology for years cannot be ignored. Therefore it will clearly reflect the characteristics, advantages and disadvantages to select the representative comprehensive PSJ having payed close attentions to palaeontology, in the field of science popularization of PSJ. And it will provide important references for promoting science communication in palaeontology, also.

Comprehensive PSJ is important carrier of popular palaeontology and its popular science function cannot be ignored. Secondly, the knowledge of palaeontology dominates PPA with high originality, while each PSJ having its own features and emphasis. Thirdly, authors of PPA are niche and professional, among which expert writers having been the main body of high quality original contents. Besides, there are some problems with PPA in PSJ. Such as topics are narrow and uneven, the perspective of topic of PPA is neither rich nor varied, also more scientific and technical errors in PPA and some statements are not standardized.

KEYWORDS: Palaeontology, popular science, journal, characteristics, popular palaeontology article.

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Chinese Views of Dinosaur Expo 2019 at the National Museum of Nature & Science, Japan

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The National Museum of Nature & Science, Tokyo (NMNS), produced a temporary exhibition called "Dinosaur Expo 2019" from 13 July through 14 October 2019. It received 678,977 visitors in 87 days, and it became one of the most attended exhibitions in the recent history of the museum. We provided an audio guide service in Chinese, English and Korean. Users had to pay 550 Japanese yen extra on top of the ticket price, but 2361 people used the audio service in Chinese. Among them were 246 visitors from China. They came to the museum in 11 tour groups organized by JC Plan of Japan and GZL International Travel Service Ltd. of China.

The tour groups are of parents and children who took part in study tours visiting NMNS, The Railroad Museum, LegoLand and Fuji-Q Highland Amusement Park in July and August. The biggest group had 27 people (7 August) and the smallest had 13 people (24 July). The most numerous were children between 6 and 10 years old (57 people) and adults on their thirties (57 people). 221 participants answered questionnaires in Chinese for the museum[1]. The questionnaire asked what the most memorable exhibit was. The popular exhibits include *Tyrannosaurus* (37 people), *Deinonychus* (13), *Tarbosaurus* (8) and a therizinosaur (8). *Tyrannosaurus* was not the major exhibit for the Dinosaur Expo 2019, but it made a big impression on the participants as one of the most famous dinosaurs. The comments included that the skeleton was large and complete, and it looked strong and heavy. It was a cast skeleton made from an individual nicknamed "Scotty" from Canada. Scotty is not the most complete specimen of the species, but the audio guide told them that Scotty is the heaviest individual of the species based on the circumference length of the femur, according to a study published in the spring of 2019[2]. *Deinonychus* is the first specimen of the Dinosaur Expo 2019, and it was one of the star exhibits. Two *Deinonychus* skeletons were on display as if they were attacking *Tenontosaurus*, a herbivorous dinosaur, as a pack. Those who liked *Deinonyuchus* thought the exhibits were beautiful. It was very interesting to see 8 people listed a therizionosaur. It was a newly discovered partial skeleton from the Gobi Desert of Mongolia. Its hand fingers are reduced to two digits from three, just like *Tyrannosaurus* and *Tarbosaurus*. It however has large claws unlike *Tyrannosaurus* and *Tarbosaurus*. Those who liked the therizionosaur commented that it was their first time to see a specimen of the group. It showed that these participants had very in-depth knowledge about dinosaurs. One child was extremely happy to see a mosasaur. Mosasaurs are not dinosaurs; they lived in the sea and are more closely related to lizards than dinosaurs. Mosasaurs became famous when one was featured in one of the Jurassic World films. It was the child's very first opportunity to see fossils of mosasaurs. Many participants saw Chinese fossils such as *Sinosauropteryx*, *Caudipteryx*, *Microraptor* and *Anchiornis* for the first time. We are proud to be able to report that many told us that they realized the importance of the Chinese fossils for the first time through Dinosaur Expo 2019.

KEYWORDS: Dinosaur Expo 2019, museum, exhibition, foreign language audio-guide.

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[178]

Characteristics of Phenanthrene Series in Over-mature Shale and Its Significance to Shale Gas

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Phenanthrene series compounds are widely found in organic rocks. They have been successfully used for maturity assessment of source rocks and crude oils (Radke et al., 1982；Boreham et al., 1988；Bao et al., 1992；Chen et al., 2010). We studied with samples from Paleozoic shale gas survey Wells in southern China, and found that methyl rearrangement and demethylation reactions of phenanthene series compounds are important indicators of shale gas generation and pore evolution in the stage of over-maturity (Wang et al., 2019). Although the maturity formula of methylphenanthrene established by Radke is no longer applicable in over-maturity stage, the parameter F1 which characterizes the relative content of 3-MP+2-MP is still a good maturity index of organic matter (Radke et al., 1982). In the over-maturity stage, F1 increases gradually to a maximum value of 0.74, and then decreased with the increase of maturity. In the process of F1 increasing with maturity, the content of β substituents, 3-MP and 2-MP, is absolutely superior to that of α substituents, 9-MP and 1-MP. Methyl rearrangement is dominant, and the pores of shales are relatively developed. The corresponding survey wells of shale gas have good gas-logging. In the process of F1 decreasing with maturity, the content of β substituents, 3-MP and 2-MP, is equal to or even lower than that of α substituents, 9-MP and 1-MP. Demethylation is dominant, and the pores of shale gradually shrink. The corresponding survey wells are relatively poor.

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[179]

Conodont Image Recognition Based on Convolution Neural Network Deep Learning Model

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Conodonts appear in the Cambrian to Triassic marine strata, with a geological age span of more than 340 million years. Conodont fossils are widely distributed in sedimentary basins and are important in stratatigraphic division. With small size (mostly 0.1 to 0.5mm), varied characteristics, geologically rapid evolution and large number, conodont fossil is difficult to identify and classify and professional knowledge is necessary. Image classification is an important research field of computer vision technology. Convolution neural network (CNN), is a deep learning model widely used to solve the problem of image classification in various fields. Based on the Pytorch software framework, CNN deep learning method is used in this study to train and test the conodont image data set, so as to achieve high-efficiency intelligent identification and classification of conodont fossils.

The image data of conodonts are from the book "Cambrian and Ordovician conodonts in China" edited by Wang Zhihao et al. (2011) and the fossil image set provided by the research group of stratigraphy and paleontology, Research Institute of Petroleum Exploration and Development of PetroChina. Six species of conodonts are involved in this study: *Cordylodus angulatus, Cordylodus proavus, Serratognathus bilobatus, Serratognathus diversus, Triangulodus brevibasis, Triangulodus proteus*. The original image numbers of the six species of conodonts are 20, 15, 19, 26, 17, and 17, respectively. In order to achieve effective training and facilitate comparative testing, all the original 114 images are standardized, and every original image is converted into a 256*256 pixel grayscale image. Considering the limited conodont images obtained from the references, this study adopts the method of data augmentation to increase the number and the diversity of the image data set. The data augmentation methods includes image flipping, rotating and filtering. After data augmentation, the quantity of the images increases from114 to 684. The image data is divided into two data sets—training data set (615 images) and testing data set (69 images).

The convolution neural network used in this study consists of five convolution layers, four pool layers, and three full connection layers. The weight initialization of neural network adopts Gauss distribution model. CNN model uses ReLU function as the activation function of each convolution layer and cross entropy function as the loss function. Loss backward algorithm is used to downlink back propagation.

After several iterations of training, the prediction accuracy of the designed CNN model reaches 99% in the training set, which shows that the CNN model can distinguish the differences of different kinds of conodonts and achieve a good fit for the training set. After 55 epochs of iteration, the prediction accuracy of training set is still rising steadily, while the prediction accuracy of test set is no longer increasing, stable at about 94%. The iteration terminates at the highest prediction accuracy of the test set. The further improvement of the training set accuracy is not pursued in this study, in order to prevent over fitting from affecting the generalization ability of the network.

The research result proves that CNN deep learning can provide an efficient way for conodont identification and classification, although much work will have to be done in the future.

KEYWORDS: Convolution Neural Network, conodont, image recognition, deep learning.

