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Middle–Late Triassic Radiolarians from the Dzhugadzhak Section (the Omolon Massif)

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Abstract—Radiolarians were found in the upper Anisian, upper Ladinian, and lower Carnian deposits of the Omolon massif. Their assemblages are less diverse than the coeval Mediterranean assemblages but very similar to the Middle Triassic assemblages of New Zealand. The identified cosmopolitan species of the assemblages enable correlation between Triassic deposits in the high and low latitudes.

Key words: *Triassic, Omolon massif, stratigraphy, correlation, paleobiogeography, radiolarians.*

INTRODUCTION

Radiolarians represent one of the fossil groups studied inadequately. This especially concerns the Mesozoic radiolarian assemblages from the high-latitude (boreal) areas, particularly from Triassic deposits. Abundant data on compositions of Triassic radiolarian assemblages and vertical ranges of individual taxa in the tropical belt (the Mediterranean region, Japan, the Far East of Russia, western areas of the United States and Mexico) were used to elaborate several valid stratigraphic schemes (Bragin, 1991; Carter, 1993; Kozur and Mostler, 1994; Yao, 1990). On the contrary, investigation of their boreal assemblages that was started recently yielded so far scanty information. However, the high-latitude radiolarian assemblages are very promising for regional paleogeographic reconstructions and for solving the fundamental problem of correlation between deposits accumulated in different paleoclimatic zones. In this respect, the radiolarian-bearing Triassic deposits in boreal areas of northeastern Asia are of great interest.

At present, radiolarians are known to occur in the bed succession exposed along the Dzhugadzhak River in the Omolon massif (figure). Hemipelagic Triassic deposits of the region accumulated at a great distance from the shore. They are represented predominantly by clay, mudstone, and rare limestone layers yielding peculiar assemblages of sculpture-lacking ammonoids, pseudoplanktonic bivalves, and radiolarians. Remains of benthic organisms occur sporadically, being especially scarce in the Middle Triassic and Carnian deposits (Dagys *et al.*, 1979, 1991; Dagys and Konstantinov, 1995; Egorov *et al.*, 1987). Radiolarians are concentrated at several stratigraphic levels of the succession and sometimes occur in the neighboring beds. In addition to their paleontological value, these finds extend our knowledge on the Mesozoic boreal assemblages of radiolarians and are useful for various paleoclimatic and tectonic reconstructions.

DESCRIPTION OF THE SECTION

The Triassic reference section is located in the middle courses of the Dzhugadzhak River (the tributary of the Korkodon River in the Kolyma River basin) within the southwestern Omolon massif. The studied outcrops are located at the left side of the Dzhugadzhak River valley immediately above to the Zhil'nyi Creek mouth. The section was described more than once (Goduntsov *et al.*, 1968; Dagys *et al.*, 1979). In this article, we present our own, more detailed description. In the local stratigraphic scheme, the deposits in question are included into the Triassic Dzhugadzhak Formation (Bychkov *et al.*, 1996). Determinations of macrofauna were performed by A.G. Konstantinov (ammonoids), E.S. Sobolev (nautiloids), N.I. Kurushin (bivalves), and A.S. Dagys (brachiopods).

The Triassic section at the Dzhugadzhak River includes the following units (from the base upward, see figure).

The Triassic system. The Dzhugadzhak Formation

The Lower Triassic

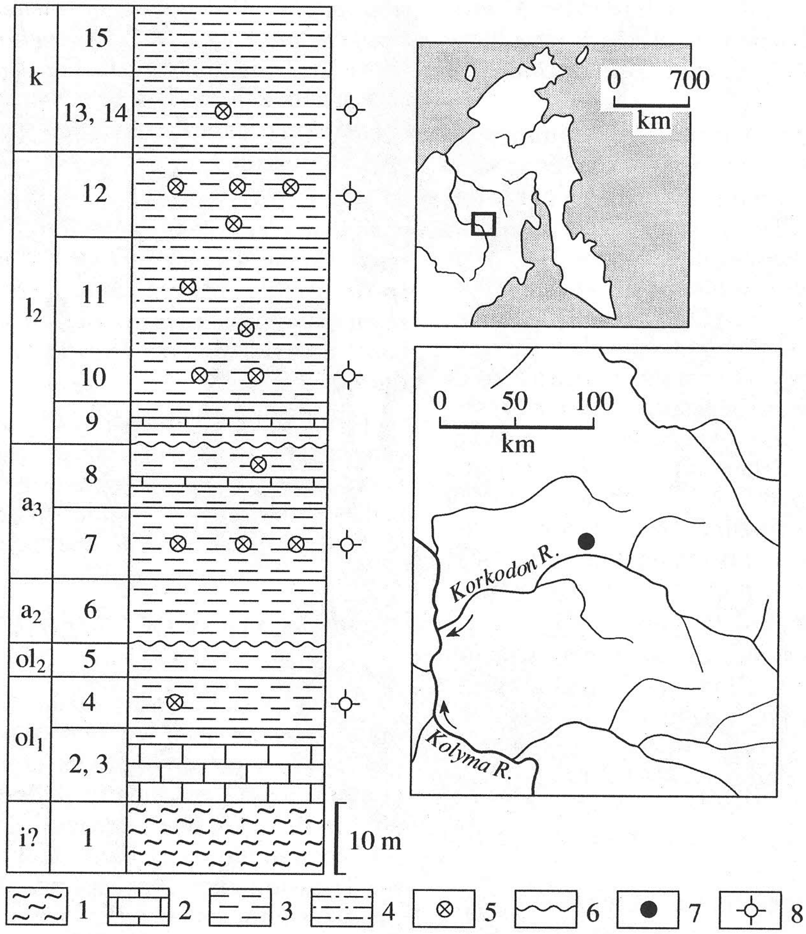
The Induan Stage (?)

