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Echinocampidae fam. nov., a New Family of Late Jurassic–Early Cretaceous Radiolarians of Arctic Siberia

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Abstract—When studying Late Jurassic–Early Cretaceous radiolarians from the Nordvik section (Arctic Siberia), unique morphotypes of multicyrtoid nassellarians with many horns in the apical part of the shell, which continue the rays A, V, 2l, D, and 2L of the cephalic spicule, were recorded. These morphotypes are assigned to a new family, Echinocampidae fam. nov., including three new genera (*Echinocampe* gen. nov., *Nordvikella* gen. nov., and *Arctocapsula* gen. nov.) and eight new species. The family Echinocampidae was probably restricted to high latitudes and belonged to the boreal fauna of the terminal Jurassic and the basal Cretaceous.

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Key words: Radiolaria, Late Jurassic, Early Cretaceous, new taxa, stratigraphy, correlation, paleobiogeography, Arctic Siberia, Russia.

INTRODUCTION

Living radiolarians occur in all seas of normal salinity, with the composition of their associations depending on climatic conditions. Tropical, subtropical, boreal, and notal assemblages are recognized. Similar relationships have been established in Cenozoic and, recently, Mesozoic radiolarians (Pessagno et al., 1987; Bragin, 1997; Vishnevskaya, 2001; Bragin, 2002, 2005). Cold-water Mesozoic radiolarian associations differ from thermophilic associations of the same age in the impoverished taxonomic composition and considerable prevalence in abundance of one or a few species. Dominant taxa are only characteristic of high latitudes and sometimes display bipolar distribution, which is particularly well-pronounced in the Triassic (Aita and Bragin, 1999; Bragin and Egorov, 2000; Bragin, 2005).

Arctic radiolarian assemblages of the Upper Jurassic and Lower Cretaceous are insufficiently understood; available data on the Pechora Depression and northern Middle Siberia (Vishnevskaya, 2001) poorly describe these faunas. It is necessary to develop descriptive works, since in the composition of Late Jurassic Arctic faunas of radiolarians and other groups (ammonites, bivalves, etc.), an important role is played by genera and families that are completely absent from southerly areas and distinguish high-latitude assemblages. Therefore, the study of these assemblages is a particularly important task.

A section of Upper Jurassic and Lower Cretaceous deposits near the Urdyuk-Khaya Cape of the Nordvik Peninsula (Fig. 1) is one of the best objects for the study of the Jurassic–Cretaceous boundary beds in the Arctic Region; it is characterized by a rich fossil fauna and detailed stratigraphy (Basov et al., 1970; Zakharov et al., 1983). This is a reference section of the Volgian Stage of northern Siberia. At present, thorough stratigraphic studies of the section are continued, including magnetostratigraphy and correlation with Tethyan sections, the position of the Jurassic–Cretaceous boundary is discussed (Zakharov and Rogov, 2006; Khosha et al., 2007). Note that this stratigraphic scheme of the section is not accepted by all researchers; in particular, Baraboshkin (2004) believes that the boundary between the Jurassic and Cretaceous is much lower, at the *Praechetaites exoticus* Zone.

During field works of 2003, V.A. Zakharov and M.A. Rogov collected extensive material (phosphate–carbonate concretions), which yielded representative radiolarian assemblages of good and even excellent preservation. Radiolarians were extracted from concretions as follows: a sample was dipped for 30 minutes in a mixture of equal proportions of concentrated nitric acid and water; the sediment obtained was washed with water and dried; radiolarians were picked from the sediment, mounted, and examined under a scanning electron microscope.

Below is a brief description of the section of the upper Volgian Stage and lowermost Berriasian in the coastal outcrops situated south of the Urdyuk-Khaya Cape on the eastern coast of the Nordvik Peninsula (Fig. 1) (Zakharov and Rogov, 2006).

Jurassic System, Volgian Stage, Middle Substage

Epivirgatites variabilis Zone, Member V Dark gray, with bluish tint, brecciated, glauconitic–leptochloritic claystone-like clay. Small pyrite nodules are scattered over the strata of the member. At the base and in the middle part of the member, two rows of loaf-shaped concretions are observed; in the lower row, concretions are composed of gray limestone; in the upper row, they show a zonal structure, with the central part formed of carbonaceous phosphorite and the peripheral part composed of siderite. The zone has yielded the ammonites *Epivigratites variabilis* Schulgina and *Laugeites* sp. aff. *L. stschurowskii* Nikitin and diverse assemblages of belemnites, bivalves, and foraminifers. Radiolarians occur in concretions of the upper row and include *Arctocapsula magna* sp. nov., *Archaeospongoprunum* sp., *Crucella* sp., *Orbiculiforma* sp., *Parvicingula* sp. cf. *P. vera* Pessagno et Whalen, *Praeconocaryomma* sp., and *Praeparvicingula* sp. The member is 3 m thick.

Praechetaites exoticus Zone. Clay similar in appearance to that of the previous member, although lacking calciferous–phosphatic concretions. The member is 1.3 m thick.

Volgian Stage, Upper Substage

Craspedites okensis Zone, Member VI. Claystone-like clay, consisting of alternating dark gray, brownish, and bluish gray interbeds. Nine rows of phosphatic–carbonaceous concretions are recorded. This zone has yielded the ammonites *Virgatosphinctes bicostatus* Schulgina and *Craspedites okensis* d'Orb. The member is 7 m thick.

