

# Radiolarians of the Volgian and Berriasian Stages of the North of Central Siberia

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**Abstract**—The stratigraphic distribution of radiolarians in the Nordvik reference section of the Volgian Stage was studied and analyzed. The *Arctocapsula magna* Bragin assemblage of the middle Volgian and the *Arctocapsula perforata* Bragin assemblage of the late Volgian—early Berriasian are distinguished in the section. Both assemblages are dominated by nassellarian radiolarians of the family Echinocampidae Bragin, which are known at present only from the Arctic and Boreal regions.

**Keywords:** radiolarians, Jurassic, Cretaceous, Siberia, stratigraphy, paleobiogeography.

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## INTRODUCTION

During the last decades, data on radiolarians has been valuable for diverse stratigraphic investigations, in particular for the analysis of the most important geological events, or for stratigraphic subdivision and correlation of boreal deposits. This paper addresses these questions, and its objective is to elucidate the taxonomic composition and stratigraphic distribution of radiolarians in the reference section of the Jurassic–Cretaceous boundary beds in the Nordvik Peninsula (Arctic Siberia). The succession of the above beds is of particular interest, because it is studied in detail and the relevant rocks bear representative assemblages of macrofossils in addition to the typical boreal fauna of radiolarians, whose specimens are perfectly preserved and represent fossil assemblages of comparatively diverse taxonomic composition.

It should be noted that radiolarians from sections of the high latitudes are far from being comprehensively studied. Accordingly, comparative analysis of concurrent radiolarian assemblages from the high and low latitudes remains considerably problematic, although it is of high importance for assessment of the correlation potential of the relevant microfossils, which is in turn important to provide insight into the high-resolution stratigraphy of boreal sedimentary successions based on distribution of radiolarians in sediments. This work is aimed at filling gaps in our knowledge of radiolarian distribution in the aforementioned section. It is my second work on the Upper Jurassic and Lower Cretaceous radiolarians from the Nordvik Peninsula. In the first one (Bragin, 2009), nassellarians of the new family Echinocampidae were described, which dominate radiolarian assemblages of the Volgian and Berriasian stages in the Nordvik sec-

tion and are unknown in assemblages of the same age from the low latitudes. General consideration of that section in terms of radiolarian biostratigraphy and description of several new radiolarian species are presented below.

## THE VOLGIAN–BERRIASIAN REFERENCE SECTION OF THE NORDVIK PENINSULA AND DISTRIBUTION OF RADIOLARIANS

The Section of Jurassic–Cretaceous boundary beds in the Cape Urdyuk-Khaya area, Nordvik Peninsula (figure), is one of the best objects for studying the Volgian and Berriasian stages in the Arctic Realm. The section stratigraphy is studied in detail, and relevant rocks bear diverse assemblages of paleontological remains (Basov et al., 1970; Zakharov et al., 1983). Recent stratigraphic investigations of this reference section of the Volgian Stage in North Siberia included comprehensive analysis of the section's magnetostratigraphy, its correlation with the Tethyan sections, and consideration of the Jurassic–Cretaceous boundary position (Zakharov and Rogov, 2006; Hosha et al., 2007). It should be noted, however, that not all researchers agree with the stratigraphic chart reproduced in the mentioned works. For instance, Baraboshkin (2004) defined the Jurassic–Cretaceous boundary at the much lower level of the Praechetaites extoticus Zone base.

In the course of fieldwork in 2003, Zakharov and Rogov sampled rocks of the section for radiolarian analysis. The samples of phosphatic carbonate nodules collected yielded representative assemblages of radiolarians whose state of preservation is in certain cases unique. The conventional procedure of macerat-



← The Nordvik section of Upper Jurassic and Lower Cretaceous deposits; (a) section locality on geographic scheme and (b) biostratigraphic column with distribution ranges of radiolarians: (1) coastal area southward of the Cape Urdyuk-Khaya, where deposits of the Volgian and Berriasian stages are exposed; (2) clays; (3) concretions; (4) occurrence levels of radiolarian taxa.

ing radiolarians from the rocks included treatment of rock samples in 50% solution of nitric acid and subsequent rinsing of the precipitate in water. Radiolarians from the dried precipitate and mounted on slides have been studied under scanning electron microscope.

Description of the section part (figure) that is exposed in coastal outcrops southward of Cape Urdyuk-Khaya, the eastern coast of the Nordvik Peninsula, and corresponds to upper interval of the Volgian Stage and basal Berriasian (Zakharov and Rogov, 2006) is presented below.

### Jurassic System, Volgian Stage, Middle Substage

#### *Epivirgatites variabilis* Zone, Member V

Glauconite-leptochlorite clay, argillite-like, splintery, dark gray with bluish tint, containing small pyrite segregations dispersed throughout the member. At the base and in the middle part of the member, there are two horizons of loaf-shaped concretions. Concretions of the basal horizon are composed of gray limestone. In the upper horizon, they are of zonal structure, with central part composed of calcareous phosphorite and the periphery of siderite composition. Paleontological remains occurring in concretions are represented by ammonites *Epivirgatites variabilis* Schulgina, *Lau-geites* sp. aff. *L. stschurowskii* Nikitin, diverse belemnite assemblages, bivalves, and foraminifers. Radiolarians have been identified in concretions of the upper horizon. Assemblages of these microfossils include *Arctocapsula magna* Bragin, *A. congelata* Bragin, sp. nov., *A. constantia* Bragin, sp. nov., *A. sp.*, *Acaeniotylopsis nordvikensis* Bragin, sp. nov., *Archaeospongoprimum* sp. cf. *A. klingi* Pessagno, *Higumastra turgida* Bragin, sp. nov., *Orbiculiforma* sp. aff. *O. teres* Hull, *Parvicingula* sp., *Praeconocaryomma* sp. cf. *P. spinosa* Yang, *Praeparvicingula* sp. cf. *P. sencilla* Hull, *P. cappa* (Cortese), *Staurosphaera* sp. cf. *S. amplissima* Foreman, and *Stylospongia* sp. aff. *S. longispina* (Rust). Thickness 3 m.

#### *Praechetaites exoticus* Zone

Clay similar to that of the previous zone but without concretions of carbonate-phosphate composition. Thickness 1.3 m.

### Jurassic System, Volgian Stage, Upper Substage

#### *Craspedites okensis* Zone, Member VI

Clay argillite-like, laminated, with alternating interlayers of dark gray, brownish, and bluish gray coloration, enclosing nine horizons of phosphatic carbonate concretions. Ammonite species known from

the member are *Virgatosphinctes bicostatus* Schulgina and *Craspedites okensis* d'Orb. Thickness 7 m.

#### *Craspedites taimyrensis* Zone, Member VII

Clay argillite-like, dark gray, containing pyrite nodules and enclosing three horizons of phosphatic carbonate concretions with ammonites *Craspedites (Taimyroceras) canadensis canadensis* Jeletz. Thickness 4.2 m.