ACKNOWLEDGMENTS

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[180]

Contributions to Radiolarian Studies in Japan and China

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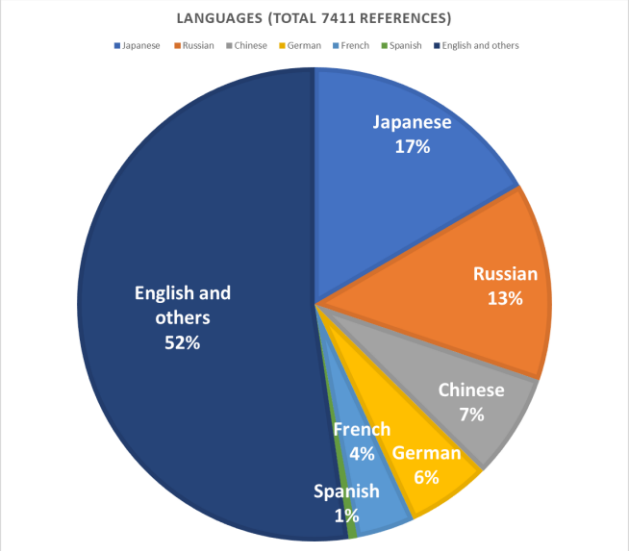
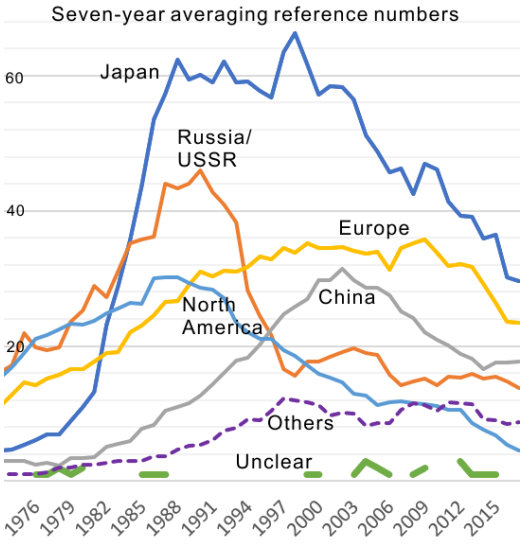
Since the original study on radiolarians was first published by the Japanese in 1907 (Okamura, 1907) and by the Chinese in 1932 (Wang C.C. & Nie D, 1932), a huge number of radiolarian papers was published by them. Our contribution will be presented by using my personal reference database with reference collection.

A total of 7411 references were published since the first article of Tilesiu (1814). The papers written in Japanese and Chinese consist of 17% and 7% to the toal number of references, respectively. These papers inevitably treated on domestic issues, but the papers written in native language are also no doubt to advertise the usability of radiolarians for their own nations. Radiolarian studies abruptly increased in number around 1982 in Japan, and this phenomen is named as “Radiolarian Revolution”. Meanwhile, the number of papers in China gradually increased in the late 1970s and showed a peak around the early 2000. Significant drops appeared after ca. 2000 in Japan and the early 2000s in China. In applied the four-divided journal category scheme for published years, these drops are largely effected on descrese in number of papers written in Japanese and Chinese, and on pressure on publishing in “high-level” journals in English. The stiff reviewing system under the international community, however, surely raises the level of radiolarian studies in both countries.





KEYWORDS: Study history, Radiolaria, China, Japan.

[181]

Differentiation and Evolution of Methane Metabolism in Prokaryotes

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Anaerobic methane metabolism is solely conducted by Archaea, through a unique pathway with the key enzyme methyl-coenzyme M reductase (MCR) for methane activation/production. While aerobic methane metabolism is mainly conducted by bacteria with the key enzyme methane monooxygenase (PMO). Recently, the MCR-based pathway was also found in propane and *n*-butane oxidation and related genes was also found actively expressed in natural environment. In this study, we then made a global metagenome-based survey of *mcr* containing archaeal genomes. Methane metabolizing archaea were found present in various environments such as lakes, hot springs, marine environments. In addition to the Euryarchaeota and Bathyarchaeota, MAGs (metagenome assembled genomes) harbouring *mcr* genes were found belonging to diverse archaeal lineages including such as the Korarchaeota, Hadesarchaeota, Verstraetearchaeota, Nezhaarchaeota (a new archaeal group named in this study using the Chinese mythological character "Nezha", who flies on the wind and fire wheels), far more diversified than ever recognized. The finding of anaerobic alkane metabolism in diverse archaeal phyla further indicates it as the most ancient biochemical process in the Archaea domain and even one of the earliest life attributes. By taking advantage of phylogenetic tree and molecular clock analyses, we found that the differentiation and evolution of both anaerobic and aerobic methane metabolisms also associate with the Great Oxygenic Events on Earth. The appearance of oxygen on Earth surface may therefore influence the carbon cycling even the climate during that time.

[182]

Description of the Dentition of *Chaohusaurus brevifemoralis* (Ichthyosauria) based on High-resolution Computed Tomographic Analysis

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Chaohusaurus, one of the earliest-braching ichthyosauriforms, plays an important role as top predator in early Mesozoic marine ecosystem. To reveal the prey preference and tooth replacement pattern of *Chaohusarus*, we described the dental morphology based on micro CT scan data of the specimen *C. brevifemoralis* (GMPKU P-3086). The three-dimensinal reconstructions reveal some new information. A dental groove is present with shallow sockets at the bottom; therefore, the implantation is subthecodont. The size and shape of the teeth vary periodically and appear as an odd-even pattern. There exist two rows of teeth at the posterior of dentary and

maxilla, indicating that the lingual row comprises replacement teeth for the labial row, and each replacement tooth is positioned disto-lingual of its predecessor. Anterior teeth form just single row, indicating the replacement tooth is on the distal postion of the fuctional tooth. The teeth are small relative to the skull width. The posterior teeth are blunt while the anterior teeth are slightly more slender, suggesting the tooth function of crunch, revealing the prey items of *Claraia wangi*, *Posidonia* sp., *Periclaraia circularis*, *Procolombites* sp. and *Ankitokazocaris chaohuensis*. The dentition of *C. brevifemoralis* is similar to that of *Grippia longirostris* and *Utatsusaurus hataii*.

KEYWORDS: *Chaohusaurus brevifemoralis*, dentition, prey preference, CT scan.

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[183]

Evolution of the Vascular System in the Archosaurian Forelimb

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The morphology of the forelimb varies greatly among extant reptiles. In particular, the avian wing is highly specialized for powered flight and its origin and modifications represent one of the major transitions in the vertebrate evolution. The evolutionary changes in the forelimb skeleton and the associated musculature in the linage leading to extant birds have been well-documented. Evolutionary analyses of its vascular system, however, have rarely been attempted. In the present study, the morphology of the vascular system in the forelimb of various reptiles including birds were observed and described in order to establish homology hypotheses of blood vessels among them, which, in turn, serve as the basis for inferring evolutionary sequences of morphological changes in their vascular system. In total, one specimen of Squamata, two specimens of Testudines, two specimens of Crocodylia and three specimens of Aves were examined in this study. The specimens were CT scanned and dissected and schematic diagrams of their vascular patterns were produced.

The present analysis resulted in two significant findings. First, in all taxa, the artery which is herein inferred homologous to A. brachialis *sensu* Beumel (1993) branches into two arteries extending to the radial and ulnar sides of the forearm. Only in archosaurians, however, the artery extending along the ulna further bifurcates at the proximal end of the bone, with these branches extending to its anterior and posterior sides, respectively. The branch extending along the posterior side of the ulna is inferred homologous among archosaurians, corresponding to A. ulnaris profunda *sensu* Baumel (1993). Therefore, this bifurcation of the artery appears to be an archosaurian synapomorphy. Moreover, A. ulnaris profunda extends into relatively large blade-like scales arranged along the ulnar side of the forearm in crocodiles and the secondary remiges in birds, respectively.

Considering that several fossil archosaurian taxa have similar structures (e.g., blade-like scutes in nodosaurid ankylosaurs and remiges in non-avian theropods), the presence of A. ulnaris profunda in the ancestral arhosaurian may have been a prerequisite creating well-developed dermal structures along the ulnar margin of the forearm.

Second, two veins interpose one artery in several regions of the forelimb in Crocodylia and Aves and create the counter current heat exchange system. In *Grus japonensis* and *Morus bassanus*, veins bifurcate and produce net-like structures covering the outer surface of an artery. This structure possibly makes heat exchange more efficient. Similar structures found in pedes of some wader birds. These are considered an adaptation for cold environments although they are also found in taxa that do not lives in cold regions. Accordinngly, such an efficient heat exchange structure may also be adaptive for maintaining appropriate body temperature for largebodied taxa. This implies that large-bodied archosaurians such as many non-avian dinosaurs may have been benefitted from such a net-like vein structure in the forelimb.

KEYWORDS: Archosauria, vascular system, evolution.

