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Discovery of Shallow-Marine Biofacies Conodonts in a Bioherm within the Carboniferous-Permian Transition in the Omalon Massif, NE Russia Near the North Paleo-Pole: Correlation with a Warming Spike in the Southern Hemisphere

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Abstract

The conodont genera *Hindeodus* and *Streptognathodus* are reported for the first time within the Carboniferous-Permian transition in the northern high latitudes of the Paren’ River, Omolon Massif, NE Russia. Several fossil groups, including brachiopods, bivalves, scaphopods and microgastropods were found to be prolific in the invertebrate-dominated bioherms. These bioherms occur within predominantly siliciclastic sequences with extremely poor fauna, whereas in the studied bioherms the diversity of the bivalves and brachiopods exceeded observed diversity elsewhere in coeval facies in NE Russia. The bioherms are biostratigraphically constrained as uppermost Pennsylvanian to lowermost Cisuralian based on ammonoids. The very unusual peak of bivalve and brachiopod diversity and the occurrence of conodonts that require minimum sea water temperatures of at least 10-12°C indicate a short lived, but significant warming event at that time, at least of provincial significance. This event most likely corresponds with a short-lived warming event recently discovered in the east of the southern hemisphere, in Timor and Australia. Thus, the event is possibly of global significance.

Keywords: Uppermost Carboniferous to Permian transition, conodonts, brachiopods, bivalves, bioherms, climate, warming event, Omolon Massif, NE Russia

1. Introduction

High latitudes in the northern hemisphere during the Late Paleozoic are areas that are quite poorly studied. The only data from the mid- to high latitudes (30-50 ^{0}N paleolatitudes) are known from Spitsbergen, North Greenland and the Canadian Arctic (Beauchamp, 1995; Davydov et al., 2001; Stemmerik and Worsley, 2005, Reid et al., 2007). Information is lacking on areas around the northern paleo-pole (60-80^{0}), especially in the regions in northeastern Russia in Verkhoyansk, Kolyma-Omolon and Chukotka (Zavodovsky, 1960; 1966; Andrianov, 1966; Zavodovsky et al., 1970; Ganelin, 1984). In the Russian literature, however, more data has become available in the last couple of decades (Kashik et al., 1990; Biakov, 2004; 2006; 2007; 2010; 2012; Klets, 2005; Ganelin and Biakov, 2006; Klets et al., 2006; Biakov and Shi, 2010). The Carboniferous and Permian shallow- and deep-water sequences in the sub-polar areas, such as Southern Verknoyansk and Okhotsk regions around 60-70°N, near the paleo-pole (Cocks and Torsvik, 2007) are predominantly sandstones, siltstones and mudstones with very few and rare horizons that are enriched with a carbonate matrix. The successions there are divided and correlated on the basis of bivalves, rare brachiopods and very rare ammonoids (Biakov, 2004, 2007, 2010; Ganelin, 1984; Klets, 2005; Ganelin and Biakov, 2006; Klets et al., 2006; Kutygin, 2006). In the latitudes at the Omolon Massif, Pre-Kolyma and the Omulevka Blocks, the shallow-water Late Paleozoic rocks become more calcareous, with a relatively diverse fauna including abundant foraminifers, brachiopods, bivalves, gastropods, rare ammonoids, solitary rugose corals, bryozoans, ostracods, and crinoids (Zavodovsky et al., 1970; Kashik et al., 1990; Ganelin and Biakov, 2006). Obviously, the shallow-water fauna in these regions are highly endemic and used mostly for local-regional correlation. Extremely rare ammonoids, although endemic, were the only fossils that provided wider correlation with mid-latitudinal sections in the Canadian Arctic, Primorie (south Far East of Russia), Russian Platform, Urals, N. America, Australia and other sections in Peri-Gondwana (Glenister and Furnish, 1961; Nassichuk, 1970; Andrianov, 1985; Kutygin, 2006).

The other stratigraphically important fossils such as conodonts that potentially could be found in mid-latitude areas have never been found in the Omolon Massif before. Several unsuccessful attempts were made previously to recover conodonts from the Upper Paleozoic in the region. The main targets for the conodont extraction were middle to upper Permian carbonates in the Omolon Massif. Very extensive sampling of several dozens of reasonably large (up to 3 kg) samples did not yield even a fragment of a conodont (Kashik et al., 1990). In 2003, twelve samples (1-2 kg) were dissolved from calcareous concretions of the Upper Permian with no conodonts found (personal data of second author).

Here we are reporting the first discovery of *Hindeodus* and *Streptognathodus* conodonts in the middle part of the Magiveem Fm of the Orochian Regional Stage (Horizon) that approximately corresponds to the uppermost Gzhelian and/or lowermost Asselian. The discovery possesses a significant implication for regional climate and may also clarify our understanding of the global Late Paleozoic climate.

2. Geological Setting and Material

The area where the conodonts were found is located in the south-east margin of the Omolon Massif in the upper stream of the Paren' River (Fig. 1). The Omolon Massif is a microcontinent with a crystalline Precambrian basement covered with sedimentary successions of Paleozoic-Mesozoic age (Bogdanov and Til'man, 1992; Chekhov, 2000). During the Phanerozoic time, this microcontinent possessed, tectonically, a very quiet platform sedimentation regime. The Upper Paleozoic and Mesozoic sedimentary rocks are folded into relatively simple isometric folds and fractured by numerous faults of different scale. During the Late Paleozoic, the Omolon microcontinent was separated from the Siberian Craton and the Okhotsk microcontinent by a system of deep-water basins: the Verkhoyansk marginal-epicontinental sea, Ayan-Yuryakh Trough, Balygychan and Sugoi Basins (Biakov et al., 2005; Biakov and Shi, 2010). To the south of these structures (in terms of recent coordinates) was located the Okhotsk-Taigonos (the Koni-Taigonos or the Uda-Murgal) volcanic arc (Parfenov, 1984; Sokolov, 1992; Parfenov et al., 2003; Biakov et al., 2005, 2010). The development of this arc started during Pennsylvanian time with the peak of the activity in the Gizhigian (Capitanian) time (Umitbaev, 1963; Biakov et al., 2005). In the south-east, Omolon microcontinent borders with the Gizhiga back-arc basin and in the east with the system of relatively shallow back-arc basins of the Alazeya-Oloi volcanic arc (Fig. 1). Fragments of the latter are preserved in the eastern margin of the Omolon microcontinent and in the western part of the Penzhina Ridge. The Omulevka and Pre-Kolyma Blocks, because of the particular character of their Permian sedimentologic sequences, were probably located far from the Okhotsk-Taigonos volcanic arc (Biakov et al., 2005). The paleomagnetic data in the region are very poor (Kolesov, 2002) and for some regions, such as the Okhotsk microcontinent, entirely lacking. Nevertheless, recent data makes it clear that no major horizontal drifting of the blocks and microcontinents at least from middle Paleozoic exists (Shapiro and Ganelin, 1988; Rodionov, 1991; Sokolov et al., 1997; Biakov and Kolesov, 2006). The tectonics at the Omolon Massif was limited to local thrusts and strike-slip activity during late Mesozoic folding (Terekhov, 1979).

The Upper Carboniferous and lower Permian deposits in the region belong to the Magiveem Formation with a total thickness of around 300 m (Ganelin, 1984). Here, the thick successions of dark-grey, fine to coarse sandy and silty clastics and volcanoclastics contain a series of horizons with bioherms (Fig. 2). We studied one bioherm within a single horizon that possessed an abnormal taxonomic diversity of invertebrates where the conodonts were recovered The lenticular bioherms in this horizon are 0.5-1.5 m in length and 0.2-0.7 m in thickness extended laterally for a distance of several kilometers. An extremely abundant assemblage of bivalves (24 genera and more than 30 species) for the area has been recovered in one of these bioherms (Table 1), including some warm-water forms of Tethyan affinity (Biakov, 2010). The brachiopods and gastropods, including microgastropods, are also very abundant and diverse, but their taxonomy is a matter for further studies.