#### *Chetaites chetae* Zone, Member VIII

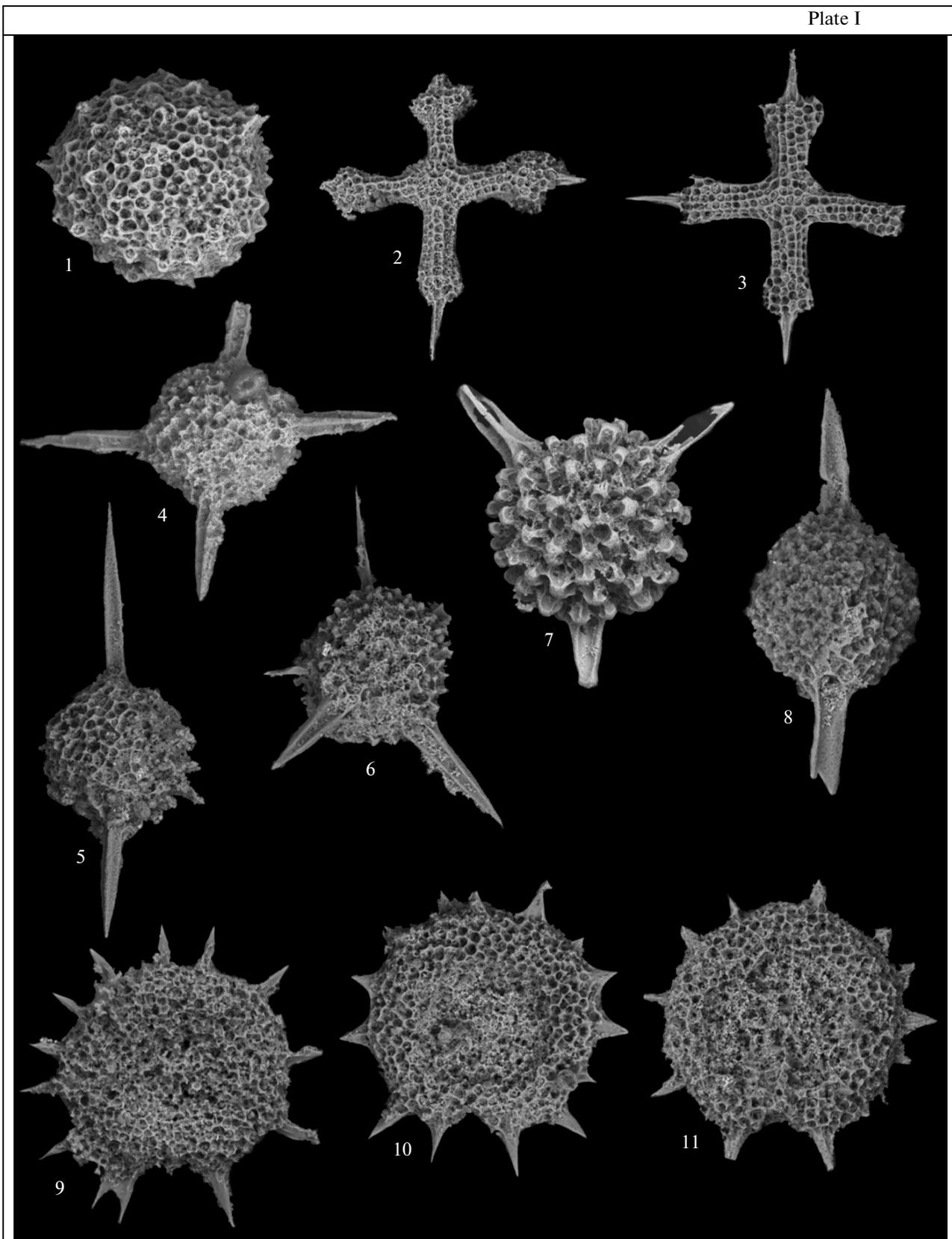
Clay thin-bedded, dark gray with brownish tint; there are two horizons of phosphatic carbonate concretions in the member, which contain ammonites *Chetaites* sp. cf. *C. chetae* Shulg. Radiolarians have been found in concretions of both horizons. Their assemblage includes the following taxa: *Acaeniotylopsis nordvikensis* Bragin, sp. nov., *A. ? sp.*, *Arctocapsula perforata* Bragin, *A. incompta* Bragin, *A. sp. aff. A. incompta* Bragin, *A. sp.*, *Bagotum? sp.*, *Crucella* sp. cf. *C. theokafkensis* Baumgartner, *Echinocampe aliferum* Bragin, *E. cristatum* Bragin, *E. aculeatum* Bragin, *E. sp.*, *Glomeropyle polygonium* Bragin, sp. nov., *Haliomma* sp., *Napora pyramidalis reticulatus* Bragin, subsp. nov., *Nordvikella elegans* Bragin, *N. improcera* Bragin, *Orbiculiforma* sp. aff. *O. railensis* Pessagno, *Parvicingula khabakovi* (Zhamoida), *Praeparvicingula rotunda* Hull, *Pyramotertonium planocephalum* (Kozlova), *Tertonium* sp., and *Tertonidae* gen. et sp. indet. Thickness 1.2 m.

### Cretaceous System, Lower Series, Berriasian Stage

#### *Chetaites sibiricus* Zone, Member IX

Clay argillite-like in places, dark gray; at the member base there is a thin bed of brownish gray to gray phosphatic limestone. Phosphatic carbonate concretions occurring higher bear ammonites *Praetollia* sp. ex gr. *maynci* Spath and *Chetaites* sp. cf. *C. sibiricus* Shulg. Concretions from the lower one-meter-thick interval of the member yield radiolarian assemblage identical to that from Member VIII. Thickness 4.0 m.

Hence there are two radiolarian assemblages recognizable in the Nordvik section (figure). One assemblage (Plates I–III), of middle Volgian age, is dominated by characteristic radiolarians belonging to the boreal genus *Arctocapsula*, which usually occur in association with species of the genus *Praeparvicingula*, including *P. cappa* (Cortese) described from the Mediterranean sections (Cortese, 1993; Kiessling, 1999). *Praeconocaryomma spinosa* Yang known from California (Yang, 1993) is species commonly present among



**Plate I.** Spumellarians of the middle Volgian Substage:

(1) *Praeconocaryomma* sp. cf. *P. spinosa* Yang,  $\times 200$ ; (2, 3) *Higumastra turgida* Bragin, sp. nov.,  $\times 135$  (both); (4) *Staurosphaera* sp. cf. *S. amplissima* Foreman,  $\times 180$ ; (5, 8) *Archaeospongoprimum* sp. cf. *A. klingi* Pessagno: (5)  $\times 150$ ; (8)  $\times 160$ ; (6) *Actinommidae* gen. et sp. indet.,  $\times 160$ ; (7) *Acaeniotylopsis nordvikensis* Bragin, sp. nov.,  $\times 160$ ; (9–11) *Orbiculiforma* sp. aff. *O. teres* Hull,  $\times 150$  (all). All specimens from the middle substage of the Volgian Stage (Epivirgatites variabilis Zone).

spumellarians. The other forms are determined in open nomenclature and thus of doubtful value for comparative analysis. Nonetheless, it is possible to readily see certain peculiarities of taxonomic composition typical of assemblages from the high latitudes: characteristic prevalence in abundance of a few typical Boreal taxa and presence of several species characteristic of southerly regions, which are apparently of wide geographic range.

The second assemblage (Plates III–VI) is confined to deposits of the upper Volgian and basal Berriasian intervals (*Chetaites chetae* and *Chetaites sibiricus* zones). Representatives of the family Echinocampidae again dominate in its composition, being simultaneously more diverse at this level: in addition to representatives of the genus *Arctocapsula* known from below, the genus *Echinocampe* and two other *Arctocapsula* forms appear at this level. As for the taxa known from the other regions, this is *Parvicingula khabakovi* described from the Valanginian strata of the Koryak Upland (Dundo and Zhamoida, 1963) and later on from the Jurassic (Kimmeridgian–Tithonian) of California (Pessagno, 1977) and Mexico (Hull, 1997), and from the Upper Jurassic–Lower Cretaceous (Kimmeridgian–Valanginian) deposits of the Koryak Upland (Vishnevskaya, 2001). The species in question is widespread in the Boreal regions and convergence zone extending along western North America, where Boreal radiolarians of the Late Jurassic occur in association with concurrent Tethyan taxa (Kiessling, 1997). In the Kimmeridgian–Tithonian of Mexico there is also the known species *Praeparvicingula rotunda*, which is probably of the Boreal origin like the other members of its genus (Hull, 1997). Finally, the species *Pyramotertonium planocephalum*, apparently of Boreal origin, was also described from the upper Volgian deposits of the Timan–Pechora plate (Kozlova, 1976a, 1994).