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We thank M. Manabe (National Museum of Nature and Science, Tsukuba) for access to the CT scan facility under his care. Specimens were provided by Junko Takayama (Chiba Biodiversity Center, Chiba Prefecture; *Chelydra serpentina*), Yuko Iima (Kushiro City Zoo; *Grus japonensis*) and Momo Yamashita (Department of Earth and Planetary Science, The University of Tokyo; *Varanus exanthematicus*).

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[184]

Functional Trade-off between Hydrostatic and Hydrodynamic Efficiencies of Shell Form in Ectoconchlete Cephalopods

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Ectoconchleate cephalopods such as ammonoids and nautilids have a conch with chambered phragmocone that serves as a buoyancy apparatus. Because of their inferred nektonic or nektobenthic mode of life, hydrostatic and hydrodynamic properties may be critical for their locomotion. The relative density of the cephalopod body depends on conch geometry as well as on shell thickness because surface-area to volume ratio of the shell affects the amount of calcium carbonate required to form the shell. Hydrodynamic efficiency also depends on shell form because form drag acting on the animal moving with respect to surrounding water is in proportion to the cross-sectional area of the body. The present study tries to generalize the relationship between conch geometries and hydrostatic and hydrodynamic efficiencies in planispiral cephalopods using a theoretical morphologic model. A hydrostatic inefficiency of shell form was represented by the surface area of totally produced shell per unit of volume, i.e., specific surface area of the shell. A hydrodynamic inefficiency of shell form was assessed by the projected area of the shell in the direction of movement per unit volume. The Raup's parameters [1] were collected from photographs of more than 6000 species published in the literatures. The specific surface areas

and the projected areas per volume were computed for theoretical morphologic models generated based on the same parameter values as the measurements.

The result of a functional morphospace analysis using theoretical morphologic models reveals a trade-off relationship between hydrostatic and hydrodynamic efficiencies of shell form producing a Pareto-front in the functional space [2]. The hydrostatic property is generally low in a laterally compressed shell form with a low whorl expansion rate which is assumed to be the most efficient for swimming at high Reynolds number. The morphometric result shows that nautilids tend to have a more depressed shell form with a higher whorl expansion rate than do ammonoids. This result suggests that hydrostatic property is more important than hydrodynamic one in the macroevolutionary history of nautilids. Among ammonoids, hydrostatic and hydrodynamic inefficiencies of shell form vary across taxonomic groups: conch geometries of prolecanitids tend to be optimized for hydrodynamics, whereas some goniatitids have hydrodynamically inefficient shell forms. Phylloceratid ammonoids seem to have been successful at both hydrostatic and hydrodynamic efficiencies. In comparison with ammonoids and nautilids, shell forms of Paleozoic tarphycerid cephalopods are not efficient for either property. The result of this study suggests considerable ethological diversity among taxa of ectoconchleate cephalopods.

KEYWORDS: Chephalopods, hydrostatics, hydrodynamics, trade-off, functional morphospace.

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[185]

Genetic Bases of Skeletal Formation in Fossiliferous Lophotrochozoans

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Lophotrochozoans, embracing such taxa as brachiopods and molluscs, represent one of the three major groups of bilaterians. They have pivotal roles in understanding the origins and evolution of animal body plans because, after Ediacaran, they left an abundant and continuous fossil record of the shells, which consitute integral parts of their body plans. To gain insight into the origins and evolution of those skeletons, it would be essential to unveil the genetic and molecular mechanisms of their formation processes, which may be decomposed into the following three mutually interwined sub-processes: (1) differentiation along a gene cascade, (2) morphogenesis, and (3) biomineralization. The transcription factor gene *engrailed* (*en*) is known to be expressed in the margin of the region where the initial formation of the shell takes place in the species of all the molluscan classes so far examined. Thus, *en* likely resides near the origin of the cascade for shell formation. In the brachiopod *Lingula*, *en* is expressed in larval mantle lobe, suggesting a role in shell development homologous to molluscs. However,

comparisons of amino acid sequences and the upstream genomic region organizations of *en* and microsynteny around *en* among lophotrochozoans indicated that the role of *en* in shell formation evolved independently in brachiopods and molluscs by gene co-option. Molluscan shells are diverse, but they share one and the same underlying rule of growth, that is, to form a logarithmic spiral. Exact molecular mechanisms to form shells of a logarithmic spiral are still unknown, but it has been shown that the signal transduction gene *dpp* has a role in the production of a coiled shell through formation of a laterally asymmetric gradient of the Dpp concentration in the shell forming tissues. Shell formation is finally achieved by the precipitation of biominerals, or biomineralization, which is believed to be controlled mainly by the proteins that become entombed in the shell matrices. Combined transcriptomic and proteomic analyses of shell matrix proteins (SMPs) revealed presence of literally hundreds of SMPs in a given molluscan or brachiopod species. SMPs are diversified in sequence and in protein repertoire even between closely related species, indicating generally high rates of evolution for SMPs. Many SMPs have a domain structure, and some domains appear to have been conserved ever since Cambrian. However, phylogenetic analyses of those seemingly conserved domains, such as the carbonic anhydrase domain, indicated a more recent and independent deployment among different bivalve lineages. In future, the roles of the gene products involved in shell formation have to be more precisely accessed so as to understand the mechanisms and the dynamic evolutionary processes of shell formation in fossiliferous lophotrochozoans.

KEYWORDS: Biomineralization, metazoan evolution, shell formation, shell matrix proteins, spiral growth.

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[186]

Influence of Changes in Wetland Salinity and Human Activity on Vegetation Abundance during the Past Two and A Half Millennia

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Betula microphylla is an important tree species in oasis wetland ecosystems, but it is vulnerable to climate change and disturbances. In order to explore the factors driving changes in species abundance in arid and semi-arid regions, we examined the relationships between wetland vegetation growth and hydrochemical characteristics of wetland water, which will help to protect the valuable natural tree species and wetland environments. Surface pollen samples were collected from 15 sites along an altitudinal gradient, from 210 to 750 m, and 183 fossil samples were collected from the Ebinur and Caotanhu wetlands in north Xinjiang, China. Three kinds of ground and surface water samples were collected from birch wetlands and the saline Ebinur Lake. The interactions between modern pollen and hydrochemical data were determined, and the findings were used to interpret historical changes in vegetation abundance in different regions (Ebinur and Caotanhu). The modern wetland

landscape, surface pollen assemblage and fossil pollen data from these areas, as well as ground and surface water hydrochemical data, indicated that there was a local wetland ecosystem during the historical period that was dominated by freshwater plants. These records showed that *B. microphylla* dominated the vegetation at the Caotanhu wetland from 900 to 700 cal. a BP. But for the Ebinur wetland, the vegetation cover of *B. microphylla* was highest between 270 and 220 cal. a BP. The two wetland ecosystems were dominated by freshwater plants during the historical period. At present, the high salinity in the wetlands (surface and ground water) might be a key factor driving the susceptibility of *B. microphylla* to extirpation. Increased human activity is an additional factor influencing wetland vegetation changes.

Overall, the results of our study on the interactions between wetland water and vegetation in different time periods (past and modern) and regions (Ebinur and Caotanhu) should be helpful for devising conservation strategies and conservation measures for *B. microphylla* in the semi-arid and arid areas of China.

KEYWORDS: *Betula*, pollen data, wetland salinity, human activity, vegetation abundance, north Xinjiang.

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Khorat Fossil Museum: Gateway to Paleontopolis

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The Khorat Fossil Museum or Northeastern Research Institute of Petrified Wood and Mineral Resources is under Nakhon Ratchasima Rajabhat University, Nakhon Ratchasima Province, Northeastern Thailand. The museum is composed of the Petrified Wood, Ancient Elephant, and Dinosaur museums. The museum grounds cover an area of 12.8 hectares with a surface of gravel and petrified wood derived from Quaternary sediments. The petrified wood dates from at least 0.8 million years ago. The fossil wood specimens belong to various families, including Fabaceae, Anacardiaceae, Combretaceae, and Irvingiaceae, and range from gravel size to trunks more than 10 meters long. The *in situ* fossil wood is in a protected patch of forest within the museum grounds, referred to as "Krok Duean Ha Petrified Forest Park". This was the first site of conservation of petrified wood in Thailand. The Petrified Wood Museum building consists of temporary and permanent exhibitions, including a hall of fame for petrified wood donors and a room to honor the royal institute. The permanent exhibition in this museum highlights petrified wood from Nakhon Ratchasima, emphasizing opal gemstone quality wood, palm wood, and the 3 ages of the fossils, Mesozoic, Neogene, and Quaternary (150 – 0.8 million years). The Ancient Elephant Museum features exhibits on the discovery of 10 of 55 genera of ancient elephants in the world along with other fossils from Neogene – Quaternary sites from Chaloem Phra Kiat District in Nakhon Ratchasima. The Dinosaur Museum displays 4 new species of dinosaurs, 3 species of iguanodonts and 1 species of carcharodontosaurian, together with other fossils from the Early Cretaceous in Mueang District, Nakhon Ratchasima. The three museums and exhibitions are a conservation and paleontological learning center for youths, the general public, and tourists, totaling more than 2 million visitors. Numerous activities have been organized, including workshops

and camps for students and teachers, festivals, international scientific conferences, and international collaboration in fossil excavations. The museum is also the central office of Khorat National Geopark and cooperates closely with local communities. The overall of the outstanding land of fossils from three periods (Cretaceous, Neogene, and Quaternary) in four directions and 20 km radius from Mueang District and nearby areas, as highlighted in the museum, we proposed Nakhon Ratchasima as a Paleontopolis or Fossil City.