The bioherm as well as all the rocks at this location are admixed with volcanoclastic material. In order to recover zircons for U/Pb IDTIMS analyses about 0.5 kg of rock was crushed and processed in a water table, a Frantz magnetic separator, and bromoform heavy liquid. The heavy minerals residue yield well-preserved and shaped datable zircons (70-80 microns), which, however, turned out to be detrital (of Devonian age; dating undertaken by Mark Schmitz, Boise State University Isotope Geology Lab). In addition to zircons, two fragments of the conodont *Hindeodus* and one juvenile specimen of *Streptognathodus* were recovered (Fig. 4). The preservation of all specimens is excellent, with CAI values around 1.0-1.5. Unfortunately, the area is quite remote and no additional sampling for conodonts has been possible.

3. Discussion

3.1 The age of the fossil-bearing bioherm horizon.

Hindeodus and *Streptognathodus* were recovered in the studied location from within the middle part of the Magiveem Fm of the Parenian Regional Stage (Horizon). At this location, the Magiveem Formation consists of inter-bedded cherty and silty tuffites and fine- to coarse-grained sandstone. Rare lenses of fossiliferous rocks with an abundant and diverse assemblage of bivalves, brachiopods, foraminifers, and gastropods (Ganelin, 1984) are found only in bioherms within the middle Magiveem Fm. Within the entire succession of the Magiveem Fm, faunas in general are very rare. The ammonoid *Eoshumardites* aff. *lenensis* (Popow) was found near the base of the formation (Kutygin, et al., 2008). The genus is an index of the Kasimovian in Siberia (Ruzhenzev, 1975; Kutygin et al., 2008), although its upper range may extend into at least the middle Gzhelian (Bogoslovskaya, 1997). The age of the succession above the studied bioherm came from another location downstream from the confluence with the Munugudzhak River, approximately 80 km north-west from the studied locality. The early Sakmarian ammonoids *Uraloceras margaritae* Kutygin and Ganelin and *Kolymoglaphyrites lazarevi* Kutygin and Ganelin were identified in the middle part of Munugudzhak Horizon (Kutygin and Ganelin, 2011), which correlates approximately with the upper part of the Magiveem Formation at the studied location (Biakov, 2010). Near the base of the Fedorov Formation that is overlying the Magiveem Formation was found the bivalve *Ahanaia lima* (Lutkevich and Lobanova, 1960; Fig. 2). The latter is the index for the middle Dzhigdalinian (Lower Permian, Artinskian) (Biakov, 2010). In Western Verkhoanie, this bivalve co-occurs in a rich ammonoid assemblage including *Paragastrioceras kirghizorum* Voinova and *P. verneuili* Ruzhentsev (Kutygin et al., 2002), which in the Urals characterizes the Artinskian deposits (Ruzhenvev, 1956). Accordingly, the age of the entire Magiveem Fm is considered here as Kasimovian- Sakmarian, although the lower Artinskian age for the uppermost part of the formation cannot be excluded (Fig. 2). Because of the stratigraphic position of the conodont-bearing horizon within the middle Magiveem Fm (middle part of the 120 m-thick member 3 on Fig. 2) and the biostratigraphy of bivalves and brachiopods, we consider the age of the horizon as Gzhelian - lower Asselian. In terms of local biostratigraphy, it corresponds to *Prothyris elongatus* bivalve Zone or *Verchojania mirandus* brachiopod Zone (Ganelin and Biakov, 2006; Biakov, 2010).

3.2 Hindeodus and Streptognathodus habitats and environments.

Soft-bodied small, marine animals such as conodonts inhabited a variety of environments in Paleozoic and Early Mesozoic seas. The ecology of *Hindeodus* is somewhat controversial. Some consider it limited to nearshore, shallow marine facies, whereas others suggest its occurrence in a wide facies range in both shallow- and deeper-water environments (Merrill and von Bitter, 1984; Driese et al., 1984; Krumhardt et al.,1996; Nicoll et al., 2002; Lai et al., 2001 and references therein). The majority of the conodont workers, however, suggest that it is a shallow-water inshore taxon adapted to rigorous, fluctuating hydrographic regime habitats (Macleod, 2012 and references therein). The shallow-water nature of the conodont *Hindeodus* is particularly characteristic of marginal shallow thermocline environments in eastern Gondwana (Nicoll and Metcalfe, 1998, 2001), that is essentially similar to the one in the studied area, i.e. southern and northern temperate to cold water zones. Cool-water *Vjalovognathus* and rare *Hindeodus* in eastern Gondwana dominated several levels in the lower Permian of W. Australia, whereas other conodonts less resistant to cold-water environments (*Mesogondolella)* are extremely rare (Nicoll and Metcalfe, 2001). The occurrence of conodonts in the generally siliciclastic and cold, shallow-water succession of Gondwana were interpreted as an invasion during periods of climatic warming events (Nicoll and Metcalfe, 2001). Essentially, the same situation applied to the occurrence of conodonts in the Omolon Basin, where *Hindeodus* could appear only at a shallow thermocline at the warming event. The same applies for the habitats of *Streptognathodu*s in the Omolon Massif. *Streptognathodus* occupied more offshore environments and is known to occur in abundance in shales but is also commonly found in limestones, and thus probably ranged from offshore to nearshore settings (Heckel and Baesemann, 1975; Merrill and von Bitter, 1984; Brown et al., 1991; Krumhardt et al., 1996). At the same time, it likely occurs in shallow-water setting in the Omolon region due to the shallow thermocline.

3.3 Lithological and biological components of bioherms

Bioherms occur in the cyclic, predominantly mixed volcanoclastic-siliciliciclastic succession of the Magiveem Formation that consists of an alternation of fine-grained sandstone and siltstone with an admixture of volcanoclastic material. The contacts between the different lithologies are diffuse. These features and the presence of abundant shelly macro- and microfaunas suggest a quiet shallow-water environment at the time of bioherm formation. Below and above the bioherm horizon the fauna is extremely rare and composed of brachiopods and bivalves. Underlying the Magiveem Formation the Ol'cha Formation consists of very shallow-water littoral and sublittoral sandstone and well-rounded gravel conglomerates (Fig. 2).

The bioherms occur laterally over a distance of several kilometers and possess a lenticular shape sometimes with a flat bottom surface (Figs. 3C-3D). Their size is 0.5-1.5 m in length and 0.2-0.7 m in thickness. The bioherms consist of solid bioclastic rock enriched with siliciclastics and volcaniclastic material without any cavities or holes. The framework of the bioherm is built with shelly fossils (Fig. 3G) such as brachiopods, bivalves, gastropods, microgastropods, rare scaphopods, crinoids and nautiloids (20-25 % of the rock) filled with coarse to fine bioclasts (~50%). The major parts of the microfossils are agglutinated and secreted calcareous attached and non-attached foraminifers. Their taxonomic diversity, however, is low. The following genera were identified *Eotuberitina*, *Tolypammina*, *Orthovertella, Glomospira, Rectocornuspira* (Fig. 4.5-4.6), *Endothyra and Protonodosaria*? The calcareous foraminifers and other bioclastic components are often silicified or pyritised partly or in whole. Pyritisation is quite significant in the rock (Fig. 3G). In both light and magnetic residues the silicified bioclasts are the dominant component. The volcanoclastic and siliciclastic clasts are about 15-20% of the rock and composed of quartz, plagioclase, and felsite cement (Fig. 3G). The shelly fauna become very rare in the periphery of the bioherms and the rock is mostly composed of fine-grained sandstone and siltstone with rare productid brachiopods (*Jakutoproductus*) and bivalves. Well-preserved *Jakutoproductus* with spines (Figure 3F) found in the periphery of the bioherm suggest quiet-water environments and in situ burial.