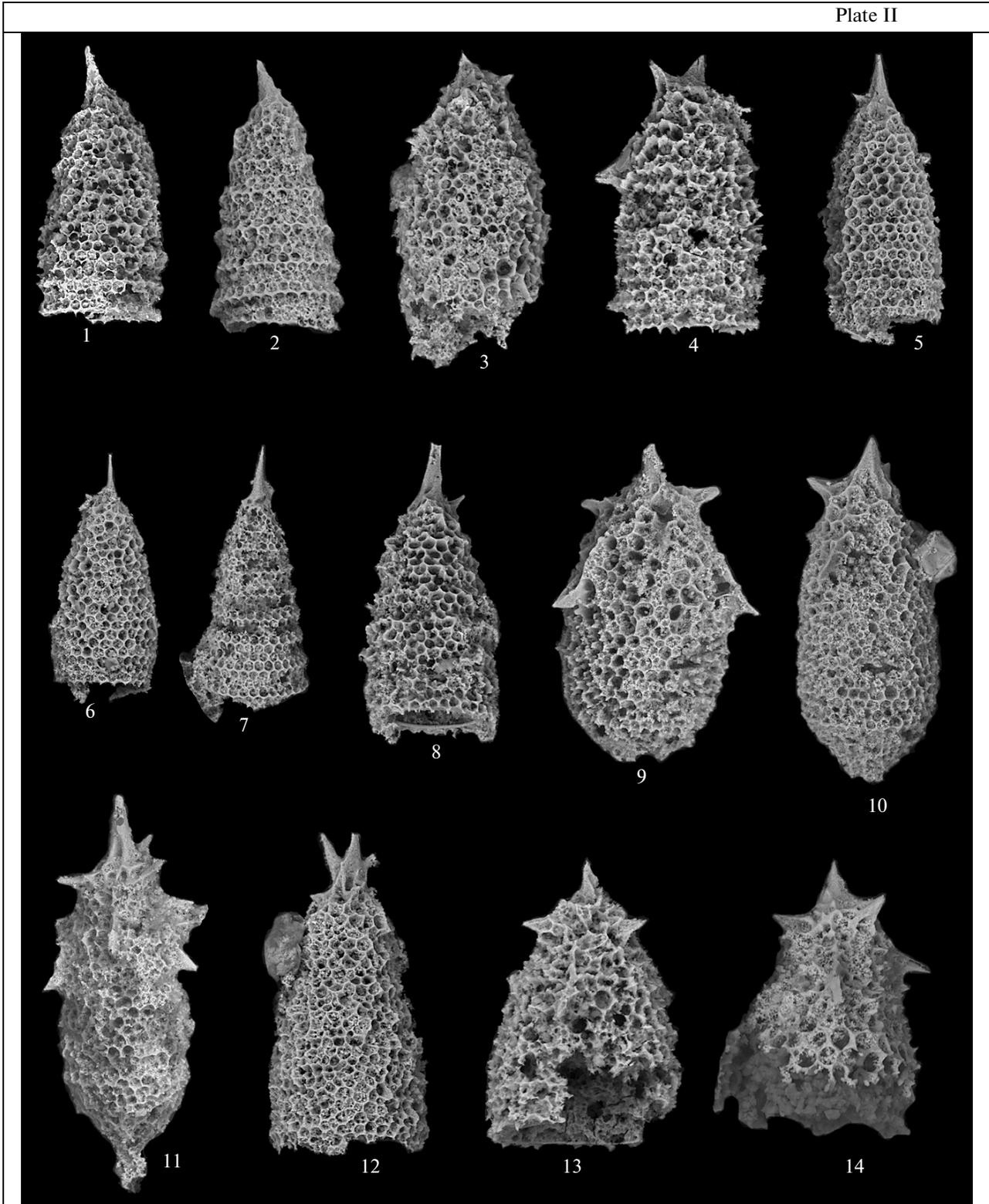
The other taxa of the assemblage are either described for the first time, or identified in open nomenclature and thus hardly appropriate for comparative analysis. Nonetheless it is noteworthy that none of the identified taxa is known from the Tethyan sections proper, which bear radiolarians of the low latitudes. Moreover, the assemblage includes none of the supergeneric taxa that are very characteristic of low latitudes. For instance, the assemblage lacks the Late Jurassic families Williriedellidae and Saturnalidae. The absence of the family Pantanelliidae is particularly interesting, as this family was formerly suggested to be an indicator of low-latitude radiolarian faunas (Pessagno et al., 1987). In fact, most species of this

family have previously been found and described only in the Tethyan regions or in the convergence zone adjacent to western North America. Subsequent investigations to some extent changed the former viewpoint, because some species of the family were identified in the South Boreal assemblages of the Late Jurassic from the East European platform (Bragin, 1997) and even in assemblages from the Antarctic Peninsula (Kiessling, 1999); however the latter include some low-latitude species, and can thus be regarded as transitional in composition. In the light of the quoted data, the complete absence of Pantanelliidae from the Nordvik assemblage implies that it is certainly of Boreal affinity and lacks warm-water radiolarians.

Thus, the radiolarian assemblage of the upper Volgian from the Nordvik section consists almost exclusively of high-latitude taxa never occurring in the Tethyan sections, although some of them could migrate into distribution areas of transitional assemblages. Hence, based on its doubtless Boreal affinity, the assemblage is appropriate for consideration in the comparative analysis of radiolarian assemblages. It seems reasonable to establish in the future the geographic ranges of comparable assemblages for depicting the boundaries of the Boreal or Arctoboreal paleobiochore. Such an objective is at present unrealizable, as only a few truly Boreal (and South Boreal) assemblages of the Volgian radiolarians are known and described.

The next problem deserving consideration concerns the stratigraphic ranges of the assemblages studied, as this is important for the use of radiolarians in biostratigraphy of the boreal deposits and for the solution of some general problems of stratigraphy such as determination of the most important stratigraphic boundaries. In this aspect, the Nordvik section is certainly of interest, because deposits of the Volgian Stage are represented here in full measure, stimulating the seeking and determination of the Jurassic–Cretaceous boundary. However, it seems reasonable to review experience of radiolarian biostratigraphy in more southern regions prior to dwelling upon the distribution of studied radiolarians and their biostratigraphic implications.