(1) Light gray clay bearing small poorly preserved Rhynchonellidae (10 m thick).

Olenekian Stage

Lower substage

(2) Light gray finely crystalline limestones, highly bituminous, flaggy, and massive, with rare interbeds of brownish gray calcareous mudstones (7 m thick).



Geographic position and lithostratigraphy of the Triassic Dzhugadzhak section and occurrence levels of radiolarians: (1) clay; (2) limestone; (3) mudstone; (4) siltstone; (5) phosphatic nodules; (6) unconformity; (7) study site; (8) level with radiolarians. Symbols for Triassic stages in the first column: (i) Induan, (ol) Olenekian, (a) Anisian, (l) Ladinian, (k) Carnian; bed numbers are marked in the second column.

(3) Gray to dark gray and brownish gray laminated mudstones with interbeds (0.1 m) of gray bituminous clayey limestone and brownish gray silty clay (3 m thick).

(4) Gray and dark gray finely bedded mudstones with interbeds (0.1–0.2 m) of black bituminous shale; the rocks enclose small phosphatic concretions with unidentifiable spherical radiolarians (6.5 m thick).

Beds 2–4 contain conodonts and bivalve mollusks indicative of the *hedenstroemi* and *tardus* zones of the lower Olenekian Substage.

The upper substage

(5) Dark gray finely bedded mudstones with abundant *Claraia aranea* Tozer (4 m thick).

Middle Triassic

Anisian Stage

Middle substage

(6) Dark gray and black thinly bedded mudstones enclosing ammonites *Czekanowskites decipiens* (Mojs.); the bed shows the erosional lower contact. Lower Anisian deposits are missing (8 m thick).

Upper substage

(7) Dark gray and black mudstones with abundant phosphatic concretions containing ammonites *Amphipopanoceras dzenginense* Arch. and radiolarians *Archaeothamnulus* (?) sp., *Entactinia* sp., *Oertlispongus* sp., *Pseudostylosphaera* (?) sp. ex gr. *P. fragilis* (Bragin), *P.* (?) sp., Spongodiscoidea (?) gen. indet. (spherical spongy shells with large inner chamber, but without spicule), *Spongopallium* (?) sp., *Stauracontium* (?) sp., and *Triassocampe* (?) sp. (9 m thick).

(8) Dark gray and black mudstones and siltstones with phosphatic concretions and interbeds of gray fine-grained calcareous sandstone, black bituminous shale, and dark brownish limestone bearing the ammonite assemblage with *Parafrechites sublaqueatus* Bytschkov (the uppermost Anisian); radiolarians are also abundant but poorly preserved (8 m thick).

Stratigraphic hiatus corresponding to the missing lower Ladinian deposits.

Ladinian Stage

Upper substage

(9) Black laminated mudstones intercalated with gray, yellow and white clays, and with dark gray bituminous limestones bearing abundant bivalves *Daonella prima* Kipar. (5.5 m thick).

(10) Dark gray and black mudstones and bituminous shales enclosing abundant phosphatic concretions with ammonites *Arctoptychites omolojensis* Archipov (in the lower 2.5 m), *Arctogymnites* sp. cf. *A. spectori* Arch., and *Indigirophyllites oimekonensis* Popov (5–5.5 m above the bed base), algae *Tasmanites* sp., and radiolarians *Archaeocenosphaera* sp., *Entactinia* sp., *Ferresium* (?) sp., *Glomeropyle boreale* Bragin, *Hindeosphaera* sp. ex gr., *H. spinulosa* (Nakaseko et Nishimura), *H.* sp., *Hozmadia* (?) sp., *Laxtorum* (?) sp., *Pachus* (?) sp., *Parentactinia pygnax* Dumitrica, *P.* sp. cf. *P. inerme* Dumitrica, *Praenanina* sp., *Poulpus* sp., *Silicarmiger costatus costatus* Dumitrica, Kozur et Mostler, *S.* sp. cf. *S. latus* Kozur et Mostler, Spongodiscoidea gen. indet. (spongy spheres analogous to those from Bed 7), *Spongopallium* sp. aff. *S. koppi* (Lahm), and *Stauracontium* (?) sp. (6.5 m thick).

(11) Alternating layers of black bituminous calcareous siltstone (0.5 m) and yellow to white clay (up to 0.1 m) containing rare phosphatic concretions with *Arctophychites* sp., *Indigirophyllites* sp., *Gryponautilus* sp. ex gr., *G. kegalensis* Sob. (1–1.2 m above the base), *Nathorstites* sp. cf. *N. mclearni* Tozer, and *Aristoptychites kolymensis* Kipar. (13.3 m above the bed base) (15 m thick).