Craspedites taimyrensis Zone, Member VII. Dark gray claystone-like clay, with pyrite nodules and three rows of phosphatic–carbonaceous concretions. This zone has yielded the ammonite *Craspedites* (Taimyroceras) *canadensis canadensis* Jeletz. The member is 4.2 m thick.

Chetaites chetae Zone, Member VIII. Dark gray, with brownish tint, thin-layer clay. The member contains two rows of ellipsoidal phosphatic–carbonaceous concretions. This zone has yielded the ammonite *Chetaites* sp. cf. *C. chetae* Shulg. Concretions from both interbeds contain the radiolarians *Acaeniotylopsis* sp., *Arctocapsula perforata* sp. nov., *A. incompta* sp. nov., *Echinocampe aliferum* sp. nov., *E. cristatum* sp. nov., *E. aculeatum* sp. nov., *Leugeo* sp., *Napora* sp., *Nordvikella elegans* sp. nov., *N. improcera* sp. nov., *Orbiculiforma* sp., *Parvicingula khabakovi* (Zhamoida), *P. ? vera* Pessagno et Whalen, *Triactoma* sp., and *Triversus* sp. The member is 1.2 m thick.

Cretaceous System, Lower Series, Berriasian Stage

Chetaites sibiricus Zone, Member IX. Dark gray clay, in places, claystone-like. A thin layer of brownish gray and gray phosphatic limestone is observed at the base of the member, with phosphatic–carbonaceous concretions in the upper strata. This zone has yielded the ammonites *Praetollia* sp. ex gr. *maynci* Spath and *Chetaites* sp. cf. *C. sibiricus* Shulg. Concretions in the lower 1.0-m-thich layer of this member contains the same radiolarian assemblage as Member VIII. The member is 4.0 m thick.

The most interesting radiolarians from this zone include previously unknown multichamber nassellarians resembling in appearance the family Parvicingulidae Pessagno 1977 and differing in the unique structure of the apical region. Note that the apical region of the nassellarian shell contains the first chamber (cephalis), with the primary frame in the shape of a multiray spicule. The spicule structure of nassellarians has been investigated in detail (Petrushevskaya, 1981). The basic element of this design is the median bar (MB). One end of MB gives rise to the rays A (apical), D (dorsal), and two rays l (lesser lateral); the opposite end bears the ray V (ventral, or vertical) and two rays L (greater lateral) (Fig. 2). Nassellarian families and genera differ in structural details of spicules; some elements are occasionally reduced or supplementary elements are developed in certain taxa; however, all variants have the same seven-rayed basic prototype.

Nassellarians coming from the Volgian and Berriasian of the Nordvik section are assigned to a new family, Echinocampidae fam. nov., and display a unique shell structure. The apical part of the shell gives rise to seven external horns, which are treated as continuations of the basic rays of the cephalic spicule. The new family has not been recorded in the thoroughly investigated thermophilic aquatic faunas of the Tethyan Region; this suggests that the group in question belongs to high-latitude taxa. The family Echinocampidae fam. nov. has been recorded in the middle substage of the Volgian Stage (*Arctocapsula magna* sp. nov.) and in the upper substage of the same stage (*Echinocampe aliferum* sp. nov., *E. cristatum* sp. nov., *E. aculeatum* sp. nov., *Nordvikella elegans* sp. nov., *N. improcera* sp. nov., *Arctocapsula perforata* sp. nov., and *A. incompta* sp. nov.); this suggests high evolutionary rates and rapid changes in the composition of Echinocampidae assemblages.

SYSTEMATIC PALEONTOLOGY

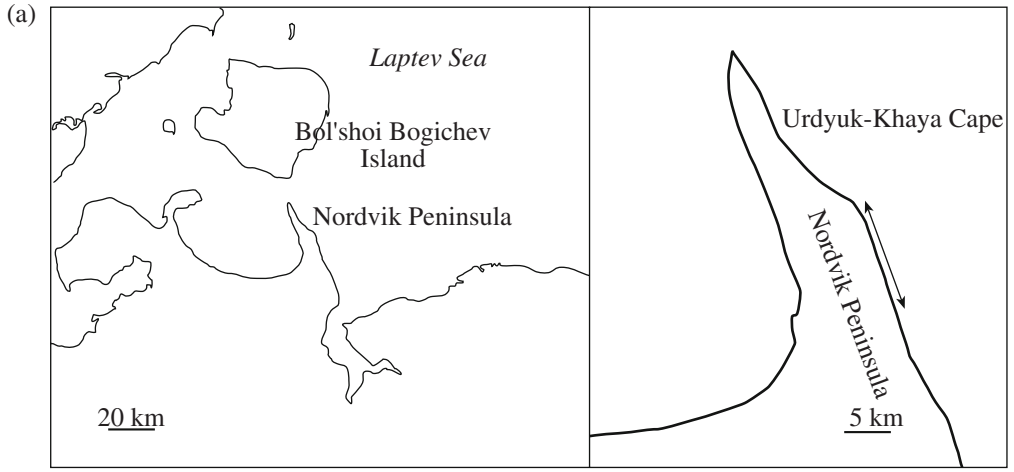
Order Nassellaria

Suborder Cyrtidina

Family Echinocampidae Bragin, fam. nov.

