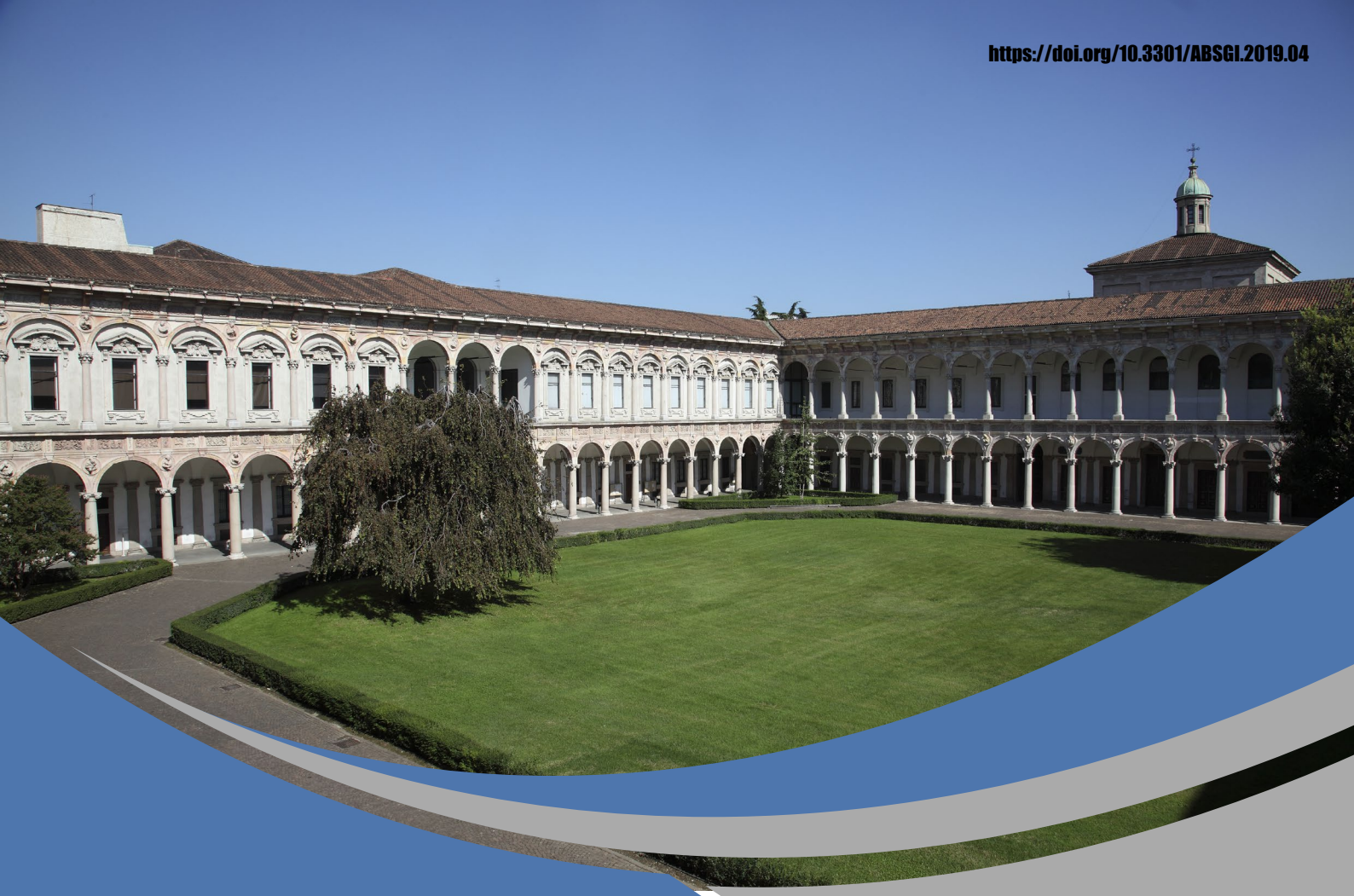
https://doi.org/10.3301/ABSGI.2019.04



Milano, 2-5 July 2019

ABSTRACT BOOK

a cura della Società Geologica Italiana

3rd International Congress on Stratigraphy

3rd International Congress on Stratigraphy

strati 2019

2-5 July 2019, Milano, Italy

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Cambrian stratigraphy, events and geochronology

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

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Keywords: Cambrian, microfossils, phosphate, Iberia.

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

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A Model for Subdividing Cambrian Stages into Substages

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Keywords: Cambrian, stage, substage, chronostratigraphy, GSSP

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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The gut elements of the Cambrian *Leanchoilia*

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Study is supported by RFBR 19-04-01027.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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The Niutitang Formation from the Cambrian in Guizhou

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

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

Distribution and biostratigraphy of the Cambrian chancelloriids: a review

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Keywords: Cambrian, chancelloriids, distribution, biostratigraphy.

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