(12) Black foliated calcareous mudstones enclosing abundant globular phosphatic concretions with macrofossils *Nathorstites mclearni* Tozer, *Aristophychites kolymensis* Kipar. (1 or 2 m above the base), *Sphaerocladiscites omolojensis* Bytschkov, *Indigirophyllites oimekonensis* Popov, *Nathorstites mcconnelli* (White), *Sinuplicorhynchia kegalensis* Dagys (2.8–9.7 m above the base), *Nathorstites lindstroemi* Bohm, and *Sphaerocladiscites omolojensis* Bytschkov (9.7–10.3 m above the bed base); associated radiolarians are *Archaeocenosphaera* sp., *Pseudostylosphaera omolonica* sp. nov., and *Ferresium* (?) sp. (10.5 m thick).

(13) Alternating black soft mudstones (up to 0.5 m) and denser platy calcareous shales (up to 0.1 m); both rock varieties contain abundant phosphatic concretions with ammonites *Mathorstites lindstroemi* Bohm and *Sphaerocladiscites omolojensis* Bytschkov (1.3–2.3 m above the bed base), which associate higher (4.1–6 m above the bed base) with nautiloids *Proclydonautilus aniamensis* (Shim.) (11.6 m thick).

Upper Triassic

Carnian Stage

(14) Dark gray bituminous–calcareous siltstone with poorly sorted clastics, reptilian bones, shell detritus, and fucoids. Abundant phosphatic concretions contain *Discophyllites* sp., *Stolleites* sp. cf. *S. tenuis* (Stolley), *Proclydonautilus aniamensis* (Shim.), *Cenoceras boreale* Dagys et Sob. (0–0.3 m above the bed base), *Proclydonautilus aniamensis* (Shim.), *Pennospiriferina popovi* Dagys, *Pennospiriferina (Dentospiriferina) costata* Dagys, *P. (D.) pepeliaevi* Dagys (1.1–3 m above the bed base), and *Holcorhynchia tibetica* (Bitt.) (4.5 m above the bed base) associated with radiolarians *Pseudostylosphaera omolonica* sp. nov. and *Ferresium* sp. (2 m thick).

(15) Black calcareous foliated siltstones with scarce phosphatic nodules containing *Discophyllites taimyrensis* Popov, *Cenoceras boreale* Dagys et Sob., *Pennospiriferina (Dentospiriferina) costata* Dagys, *Planirhynchia yakutica* Dagys (4.5 or 4.9 m above the bed base) and radiolarians *Pseudostylosphaera* sp. (10 m thick).

(16) Dark gray, bioturbated massive to flaggy calcareous siltstones with rare carbonate and phosphatic nodules enclosing *Discophyllites taimyrensis* Popov, and *Pennospiriferina (Dentospiriferina) costata* Dagys (5.3 m above the bed base); the apparent thickness is 8 m.

CORRELATION OF TRIASSIC RADIOLARIAN ASSEMBLAGES

The Triassic deposits of the Omolon massif accumulated in the open sea settings and yield radiolarian assemblages considerably changing upward in their composition. Consequently, radiolarians can be considered in this case as a paleontological group important for biostratigraphy of the boreal Triassic. In addition, the Triassic radiolarian assemblages from the Omolon massif significantly differ from radiolarians of the Koryak Upland, Sikhote-Alin, and Sakhalin, which supposedly originated under the tropical conditions (Bragin, 1991). For instance, the radiolarian assemblages of the boreal Middle Triassic succession at the Dzhugadzhak River are absolutely devoid of species representing the tropical families Eptingiidae, Muelleritortiidae and Oertlispongiidae, genus *Yeharaia*, and other groups. The genus *Triassocampe* occurs here sporadically. These data indicate a considerable biogeographic differentiation between radiolarian faunas of the Middle Triassic time. Accordingly, there are two main objectives of the study. First, we have to analyze vertical ranges of the distinguished assemblages, to subdivide the bed succession on this basis, and to establish facies-dependent variations in abundance and diversity of radiolarians. The second objective is a comparative analysis of coeval boreal and tropical assemblages for evaluation of their correlation potential.

In the Dzhugadzhak section, the oldest radiolarians are those of the upper Olenekian deposits, which yielded only rare and simple spherical forms probably representing Entactiniidae. This is a characteristic feature of the upper Lower Triassic deposits in different regions, where corresponding beds are characterized by similar and taxonomically uniform Entactiniidae assemblages (Sashida, 1983; Bragin, 1991; Sugiyama, 1992; Kozur and Mostler, 1994). Similarly to some other faunal groups of the Early Triassic, distinctions