Type genus. *Echinocampe*, gen. nov.

Diagnosis. Multichamber Cyrtidina with cephalic spicule, consisting of elements MB, A, V, D, 2L, 2l. Based of rays of spicule, seven external horns developed, diverging in various directions from apical part of shell. Apical horn (A) directed upwards and inclined to greater or lesser extent, three lateral horns (V, 2l) directed almost perpendicular to shell surface, and three lower horns (D, 2L) directed subparallel to shell


(a)
Laptev Sea
Bol'shoi Bogichev Island
Nordvik Peninsula
20 km
Urdyuk-Khaya Cape
Nordvik Peninsula
5 km

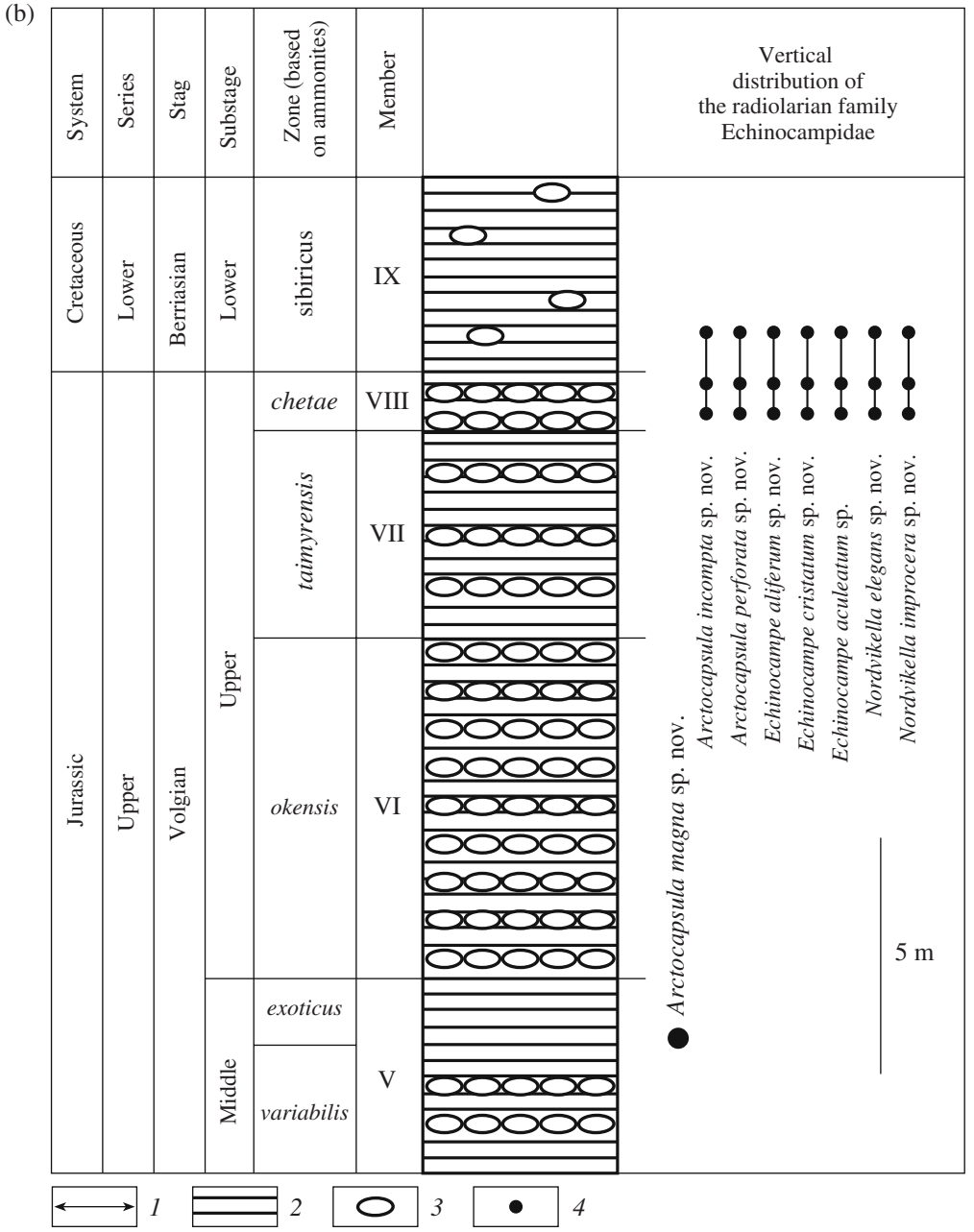

(b)
System
Series
Stag
Substage
Zone (based on ammonites)
Member
Vertical distribution of the radiolarian family Echinocampidae
Cretaceous
Lower
Berriasian
Lower
sibiricus
IX
Jurassic
Upper
Volgian
Upper
chetae
VIII
taimyrensis
VII
okensis
VI
Middle
exoticus
variabilis
V
Arctocapsula magna sp. nov.
Arctocapsula incompta sp. nov.
Arctocapsula perforata sp. nov.
Echinocampe aliferum sp. nov.
Echinocampe cristatum sp. nov.
Echinocampe aculeatum sp.
Nordvikella elegans sp. nov.
Nordvikella improcera sp. nov.
5 m
1
2
3
4

Fig. 1. Nordvik section of the Upper Jurassic and Lower Cretaceous beds and distribution of radiolarians of the family Echinocampidae fam. nov.: (a) position of the Nordvik section and (b) stratigraphic column of the Jurassic–Cretaceous boundary beds of the Nordvik section and levels that have yielded radiolarians of the family Echinocampidae fam. nov. Designations: (*1*) coastal site south of the Urdyuk-Khaya Cape, where a section of the Volgian and Berriasian stages outcrops; (*2*) clay; (*3*) concretions; and (*4*) points where radiolarians were recorded.

surface towards aperture and partially included in shell wall particularly well pronounced (Fig. 2b, 2c). Shell conical, subcylindrical, or spindle-shaped; wall porous, smooth or with transverse ridges or grooves at articulations between segments; pores arranged randomly or in transverse rows.