3.4 Bivalve habitats and environments

Two types of bivalve habitats were established in the Permian of North-East Asia basins (Biakov, 2006, 2010): deep- and shallow-water paleocommunities. The deep-water paleo-communities are uniform throughout all basins in Northeast Asia. They are distinguished in the Ayan-Yuryakh, Balygychan and Gizhiga Basins. The shallow-water paleocommunities are specific in each of the basins. The Omolon, Okhotsk and Siberian paleocommunities within particular shallow-water sedimentologic settings are recognized (Biakov, 2006, 2010).

The shallow-water paleocommunities are characterized by much higher diversity and abundance and occur within the wider types of lithofacies and settings. In the Omolon Basin, seven types of the paleocommunities were recognized including two in reefs and bioherms (Biakov, 2010):

In general, the bioherms occur in the region within the Pennsylvanian starting from the Ol'cha Formation (middle Bashkirian-Moscovian), but their poor taxonomic composition and diversity differ significantly from the bioherms found in the middle Magiveem Fm and described here. The latter bioherms are characterized by the greatest diversity and abundance among all types of paleocommunities found elsewhere in the Omolon and surrounding regions.

The dominant fauna in the bioherms from Magiveem Fm are abundant and diverse brachiopods and bivalves. The brachiopods are represented mostly by *Verchojania*, but other rare productids, such as *Lanipustula*, *Costatumulus* occur as well. In addition, rare chonetids, rhynchonellids and spiriferids were found. The latter fauna usually dominated the periphery of the bioherms.

The bivalves are abnormally abundant within the entire body of the studied bioherms. The taxonomic diversity of bivalves recovered in just one bioherm consists of 34 species of 24 genera (Table 1), what is unprecedentedly high compared with bivalves in the sediments stratigraphically below and above the studied bioherm in the Permian and Carboniferous in the Omolon Massif and surrounding regions. Usually, the bivalve diversity in the bioherms in the regions is of an order of magnitude lower and on average consists of 2-6 genera and 2-7 species.

Among the bivalves in the studied bioherm, the dominant fauna are schizodids (*Schizodus*), astartids (*Astartella*), prothyrids (*Prothyris*), some representatives of aviculopectinoids (*Streblopteria*), vacunellins (*Vacunella*), sanguinolitins (*Grammysiopsis*, *Cosmomya*), and megadesmatids (*Pyramus*). The specimens of the *Myalina* similar to warm-water *Myalina permiana* Meek et Hayden from the Great Basin and Texas of North America are also present in this paleocommunity. Moreover, a typical warm-water taxon such as *Pteronites* and other were recently found in the corresponding stratigraphic horizon in the other locations at Ledyanaya River and Avlondya River of the Omolon Basin (Biakov, 2013). All these suggest that the shallow sea in the Omolon microcontinent at that time was relatively warm.

A very prominent element of the bivalves assemblage are several taxa that are known from the late Pennsylvanian and Cisuralian of the Urals (Likharev, 1927), such as *Neptunopecten*? *keyserlingiformis* (Licharew), *Leptochondria simensis* (Licharew), *Kolymopecten mutabilis* (Licharew), *Streblopteria eichwaldi* (Stuckenberg), *S. krasnoufimskensis* Frederiks, S. *englehardti* (Etheridge et Dun), and the number of others species of this genus (see Table 1). *Streblopteria* are very common in this bioherm. The phenomena of abundance of *Streblopteria* in the Cisuralian reefs in the Urals and Timan has been reported by Likharev (1927, p. 27). Some of the *Streblopteria* from the studied bioherm are identified in open nomenclature, but at least four species of this genus are recognized (Table 1).

Pseudomonotis kumpani Fedotov from the bioherm is described from the Late Pennsylvanian of the Donets Basin (Fedotov, 1932). *Leptochondria simensis* (Licharew) is known from the Cisuralian of the Urals (Likharev, 1927) and from the Late Pennsylvanian of the Donets Basin (Fedotov, 1932). The genus *Pseudomonotis* commonly occurs in the subtropics (Greenland, the central and northern parts of the Russian Platform) but is also known to occur in the southern hemisphere in West Timor and the Salt Range in Pakistan (Spath, 1935; Schindewolf, 1954). Artinskian assemblage of these bivalves is likewise known from the shallow-water Permian tropics (Park City Group) in Utah and Nevada (Wilmer, 1938;). The genus *Leptochondria* is typical for the tropical basins (China, Japan, and West Texas of the United States) (Newell and Boyd, 1995).

In general, the taxonomic composition of the bivalves in the bioherm is typical for the Omolon region, except for the presence of *Myalina, Pseudomonotis* and *Leptochondria*. The latter forms are characteristic for the lower latitudes within the subtropics in the Boreal Realm (Greenland, the central and northern parts of the Russian Platform and Urals) and the tropics of the North American province. At the same time, none of the typical Tethyan taxa such as pterinopectinids, carditids, lucinids, posidoniids, entoliids, annuliconchids, isognomonids, ostreids, alatoconchids, and the number of specific genera (*Goniophora, Cassianella, Costatoria* etc.), which are widespread in the Tethyan basins were found in the studied location. Nevertheless, the occurrence of myalinids, pinnids, *Leptochondria* and some other warm-water forms, in addition to the occurrence of conodonts *Hindeodus* and *Streptognathodus*, clearly indicate the warming but short-lived event at that time.

The other benthic groups in the bioherms are very abundant and diverse as well. These are microgastropods and large gastropods (more than 10 genera, mostly bellerophontids), very abundant but not diverse smaller foraminifers, very rare pelmatozoans (apparently crinoids), very large (up to 0.2 m) nautiloids, small scaphopods, and scyphoids (*Conularia*). The most characteristic representatives of the assemblage are given in Figures 4-5.

4. Paleoclimate Implications

The phenomena of the occurrence of warm water faunas within the high latitudes of cool- to cold marine environments are, including conodonts and brachiopod/bivalves, well studied in Australia (Nicoll and Metcalfe, 1998; Waterhouse and Shi, 2013). Marine faunas there were strongly affected by the shifts in climate, so, as in the Permian high latitudes of eastern Australia and New Zealand faunas, associated with tillites and dropstones differ from those of the paleo-tropics/subtropics. It has also been proposed that these shifts might occur quite rapidly and within short time intervals (Davydov et al., 2013; Waterhouse and Shi, 2013).

The late Pennsylvanian was a time of glaciation that in Australia is represented by a significant stratigraphic hiatus in basins to the south of Timor in the East Gondwana rift system (Fig. 6). Recently, a global warming spike in the latest Gzhelian time has been documented in Timor and Western Australian (Davydov et al., 2013). In Timor, the warming event associated with the appearance of a large bioherm of about 20 m in height is within the siliciclastic sequences of the Maubisse Group. The bioherm consists of a massive, lower unit, including a reef framework at the base, and a bedded grainstone upper unit. The bioherm developed on a basalt substrate in warm shallow-water, as indicated by the photozoan assemblages in the massive lower unit with diverse and abundant assemblage of large benthic foraminifers. The bedded upper unit is characterized by a dominantly heterozoan composition of the skeletal component of the limestone (except for the basal photozoan assemblage). The taxonomic diversity of the larger foraminifers suggests a subtropical environment consistent with a paleolatitude of about 40-45° S. At this paleolatitude within the more-open reaches of an interior sea that flooded the East Gondwana rift system, subtropical conditions prevailed during the latest Gzhelian (and possibly earliest Asselian) coinciding with a global warm spike as suggested by the fusulinid biogeography and reef development. At about the same time, a rapid influx of glaciogene sediment (diamictite alternating with mudstone) occurred in basins further south in the rift system, suggesting the initiation of a rapid melting of continental ice sheets (Davydov et al., 2013).