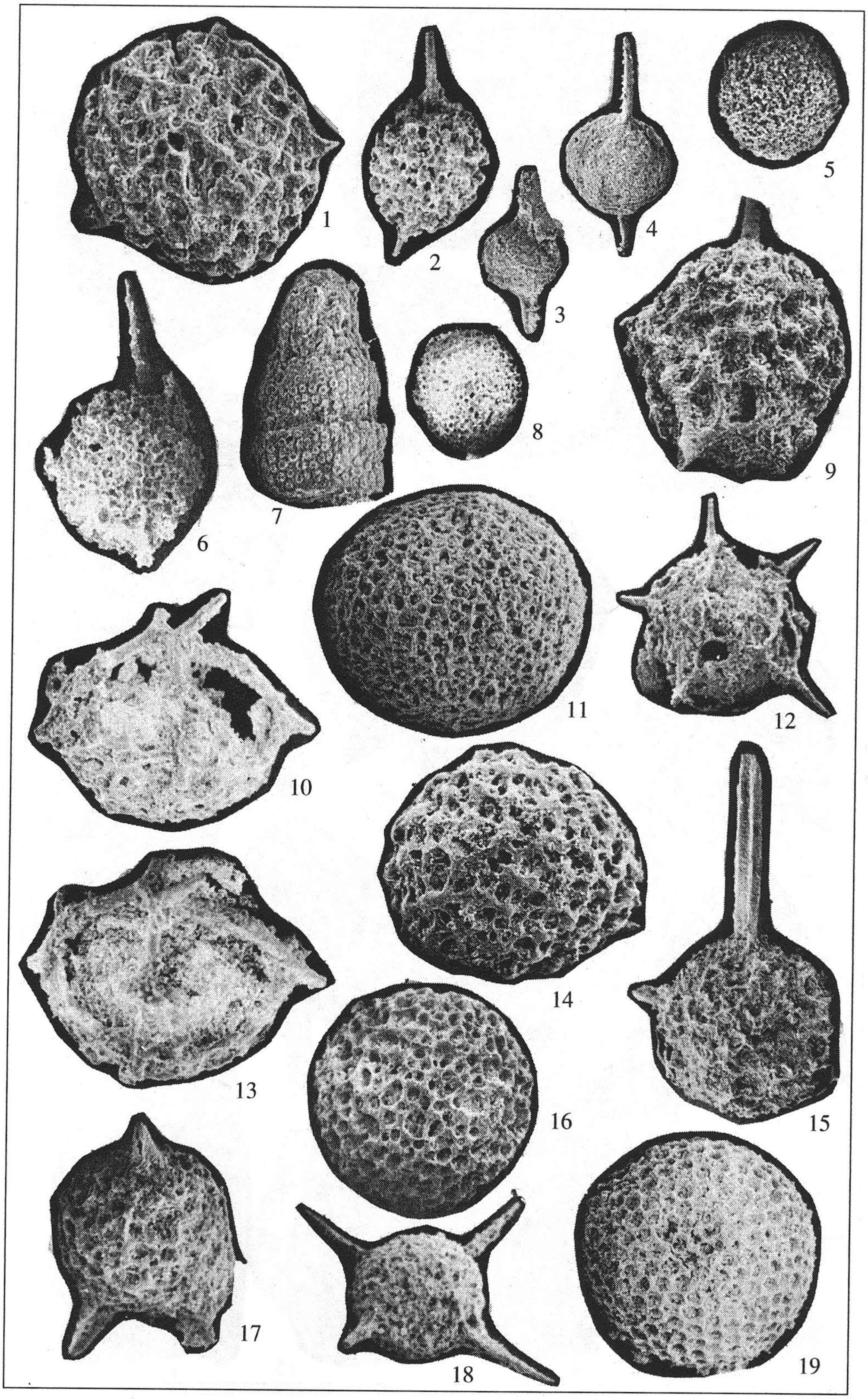


Plate I. Radiolarians from the Middle and Upper Triassic deposits of the Dzhugadzhak River locality (Plates I–IV).
(1, 9) *Entactinia* (?) sp., ×250; (2, 6); *Pseudostylosphaera* (?) sp. ex gr. *P. fragilis* (Bragin), ×100; (3, 4) *Pseudostylosphaera* sp., ×100; (5, 8, 11, 16) *Spongodiscoidea* (?) gen. indet., (5, 8) ×100; (11, 16) ×250; (7) *Triassocampe?* sp., ×250; (10, 13) *Parentactinia* sp. cf. *P. inerme* Dumitrica; ×250; (12) *Sphaerellaria* gen. et sp. indet., ×200; (14) *Praenanina* sp., ×250; (15) *Sphaerellaria* gen. et sp. indet., ×250; (17) *Sphaerellaria* gen. et sp. indet., ×250; (18) *Stauracontium?* sp., ×200; (19) *Archaeocenosphaera* sp., ×250. Specimens 1–8 are from the upper Anisian and 9–19 from the upper Ladinian deposits.