Generic composition. Genera *Echinocampe* gen. nov., *Arctocapsula* gen. nov., and *Nordvikella* gen. nov., Upper Jurassic, Volgian Stage, Lower Cretaceous, Berriasian Stage of Arctic Siberia.

Comparison. The new family differs from the family Parvicingulidae Pessagno in the horns developed on the basis of the ventral, dorsal, and all lateral rays of the cephalic spicule; it differs from the Sethophormididae Haeckel, 1881 in the presence of the lesser lateral horns, which, along with the ventral horn, form

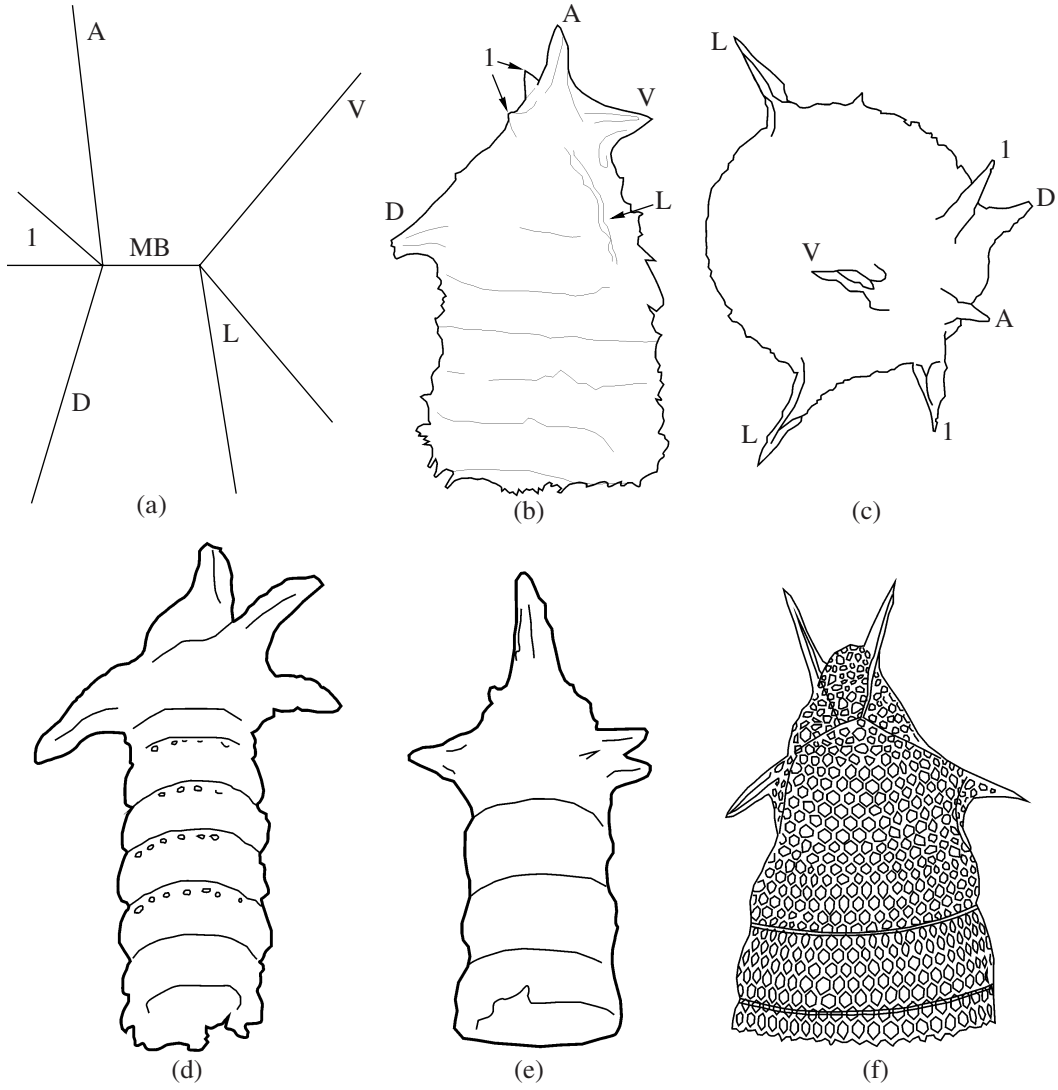


Fig. 2. The structure of horns in the apical part of the shell of Echinocampidae fam. nov. and other Mesozoic and Cenozoic nassellarians. Designations: (a) structural pattern of the cephalic spicule of nassellarians (after Petrushevskaya, 1981), simplified; (b) *Echinocampe aculeatum* sp. nov.; (c) *Arctocapsula perforata* sp. nov., view from above; (d) *Planispinocyrtis longispinosa* Kozur et Mostler, Middle Triassic (Kozur and Mostler, 1994); (e) *Tetraspinocyrtis anisica* Kozur et Mostler, Middle Triassic (Kozur and Mostler, 1994); and (f) *Stichopilium bicorne* Haeckel, 1887, Cenozoic (Petrushevskaya, 1981).

three flank horns; it differs from the family Planispinocyrtiidae Kozur et Mostler, 1981 in the three lower horns developed based on the rays D and 2L.