KEYWORDS: Nakhon Ratchasima, petrified wood, ancient elephant, dinosaur, conservation, Paleontopolis.

[188]

Marine Environment Change during MIS1-12 in South China Sea as Evidence by Comparison Foraminiferal Assemblage Changes in Core MD05-2901、ODP1146 and 17957

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Foraminifera assemblage changes are compared in the cores of western, Southern and Northern South China Sea (SCS) during MIS1-12. The results display that foraminifera assemblages have different characteristics in the northern, western and southern SCS. In the core ODP1146 (northern SCS), *N.dutertrei* (27.9% / 34.8%), *G.inflata* (10.2%/9.5%), *P. obliquiloculata* (8.95%/3.97%) show high percentage content, and *Gs.sacculifer* (14.0%/17.1%)、*Gs.ruber* (14%/17%) show low percentage content in foraminiferal assemblage. The foraminifera species compositions change very large during the glacial and interglacial periods. This phenomenon may imply the marine environment is strongly controlled by winter monsoon in the northern SCS; In the Core 17957 (South SCS), *Gs.ruber* (average 31.6% in the interglacial periods/ average 30.7% in the glacial periods), *Gs.sacculifer*(31.6%/30.7%), *G.menardii* (6.0%/6.5%) and *P. obliquiloculata* (7.34%/10.10%) have relatively higher percentage content, *G.inflata, N.pachyderma* have relatively lower percentage content. The main foraminifera species contents change little between the glacial and interglacial periods transition. This character show the marine environment in the south SCS is reflected strongly by the Western Pacific Warm Pool (WPWP). In the Core MD05-2901 in the western SCS, *G.glutinata* (9.7% / 8.1%)、*N.pachyderma* (6.9%/8.1%) have higher percentage content, and *P. obliquiloculata* (5.4%/5.7%) show lower percentage content. The foraminifera assemblage composition in the western SCS shows transitional region marine environment character in the SCS. In the glacial and interglacial periods cycle scale, foraminifera species change largest in the northern SCS, and smallest in the western SCS. Foraminifera assemblage composition variations reflect the different marine environment change in South China Sea.

KEYWORDS: Foraminifera species, Northern SCS, Western SCS, Southern SCS.

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[189]

Muscle Moment Arm as a Useful Tool to Determine the Limb Posture of Ceratopsian Dinosaurs

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How can we make the skeletal reconstructions of extinct animals as accurate as possible? The forelimb posture is especially problematic, because it involves determining the positions of the scapule in relation to the ribcage that are not directly connected with each other, and also involves determination of the limb joint angle in the support phase into the limited range, although they usually have a wider range of motion. These problems are due to our poor knowledge on the relationship between the skeletal morphology and the limb postures even among the extant taxa. Accordingly, the forelimbs of many extinct taxa, such as ceratopsian dinosaurs, have been reconstructed in various postures, but with an insufficient scientific basis. Here I introduce some recent studies that tackled these problems using the moment arms of anti-gravity muscles.

In the support phase of quadrupedal tetrapod, the ribcage is suspended between the scapulae via serratus and rhomboid muscles against the gravity. Three-dimensional muscle moment analyses on extant quadrupedal taxa revealed that roll, yaw, and pitch moments of the trunk caused by the contraction of these muscles and the gravity are minimized if the scapula in support is located in the median, dorsal, and anterior portion on the ribcage. This scapular position is shared among all the extant tetrapods that facultatively/obligately support their body on the forelimbs. Muscle moment arm analyses using 300< extant quadrupedal taxa found that the extant tetrapods in sagittal, creeping, and sprawling postures emphasize moment arms of the each anti-gravity muscles of the elbow joint—the elbow extensor, flexor, and adductor muscles, respectively. Another study found that extant tetrapods keep the elbow joint angle where the moment arm of the anti-gravity muscle is maximized.

According to the above-mentioned interpretations, the forelimb postures were indicated to be different among the ceratopsians. Among the ceratopsians, ceratopsids and protoceratopsids likely employed sagittal and sprawling forelimb postures, respectively. However, both families shared the scapular positions at along the median plane. The forelimb postures indicated for these taxa are consistent with the preservation of articulated specimens, the manus anatomy, and the ichnological evidence.

KEYWORDS: forelimb posture, extinct taxa, muscle moment arm, *Triceratops*.

ACKNOWLEDGMENTS

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[190]

New Progress on the Radiolarian Study from East Yarlung Zangbo Suture Zone, Southern Tibet

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A kinds of rocks such as ophiolite, mélange and radiolarites etc., which may be the remnants of the Neo-Tethys along the convergence edge, are well exposed within the east Yarlung-Tsangpo suture zone (YTSZ) in the Zedong area, southern Tibet. Since 2012, a systematic studies on radiolarians from these radiolarites have been taken on in order to establish or improve a biostratigraphical framework in this area. This radiolarian study will help us to better understand the whole evolutional history of the Neo-Tethys Ocean in the east YTSZ.

Abundant Triassic radiolarian fossils were obtained from varicolored bedded cherts belonging to the mélange complex exposed in the Buruocang section near Jinlu village, Zedong. Two late Anisian radiolarian assemblages, named *Oertlispongus inaequispinosus* and *Triassocampe deweveri* respectively, are compared with those known from Europe, Far East Russia, Japan and Turkey. These Anisian radiolarian fossils are the first reported in southern Tibet and the oldest radiolarian record within the YTSZ.

Highly diverse and moderately well-preserved middle Jurassic radiolarians were extracted from greyish green and purplish red bedded cherts in the Jinlang section near Jinlu village, Forty-two species belonging to 27 genera were recognized from nine cherty samples. Some typical middle Jurassic species, such as *Laxtorum* (?) *jurassicum* Isozaki & Matsuda; *Stichocapsa japonica* Yao; *Stichocapsa robusta* Matsuoka; *Parahsuum* (?) *magnum* Takemura; *Sella chrafatensis* (El Kadiri) and *Sella beniderkoulensis* (El Kadiri) etc., were found and they indicated that these bedded cherts were from the Aalenian to early Callovian in age.

An Aptian radiolarian assemblage was extracted from 25 samples collected from a sequence of dark grey cherts near Zouxue Ferry, Zedong. Twenty-seven radiolarian species belonging to 25 genera have been recognized. They are characterized by the dominant *Archaeospongoprunum patricki* Jud, *Holocryptocanium* sp. cf. *H. barbui* Dumitrica and *Turbocapsula costata* Wu. This assemblage is very similar to that found in Congdu Formation in Xigaze area, southern Tibet.

KEYWORDS: Radiolarians, biostratigraphy, Neo-Tethys, Yarlung-Tsangpo suture zone, Tibet.

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[191]

Origin of Land Plants: Integrating "Rocks" and "Genomes"

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The origin of land plants has been one of the key-events in the history of life because the colonisation of terrestrial habitats by green algae provided a crucial component in the establishment of terrestrial ecosystems. In turn, the early diversification of land plants is expected to coincide with the diversification of terrestrial fungal lineages and animal lineages, such as terrestrial arthropods. Until now, the inference of the origin of land plants was hampered by the lack of integration of the information provided by two crucial resources. At one hand, the fossil record provide important information about the appearances and habits of the earliest land plants. At the other hand, the early history of land plants was also preserved in the genomes of the extant representatives. In this presentation, I summarise the results of recent studies aiming to overcome the challenges provided by nearly 500 million years to establish a robust time frame of the early divergence of land plants. Firstly, I discuss our current understanding of the relationships among the four extant land plant lineages and the implications for the interpretation of the fossil record. Secondly, I discuss estimates of the origin of land plants obtained by divergence time estimates based on transcriptome sequence data and fully integrates fossil calibrations using a node-dating approach. Finally, I discuss the challenges required to be addressed to obtain a total-evidence perspective on the early land plant evolution that incorporates all data available without any biases. Thus, the talk will discuss in general the possibility to overcome well established boundaries by employing a molecular-paleontological approach enabled by the tree-of-life.