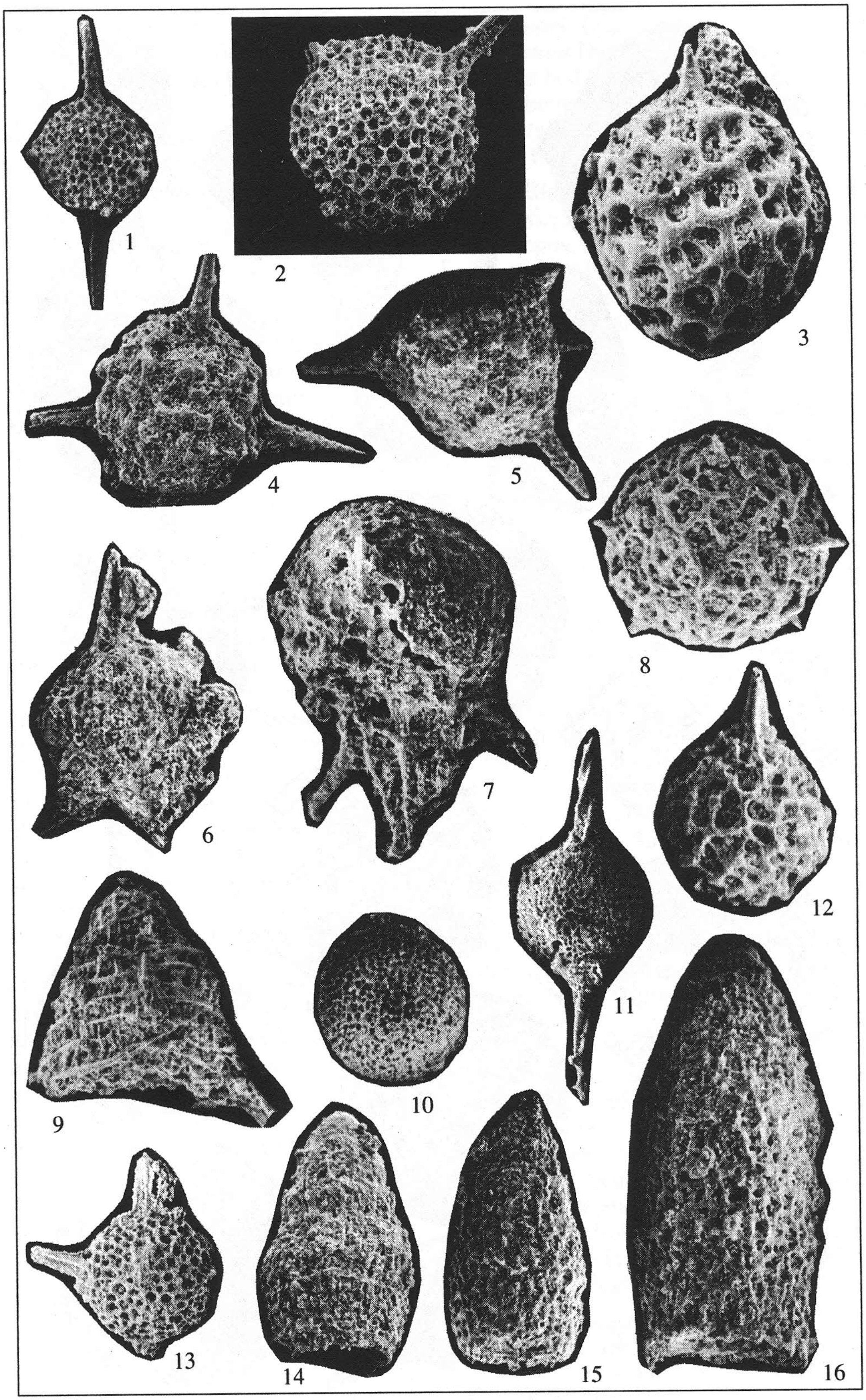


Plate II.

(1, 2) *Pseudostylosphaera* sp.: (1) ×80, (2) ×150; (3, 9) *Hindeosphaera* (?) sp. ex gr. *H. spinulosa* (Nakaseko et Nishimura): (3) ×300, (9) ×200; (4, 5) *Ferresium* (?) sp., ×250; (6) *Sphaerellaria* gen. et sp. indet., ×250; (7) *Hozmadia* (?) sp., ×250; (8) *Poulpus* sp., ×300; (10) *Silicarmiger* sp. cf. *S. latus* Kozur et Mostler., ×250; (11) *Spongodiscoides* (?) gen. indet., ×150; (12) *Spongopallium* sp. aff. *S. koppi* (Lahm), ×250; (13) *Sphaerellaria* gen. et sp. indet., ×150; (14) *Pachus* (?) sp., ×200; (15, 16) *Laxtorum* (?) sp.: (15) ×200, (16) ×320. All radiolarians are from the upper Ladinian deposits.