Remarks. Nassellarians with horns in the apical part of the shell, which develop based on the rays of the cephalic spicule, were most frequent in the Early Mesozoic. In the Triassic, they are observed in members of three families: Anisicyrtidae Kozur et Mostler, 1981, Monicastericidae Kozur et Mostler, 1994, and Planispinocyrtiidae Kozur et Mostler, 1981; in different taxa, horns developed based on different rays. For example, the genus *Planispinocyrtis* Kozur et Mostler, 1981 has an apical horn and three strongly inclined horns, which deviate from the cephalic base and continue the ventral and two lesser lateral rays of the spicule (Kozur and Mostler, 1981, 1994) (Fig. 2). The genus *Spinotriassocampe* Kozur, 1984 from the same family has an apical horn and two lateral horns developing from the base of the lesser lateral rays (Kozur, 1984, Kozur and Mostler, 1994). The family Tetraspinocyrtiidae Kozur et Mostler, 1994 is characterized by the apical horn and three lateral horns developing based on the rays D and 2L (Fig. 2). In Early Jurassic nassellarians, three lateral horns, continuations of D and 2L, are present in the genus *Thetis* De Wever, 1982 (Gorican et al., 2006). The Jurassic–Cretaceous genera *Napora* Pessagno, 1977 and *Ultranapora* Pessagno, 1977 are characterized by three apertural spines, which continue the rays D and 2L (Pessagno, 1977a, 1977b). Similar continuations have been recorded in the Cretaceous genus *Crolanium* Pessagno, 1977, which has a multichamber shell; they form ribs in the shell wall, providing a trihedral cross section (Pessagno, 1977a, 1977b). Note that taxa with many horns are frequent in the Cenozoic; this concerns both one–three-chamber and multichamber shells. In particular, the family Clathromitridae Petrushevskaya, 1971 displays apertural spines developing based on the rays D and 2L (Petrushevskaya, 1971, 1981). An example of multichamber taxa is provided by members of the family Sethophormididae Haeckel, 1881, particularly, the genus *Stichopilium* Haeckel, 1881, which has two vertical horns, developing from A and V, and three lateral horns, developing from D and 2L (Petrushevskaya, 1981) (Fig. 2). The forms mentioned are rather diverse but share one character, some rays of the spicule (usually from three to five) are continued by horns, while others are not. In the new family, horns develop based on all rays of the spicule, including 2l.

Genus *Echinocampe* Bragin, gen. nov.

Etymology. From the Latin *echinus* (hedgehog, sea urchin) and *campe* (caterpillar).

Type species. *Echinocampe aliferum* sp. nov.

Diagnosis. Apical part of shell with narrow trihedral apical, ventral, and lesser lateral horns and lamellar greater lateral and dorsal horns directed to apertural part of shell and forming ribs. Shell wall with distinct sculpture of transverse ridges and transverse rows of pores; shell having from four to six postabdominal segments.

Species composition. In addition to the type species, *E. cristatum* sp. nov. and *E. aculeatum* sp. nov.

Comparison. The new genus differs from *Nordvikella* gen. nov. in the trihedral structure of the apical and ventral horns and in the well-developed lesser lateral horns; it differs from *Arctocapsula* gen. nov. in the development of transverse ridges on the articulations between the shell segments.

***Echinocampe aliferum* Bragin, sp. nov.**

Plate 1, figs. 1 and 4

Etymology. From the Latin *alifer* (wing-bearing).

Holotype. GIN, no. 4850-9101, Arctic Siberia, Nordvik Peninsula, Urdyuk-Khaya Cape; Upper Jurassic, Volgian Stage, upper substage, *Chetaites chetae* Zone.

Description. The cephalis is subconical, relatively large, pierced by many small rounded, randomly arranged pores. The apical horn is longer than the cephalis, massive, trihedral, deviating vertically without inclination from the apex of the cephalis. The ventral horn is almost as long as the apical horn, massive, trihedral, deviating from the upper part of the cephalis and inclined at an angle of 60° to the longitudinal axis of the shell. The lesser lateral horns are as long as the vertical horn, massive, trihedral, deviating from the middle part of the cephalis at an angle of 75°–90° to the longitudinal axis of the shell in the direction opposite to the ventral horn. Two greater lateral horns and dorsal horn begin from the lower part of the cephalis; their proximal parts are included in the cephalic wall and form lamellar ridges pierced by a row of pores; their dorsal parts deviate from the shell and gradually narrow; the ends of horns are pointed. Two greater lateral horns extend to the postabdominal part of the shell, or even to the apertural part; the dorsal horn extends to the abdo-