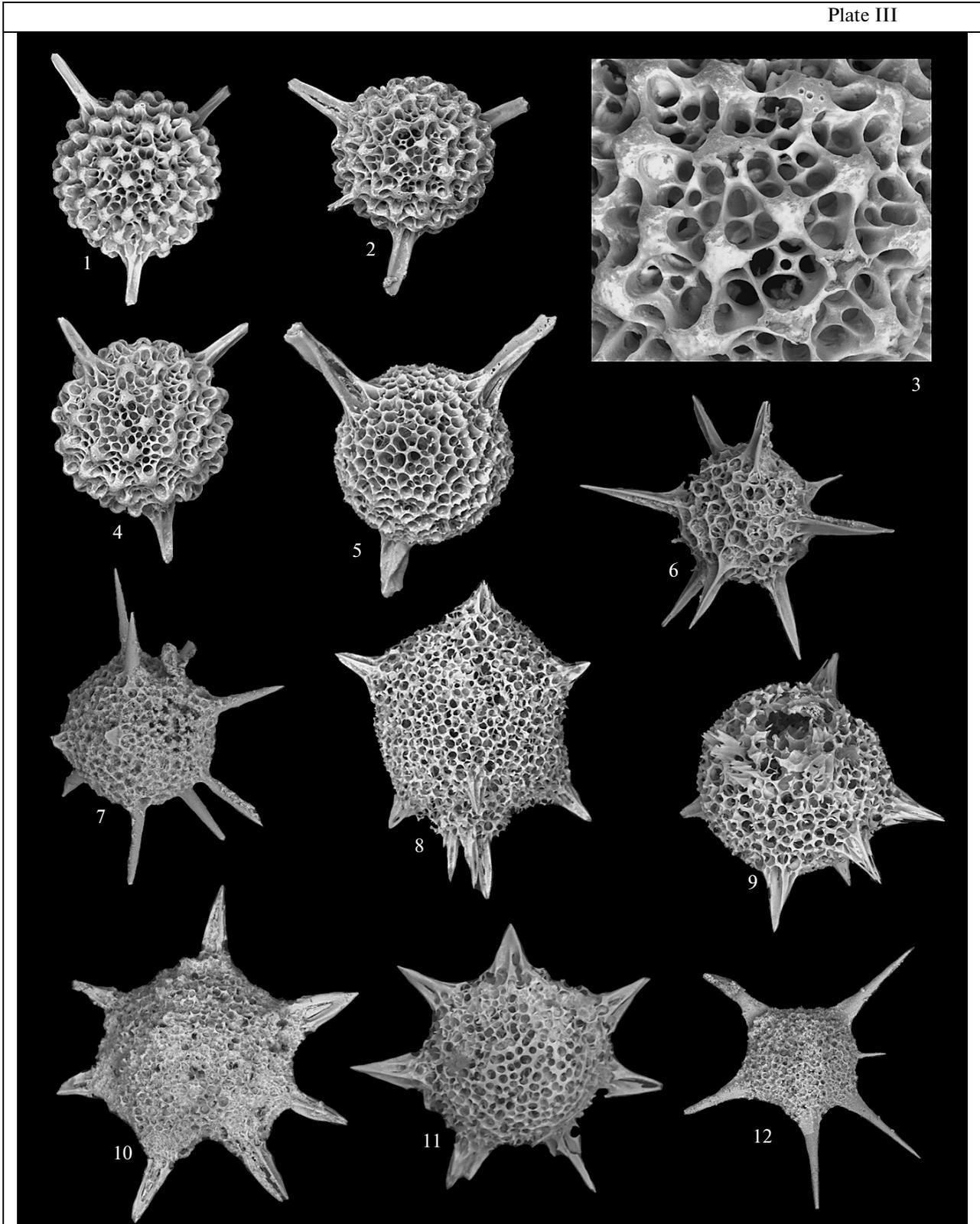
In the Tethyan regions, radiolarian zonation of the Middle Jurassic–Lower Cretaceous has been elaborated in detail (Baumgartner et al., 1995). During compilation of that zonation, it became clear that stratigraphic ranges of the Jurassic–Cretaceous radiolarians are mostly very considerable. For instance, the stratigraphic range of *Mirifusus diana* (Karrer) corresponds to the Bajocian–lower Hauterivian inter-



**Plate II.** Nassellarians of the middle Volgian Substage:

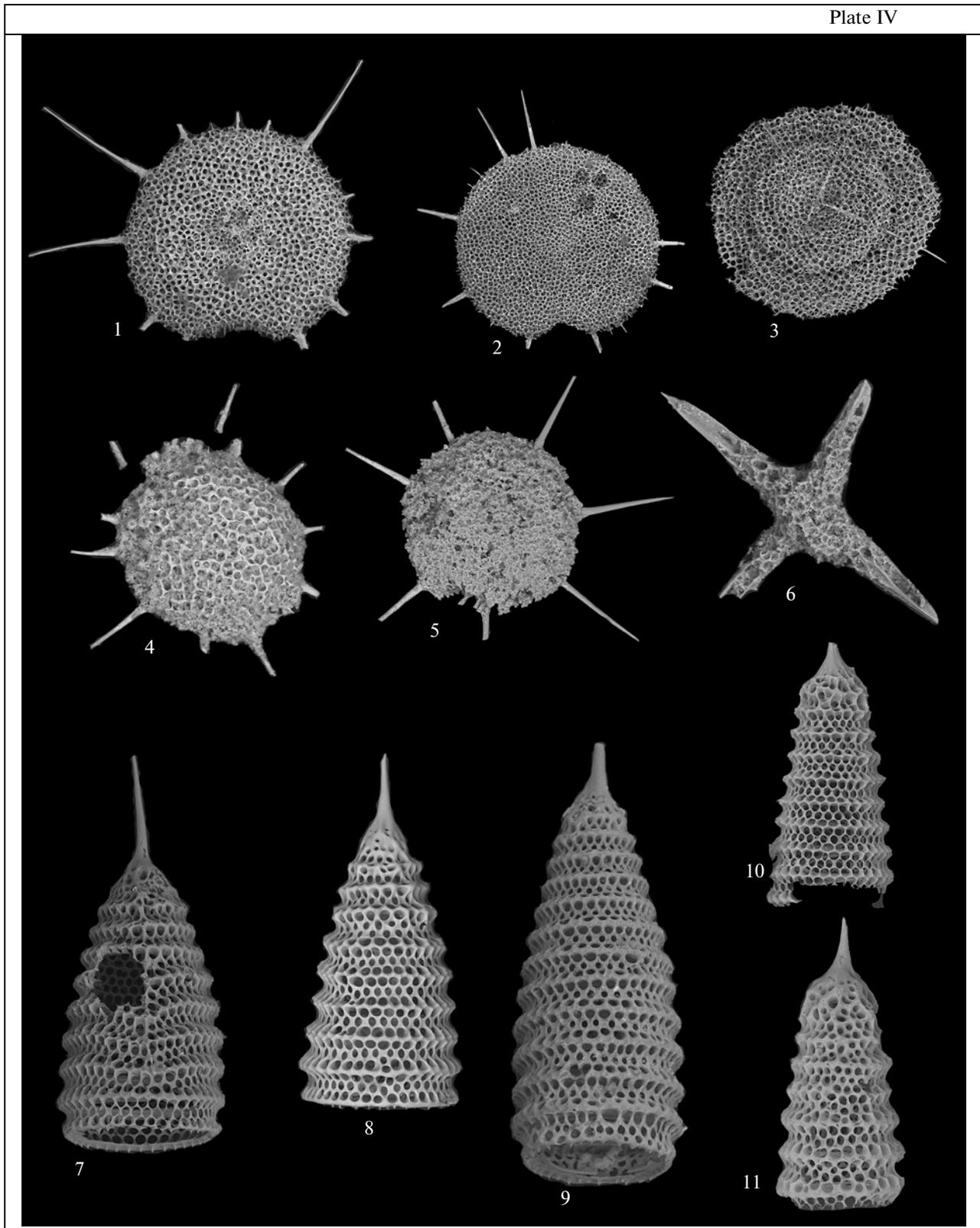
(1, 2) *Praeparvicingula* sp. cf. *P. sencilla* Hull,  $\times 130$  (both); (3, 4) *Arctocapsula congelata* Bragin, sp. nov.,  $\times 210$  (both), (4) holotype; (5, 6) *Praeparvicingula cappa* (Cortese): (5)  $\times 160$ , (6)  $\times 170$ ; (7) *Praeparvicingula* sp.,  $\times 160$ ; (8) *Parvicingula* sp.,  $\times 160$ ; (9–11) *Arctocapsula magna* Bragin: (9)  $\times 150$ , (10, 11)  $\times 160$ ; (12) *Arctocapsula* sp.,  $\times 150$ ; (13, 14) *Arctocapsula constantia* Bragin, sp. nov.,  $\times 220$  (both), (13) holotype. All specimens from the middle substage of the Volgian Stage (Epivirgatites variabilis Zone).