[192]

Patterns and Efficiency of Microbial Carbon Accumulation in Soils

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Microbes are increasingly recognized to play a key role in the accumulation of soil organic carbon not only as a decomposer of plant-derived organic matter but also as a producer of necromass with longer turnover times and higher stabilities compared to plant detritus. However, large-scale evidence for the so-called 'microbial carbon pump' and assessment of its efficiency relative to organic carbon mineralization are still lacking, which has important implications for ecosystem carbon fluxes and soil carbon sequestration. Here we first utilize amino sugars and lignin phenols as tracers for microbial necromass and plant lignin components, respectively, and show continental-scale evidence for the key role of microbial necromass in soil carbon accumulation across Mongolian grasslands. We then utilize ^{13}C analysis of amino sugars in comparison with CO_2-^{13}C and assess microbial carbon accumulation efficiency in a soil incubation experiment with ^{13}C-labeled glucose. We find that microbes in the subsoil of an alpine grassland use a lower portion of the added glucose to produce necromass and a higher portion for respiration compared to those in the topsoil, yielding a lower microbial carbon accumulation efficiency in

the deeper soil. Using another suite of experiments, we further assess mineral and substrate influences on microbial necromass accumulation under controlled conditions. These results help us to better understand factors regulating the efficiency of "microbial carbon pump" in the soil.

[193]

Possibility of Gene Co-option in the Larval Shell Development of Molluscs and Brachiopods

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Brachiopods and molluscs are the major lophotrochozoans taxa and they have independently evoleved similar mineralized exoskeleton that is called shell. Their fossils appeared in early Cambrian times and are useful for understanding their evolutionary histories. In the past decade, omics studies (e.g. genomics for genomic DNA analysis, trasnscriptomics for RNA analysis, and proteomics for protein analysis) are well developed to become helpful to analyze the molecular mechanisms for the phenomena of interest in non-model species. In molluscs, many shell matrix proteins (SMPs), that are contained in the shell and may be involved in the shell formation, have been identified using transcriptome and proteome analyses. However, the molecular basis of shells formation in brachiopods or in molluscs remains unclear. Two homeobox genes, *engrailed* (*en*) and *distal-less* (*dlx*) are expressed in the shell field cells of limpet and/or oyster larvae. We first confirmed the expression patterns of these genes in the brachiopod *Lingula anatina* (*Lan*), and found that *Lan-en* is expressed in the mantle lobe that is involved in shell secretion. In contrast, *Lan-dlx* is not expressed in the mantle lobe, but is expressed in the tentacle domain. Then, we treated early stage exmbryos (2-8 cells) of limpet (*Nipponacmaea fuscoviridis*), pacific oyster (*Crassostrea gigas*), and brachiopod (*L. anatina*) with all-trans retinoic acid (ATRA), and cultured to larvae (~24 h post fertilization). Small shelled-larvae were observed in the ATRA-treated larvae for all the three species. We analyzed the expression patterns of shell-related genes and homeobox genes (*en* and/or *dlx*), and found that the expression of the shell-related genes and *en* were relatively weaker in the shell field than control larvae in all three species. These results indicated that ATRA leads to suppress the shell development both in those molluscs and the brachiopod. Our results suggest that involvement of Engrailed in shell formation probably evolved by independent gene co-option in molluscs and brachiopods.

KEYWORDS: Shell development, Gene expression, Mollusca, Brachiopoda.

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[194]

Researches on Microbial Carbonates: Progresses and Problems

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Microbial carbonates include all carbonates mainly formed through microbial-induced precipitation of carbonates or trapping of micrites and lime grains by microbes. Microbialites is originally defined to include carbonates mainly formed by benthic microbes. We proposed to it to include carbonates formed by planktonic microbes, such as whitings and the P-T boundary carbonates composed of colonial casts of cyanobacterium *Microcystis* (Wu et al., 2014, 2018). Researches on microbial carbonates are globally performed in three fields: (1) experiments on mineralization of microbes, (2) studies on microbial carbonates in modern environments, and (3) studies on microbial carbonates formed in geological periods. Experimental studies have revealed that at least 7 bacterial genera have the capacity to induce carbonate precipitation in lab conditions, and at least 10 cyanobacterial genera can induce carbonate precipitation in lab conditions. Future efforts in experimental studies should be on (1) experiments under conditions more close to the modern and ancient natural environments with microbial precipitation, and (2) finding more microbial taxa that have carbonate-induced capacity. More studies are needed on archaea about their carbonate-inducing ability.

Microbial carbonates in modern environments have been found from shallow subtidal, neritic, and bathyal regions, as well as hyperhaline lagoons, warm spring waters, hot spring waters, lakes and rivers, and can be classified into two types: stromatolites and thrombolites. These studies have contributed to understanding the microbial communities responsible for the carbonate precipitation and the features of the carbonates. However, few works are on the biotic processes of the inducing. Most studies were based on samples from fields, and more in situ observation-centered studies are needed.

Microbial carbonates have been reported from strata ranging from Archean to Cenozoic. Studies are focusing on their features on outcrops and in thin sections. In most cases the microbial carbonates from the Archean, Proterozoic and Cambrian are dolomitic and their original fabrics are difficult to recognize, which cause difficult in interpretation of their formation mechanism and formation environments, weakening the accuracy of the interpretations. The microbial carbonates from geological times include stromatolites, laminates, thrombolites, microbial reefs, oncolites and castolites. We defined the carbonates composed of casts of microbial individuals or colonies as castolites, such as the P-T boundary microbialites widely distributed in South China (Wu et al., 2014). The term laminate refers to the microbial carbonates with laminated fabric and in not columnar but stratiform shapes.

KEYWORDS: Microbial carbonate, microbialite, microbial mineralization, castolite, stromatolite, thrombolite.

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[195]

Shell Microstructural Evolution of Protobranch Bivalves

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The shell microstructure is the micro-scale morphological trait of molluscan shells. It can be potentially preserved in fossils, and therefore is considered as a clue for inference on evolution and phylogeny of the past life. The presenter described the shell microstructures of Recent and fossil protobranchs, the ancestral taxon of bivalve, using scanning electron microscopy to clarify the evolution of shell microstructures through the origin. Furthermore, microstructural characters have been evaluated phylogenetically through molecular phylogenetic analysis using DNA sequences. Mapping of shell-microstructure characters on the phylogenetic tree confirmed that the composition of shell microstructures is conservative at the superfamily level and can be divided into three major groups; RESP (radially elongate simple prismatic structure) group, homogeneous group and nacreous group. However, this trend is not necessarily applied to that of fossil protobranchs. Previous studies showed that the ancestral taxon of each protobranch superfamily possessed primitive nacreous structure (i.e. nacreous group), and therefore the nacreous structure can be considered as one of the ancestral states of their shell microstructures. The presenter described shell microstructures of fossil protobranchs mainly from the Late Mesozoic and revealed that several taxa changed their shell microstructural composition from homogeneous to nacreous group around the Jurassic-Cretaceous boundary. Acquisition of homogeneous group microstructure can be one of strong driving force supporting non-nacreous protobranch diversity according to the paleobiological evidence.

KEYWORDS: Shell microstructure, nacreous structure, bivalve, Protobranchia.

[196]

The Important Yet Elusive Fossil Crayfishes

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Crayfishes (Decapoda: Astacidea) are one of the most successful group of freshwater crustaceans. Crayfishes appeared as early as Permian, but may well have separated from their marine relatives during the Carboniferous. As crayfishes are almost entirely restricted to freshwater, their distribution has been deeply influenced by major geologic events such as the break-up of Pangaea. Surprisingly perhaps, the majority of our knowledge is currently known from the study of extant crayfishes: fossils are rare, and have been misinterpreted in several cases. For this reason, we have compiled a list of all known occurrences of fossil crayfishes, and their traces; we are now in the process of reviewing these fossils. Our work highlights some interesting aspects of the fossil

record of crayfishes: its inherent discontinuity, how it differs distinctly from that of marine crustaceans, the diversity of fossil traces linked to crayfishes, broader past distribution areas, and the puzzling presence of southern hemisphere crayfishes in Canada.