Explanation of Plate 1

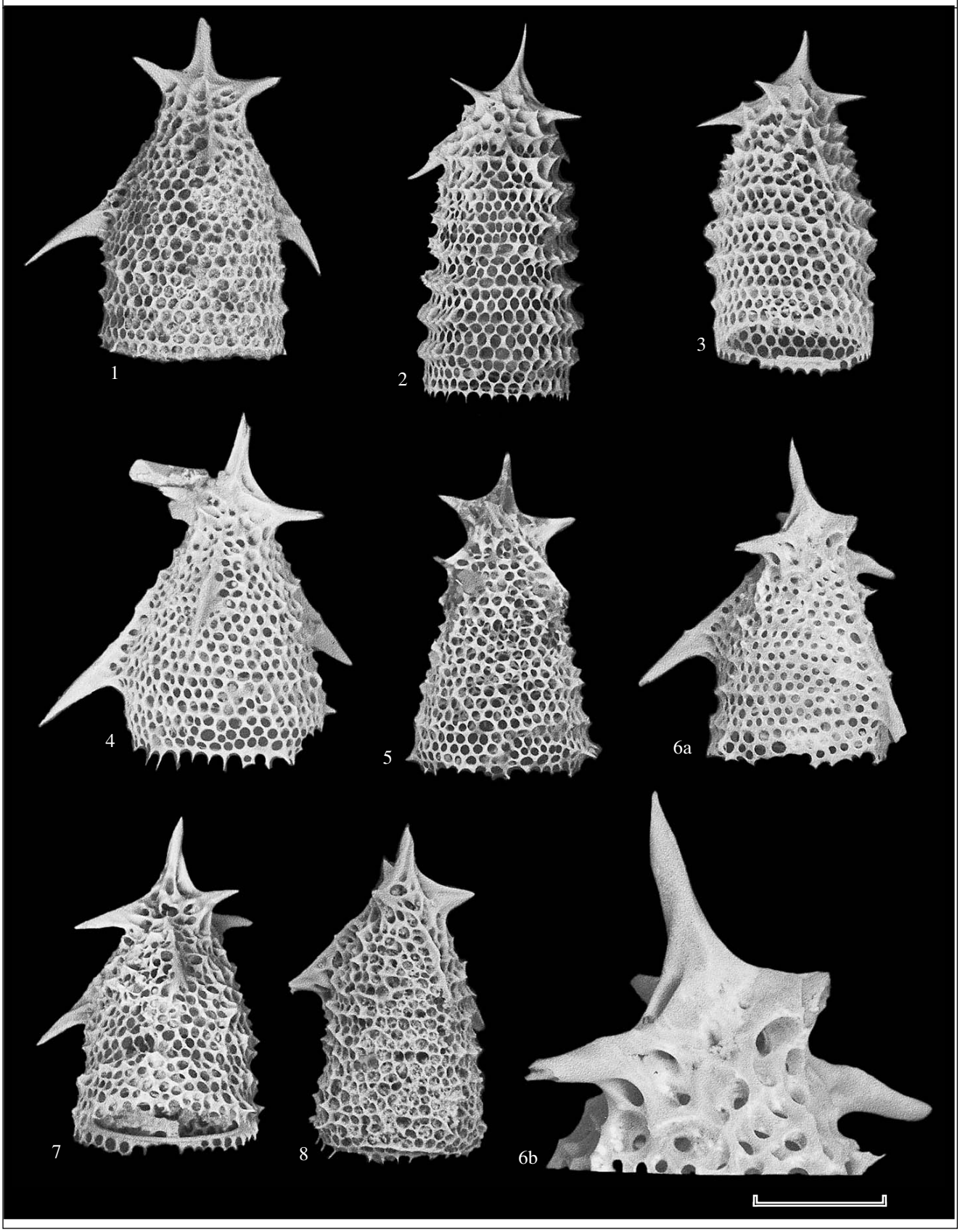
Radiolarians of the genus *Echinocampe* gen. nov. All specimens come from the Nordvik section, Volgian Stage, upper substage. Scale bar in Fig. 6b, 40 μm; in other figures, 100 μm.

Figs. 1 and 4. *Echinocampe aliferum* sp. nov.: (1) holotype GIN, no. 4850-9101; (4) paratype GIN, no. 4850-9102.

Figs. 2 and 3. *Echinocampe cristatum* sp. nov.: (2) holotype GIN, no. 4850-9103; (3) paratype GIN, no. 4850-9104.

Figs. 5–8. *Echinocampe aculeatum* sp. nov.: (5) paratype GIN, no. 4850-9106; (6) holotype GIN, no. 4850-9105: (6a) general appearance and (6b) view of the apical region; (7, 8) paratypes: (7) GIN, no. 4850-9107 and (8) GIN, no. 4850-9108.

Plate 1



men. A weak constriction is observed between the cephalis and thorax. The thorax and abdomen are truncated conical, pierced by circular pores, which form irregular transverse rows. Four relatively short subcylindrical postabdominal segments are present, increasing in width to the third segment; the fourth segment is as wide as, or narrower than, the third segment. The articulations between the segments have low narrow ridges. The segments are pierced by circular pores enclosed in hexagonal fenestrated frames and arranged in transverse rows, three rows per segment. The aperture is wide and rounded.

Measurements, μm. Length of the apical horn, 50–70; length of the ventral horn, 45–50; length of the greater lateral horns, up to 200; length of the cephalis without the apical horn, 50; greatest width of the cephalis, up to 70; length of the shell without the apical horn, 210–220; greatest width of the shell without the greater lateral horns, 150–170.