Plate III



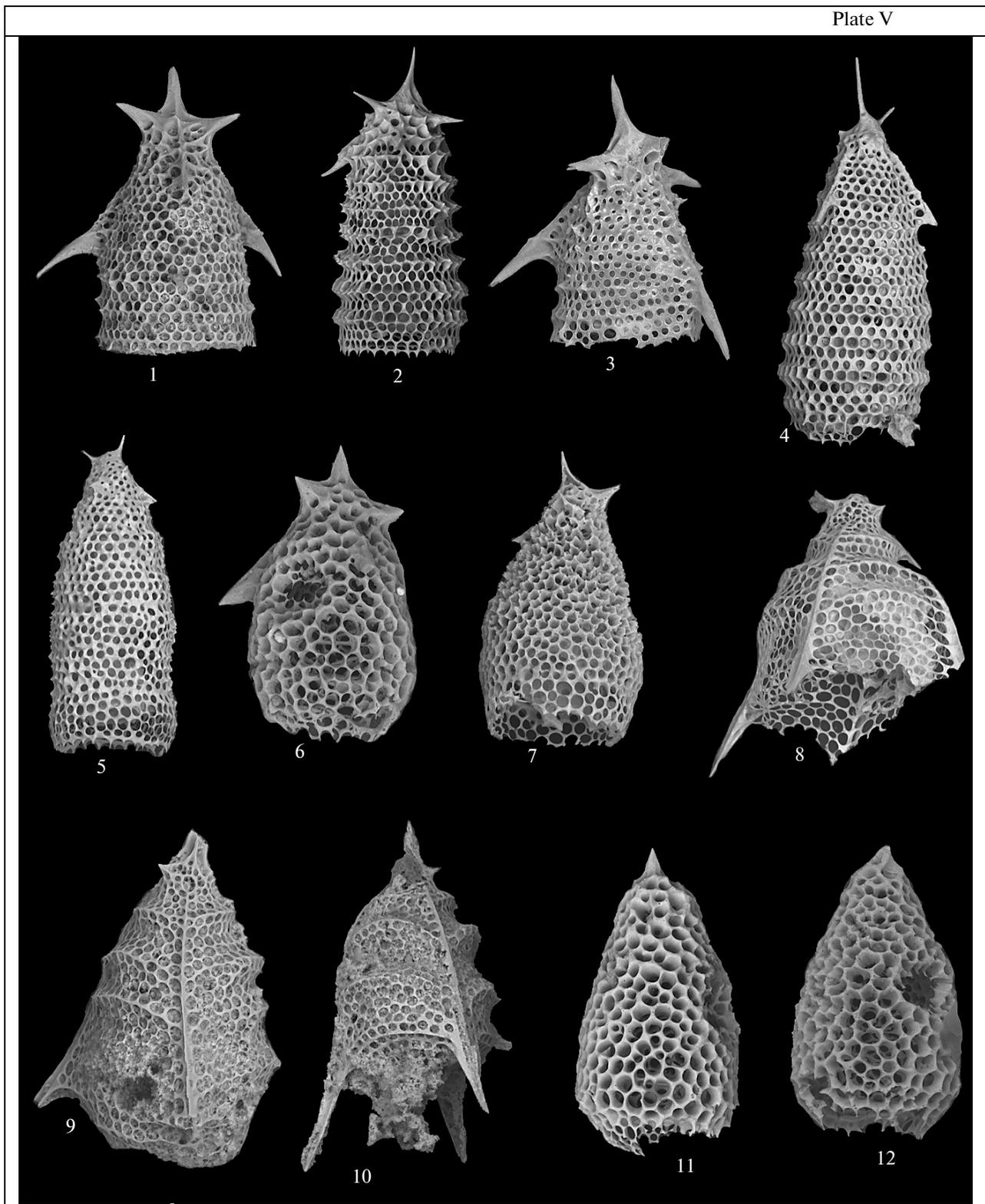
**Plate III.** Spheroidal morphotypes from the Volgian Stage:

(1–4) *Acaeniotylopsis nordvikensis* Bragin, sp. nov.: (1, 2, 4)  $\times 135$ ; (3)  $\times 600$ , (4) holotype; (5) *Acaeniotylopsis* ? sp.,  $\times 135$ ; (6) *Haliomma* sp.,  $\times 170$ ; (7) Actinommidae gen. et sp. indet.,  $\times 170$ ; (8, 9) *Glomeropyle polygonium* Bragin, sp. nov.,  $\times 170$  (both), (8) holotype; (10, 11) *Stylospongia* sp. aff. *S. longispina* (Rust),  $\times 170$  (both); (12) *Orbiculiforma* ? sp.,  $\times 170$ . Specimens 1–5, 8 and 9 are from upper substage of the Volgian Stage (Chetaites chetae Zone); specimens 6, 7, and 10–12 from the middle substage of the Volgian Stage (Epirigatites variabilis Zone).



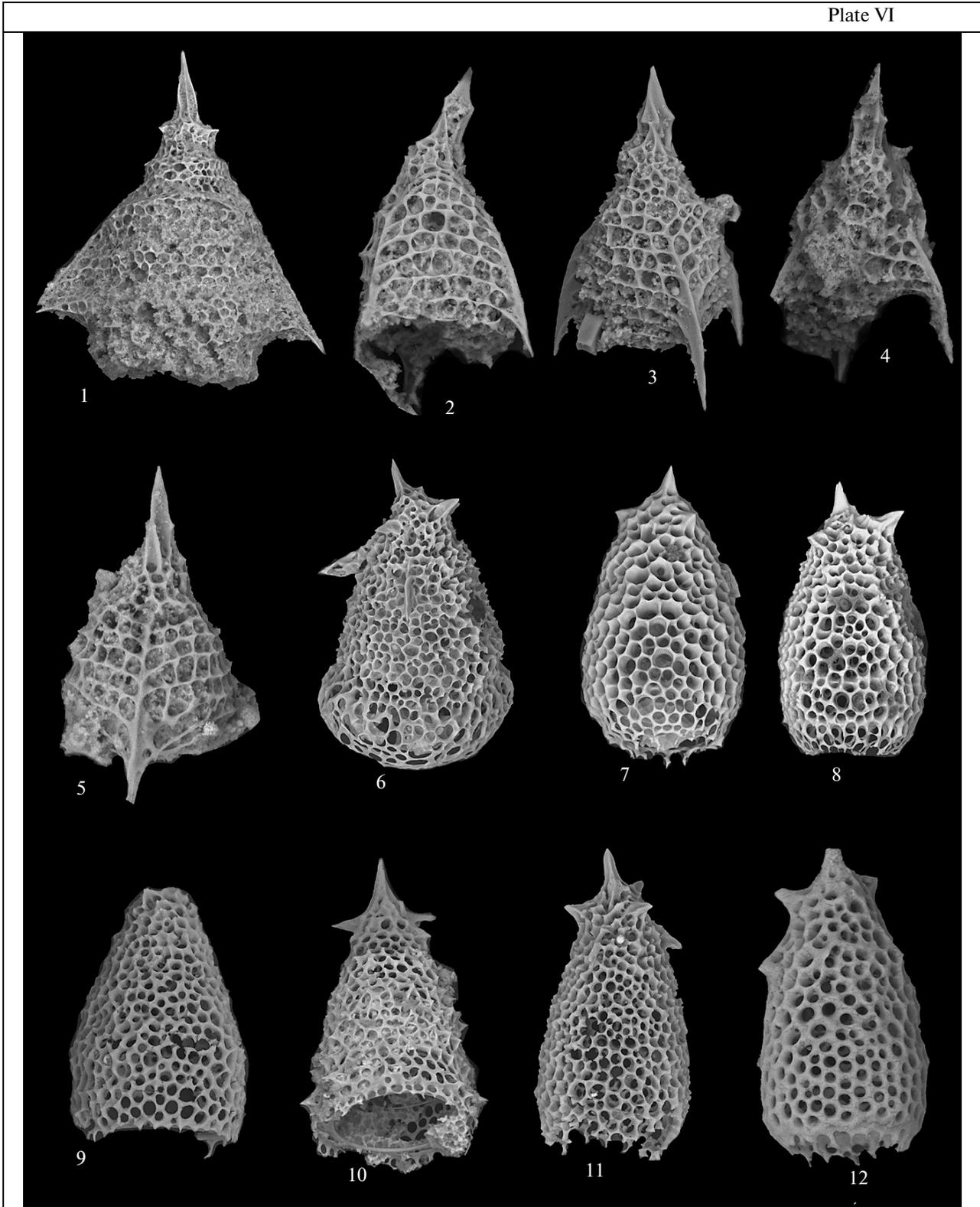
**Plate IV.** Discoidal morphotypes and nassellarians of the upper Volgian Substage:

(1–3) *Orbiculiforma* aff. *railensis* Pessagno (Kiessling, 1999),  $\times 135$  (all); (4, 5) *Orbiculiforma* sp.,  $\times 170$  (both); (6) *Crucella* sp. cf. *C. theokafkensis* Baumgartner,  $\times 170$ ; (7–9) *Parvicingula khabakovi* (Zhamoida),  $\times 160$  (all); (10, 11) *Praeparvicingula rotunda* Hull (Kiessling, 1996, pl. 42, figs. 13–16), (10)  $\times 170$ , (11)  $\times 180$ . All specimens from the upper substage of the Volgian Stage (Chetaites chetae Zone).



**Plate V.** Upper Volgian nassellarians of the family Echinocampidae:

(1) *Echinocampe aliferum* Bragin,  $\times 170$ ; (2) *Echinocampe cristatum* Bragin,  $\times 170$ ; (3) *Echinocampe aculeatum* Bragin,  $\times 170$ ; (4) *Nordvikella elegans* Bragin,  $\times 170$ ; (5) *Nordvikella improcera* Bragin,  $\times 220$ ; (6) *Arctocapsula perforata* Bragin,  $\times 170$ ; (7) *Arctocapsula incompta* Bragin,  $\times 200$ ; (8) *Tertonium* sp.,  $\times 170$ ; (9, 10) *Pyramotertonium planocephalum* (Kozlova): (9)  $\times 200$ , (10)  $\times 150$ ; (11, 12) *Bagotum?* sp.,  $\times 220$  (both). All specimens from the upper substage of the Volgian Stage (Chetaites chetae Zone).



**Plate VI.** Nassellarians of the upper Volgian Substage:

(1) Tertoniidae gen. et sp. indet.,  $\times 200$ ; (2–5) *Napora pyramidalis reticulatus* Bragin, subsp. nov.; (2–4)  $\times 300$ , (5)  $\times 350$ , (3) holotype; (6) *Arctocapsula* sp.,  $\times 170$ ; (7, 8) *Arctocapsula* sp. aff. *A. incompta* Bragin,  $\times 200$  (both); (9) Nassellaria gen. et sp. indet.,  $\times 220$ ; (10) *Echinocampe* sp.,  $\times 200$ ; (11) *Arctocapsula* sp.,  $\times 220$ ; (12) *Arctocapsula* sp.,  $\times 300$ . All specimens from the upper substage of the Volgian Stage (Chetaites chetae Zone).

val (Baumgartner et al., 1995). For species *Parvicin-gula altissima* (Rust), there had been originally established the Bajocian–Tithonian interval of its occurrence (Baumgartner et al., 1995), but later on this taxon was also found in the Berriasian and Valanginian (Dumitrica et al., 1997; Bragin and Tekin, 1999). As a consequence, the Upper Jurassic–Lower Cretaceous radiolarian zonation is substantiated using the method of unitary fossil assemblages with due account for practically all the well-known species. In other words, we can establish that particular beds belong to one or the other zone only if their rocks bear diverse assemblages of well-preserved fossils whose species can be precisely identified, without recourse to open nomenclature. Only in such cases, can we recognize biostratigraphic zones of sufficiently high resolution. In the Nordvik section, the well-known Tethyan species are practically absent, and the radiolarians present can be either mainly determined in open nomenclature, or described as new species. Consequently, it is impossible at present to recognize equivalents of the Tethyan biostratigraphic units in this section.

Determination of the Jurassic–Cretaceous boundary based on radiolarians is similarly problematic. Despite the boundary's considerable geological significance, neither bivalve mollusks, ammonoids, nor any other group of orthostratigraphic fossils demonstrate meaningful biotic events recorded across the relevant stratigraphic level. Radiolarians are not an exception, and it is not a coincidence that the boundary under consideration is defined inside Zone 13 (uppermost Tithonian–lower Berriasian) of the Middle Jurassic–Lower Cretaceous radiolarian zonation acknowledged in the low-latitude regions (Baumgartner et al., 1995). Moreover, the correctness of this boundary determination in the Boreal regions and the range of the Volgian Stage are still topics of debate.

As is established in this work, radiolarians do not occur throughout the Nordvik section (figure): their oldest assemblage is found in Member V (middle Volgian Substage, *Epivirgatites variabilis* Zone); the youngest in members VIII–IX (topmost upper Volgian–basal Berriasian interval, *Chetaites chetae* and *Chetaites sibiricus* zones). Between the designated intervals, i.e., at the top of the middle Volgian and in the middle and upper parts of the upper Volgian, radiolarians have not been detected. It is also necessary to note that the middle and upper Volgian–Berriasian radiolarian assemblages are very different in taxonomic composition: they contain none of the species in common and considerably different sets of generic taxa. One can hardly doubt that this difference implies a quick taxonomic change and complete compositional turnover in radiolarian community at the very end of the Jurassic. We cannot simply determine the levels and dynamics of the relevant changes, but there is a hope that additional data on distribution of radiolarians in the section will help to distinguish here biostratigraphic radiolarian zonation of sufficiently high

resolution. Of course, the expected zonation will be different in paleontological characterization from the Tethyan scale but nevertheless useful for biostratigraphic subdivision of the section.

On the other hand, the Jurassic–Cretaceous transition is lacking records of comparable quick changes in taxonomic composition of radiolarian assemblages: radiolarians from the topmost part of the Volgian stage and basal Berriasian are of the same composition. We can therefore expect that even with the addition of new data enabling recognition of radiolarian biostratigraphic units, the Jurassic–Cretaceous boundary will be defined inside one radiolarian zone, as takes place in radiolarian zonation of the low-latitude regions (Baumgartner et al., 1995). In such a case, the result will be of certain interest, probably meaning that in the Jurassic–Cretaceous boundary epoch the evolutionary trends of radiolarian communities were similar in different paleobiochores despite the drastic taxonomic distinctions of their assemblages from the low and high latitudes.