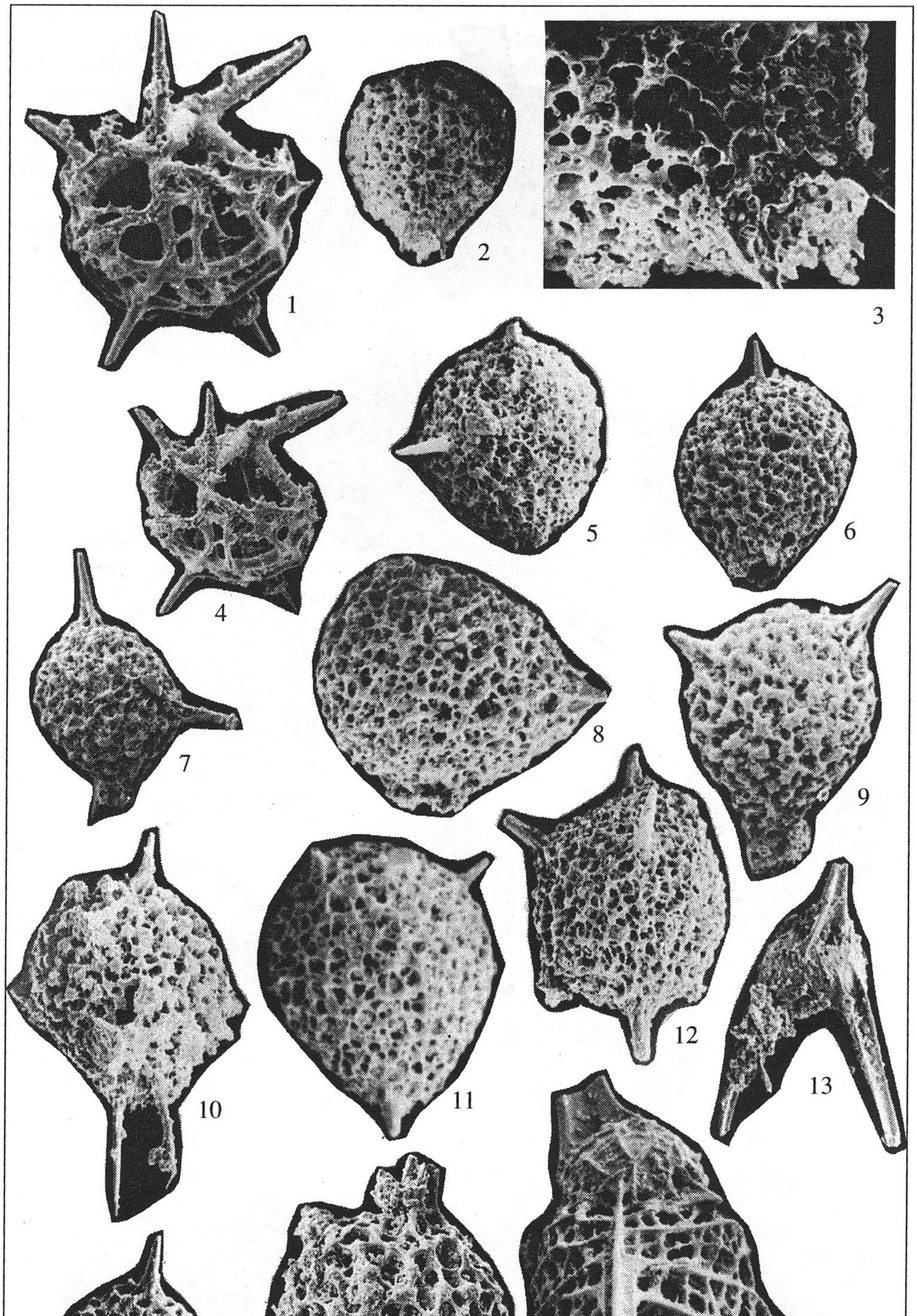


Plate III.

(1, 4) *Parentactinia pygnax* Dumitrica: (1) ×350, (4) ×250; (2, 3, 5–12) *Glomeropyle boreale* Bragin: (2, 3) holotype: (2) ×80, (3) ×250; (5–12) paratypes: (5–7) ×80, (8–12) ×100; (13) *Triassobipedis* sp., ×150; (14) *Sphaerellaria* gen. et sp. indet., ×100; (15) *Ferresium* (?) sp., ×250; (16) *Silicarmiger costatus costatus* Dumitrica, Kozur et Mostler, ×300. All radiolarians are from the upper Ladinian deposits.