Comparison. The new species differs from *E. cristatum* sp. nov. in the short and wide shell, the longer greater lateral horns, and in the more poorly pronounced segmentation of the shell.

Material. Twenty-two specimens from the Upper Volgian (*chetae* Zone) and Lower Berriasian (*sibiricus* Zone) substages of the Urdyuk-Khaya Cape, Nordvik Peninsula, Arctic Siberia.

***Echinocampe cristatum* Bragin, sp. nov.**

Plate 1, figs. 2 and 3

Etymology. From the *Latin cristatus* (cristate).

Holotype. GIN, no. 4850-9103, Arctic Siberia, Nordvik Peninsula, Urdyuk-Khaya Cape; Upper Jurassic, Volgian Stage, upper substage, *Chetaites chetae* Zone.

Description. The cephalis is relatively large, conical, pierced by circular pores randomly arranged in polygonal porous frames with small thorns at the articulations. The apical horn is relatively short, slightly longer than the cephalis, massive, trihedral at the base, rapidly narrowing to a smooth thin pointed end. The apical horn begins from the apex of the cephalis; it is slightly inclined (5°–10°) relative to the longitudinal axis of the shell. The ventral horn is approximately half as long as the apical horn, wide, and trihedral at the base, with a narrow pointed end; it is inclined at an angle of 60° to the longitudinal axis of the shell and directed towards the side opposite to the inclination of the apical horn. The ventral horn deviates from the middle part of the cephalis. Two lesser lateral horns deviate from the middle of the cephalis perpendicular to the longitudinal axis of the shell; they are as long as the ventral horn, wide at the base, becoming narrow and pointed at the end. Two greater lateral horns deviate from the base of the cephalis; they are short, pointed, terminating at the level of the thorax and abdomen, not included in the shell wall. The dorsal horn is completely included in the shell wall. The articulation between the cephalis and thorax is indiscernible in the external structure of the shell. The thorax is truncated conical, twice as wide as the cephalis, pierced by circular, randomly arranged pores enclosed in polygonal frames, some of which cover several pores. The articulation between the thorax and abdomen and articulations between postabdominal segments have distinct narrow transverse ridges. Six postabdominal segments are present. The abdomen and postabdominal segments are cylindrical in outline, with concave walls, pierced by circular pores in hexagonal frames, which form three transverse rows in each segment. The shell width gradually increases to the second postabdominal segment, remaining constant in subsequent segments. The aperture is wide, open.

Measurements, μm. Length of the apical horn, 50–55; length of the ventral horn, 25–30; length of the greater lateral horns, up to 100; length of the cephalis without the apical horn, 25–30; greatest width of the cephalis, up to 80; length of the shell without the apical horn, 260–270; greatest width of the shell without the greater lateral horns, 140–150.

Comparison. The new species differs from *E. aliferum* sp. nov. in the longer and narrower shell, the shorter and narrower greater lateral horns, and in the distinctly developed transverse ridges and transverse rows of pores in the postabdominal part of the shell.

Material. Eighteen specimens from the Upper Volgian (*chetae* Zone) and Lower Berriasian (*sibiricus* Zone) substages of the Urdyuk-Khaya Cape, Nordvik Peninsula, Arctic Siberia.

***Echinocampe aculeatum* Bragin, sp. nov.**

Plate 1, figs. 5–8

Etymology. From the Latin *aculeatus* (spinate).

Holotype. GIN, no. 4850-9105, Arctic Siberia, Nordvik Peninsula, Urdyuk-Khaya Cape; Upper Jurassic, Volgian Stage, upper substage, *Chetaites chetae* Zone.

Description (Figs. 2b, 3k). The cephalis is small, conical, pierced by widely spaced, randomly arranged circular pores. The apical horn is relatively long, thrice as long as the cephalis, massive, trihedral, with a pointed end; it begins from the apex of the cephalis and is slightly inclined (5°–10°) relative to the longitudinal axis of the shell. The ventral horn is massive, trihedral, three-fourth as long as the apical horn, begins from the apex of the cephalis and is positioned at 75° to the longitudinal axis of the shell. Two lesser lateral horns deviate from the middle part of the cephalis at an angle of 120° to the direction of the inclination of the ventral horn; they are positioned almost perpendicular to the longitudinal axis of the shell and are as long as the ventral horn. Two greater lateral horns are long (closely approach the apertural part of the shell), partially included in the shell wall; their ends are flattened trihedral, pointed. One greater lateral horn is 1.33 as long as the other. The dorsal horn is much smaller than

the greater lateral horns and is not included in the shell wall. The articulation between the cephalis and thorax is indiscernible in the external structure of the shell. The thorax is truncated conical, pierced by small, circular, randomly arranged pores. The abdomen and four or five postabdominal segments are subcylindrical, with weak transverse ridges on the articulations between them; each segment has three indistinct transverse rows of small circular pores. The shell gradually increases in width to the third postabdominal segment, remaining constant in subsequent segments. The aperture is wide, rounded.

Measurements, μm. Length of the apical horn, 60–70; length of the ventral horn, 50–60; length of the greater lateral horns, up to 180; length of the cephalis without the apical horn, 40–50; greatest width of the cephalis, up to 60–70; length of the shell without the apical horn, 180–210; greatest width of the shell without the greater lateral horns, 140–160.