[197]

The Botanical War Triggered by *Nanjinganthus*

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The publication of *Nanjinganthus* (Fu et al., 2018) has triggered heated debate among botanists all over the world. *Nanjinganthus* is surprising to many botanists in several terms. First, it is far too older than former recognized fossil record of angiosperms, implying an imperfect current understanding of history of angiosperms. Second, its morphology is beyond the expectations of all dominating theories in botany, implying a currently distorted understanding of plants (especially angiosperms). It is not surprising that *Nanjinganthus* attracts darts and rose from botanists in the international scope. Coiro et al. (2019) cast doubt over *Nanjinganthus* based on "obscure" morphology of its ovary. Sokoloff et al. (2019) rejected *Nanjinganthus* as an angiosperm due to the lack of pentamery in *Nanjinganthus*, and they also thought Herendeen et al. (2017) conflicted with Friis et al. (2001, 2009, 2011). Bateman (2019) also rejected *Nanjinganthus* as an angiosperm based on his newly proposed criteria for angiosperms. The dark side for Fu et al. (2018) of these publications is that they all rejected angiospermous affinity of *Nanjinganthus*. However, the bright side of them is that all of the criteria for angiosperms proposed by these authors are different each other and not applicable in the fossil world, and each author group is of an opinion different than the others and fighting hard against others. The ironic example is Bateman, who is a member of Sokoloff et al. and is of an opinion on criterion for angiosperms different Sokoloff et al. Apparently, after hundred years of silence and ambiguity, botanists realize their difference and conflicts on the criterion on angiosperms, start to establish a consensus on criterion for angiosperms, making botany more applicable and closer to a science. However, such a consensus is not easy to reach and botanists have to pay the price. It appears that botanists just started a war for the truth, and a peace comes only after casualty.

[198]

To Popularize General Education of Paleontology in Universities

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General education is an important part of higher education, and many First-Class universities have all implemented general education as the focus of teaching and curriculum reformation. The general education should conform to modern educational thoughts, scientific, advancement and the universal laws of education and teaching.

This paper investigated that the students had selected the class of general education of paleontology in Lanzhou University. We discovery that the current situation of implementation of the course is that students have no preliminary concept of content of the class before the course selection, which has affected the students' enthusiasm for class selection to a certain extent. They hope that the general education curriculum will give priority to content that is of interest and ease. The study believes that both general education and professional education are conducive to the cultivation of students' knowledge accumulation and mastery of learning ability. Therefore, both of them can help the cultivation of innovative talents.

The studies have shown that general education has an important connection with the development of popular science culture. If we carry out general education of earth history and paleontology fossils in the course of university curriculum and build them as an online open course, it will help to become a student-centered system and give them access to the natural science knowledge necessary for lifelong learning and development. The students' interest in science is stimulated. Judge today with the ancient, and we should guide students to cherish life and nature, learn the basics of fossil protection and popular science culture, and enhance the sense of responsibility for protecting human beings from living in their homes. This will arouse the concern and attention of a large number of young people. This kind of general education course will make positive contributions to fossil protection and the development of fossil science culture of the world.

We tries to explore the balance between the implementation of "complete education" and "elite education" in First-Class universities by studying the relationship between general education and professional education in first-class undergraduate education. Furthermore, it combines the training mode of high-quality innovative talents in foreign research universities (Universitaet Tuebingen of Germany，University of Florida of USA，Trinity College Dublin, the University of Dublin of Ireland). The experience and advantages provide an important basis for the reform of general education construction and innovative talent training mode in First-Class universities of China.

Comparisons of Lanzhou University with the Universitaet Tuebingen, Germany

Investigation content	Universitaet Tuebingen	Lanzhou University
Percent of course credits	20%	5%
Teacher: student	1：8	1：10
Percent of Undergraduates	68%	60%

Comparisons of Lanzhou University with the University of Florida, USA

Investigation content	University of Florida	Lanzhou University
Percent of course credits	29%	5%
Teacher: student	1：8	1：10
Percent of Undergraduates	69%	60%

Comparisons of Lanzhou University with Trinity College Dublin, the University of Dublin, Ireland

Investigation content	University of Dublin	Lanzhou University
Percent of course credits	30%	5%
Teacher: student	1：6	1：10
Percent of Undergraduates	77%	60%

KEYWORDS: Popularize, general education, paleontology, higher education.

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[199]

The Rise of Rhinoceroses and Phylogeny of Ceratomorpha (Mammalia, Perissodactyla)

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Rhinocerotoidea conventionally comprises Hyracodontidae, Amynodontidae, and Rhinocerotidae; however, the paraceratheres were recently treated again as a separated family from Hyracodontidae. Rhinoceroses probably originated from some tapiroids during the middle Eocene, and their appearance was much later than the earliest tapiroids (e.g. *Heptodon*). '*Hyrachyus*' (or Hyrachyidae) was usually considered to be a transitional form from the tapiroids to different rhinocerotoids, however, the status and classification of '*Hyrachyus*' complex still remained to be controversial. Here on the basis of diverse rhinocerotoid materials from the late early Eocene to the early middle Eocene deposits of the Erlian Basin, China, we describe three genera (including a new genus) and four new species of rhinoceroses that represent early members of hyracodontids and/or paraceratheriids. We further resurrected the genus *Ephyrachyus*, which has been considered to be a synonym of *Hyrachyus*, and erected a new species of *Ephyrachyus* from the Arshanto Formation. In addition, we tentatively assigned a fragmentary maxilla to a new species of *Hyrachyus* with a query from the Arshanto Formation, noting its similarities with rhinocertid *Uintaceras*. Thus, these new rhinocerotoid materials from the Bumbanian and Arshantan ALMA fill the gap between the early Eocene ceratomorphs and Uintan/Irdinmanhan rhinoceroses, indicating divergence of different rhinocerotoid groups occurred as early as the late early Eocene, contemporary or soon after the split of rhinoceroses from the tapiroids. The phylogenetic analyses based on a large group of ceratomorphs and more than 300 cranodental characters suggest that all these new materials are allied with rhinoceroses, Lophialetidae is a stem group of the crown group Ceratomorpha, Depetellidae is the sister group to Tapiridae, the clade comprising Rhinocerotidae and Paraceratheriidae is a sister group to Amynodontidae, and the monophyletic Hyracodontidae is placed in a relatively basal position.

KEYWORDS: Rhinocerotoidea, Eocene, Nomogen and Arshanto formations, Erlian Basin, phylogeny of Ceratomorpha.

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[200]

The Role of Museums in Fossil Protection

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The importance of fossil protection is now widely recognized. Fossil protection is a comprehensive governance project, but there is no doubt that museums play an irreplaceable role in fossil protection. Since the birth of the museum, the museum has been leading the trend of fossil collection and protection, because the museum collection has a long history. Especially in the period of modern museum development, museums play an increasingly important role in collecting, protecting and utilizing fossil resources for scientific research and social education services.

In the process of museum collection and protection, scientists have made outstanding contributions to the discovery of important fossils, such as the discovery of Chengjiang biota, Bourges shale biota, and Qingjiang biota. Many natural museums in the world have collected most of the fossil treasures. Like Nanjing Museum of Paleontology, it has more than 180,000 holotypes, ranking first in Asia.

Obviously, the museum is the top priority of fossil collection and protection. Because the museum is the best destination for fossils, it has functions such as fossil restoration, fossil true and false screening, fossil science cataloging, and fossil temperature control preservation. Some museums are also architected in fossils in the wild, providing the best conditions for fossil protection. The museum fossil collection is not a short-term behavior, it is not changed by social climate change, and it is also not affected by the replacement of political parties, because it is a national behavior and is the interests of all mankind. Therefore, the museum fossil collection is always in progress.

The museum's extensive collection of fossils makes it a hallmark of promoting fossil culture. Because the museum protects the history of biodiversity, it lays the foundation for the interpretation of biodiversity evolution. The ever-discovered fossil localities and the constantly emerging research results are constantly updating people's perceptions of life and nature. Therefore, the museum is the birthplace of fossil knowledge innovation. At the same time, the museum also displays the rich aesthetic connotation of fossils. The beauty of the sculptures, the beauty of the ancient times, the beauty of the wonders and the beauty of evolution have greatly inspired paleontologists to discover fossils and explore biological evolution throughout their lives.