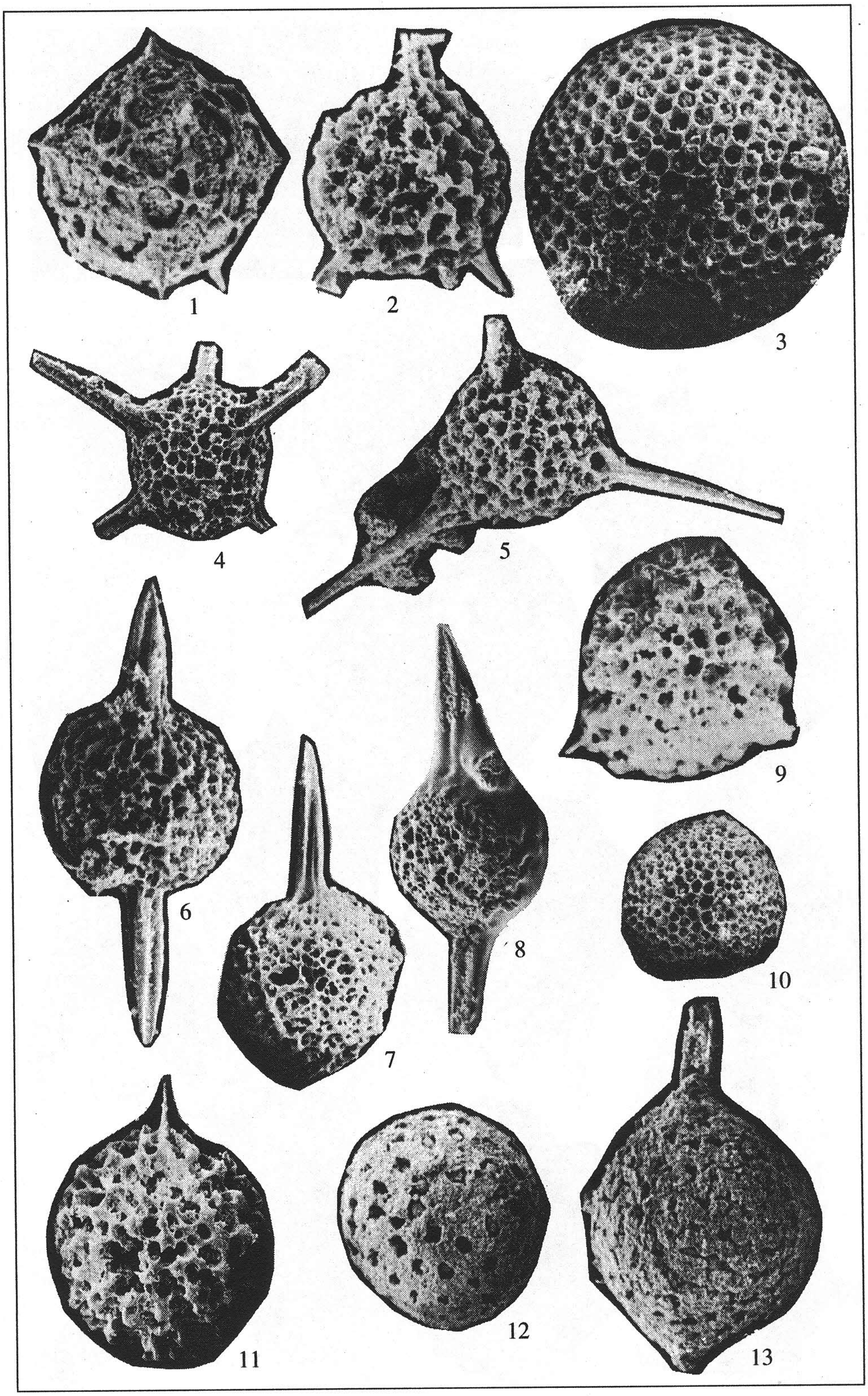


Plate IV.
(1) *Sphaerellaria* gen. et sp. indet., ×200; (2, 5, 6) *Ferresium* sp.: (2, 6) ×250, (5) ×200; (3, 10) *Archaeocenosphaera* sp.: (3) ×300, (10) ×100; (4) *Sphaerellaria* gen. et sp. indet., ×200; (7–9) *Pseudostylosphaera omolonica* sp. nov., ×200; (7) holotype; (11) *Sphaerellaria* gen. et sp. indet., ×250; (12) *Sphaerellaria* gen. et sp. indet., ×250; (13) *Pseudostylosphaera* (?) sp., ×250. Specimens 1–3, 6, 7 are from the upper Ladinian and 4, 5, 8–13 from the lower Carnian deposits.

between boreal and tropical assemblages of radiolarians may be insignificant. Regretfully, the comprehensive analysis and identification of the Early Triassic radiolarians from the Omolon massif is impossible because of their poor preservation.

The upper Anisian deposits of the section yielded the radiolarian assemblage of a low taxonomic diversity, in which representatives of Eptingiidae and spherical forms with spongy walls (Spongodiscoidea gen. indet.) are dominant. Despite the low diversity, these radiolarians are very abundant, locally rock-forming. They may be considered as indicators of an extensive sea transgression at the late Anisian time that was able to sharply increase the plankton productivity and subsequent accumulation of phosphorite and bituminous shales.

The richest radiolarian assemblage is detected in the upper Ladinian deposits, where phosphorites and bituminous shales especially widespread and mark an episode of the extremely high biological productivity. This assemblage is of greatest interest, especially when compared with known assemblages of the same age. The assemblage from the lower part of the upper Ladinian comprises two groups of species: (1) those described earlier from the tropical belt of the Triassic time, and (2) taxa unknown from the tropical regions.

The tropical group includes *Hindeosphaera* sp. ex gr. *H. spinulosa* (Nakaseko et Nishimura), *Parentactinia pygnax* Dumitrica, *P.* sp. cf. *P. inerme* Dumitrica, *Silicarmiger costatus costatus* Dumitrica, Kozur et Mostler, *S.* sp. cf. *S. latus* Kozur et Mostler, *Spongopallium* sp. aff. *S. koppi* (Lahm), and *Triassobipedis* sp. These species are known from the Middle Triassic deposits of the Alpine–Mediterranean region (Kozur and Mostler, 1981, 1994; Lahm, 1984; Gorican and Buser, 1990) and Japan (Yao, 1990). Many of them, except for representatives of genera *Pseudostylosphaera* and *Spongopallium*, occur also in the Middle Triassic of New Zealand (Aita, 1994), which was considered, in accordance with the radiolarian distribution patterns, as an area of the Notal paleobiogeographic realm (Bragin, 1994). To all appearances, the species listed were cosmopolitan organisms. This opens a new biostratigraphic perspective for a direct correlation of boreal and tropical Triassic successions on the basis of radiolarians.

The problem of correlation between the boreal Triassic stratigraphy in northeastern Asia and the standard stratigraphic scale is well known to stem from a high biogeographic differentiation in the Middle–Late Triassic time. The boreal Triassic assemblages of mollusks considerably differ in their species composition from the tropical ones. Scarce cosmopolitan species of ammonoids have very wide stratigraphic ranges and are of no correlation value. The commonly used in biostratigraphic investigations are data on boreal and tropical ammonoid forms coexisting in some sections of British Columbia (Dagys *et al.*, 1979).

The lower part of the upper Ladinian deposits yielded several species, which are known from the Mediterranean region and show narrow stratigraphic ranges (Kozur and Mostler, 1994). For example, *Silicarmiger costatus costatus* was found in the lower and middle parts of the lower Ladinian. Distribution interval of *Silicarmiger latus* ranges from the middle part of the lower Ladinian to the upper Ladinian inclusive. *Parentactinia pygnax* is confined to the upper Anisian–lower Ladinian, while *P. inerme*, is typical of the lower Ladinian, and *Spongopallium koppi* is known from the lower Ladinian deposits. All these data permit a reliable correlation of Beds 9–11 of the Dzhugadzhak section with the lower Ladinian deposits of the Mediterranean region. This is very important because the same beds were attributed to the upper Ladinian based on assemblages of macrofauna (Dagys *et al.*, 1991; Dagys and Konstantinov, 1995).