In Western Australia, no conodonts are known yet from the Pennsylvanian and Asselian-early Sakmarian, but they were documented in the upper Artinskian, Kungurian and Roadian (Nicoll and Metcalfe, 1998). The latter authors propose that, during Cisuralian time, the Southern Carnarvon Basin was located at 60-65°S, which is consistent with the low abundance/diversity of conodonts that include rare and pandemic *Hindeodus* and endemic *Vjalovognathus australis* Nicoll and Metcalfe in the Artinskian. In the Canning Basin, which was located closer to the tropics at 55-50°S, the conodonts, although of different Kungurian age, are more abundant and except *Vjalovognathus*, include rare specimens of *Hindeodus* and *Mesogondolella idahoensis.* In Timor (about 40-45° S), the conodonts possess greater diversity and consist of *Diplognathodus oertfii* Kozur, *Hindeodus* sp., *Merrillina praedivergens* Kozur and Mostler, *Hindeodus* sp., *Sweetocristatus* sp., *Sweetognathus* aff. *whitei* (Rhodes), *Mesogondolella bisselli* (Clark and Behnken), *Sweetognathus "inornatus"* Ritter and *Vjalovognathus australis* Nicoll and Metcalfe (van den Boogaard, 1987; Nicoll and Metcalfe, 1998).

In addition to the conodonts from the Omolon Massif, we also recovered one juvenile specimen of *Streptognathodus* from the residue of a small sample (about 60 grams) in the uppermost Gzhelian bioherm in Timor (Figure 4.5). The Timor has been positioned at 45°S (Nicoll and Metcalfe, 1998; Davydov et al., 2013). In the latter publication it was proposed that the lower Calytrix Member of the Grant Formation in the Canning Basin with exceptionally diverse fauna including foraminifers (*Tetrataxis* and *Protonodosaria*), crinoids, bryozoans, mollusks and brachiopods might correspond to a deglaciation cycle. At the same it is linked to the warm spike evidenced by the latest Gzhelian bioherm in Timor (Davydov et al., 2013). All the above suggests that the Calytrix Member of the Grant Group in the Canning Basin might be the most promising target to recover conodonts and to test the warm-event hypothesis.

The discovery of conodonts and a high diversity assemblage of bivalves, brachiopods and gastropods as well as the occurrence of other groups of fauna at northern high latitudes within the upper Gzhelian - lower Asselian transition and documentation of the upper Gzhelian bioherm in Timor in northern hemisphere strongly suggest the global scale of this warming event.

To be cautious, we cannot exclude other factors that potentially could cause the local warming event in the region. One could suggest that the change in the pattern or perhaps reconfiguration of the ocean currents and re-direction of warm water currents towards the Omolon Massif might produce a similar event horizon. We think, however, it is a less likely scenario, first, because of the configuration of the blocks surrounding the Omolon and the occurrence of arc system developed in the area since Devonian time (Fig. 1B). Second, it is hard to expect that such an warm ocean current would exist for a very short time (approximately 1 Myr or less). Still, we should keep this in mind and explore all the possibilities further.

5. Conclusions.

The conodonts *Hindeodus* and *Streptognathodus* have been discovered for the first time in the Carboniferous-Permian transition at the Omolon microcontinent. The position of the latter at that time was around 60-65°N. The discovery of these shallow-water conodonts at high latitudes is consistent with the occurrence of conodonts at southern mid- and high latitudes in Timor (40-45°S) and Western Australia (50-65°S), where their appearance is similarly interpreted as being associated with several warming events. The warming event in the Omolon microcontinent is expressed in the highest taxonomic diversity of the bivalves in the bioherms and appearance of several warm-water subtropical forms. It is most likely that the conodont-bearing horizon in the Omolon Basin corresponds with the upper Gzhelian bioherm in Western Timor and thus to the warming event on a global scale, although other factors, such as oceanic current shift cannot be entirely excluded. The Calytrix Member of the Grant Group in the Canning Basin, which possesses an exceptionally diverse fauna, might be also associated with this warming event and is therefore a promising target to recover conodonts and to test our suggestion and model.

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Explanations of Figures

Collection of all fossils reported in this paper housed in the Museum of North-East Interdisciplinary Scientific Research Institute n. a. N.A. Shilo, Far East Branch of the Russian Academy of Sciences, 16 Portovaya, Magadan, 685000, Russia, collection number 02-06.103.

Figure 1. Location map, geologic map of the upper stream of the Paren' River (**A**) and Paleogeographic map of the Omolon microcontinent and surrounding regions in Asselian time (**B**). Note the position of the Omolon microcontinent is around 60^0N. **A**: 1, Quaternary; 2, Cretaceous; 3, Triassic' 4, Armandzha Fm., 5, Aulandzha Fm., 6, Fedorov Fm., 7, Magiveem Fm., 8, Ol'cha Fm., 9, Hayam Fm., 10, faults, 11, geological boundaries; 12, studied location where conodonts were found. **B**: 1, highlands; 2, lowlands; 3, shallow sea; 4, offshore; 5, deep sea; 6, volcanic arch; 7, the boundaries of tectonic units; 8, zones of initial rifting; 9-12, migrational directions of bivalves, 9, from North American basins; 10, from other tropical regions; 11, from west boreal regions.

Figure 2. Stratigraphic log of the upper Paleozoic succession in the upper part of the Paren' River. 1, mixed siliciclastic-volcanoclastic mudstone; 2, bedded volcaniclastic siltstone; 3, sandstone; 4, coarse sandstone and conglomerate; 5, bioherms; 6, small clasts of coal; 7-14 -- faunistic occurrences: 7, foraminifera; 8, conodonts, 9, ammonoids, 10, bivalves, 11, brachiopods, 12, crinoids and other pelmatozoans; 13, nautiloids, 14, scaphopods; 15 - gastropods. A-E assemblages of the fossils found at different horizons: **A** - *Lanipustula mirabilis* (Zavodowsky), *Lissochonetes* sp., *Modiolus* sp., *Schizodus* aff. *jakovlevi* Fedotov, *Astartella* cf. *permocarbonica* Tschernyschew, *Cypricardinia* sp., *Praeundulomya?* sp., **B** - *Verkhoyania taimyrensis* (Ustritsky), *Lanipustula mirabilis* (Zavodowsky), *Attenuatella omolonensis* (Zavodowsky), *Eoshumardites* ex gr. *lenensis* (Popow), *Modiolus* sp., *Kolymopecten* cf. *mutabilis* (Licharew), *Cypricardinia?* sp., *Palaeolima laticostata* Tschernyschew **C** - *Verkhoyania monstrosus* (Ganelin), *Costatumulus missouriensis* (Sayre), *Pyramus aenigmaeformis* Biakov, sp. nov., *Astartella* cf. *permocarbonica* Tschernyschew; **D** - *Verkhoyania mirandus* (Ganelin), *Anidanthus boikowi* (Stepanov), *"Pterospirifer"terekhovi* Zavodowsky, *Tomiopsis* ex gr. *tricostatus* Kotlyar, for the list of bivalves and foraminifera see text and table 1; **E** - *Protonodosaria quadrangula* Gerke, *Verkhoyania expositus* (Ganelin), *Costatumulus missouriensis* (Sayre), *Astartella permocarbonica* Tschernyschew, *Schizodus* sp., *Pyramus aenigmaeformis* Biakov, *Wilkingia* sp.; **E`**- *Uraloceras margaritae* Kutygin et Ganelin and *Kolymoglaphyrites lazarevi* Kutygin et Ganelin. These ammonoids found in different location (Kutygin and Ganelin, 2011) about 120 km west from the studied locality in Paren' River at the level corresponding to the upper part of Magiveem Formation (see the text for details); **F** - *Costatumulus janischewskianus* (Stepanov), *Rhynoleichus subglobosus* Abramov et Grigorjeva, *Aphanaia*? sp.