The rich natural science knowledge embodied in museum fossils undoubtedly makes the museum play an important role in social education. The museum is a place for young people to enlighten, a place for public scientific literacy to be promoted, and a place for the public to establish a correct world view and a view of life.

The value of the museum comes from fossil collection and conservation, and its future depends on its role in fossil collection and protection.

[201]

Mid-Paleozoic "Great Hiatus" across North China Block (Sino-Korean Block): Palaeontological Perspectives Based on North Korean Fossils

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Palaeontological data from the Upper Ordovician to Devonian strata in the Korean Peninsula were reviewd and their tectonostratigraphic implications were discussed. The Upper Ordovician–Devonian fossil-bearing strata are largely distributed in North Korea, and tectonostratigraphically in the southern margin of the Pyeongnam Basin and in the northern part of the Imjingang Belt. The fossils have been regarded as evidence that the "great hiatus" of the middle Paleozoic is not a prevalent phenomenon across the North China Block.

Selected fossils from the Sangsori, Koksan and Wolyangri Series and Rimjin System in North Korea were examined upon the basis of most recent taxonomic schemes. The fossils are of the Late Ordovician to Devonian and show affinity to the coeval fauna and flora of South China Block. In addition, the marine invertebrate fossils included within clasts of the Songrim Conglomerate, the basal unit of the Jurassic Daedong (=Taedong) System, are of the Silurian to Devonian, which also display affinity to those from the Yangtze Platform. Such affinity suggests that the Upper Ordovician to Devonian strata in North Korea most likely formed in a basin(s) of or peripheral to the South China Block. This further suggests that the strata distributed in North Korea are allochthonous, contrary to the traditional interpretation of their autochthonous origin.

The Permo-Triassic collision between the two Chinese cratons which resulted in the amalgamation of three massifs of the Korean Peninsula is considered to be responsible for the accretion and juxtaposition of the Upper Ordovician to Devonian strata onto the North China Block. The previous notion of the "autochthonous" origin of the strata suggested the apparent absence of the "great hiatus" at least in North Korea, whereas the new view of allochthonous origin of these strata reconfirms the presence of the "great hiatus" across the North China Block.

KEYWORDS: "Great hiatus", North China Block, Fossils from North Korea, Sangsori, Koksan and Wolyangri Series, Rimjin System.

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[202]

A Jurassic Petrified Forest Reconstruction in the Sichuan Basin of Southern China

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The Jurassic system is well developed in the Sichuan Basin of southern China, represents a fluvial-lacustrine deposit with hot and arid climate conditions. In particular, the Upper Jurassic formations are represented by two lithological units, including the Suining Formation and the Penglaizhen Formation. Previous studies show a variety of inveterate and vertebrate fossils found in the Upper Jurassic deposits, including bivalves, ostracodes, conchostracas, dinosaurs, and turtles. However, fossil plant remains are very rare in the Upper Jurassic deposits in this basin due to the severe climate conditions. In recent decade, over 500 fossil wood specimens have been discovered in the Upper Jurassic Penglaizhen Formation in Shehong County of Suining City, Sichuan Province. On the basis of this, a petrified forest national geopark was established in this region. These wood fossils are systematically ascribed to several conifer taxa, including *Agathoxylon*, *Brachyoxylon*, and *Xenoxylon*, belonging to Araucariaceae, Cheirolepidicaceae, and incertace cedis conifers as well. Based on field mapping on these fossil wood logs and trunks, we use software to make a forest reconstruction, showing the vegetation aspects of the Late Jurassic episode. Furthermore, we use growth ring proxy analysis to infer and explore the palaeoclimate, and palaeoecology of this fossil forest. We show that this fossil forest devastation was triggered by the severe seasonal flooding events in the Sichuan basin, and the prevailing warm and hot climate condition was sandwiched by short climate cooling event.

KEYWORDS: Fossil forest, conifer, Jurassic, palaeoclimate, the Sichuan Basin.

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[203]

A New Bennettitalean Flower from the Jurassic in Southern China

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The Order Bennettitales (Cycadopsida, Gymnospermophyta) represents a highly interesting group of extinct gymnosperms with a widespread distribution and a high diversity during the Mesozoic interval all around the world. The bennettitaleans have a high evolutionary significance due to their peculiar reproductive structures and vegetative organs, due to their diversity as well as due to their palaeoecology and palaeogeographic distribution. Their systematic position is still disputed, with suggested affinities with the Gnetales or considered as an independent clade. Peculiar reproductive structures with radial symetry, such as *Williamsonia*, *Wielandiella*

and *Williamsoniella* et al., hint them as possible ancestors for a part of the angiosperm polyphyletic group. Diverse foliage records belonging to Bennettitales are widely documented in China. However, the bennettitalean reproductive structures have been very rarely reported. Here we report a new species of *Williamsonia* Carruthers 1870, from the Lower Jurassic terrestrial Jinji Formation in Shuitousha, Guangdong Province, China. The new species is represented by an ellipsoidal ovuliferous cone surrounded by two whorls of smooth and elliptical-elongated bracts. *Williamsonia shenzheniana* sp. nov. has systematic affinities with *W. gigas* Carruthers 1870, *W. banatica* (Krasser) Popa 2014, *W. latecostata* (Krasser) Popa 2014, among other *Williamsonia* species, and it is associated with *Otozamites hsiangchiensis* Sze 1949 foliage and branches, hinting to belonging to the same whole plant. *Williamsonia shenzheniana* is the first species belonging to genus *Williamsonia* reported from China.

KEYWORDS: Bennettitales, Williamsoniaceae, *Williamsonia*, reproductive structure, Lower Jurassic, China.

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[204]

Tricalycites and a New Genus of Winged Fruit from the Cretaceous of North America

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Prominently winged fruits occur in many families of angiosperms today, but are rare and poorly documented in the mid-Cretaceous. The Cretaceous winged fruit or seed genus *Tricalycites* has been considered a mysterious plant. The formal description was published in 1895, for these enigmatic winged disseminules. Fossils of this genus have since been reported from 15 mid- to upper Cretaceous sediments localities distributed in New Jersey, New York, Massachusetts, Rhode Island, Alabama, and Texas. Previous researchers used it as a marker for stratigraphic correlation. However, the genus has not been investigated since early in the last century and has been overlooked in recent treatments of the Cretaceous angiosperm flora. New information from epifluorescence microscopy and micro-CT scanning, is not only helping to better characterize the morphology and possible affinities of *Tricalycites*, but also to recognize a new genus. Improved knowledge of the morphology and affinities of these plants will help to provide a better understanding of late Cretaceous coastal vegetation, and the diversification of angiosperms.

We recognized a new genus of tri-winged fruit based on compression and impression fossils from the Cretaceous of Alabama and New England, which is distinguished from *Tricalycites* by important characters of morphology and epidermal anatomy. Although the affinities of *Tricalycites* remain uncertain, the new genus displays features consistent with eudicot affinities. The disseminules include a pedicellate globose body with longitudinal ribs and a slender apical protrusion interpreted as a style. Three prominent longitudinal wings arise from the base of the fruit, with parallel sides, rounded apices and subparallel venation and the combination of

paracytic and cyclocytic stomata, accompanied with trichome bases. The new genus shows in addition to these wings, a pair of prominent antler-like branched spines arising laterally from the base of the fruit and some diminutive rounded basal laminar lobes on the "front" side of the fruit body. This species differs from the type species of *Tricalycites* which has only a single wing that is tri-lobed, a miniscule seed body and paracytic and tetracytic stomata, and lacks trichome bases. An additional species formerly misassigned to *Tricalycites,* from the late Cretaceous of New York, New Jersey and Massachusetts, is also attributed to the new genus. This species differs by lacking the branched basal spines, and the epidermal anatomy of its wings remains unknown, but conforms to the new genus in wing number and position, venation pattern, fruit body morphology and pedicel thickness. Morphologically, the winged fruits from new genus display some characters in common with extant Fagales, Malvales and Malpighiales.

KEYWORDS: *Tricalycites*, new genus, winged fruits, epidermal anatomy, Cretaceous, North America.