The mentioned difference in the age determinations based on macrofauna and radiolarians needs to be explained. Two possible interpretations can be suggested:

(1) Radiolarian species had different existence periods in tropical and boreal areas. For instance, *Parentactinia pygnax, Silicarmiger costatus*, and some other species, which became extinct in the tropical region by the end of the early Ladinian, continued to exist in the Boreal and Notal areas.

(2) The macrofauna-based attribution of the boreal Ladinian deposits to the units of the standard scale is insufficiently precise.

The available materials are inappropriate for checking these interpretations. The problem can be solved after a thorough investigation of Triassic radiolarian distribution in other boreal sections (e.g., in Novosibirskie Islands, Brooks Ridge, Spitsbergen) and better understanding of Triassic stratigraphy in tropical regions. In addition, we should find and analyze radiolarians from transitional zones between tropical to boreal areas.

Species like *Glomeropyle boreale*, and early *Ferresium* (?), as well as spherical spongy forms, are untypical of the Middle Triassic deposits in the tropical belt. Probably, their range of geographic distribution was limited by the high latitudes. The genus *Glomeropyle* occurs in the Middle Triassic beds of both the Omolon massif and New Zealand (Aita, 1994). This genus likely had bipolar distribution areas that is not surprising, if we take into consideration a great amount of recent radiolarian taxa showing the same distribution pattern (Petrushevskaya, 1986). A series of species in common permits correlation between Triassic deposits of the Omolon massif and New Zealand, where the corresponding rocks are poorly characterized by macrofauna.

The uppermost Ladinian–lower Carnian radiolarian assemblages from the Dzhugadzhak section are of a low taxonomic diversity. They comprise only few species (*Archaeocenosphaera* sp., *Pseudostylosphaera omolonica* sp. nov., and *Ferresium* (?) sp.) unknown from other regions, thus being useless for correlation. In this stratigraphic interval of the section, phosphorites and fine clastic deposits become gradually less widespread. No radiolarians have been found at the higher level of the Carnian Stage, where siltstones and sandstones finally replace mudstones and phosphorites disappear. This level in the study region may correspond to the sea regression at the early Late Triassic time.

CONCLUSION

Analyzing distribution of the Middle and Late Triassic radiolarians in the Dzhugadzhak section, we arrived at the following conclusions:

(1) The section contains three successive assemblages: that of the late Anisian with *Entactinia* and *Pseudostylosphaera* (?) sp. ex gr. *P. fragilis*, the late Ladinian *Glomeropyle boreale–Silicarmiger costatus costatus* assemblage, and the late Ladinian–early Carnian assemblage with *Pseudostylosphaera omolonica*. The facies-dependent taxonomic diversity of the assemblages increases at the stratigraphic levels rich in phosphorites and bituminous shales, which probably correspond to transgression episodes. The radiolarian assemblages identified can be used for local subdivision of the sections.

(2) The boreal Triassic radiolarian assemblages that are studied for the first time significantly differ in taxonomic composition from the coeval tropical assemblages. They lack characteristic tropical taxa of the families Muelleritortiidae and Oertlispongiidae including only few representatives of Triassocampidae. Accordingly, radiolarians can serve as paleoclimatic indicators for the Middle–Late Triassic period.

(3) The Ladinian radiolarian assemblages from the Omolon massif and New Zealand include a number of cosmopolitan species having narrow stratigraphic ranges. Using them, we can correlate the studied Triassic deposits with those of the Mediterranean region. This approach is particularly helpful for solving the fundamental problem of correlation between Triassic deposits accumulated in the high- and low-latitude zones.

PALEONTOLOGICAL DESCRIPTION

Genus *Pseudostylosphaera* Kozur et Mostler, 1981

Pseudostylosphaera omolonica sp. nov.

Plate IV, figs. 7–9.

The name is derived from the Omolon River in northeastern Siberia.

Holotype: GIN no. 7438-89-2, the Omolon massif, Dzhugadzhak River, Bed 14, specimen L-2 (0.3 m above the bed base); Upper Triassic, lower Carnian, the *Nathorstites tenuis* Zone.

Description. Large, spherical, slightly tubercular cortical shell of the two-layer structure. The outer layer is formed of big polygonal (predominantly pentagonal) porous frames with massive nodes at vertices, which appear as tubercles on the shell surface. Two main spines are moderately long (sometimes slightly longer than the cortical shell diameter), relatively thin, Y-shaped in cross section, having massive flattened ridges separated by narrow grooves extending nearly up to spine ends. Some specimens show indistinct right-spiral sculpturing of a spine.

Comparison. The species differs from *Pseudostylosphaera compacta* (Nakaseko et Nishimura, 1979) as having shorter spines and larger cortical shell. Poorly developed spiral sculpturing of thinner spines makes it distinct from *P. inaequata* (Bragin, 1986) and *P. goestlingensis* (Kozur et Mostler, 1981).

Material: 14 specimens from two samples of the Dzhugadzhak section (Sample 8-25 from the upper Ladinian and Sample L-2 from the lower Carnian levels).

Distribution: the Middle–Upper Triassic (upper Ladinian–lower Carnian) of the Omolon massif.

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