Figure 3. Field photos and petrography of the middle Magiveem Formation in the upper stream of the Paren' River. **A**, general view of siliciclastic succession of the Magiveem Formation; **B**, close view of the part of the succession with bioherms (next to the backpack), the major part of the bioherm, has been removed due to fossils collection; **C**, the exposure of the invertebrate-dominated bioherm (Bh) within the siliciclastics (yellow) with rare conodonts; **D** – example of a better exposed bioherm from the Ol'cha Formation, faunistic composition in this bioherm is poor; **E**, diverse assemblage of brachiopods and bivalves in the bioherm from Magiveem Formation; **F** – brachiopod shell with well-preserved spines (arrows) suggesting the shallow-water environments and *in situ* burial; **G** – thin-section of the studied bioherm; Sh – shelly framework; Fr.- foraminifera; Pl. – pelmatazoans; Sp –brachiopod spines; Pr and other black sharp grains – pyrite; white sharp grains are quartz and plagioclase clasts. The most of the rest bioclasts cannot be identified. Scale bars for E – 10mm, for F, G – 1 mm

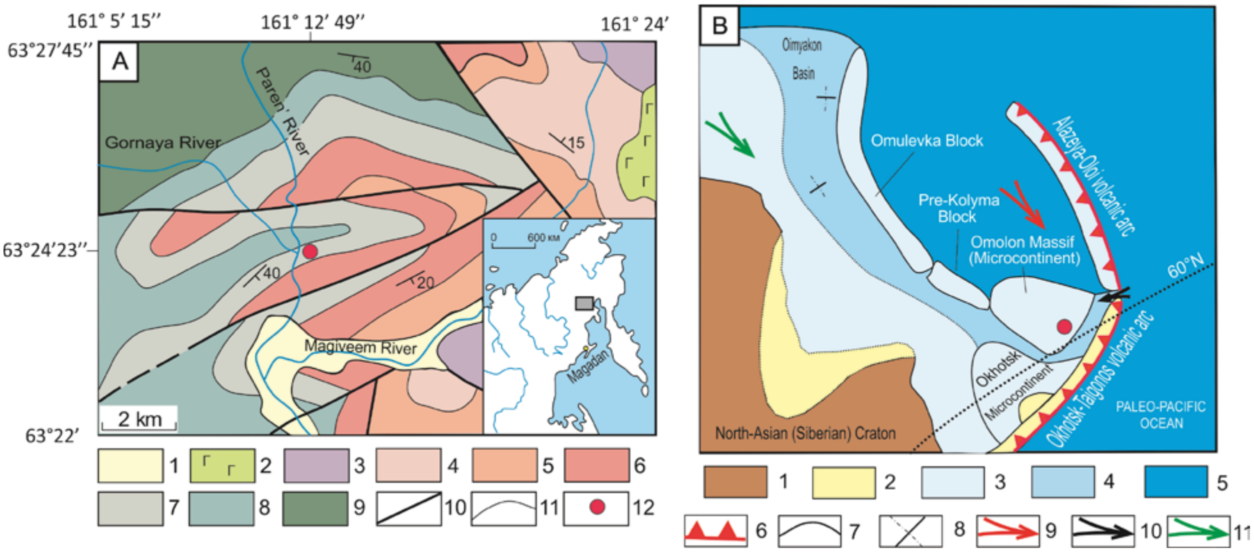
Figure 4. Conodonts, microgastropods and foraminifera from the bioherms in the middle Magiveem Formation, the Omolon Massif, NE Russia and Timor Island [specimen 3.5]. 1-2, *Streptognathodus* sp., juvenile specimen, 1- upper view SEM photograph, 2, lateral view, 22/02-06.103, 3-4, lateral view of the fragments of *Hindeodus*, 23/02-06.103 and 24/02-06.103; 5, *Streptognathodus* sp., juvenile specimen from sample S6119a, Oharaikiik River area, Horai Kiik Suco, Maubisse Subdistrict, Timor Leste (for more information see Davydov et al., 2013, p. 24); 6-7, foraminifera *Rectocornuspira* sp. All foraminifers silicified and often pyritised; 8-9, microgastropods; 10-11, residue from dissolved sample composed of dominantly bioclasts of brachiopods and bivalves Sh), microgastropods (Mcg), foraminifera (Fr), other fossils and quartz (Qrz) fragments. The scale bars figures 1-2 are 0.2 mm, 3-9 – 0.1mm, 10-11 – 1mm.

Figure 5. Bivalves and scaphopods from the bioherms in the middle Magiveem Formation, the Omolon Massif, NE Russia (collection of fossils housed in the Museum of North-East Interdisciplinary Scientific Research Institute n. a. N.A. Shilo, Far East Branch of the Russian Academy of Sciences, 16 Portovaya, Magadan,

685000, Russia, collection number 02-06.103). 1–3 – *Myalina permiana* Meek et Hayden: **1,** right valve, 1/02-06.103; **2** – right valve, 2/02-06.103; **3** – left valve, 3/02-06.103; **4**, **5** – *Streblopteria eichwaldi* (Stuckenberg), **4** – the mould of the left valve, 4/02-06.103; **5** – incomplete mould of the right valve, 5/02-06.103; **6**, **7** – *Streblopteria englehardti* (Etheridge et Dun): **6** – the mould of the right valve, 6/02-06.103; **7** – right valve, 7/02-06.103; **8-9** – *Streblopteria krasnoufimskensis* (Fredericks), the moulds of the right valves, 8/02-06.103 and 9/02-06.103; **10** – *Streblopteria* sp.5, the mould of the left valve, 10/02-06.103; **11-12** – *Pseudomonotis kumpani* Fedotov: **11** – right valve, 11/02-06.103, **12** – left valve, 12/02-06.103; **13** – *Leptochondria simensis* (Licharev), left valve, 13/02-06.103; **14** – *Neptunopecten*? *keyserlingiformis* (Licharev), latex cast of the left valve, 14/02-06.103; **15** – *Kolymopecten mutabilis* (Licharev), mould of the left valve, 15/02-06.103; **16–20**, various indeterminate scaphopods, 16/02-06.103, 17/02-06.103, 18/02-06.103, 19/02-06.103, 20/02-06.103; **21** – incomplete shell of the indeterminate nautiloids, 21/02-06.103. All scale bars are 1 cm, the magnification of figures 1-15 is x 3; figures 16-20, x 5 and figure 21 is of natural size.

Figure 6. Correlation chart comparing the Omolon Massif and East Gondwana rift system Carboniferous-Lower Permian successions. The bioherms/buildups documented within the Gzhelian-Asselian transition in both Timor and Omolon regions. The red dots on palaeogeographic map: 1, Omolon Massif; 2, Timor; 3, south Eastern Gondwana Basins (modified from Davydov et al., 2013).