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[205]

An Inter-Comparison Study of Three Stomatal-Proxy Methods for CO_2 Reconstruction Applied to Early Jurassic Ginkgoales Plants

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The inverse relationship between concentrations of CO_2 in the atmosphere (pCO_2) and the stomatal index of vascular plant has been widely used to estimate ancient levels of atmospheric CO_2. However, some atmospheric concentration of CO_2 in the geological past (paleo-pCO_2) estimates show little congruence because they are derived using different correlative methods, or from different fossil plant species with different calibration approaches. Here we apply three methods, including (1) the empirical method of McElwain (1998), (2) the empirical method of Barclay and Wing (2016) and (3) the mechanistic method of Franks et al., (2014) to a single

fossil *Ginkgo* species (*Ginkgoites marginatus*) to track and assess their consistency of pCO_2 estimates for the Early Jurassic. By using an inter-comparison of three methods, a high degree of consistency in pCO_2 estimates and trends has been observed in two empirical proxy methods. In addition, the mechanistic method and both the empirical methods also show generally good consistent paleo-pCO_2 estimates at the bed-level. To test the congruence of paleo-pCO_2 estimates, we also apply all three methods to one additional Ginkgoalean fossil species (*Sphenobaiera huangii*). All three methods show species-dependent uncertainty in paleo-pCO_2 estimates when applied to different Ginkgalean fossil species collected from the same fossiliferous bed. *Moreover,* considering the potencial effect of guard cell size to the mechanistic method, the genome size of fossil and living *Ginkgo* taxa was analyzed based on the significant positive relationship between genome size and guard cell size. The result demonstrates that a likely occurrence of polyploidy in *Sphenobaiera huangii* may result in underestimated paleo-pCO_2 when applying mechanistic method due to an increase in the size of the stomatal complex.

KEYWORDS: Early Jurassic, Stomatal-proxy, *Ginkgoales,* pCO_2, empirical proxy methods, mechanistic method, polyploidy

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[206]

New Fossil Material of *Equicalastrobus* (Equisetales) and Associated Leaves from the Late Triassic of Baojishan Basin, Gansu Province, China

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A new species of *Equicalastrobus pusillus* L. Zhang et D.F. Yan sp. nov. and associated leaves *Schizoneura koningensis* were reported from the Late Triassic of Baosjishan basin, Gansu Province, China. Cones found here were spicate, with peltate discs surrounding the axis, and leaf-like umbo projections were smaller in size compared to the type species. Sporangiophores showed a loose arrangement implying the cones had been expanded before buried. The associated leaves had been attributed to *Schizoneura koningensis*, due to their characteristic features of stem thickness, trap-shaped leaf-sheath and linear, single vein leaves. The evolutionary pathways of Equisetales during geological period were discussed widely but still controversial. In this study, to discuss the relationship of fertile genus *Equicalastrobus* with other Equisetales cones, a clustering analysis on characters of reproductive organs covering 46 equisetalean cones (14 extant and 32 extinct) was performed. Character matrix was based on 36 discrete characters (DCs) and 6 continuous characters (CCs). The clustering results suggested that the new species reported here had a close relationship with *Equisetum*-type cones and a more distant relationship with *Calamites*-type cones. Besides, based on the clustering analysis, it was suggested

that *Equicalastrobus* should be assigned to Family Equisetaceae. The cone fossils reported here were the first records of *Equicalastrobus* in China, supporting the hypothesis that equisetalean were diverse and widespread during the Triassic World.

KEYWORDS: *Equicalastrobus*, *Schizoneura*, cluster analysis, classifications, Late Triassic, China.

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AFTERWORDS

As we all expected, the 1st Asian Palaeontological Congress-with celebrations on the 90th Anniversary of the Palaeontological Society of China will be held in Beijing from Nov. 18th to 19th, 2019. The main aim of this congress is to present a series of progress in paleontology in Asia in recent years, and further promote the collaboration and communication of the scientific research, popular science education, fossil protection and museum exhibitions in the Asian Palaeontological community.

The congress is hosted by the Palaeontological Society of China (PSC), the Palaeontological Society of Japan (PSJ) and the Palaeontological Society of Korea (PSK), and is organized by Nanjing Institute of Geology and Palaeontology, CAS (NIGPAS), Institute of Vertebrate Palaeontology and Palaeoanthropology, CAS (IVPP), Peking University, Institute of Geology, Chinese Academy of Geological Sciences, China University of Geosciences, co-organized by the State Key Laboratory of Palaeobiology and Stratigraphy, Capital Normal University, China Geological Museum, Palaeozoological Museum of China, Beijing Museum of Natural History, Palaeontological Museum of Nanjing, Tianmu Geoscience Museum, and Tianyan Museum of Chongzhou, etc.

We have received 206 abstracts from over 300 participants of 20 countries, such as Democratic People's Republic of Korea, Denmark, France, Germany, Japan, India, Iran, Italy, Lebanon, Malaysia, Mongolia, Pakistan, Russia, Republic of Korea, Romania, Sweden, Thailand, United Kingdom, and China. The abstract volume covers a variety of topics of the congress sessions, i.e. *Early life evolution and Cambrian Fossil Lagerstätten*, *Biodiversity and palaeoenvironment in the Paleozoic, Biodiversity and ecosystem in the Mesozoic and Cenozoic, Dinosaurs and their evolution, Origin and evolution of fossil vertebrates and humansi*, *Molecular palaeontology and geobiology*, *Palaeobotany and palynology*, *Micropalaeontology and its practical applications*, *New technologies and methods in palaeontological research*, *Natural history and palaeontology museums and science education*, etc.

All the abstracts are generally arranged according to the geological age of the topics, and some late submission abstracts are listed in the end of the volume. The scientific secretary staffs have edited the abstracts for the format, but without further editions of the content. In the end of the volume, the authors index are listed.

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Nov. 11, 2019

编后记

翘首期盼中，我们迎来了亚洲古生物学界的一次盛会——第一届亚洲古生物学大会暨中国古生物学会成立 90 周年纪念于 2019 年 11 月 18 日至 19 日在北京召开。本次大会得到中国科学技术协会、自然资源部矿产资源保护监督司、国家自然科学基金委地球科学部、中国科学院前沿科学与技术局、国家古生物化石专家委员会、中国古生物化石保护基金会的大力支持。会议由中国古生物学会、日本古生物学会和韩国古生物学会主办，中国科学院南京地质古生物研究所、中国科学院古脊椎与古人类研究所、北京大学、中国地质科学院地质所、中国地质大学（北京）联合承办；现代古生物学和地层学国家重点实验室、首都师范大学、中国地质博物馆、中国古动物馆、北京自然博物馆、南京古生物博物馆、天目地学博物空间及崇州天演博物馆等协办。

会议将举行中国古生物学会成立 90 周年纪念活动，展示亚洲地区古生物学研究近年来所取得的一系列新成果和新进展，进一步推动亚洲各国古生物学术团体在科学研究、科普教育、化石保护和博物馆展览展示等领域的合作与交流。参会者来自日本、俄罗斯、韩国、蒙古、印度、泰国、菲律宾、马来西亚、朝鲜、伊朗、巴基斯坦、黎巴嫩、缅甸和中国等亚洲国家，以及来自法国、英国、意大利、罗马尼亚、瑞典、丹麦等共计 20 个国家，还包括国际古生物学协会、国际地层委员会等国际组织代表，以及瑞典和丹麦皇家科学院院士、英国皇家学会会员、俄罗斯科学院院士、蒙古科学院院士、中国科学院院士和外籍院士等嘉宾，共计在 300 余人。

在全体参会者的大力支持下，截至 2019 年 10 月 31 日，秘书处共收到论文摘要 206 篇。现将这些摘要编辑成《第一届亚洲古生物学大会——暨中国古生物学会成立 90 周年纪念摘要集》，并统一编印成册，供参会者交流与参阅。秘书处编辑人员对全部摘要仔细地进行了格式的统一和顺序的编排加工等工作。由于时间有限，除了对少数摘要进行必要的修改删减外，其它绝大多数摘要均未逐个进行内容的校订。为了方便读者检索和查找，本摘要集列有目录和全部作者检索表，可以按照作者的姓氏首字母、论文摘要的序号以及页码进行查询和检索。

在论文集的编排过程中，得到了中国古生物学会领导、有关理事及专家同行的大力支持。中国科学院南京地质古生物研究所王姿晰博士、郭文博士、鲁宁博士、彭俊刚博士、梁艳博士、谭超等为论文摘要集的目录编排、索引检索、封面设计以及最后校对编排等付出了辛勤劳动。中国古生物学会副理事长王永栋研究员、秘书长蔡华伟研究员、常务副秘书长吴荣昌博士对摘要论文集文本做了进一步审定。学

会办公室唐玉刚、王丹博士、张玲芝、刘芸等在摘要编排中提供了诸多支持，在此一并表示感谢。摘要集的编排难免存在一些疏漏和不当之处，敬请各位专家和参会代表批评指正！

中国古生物学会秘书处

2019 年 11 月 11 日