Description of new and revision of formerly known radiolarian taxa is an important task in the study of Mesozoic radiolarians from the Boreal regions. In the present work, attention is also paid to this topic of study, because it is necessary for correct comparative analysis of these microfossils and their application for biostratigraphic subdivision and correlation. As for subdivision of the Nordvik section, it appears quite probable in the future, but its subsequent correlation with southerly sections will certainly lead to difficulties, because none of the known radiolarian species from the section is of certain Tethyan affinity. Hence it seems more fruitful to correlate the studied section with sections of transitional type (e.g., with the South Boreal sections of the East European platform or with “Californian” sections in the convergence zone of western North America), which yield some radiolarian species occurring in the Nordvik assemblages.

## CONCLUSION

1. In the Nordvik section of the Volgian and Berriasian stages, two radiolarian assemblages of the middle Volgian and late Volgian–early Berriasian are distinguished. The assemblages differ considerably in taxonomic composition, suggesting a quick compositional turnover in the radiolarian community during the second half of the Volgian. Within the Jurassic–Cretaceous transition there are no records that would be indicative of comparable biotic events at the relevant time, and this is consistent with data on the evolution of radiolarians in the Tethyan regions.

2. New radiolarian species described in the work, and species known exclusively from the Boreal regions, dominate the studied assemblages, which also contain some species occurring in the South Boreal and transitional sections. The latter appear to be of certain interest for interregional correlation. Distinc-

tions of the Tethyan and studied assemblages are extremely great.

## PALEONTOLOGICAL DESCRIPTIONS

### CLASS RADIOLARIA MUELLER

#### ORDER ENTACTINARIA KOZUR ET MOSTLER, 1982

##### Genus *Glomeropyle* Aita et Bragin, 1999

*Glomeropyle polygonium* Bragin, sp. nov.  
Plate. III, figs. 8, 9

Name from “polygonius” (Latin), polygonal.

**Holotype.** GIN 4850-9128, Arctic Siberia, Nordvik Peninsula, Cape Urdyuk-Khaya, Upper Jurassic, Volgian Stage, upper substage, Chetaites chetae Zone.

**Description.** Shell large, of rounded-hexagonal outline in lateral view and subcircular in apertural view. Aperture is surrounded by three short massive spines Y-shaped in cross-section. There are up to 10 short radial spines, Y-shaped in cross-section, with pointed ends. Radial spines are attached by their base to eminences at the shell surface, which impart to it a smoothed polygonal shape. Cortical shell spongy, with large round to oval pores arranged chaotically.

**Dimensions.** Shell with apertural spines is 290–320 µm long and 200–220 µm wide.

**Comparison.** The new species differs from *Glomeropyle boreale* Bragin in the greater number of Y-shaped in cross-section spines and in the more massive apertural spines.

**Remarks.** The described shell is included into the genus *Glomeropyle* tentatively, since its inner structure is unknown. Until present, representatives of this genus have only been known from Triassic deposits. In external morphology and presence of aperture, the described forms are comparable with morphotypes of Triassic age.

**Stratigraphic range.** Upper Jurassic, upper substage of Volgian Stage, Arctic Siberia.

**Material.** 23 specimens.

### ORDER SPUMELLARIA EHRENBERG

#### FAMILY LEUGEONIDAE YANG ET WANG, 1990

##### Genus *Acaeniotylopsis* Kito et De Wever, 1994

*Acaeniotylopsis nordvikensis* Bragin, sp. nov.  
Plate I, fig. 7; Plate III, figs. 1–4

Name for the occurrence locality Nordvik Peninsula.

**Holotype.** GIN 4850-9133, Arctic Siberia, Nordvik Peninsula, Cape Urdyuk-Khaya, Upper Jurassic, Volgian Stage, upper substage, Chetaites chetae Zone, Plate III, fig. 4.

**Description.** Cortical shell spherical, with massive blunt rounded tubercles interconnected by thin ridges that form subtriangular pore frames. Inside the latter, there are 3 to 5 round pores of variable size. Three

massive radial spines are blunt at their ends. Spines are Y-shaped in cross-section, lacking spiral coiling, with massive smooth transverse ridges and wide grooves.

**Dimensions.** Shell size across is 200–205 µm, spines 75–85 µm long.

**Comparison.** The described form differs from *Acaeniotylopsis variatus* (Ozoldova) in having thinner spines, which are thinner and one-third of the length, and in the highly tuberculate shell of larger size.

**Stratigraphic range.** Upper Jurassic–Lower Cretaceous, middle substage, Volgian–Lower Berriasian, Arctic Siberia.

**Material.** 32 specimens.

### FAMILY HAGIASTRIDAE RIEDEL, 1971

##### Genus *Higumastra* Baumgartner, 1980

*Higumastra turgida* Bragin, sp. nov.  
Plate I, figs. 2, 3

Name from “turgidus” (Latin), swollen.

**Holotype.** GIN 4850-9135, Arctic Siberia, Nordvik Peninsula, Cape Urdyuk-Khaya, Upper Jurassic, Volgian Stage, middle substage, Epivirgatites variabilis Zone.

**Description.** Shell not large, with short thick rays. Central part of shell is subquadrate in outline, and rays originate at the corners of a square. Ends of rays are swollen, with one thin acute spine Y-shaped in cross-section. In central part, round to oval pores are set within the irregularly polygonal pore frames. Round pores within subquadrate pore frames on the rays are arranged into longitudinal rows; on the visible side of the ray, up to five rows of pores can be distinguished.

**Dimensions.** In the shell central part, maximum size across is 85 µm; complete length of ray is 190–200 µm, maximum width 80 µm; spines are 70 µm long.

**Comparison.** As compared to *Higumastra imbricata* (Ozoldova), rays are longer and thinner, terminated by inflation with one spine.

**Stratigraphic range.** Upper Jurassic, Volgian Stage, middle substage, Nordvik section, Arctic Siberia.

**Material.** 14 specimens.

### ORDER NASSELLARIA EHRENBERG

#### FAMILY ECHINOCAMPIDAE BRAGIN, 2009

##### Genus *Arctocapsula* Bragin, 2009

*Arctocapsula congelata* Bragin, sp. nov.  
Plate II, figs. 3, 4

Name from “congelato” (Latin), to freeze.

**Holotype.** GIN 4850-9137, Arctic Siberia, Nordvik Peninsula, Cape Urdyuk-Khaya, Upper Jurassic, Volgian Stage, middle substage, Epivirgatites variabilis Zone.

**Description.** Cephalis small, hemispherical, with large faveolate pores. Apical horn short, trihedral, apiculate, deviating from the longitudinal shell axis approximately at 25°. Ventral horn approximately

equal in length to the apical one is also trihedral, apiculate, but inclined relative to the longitudinal shell axis toward the opposite side at the angle of 40°–45°. Small lateral spines short, thin and apiculate radiate from the cephalis lower part at the right angles to the longitudinal shell axis. Large lateral spines and dorsal spine are almost completely enclosed in the shell wall, but one spine projects outside orthogonally to the axis. Constrictions or ridges between cephalis, thorax, and other shell segments are imperceptible. Thorax and abdomen are of truncated cone shape, and first post-abdominal segment of maximum width grades into subsequent, gradually narrowing segments. On all segments there are large pores in hexagonal and pentagonal pore frames with tubercles and spinules at junction points of frames; pores may be grouped into transverse rows. Aperture, when observable in well-preserved specimens, is narrow, lacking tube.