Table 1. The taxonomic composition of the abnormally diverse bivalves from the bioherm in the middle Magiveem Formation, upper part of Paren’ River, the Omolon Massif, NE Russia.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Oimyakon
Basin
Omulevka Block
Pre-Kolyma
Block
Omolon Massif
(Microcontinent)
Alazeya-Oloi volcanic arc
60°N
Okhotsk
Microcontinent
Okhotsk-Taigonos volcanic arc
PALEO-PACIFIC
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North-Asian (Siberian) Craton
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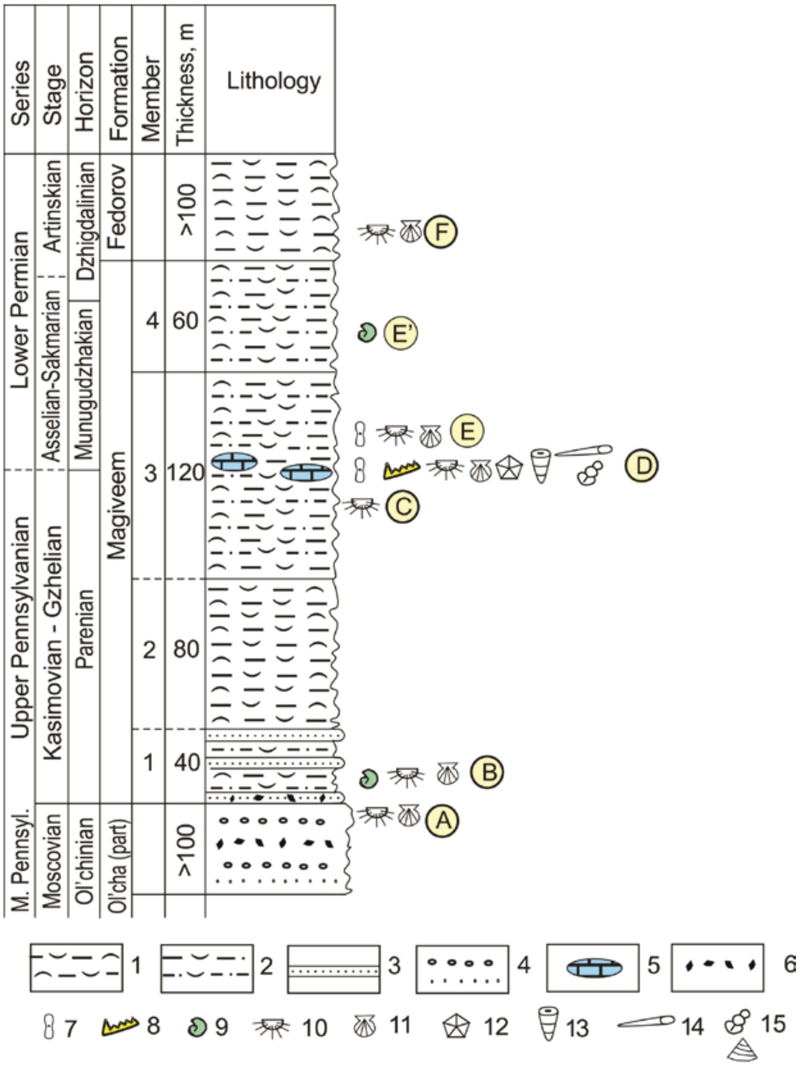
Figure 1


Series
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Lower Permian
Upper Pennsylvanian
M. Pennsyl.
Artinskian
Asselian-Sakmarian
Kasimovian - Gzhelian
Moscovian
Dzhigdalinian
Munugudzhakian
Parenian
Ol'chinian
Fedorov
Magiveem
Ol'cha (part)
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Figure 2

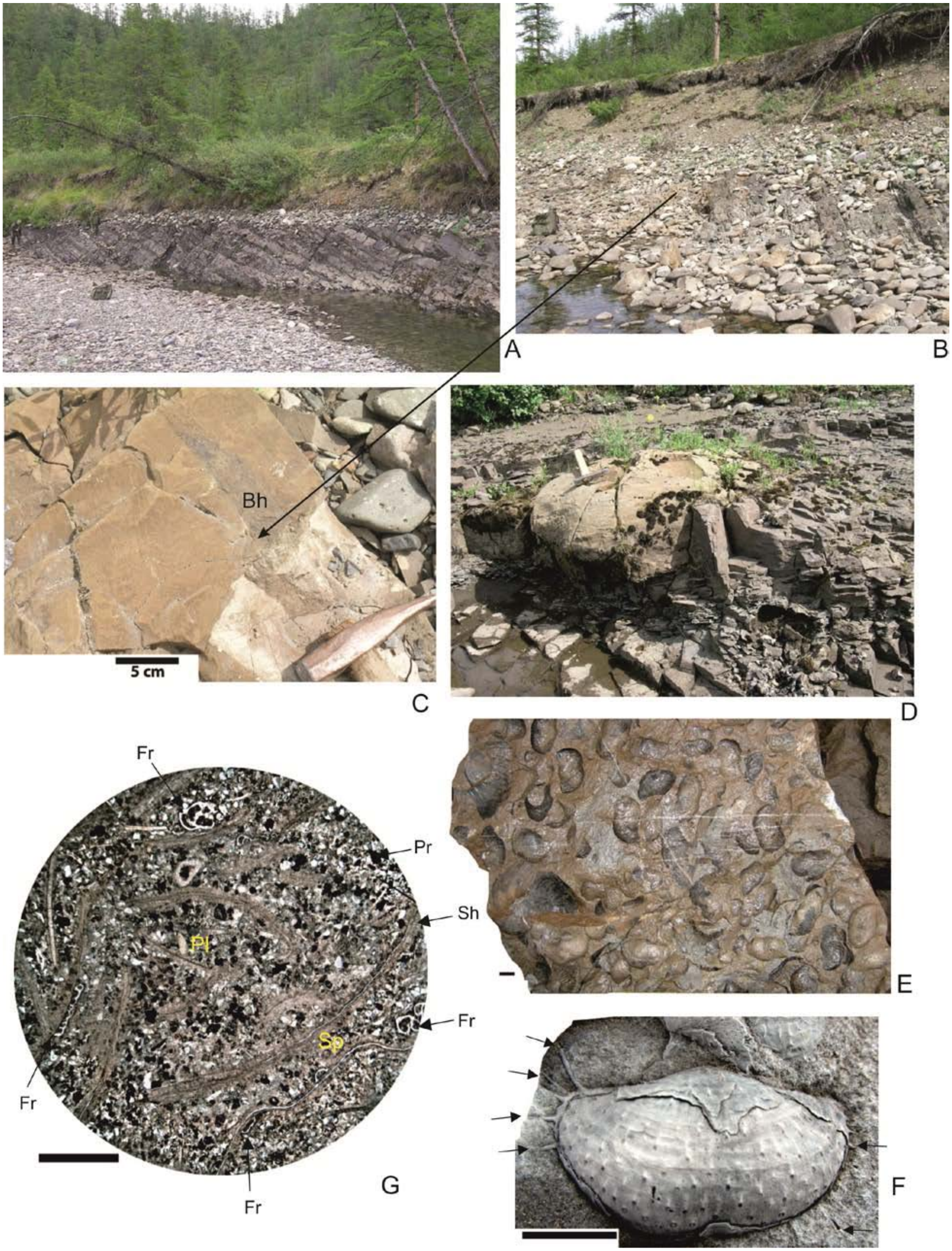


Figure 3

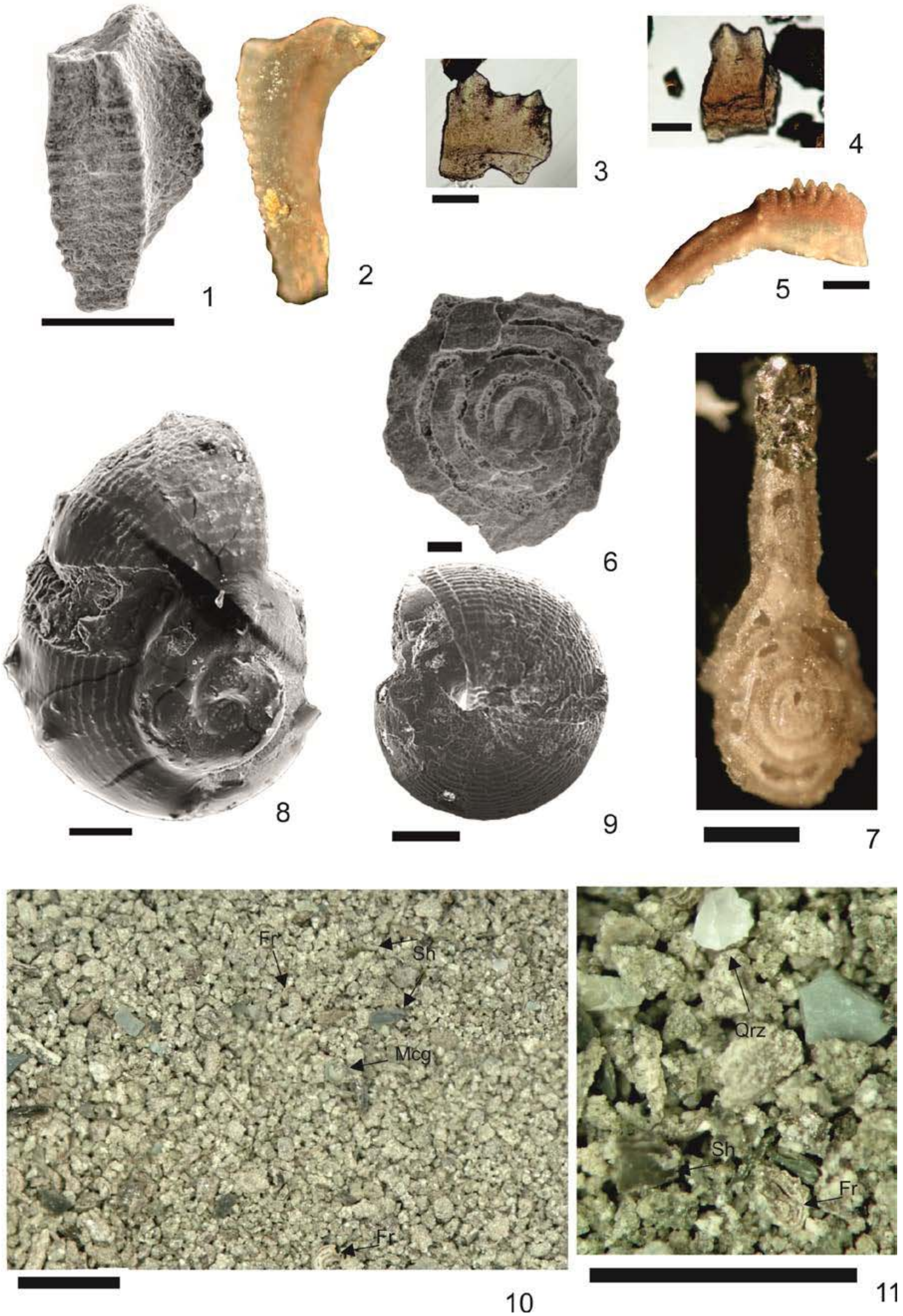


Figure 4

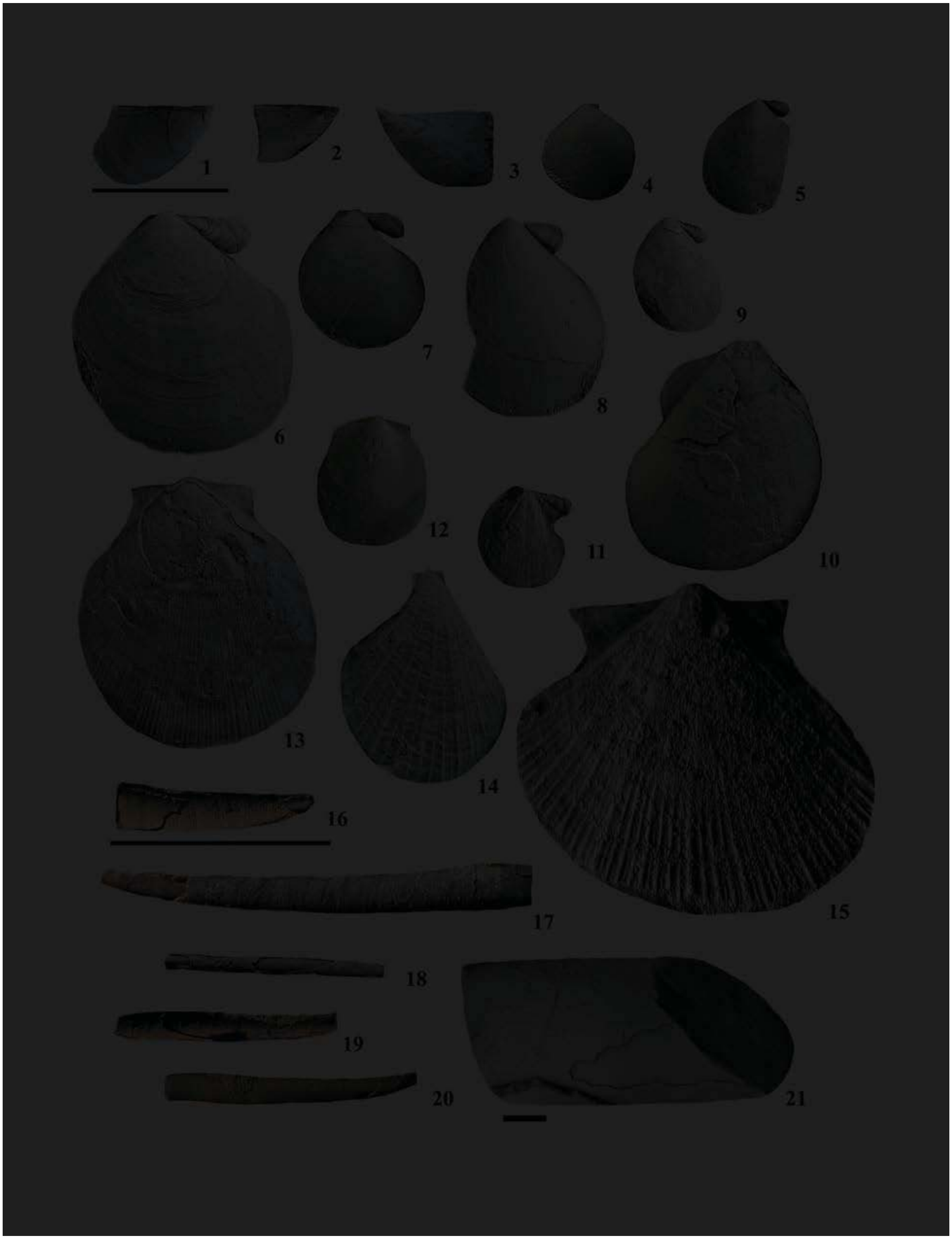


Figure 5

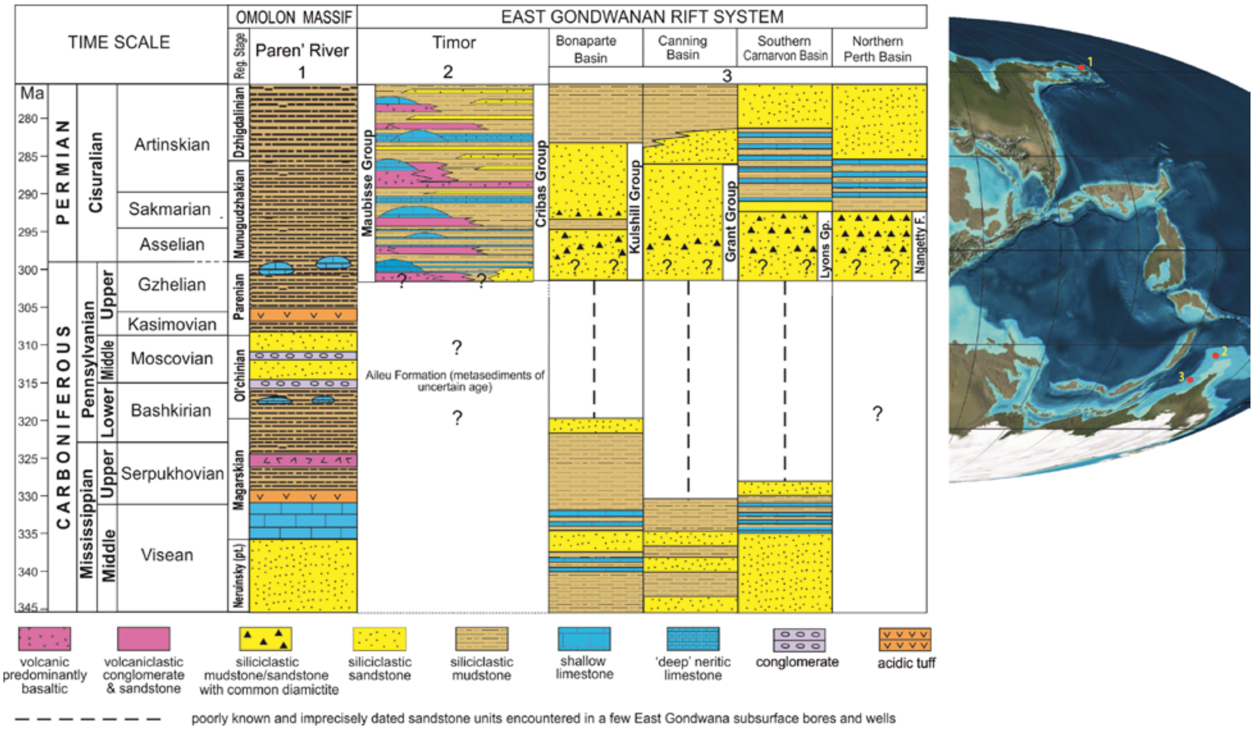
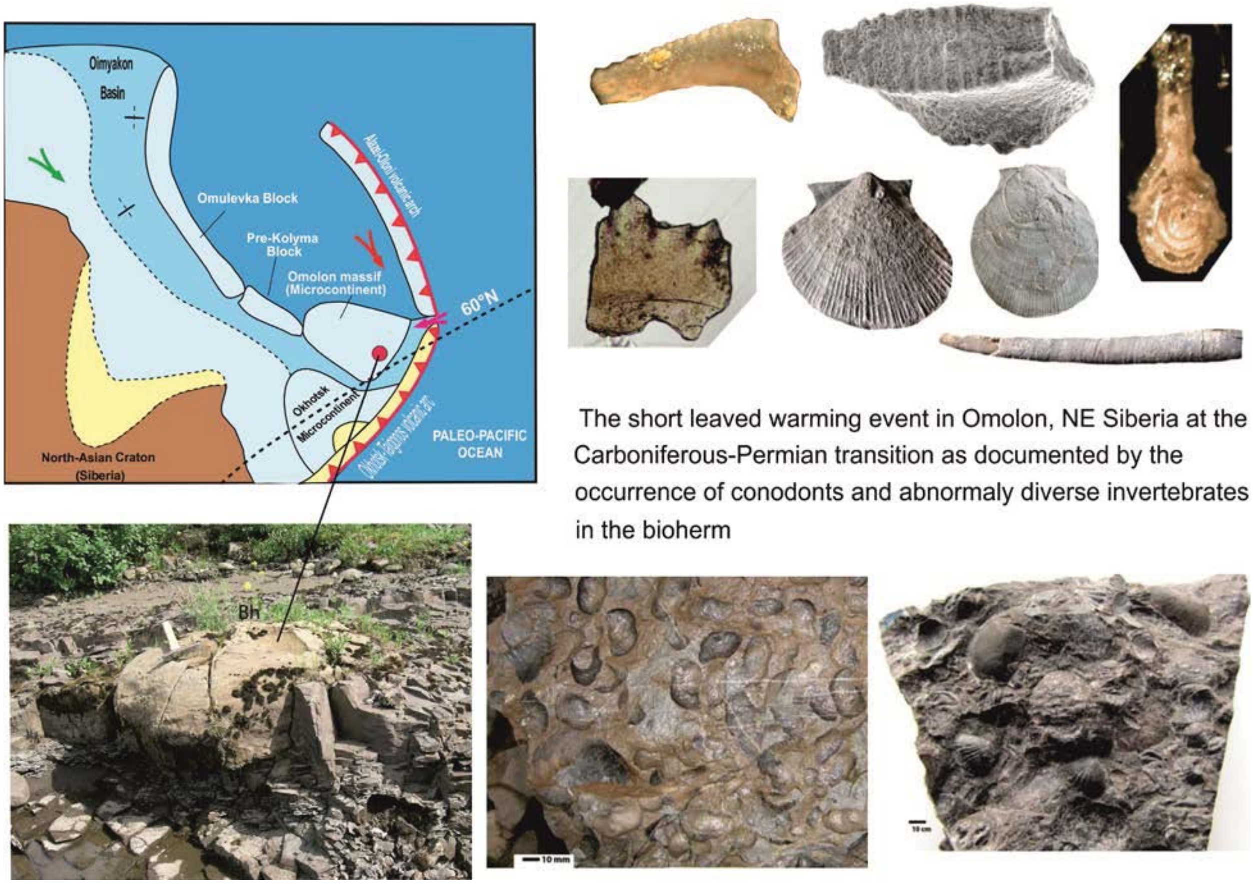

TIME SCALE
OMOLON MASSIF
EAST GONDWANAN RIFT SYSTEM
Reg. Stage
Paren' River
1
Timor
2
Bonaparte Basin
Canning Basin
Southern Carnarvon Basin
Northern Perth Basin
3
Ma
280
285
290
295
300
305
310
315
320
325
330
335
340
345
PERMIAN
Cisuralian
Artinskian
Sakmarian
Asselian
CARBONIFEROUS
Pennsylvanian
Mississippian
Upper
Middle
Lower
Gzhelian
Kasimovian
Moscovian
Bashkirian
Serpukhovian
Visean
Dzhigdalinian
Munugudzhakian
Parenian
Ol'chinian
Magarskian
Neruinsky (pt.)
Maubisse Group
Cribas Group
Kulshill Group
Grant Group
Lyons Gp.
Nangetty F.
Aileu Formation (metasediments of uncertain age)
?
volcanic predominantly basaltic
volcaniclastic conglomerate & sandstone
siliciclastic mudstone/sandstone with common diamictite
siliciclastic sandstone
siliciclastic mudstone
shallow limestone
'deep' neritic limestone
conglomerate
acidic tuff
poorly known and imprecisely dated sandstone units encountered in a few East Gondwana subsurface bores and wells
1
2
3

Figure 6

No	**Genus**		**species**	**Author**
1	*Palaeoneilo*		*parenica*	Biakov
2	*Phestia*		*jamesi*	(Biakov)
3	*Solemya*	cf.	*holmwoodensis*	(Dickins)
4	*Vorkutella*	sp.	*nov.*	