**Dimensions.** Shell is 245–250 µm long and 125–130 µm wide; apical and ventral horns 20 µm long each.

**Comparison.** As distinct from *Arctocapsula constantia* sp. nov., apical horn is inclined relative to the main shell axis, and pores on segments are grouped into transverse rows.

**Stratigraphic range.** Upper Jurassic, Volgian Stage, middle substage, Nordvik section, Arctic Siberia.

**Material.** 14 specimens.

*Arctocapsula constantia* Bragin, sp. nov.

Plate II, figs. 13, 14

Name from “constantia” (Latin), stability, firmness.

**Holotype.** GIN 4850-9138, Arctic Siberia, Nordvik Peninsula, Cape Urdyuk-Khaya, Upper Jurassic, Volgian Stage, middle substage, Epivirgatites variabilis Zone.

**Description.** Cephalis small, conic, with large faveolate pores. Apical horn short, trihedral deviates from the main shell axis very weakly. Somewhat shorter ventral horn also trihedral and pointed angles for 45° relative to the shell axis. Small lateral spines short, thin and apiculate radiate from the lower part of the cephalis at right angles to the longitudinal shell axis. Large lateral spines and dorsal spine merged partially or completely with the shell wall, sometimes with short external continuations dorsally oriented at an angle of 60° to the shell axis. Constrictions or ridges between cephalis, thorax, and other shell segments imperceptible. Thorax and abdomen are of truncated cone shape. Of the two postabdominal segments, the first is of maximum width and the subsequent segment is somewhat narrower. On all segments, there are large pores in hexagonal and pentagonal pore frames with tubercles and spinules at junction points; pore rows have not been observed. Aperture is slightly narrowed, open.

**Dimensions.** Shell is 170–210 µm long and 110–135 µm wide; apical and ventral horns are 20 and 15 µm in length respectively.

**Comparison.** As opposed to *Arctocapsula congelata* sp. nov., the apical horn of the shell described is almost vertical, and placement of pores is chaotic, without transverse rows.

**Stratigraphic range.** Upper Jurassic, Volgian Stage, middle substage, Nordvik section, Arctic Siberia.

**Material.** 10 specimens.

#### FAMILY TERTONIIDAE DUMITRICA ET ZUGEL, 2003

##### Genus *Pyramotertonium* Bragin, gen. nov.

*Pseudocrolanium* Kozlova, 1994 (nomen nudum).

**Type species.** *Stichopilidium planocephala* Kozlova, Upper Jurassic, Volgian Stage, upper substage, Timan–Pechora plate.

**Diagnosis.** Tertoniidae with three basic spines forming three lengthwise ribs at the shell surface; shell sections triangular. Apical horn large, well developed.

**Comparison.** Differs from the genus *Tertonium* Dumitrica et Zugel in having three but not four basal spines forming lengthwise ribs on the shell surface.

**Remarks.** Forms described as *Stichopilidium planocephala* (Kozlova, 1976a) were later attributed to the new genus *Pseudocrolanium* by Kozlova (1994). Consequently, the name *Pseudocrolanium* Kozlova should be regarded as invalid (nomen nudum).

**Composition.** Type species.

*Pyramotertonium planocephalum* (Kozlova, 1976)

Plate V, figs. 9, 10

*Stichopilidium planocephala*: Kozlova, 1976a, p. 82, fig. 3; Kozlova, 1976b, fig. 9, fig. 6.

*Pseudocrolanium planocephala*: Kozlova, 1994, Plate 7, figs. 1–3.

**Holotype.** VNIGRI 667/41, Kolguev Island, Borehole 140, depth 472–481 m, Upper Jurassic, Volgian Stage, upper substage.

**Description.** Cephalis small, subconical, with small subround, chaotically dispersed pores. Apical horn is thick, short, three-bladed, pointed, inclined at the angle of 10°–15° from the lengthwise shell axis. A short ventral horn is inclined at an angle of 60° towards the opposite side. Pores on the thorax of truncated cone shape are larger than on the cephalis, tending to be arranged in transverse rows. The large dolioform abdomen gradually expands over three-quarters of its length, quickly narrowing afterwards. In fine hexagonal and pentagonal pore frames, the large subcircular pores of abdomen are arranged into transverse rows. Three massive acuminate ridges extend lengthwise throughout the shell originating from the blades of the apical horn. Prolonging the ridges are three thick, slightly arcuate, apertural spines trihedral in cross-section. The lengthwise ridges are interconnected via narrow arcuate transverse ridges (up to 3 ridges per

shell length are observable). Within the thorax, transverse section of shell is triangular due to the development of lengthwise ridges. The aperture is small.

**Dimensions.** Length of shell with apical horn and apertural spines is 350–400  $\mu\text{m}$ , width 180–200  $\mu\text{m}$ ; apical horn 50  $\mu\text{m}$  long, apertural spines up to 90  $\mu\text{m}$  long.

**Remarks.** In the original description of the species, it is reported that shell consists of many segments. On modern photographs, however, it is clear that the thorax surface has numerous transverse ridges, which could be mistaken for junctions between different shell segments. The described specimen has a certainly dicyrtid shell typical of the family Tertoniidae (Dumitrica and Zugel, 2003).

**Stratigraphic range.** Upper Jurassic, upper substage of the Volgian Stage, Timan–Pechora plate and Arctic Siberia.

**Material.** 38 specimens.

#### FAMILY ULTRANAPORIDAE PESSAGNO, 1977

##### Genus *Napora* Pessagno, 1977

*Napora pyramidalis* Baumgartner, 1984

*Napora pyramidalis*: Baumgartner, 1984, p. 775, pl. 6, figs. 11, 12; Baumgartner et al., 1995, p. 332, pl. 3033, figs. 1, 2.

*Napora pyramidalis reticulatus* Bragin, subsp. nov.  
Plate VI, figs. 2, 3

Name from “reticulatus” (Latin), netlike.

**Holotype.** GIN 4850-9141, Arctic Siberia, Nordvik Peninsula, Cape Urdyuk-Khaya, Upper Jurassic, Volgian Stage, upper substage, Chetaites chetae Zone.

**Description.** Cephalis small, hemispherical, with thick apical horn inclined at the angle of 20° from the lengthwise shell axis. In proximal part of apical horn, there are three high, thick ridges giving Y-shaped outlines to the cross-sections. The distal part of the horn narrows towards the pointed end, and ridges become smoothed and lower. The cephalis wall is chaotically perforated with small round pores whose groups are surrounded by polygonal pore frames of irregular outlines. Thorax, of truncated cone shape, is triangular in cross-section, having large subcircular pores grouped into transverse rows and surrounded by thin irregular polygonal pore frames with minute spinules at their junction points. Due to development of pore frames, structure of the thorax surface looks reticulate. Three thin acuminate ridges extend lengthwise throughout the thorax from its junction with the cephalis are prolonged by three slightly arcuate apertural spines. Wide aperture is subtriangular in outline.

**Dimensions.** Length of shell with apical horn and apertural spines is 200–220  $\mu\text{m}$ , shell width is 100–115  $\mu\text{m}$ , apical horn 45–50  $\mu\text{m}$  long, apertural spines 50  $\mu\text{m}$  long.

**Comparison.** The described specimen differs from the type species in development of irregular polygonal

pore frames forming areticate structure of the thorax surface.

**Stratigraphic range.** Upper Jurassic–Lower Cretaceous, upper Volgian–lower Berriasian, Arctic Siberia.

**Material.** 38 specimens.

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