5	*Modiolus*	sp.	*nov.*	
6	*Modiolus*	cf.	*koneckii*	Dickins
7	*Myalina*		*permiana*	Meek et Hayden
8	*Kolymopecten*		*mutabilis*	(Licharew)
9	*Leptochondria*		*simensis*	(Licharew)
10	*Neptunopecten?*		*keyserlingiformis Licharew*	(Licharew)
11	*Pseudomonotis*		*kumpani*	Fedotov
12	*Streblopteria*		*krasnoufimskensis*	(Fredericks)
13	*Streblopteria*		*eichwaldi*	(Stuckenberg)
14	*Streblopteria*		*englehardti*	(Etheridge et Dun)
15	*Streblopteria*	sp. 5		
16	*Schizodus*		*fitzroyensis*	Dickins
17	*Schizodus*	aff.	*jakovlevi*	Fedotov
18	*Schizodus*	sp.		
19	*“Permophorus”*	sp.		
20	*Astartella*		*omolonica*	Muromzeva
21	*Astartella*		*permocarbonica*	Tschernyschew
22	*Astartella*	sp.		
23	*Astartila?*	cf.	*tumida*	Dickins
24	*Cypricardinia*	sp.		
25	*Pleurophorella*	sp.	*nov.*	
26	*Parenia*		*gen. and species nov.*	
27	*Pyramus*		*aenigmaeformis*	Biakov, sp. nov.
28	*Pyramus*	aff.	*aenigmaeformis*	Biakov, sp. nov.
29	*Vacunella*	ex gr.	*curvata*	(Morris)
30	*Vacunella*		*praecurvata*	Astafieva-Urbajtis
31	*Grammysiopsis*		*omolonicus*	Muromzeva
32	*Cosmomya*	sp.	*nov.*	
33	*Undulomya*	sp.	*nov.*	
34	*Prothyris*		*elongatus*	Biakov

Table 1: Bivalves



The short leaved warming event in Omolon, NE Siberia at the Carboniferous-Permian transition as documented by the occurrence of conodonts and abnormaly diverse invertebrates in the bioherm

Graphical Abstract