Comparison. The new species differs from *E. aliferum* sp. nov. in the narrow shell, distinct deviation of the apical horn from the vertical position, and in the unequal lengths of the greater lateral horns.

Material. More than 50 specimens from the Upper Volgian (*chetae* Zone) and Lower Berriasian (*sibiricus* Zone) substages of the Urdyuk-Khaya Cape, Nordvik Peninsula, Arctic Siberia.

Genus *Nordvikella* Bragin, gen. nov.

Etymology. From the Nordvik Peninsula, where the type locality is situated.

Type species. *Nordvikella elegans* sp. nov.

Diagnosis. Apical part of shell with narrow and smooth apical and ventral horns. Lesser lateral horns poorly developed, very thin and short. Dorsal horn and greater lateral horns partially or completely included in shell wall and inclined towards apertural part. Shell wall with transverse ridges or grooves on articulations between segments and with transverse rows. Shell having from five to eight postabdominal segments.

Species composition. *Nordvikella elegans* sp. nov. and *N. improcera* sp. nov.

Comparison. The new genus differs from *Echinocampe* gen. nov. in the smooth apical and ventral horns and the weak development or absence of lesser lateral horns; it differs from *Arctocapsula* gen. nov. in the smooth horns and distinctly developed transverse rows of pores and transverse ridges, or grooves.

Nordvikella elegans Bragin, sp. nov.

Plate 2, figs. 1–6 and 8

Etymology. From the Latin *elegans* (graceful).

Holotype. GIN, no. 4850-9109, Arctic Siberia, Nordvik Peninsula, Urdyuk-Khaya Cape; Upper Jurassic, Volgian Stage, upper substage, *Chetaites chetae* Zone.

Description. The cephalis is relatively small, hemispherical, with a small number of small circular randomly arranged pores. The apical horn is narrow, smooth, rounded in cross section; in well-preserved specimens, it is several times longer than the cephalis, deviates from the apex of the cephalis, and is slightly inclined (10°) relative to the longitudinal axis of the shell. The ventral horn is narrow, smooth, rounded in cross section, half as long as the apical horn, deviates from the lower part of the cephalis, inclining at an angle of 75° to the side opposite to the inclination of the apical horn. The lesser lateral horns are very short, deviate from the lower part of the cephalis at an almost right angle to the longitudinal axis of the shell. The greater lateral horns and dorsal horn extend from the articulation between the cephalis and thorax; their proximal parts merge into the shell wall and look like relatively low narrow straight ridges pierced by a row of circular pores, which gradually increase in size in the distal direction. The dorsal horn is half as long as the greater lateral horns. The ends of the greater lateral horns freely deviate from the shell surface at an angle of 30°–40°; they are narrow, smooth, circular in cross section. A poorly pronounced constriction is observed between the cephalis and thorax. The thorax is relatively small, truncated conical, 1.5 times as wide as the cephalis, has small circular pores, which tend to form transverse rows. The abdomen is truncated conical, with slightly concave walls and a poorly developed ridge on the articulation with the thorax, with three transverse rows of circular pores; the abdomen is as long as and slightly wider than the thorax. The shell has seven or eight subcylindrical postabdominal segments, with slightly concave walls, well-pronounced thin transverse ridges on articulations between segments. Each segment has three transverse rows of circular pores enclosed in thin-walled hexagonal frames. The segments gradually increase in width, reaching the maximum in the penultimate segment; then, the shell slightly narrows. The aperture is wide, rounded.

Measurements, μm. Length of the apical horn, 50–60; length of the ventral horn, 25–30; length of the greater lateral horns, up to 150; length of the cephalis without the apical horn, 30–35; greatest width of the cephalis, up to 50; length of the shell without the apical horn, 290–320; greatest width of the shell without the lateral horns, 120–130.

Comparison. The new species differs from *Nordvikella improcera* sp. nov. in the twice as long apical and ventral horns, the development of transverse ridges on the articulations between the abdomen and subsequent segments, and in the larger pores in the segments, which form regular transverse rows.

Material. More than 50 specimens from the Upper Volgian (*chetae* Zone) and Lower Berriasian (*sibiricus* Zone) substages of the Urdyuk-Khaya Cape, Nordvik Peninsula, Arctic Siberia.

Nordvikella improcera sp. nov.

Plate 2, figs. 7, 9, and 10

Etymology. From the Latin *improcerus* (unprepossessing).

Holotype. GIN, no. 4850–9116, Arctic Siberia, Nordvik Peninsula, Urdyuk-Khaya Cape; Upper Jurassic, Volgian Stage, upper substage, *Chetaites chetae* Zone.

Description. The cephalis is small, hemispherical, with small circular randomly scattered pores. The apical horn is short, narrow, smooth, at most as long as the cephalis; it deviates laterally from the apex of the cephalis at an inclination of 30° to the longitudinal axis of the shell. The ventral horn is small, narrow, smooth, shorter than the apical horn, deviates from the middle of the cephalis, inclining at an angle of 45° to the side opposite to the inclination of the apical horn. The lesser lateral horns are very poorly developed, look like short narrow thorns. The greater lateral horns and dorsal horn are completely included in the shell wall and differ in length; the lateral horns reach the middle of the abdomen, while the dorsal horn is terminated at the articulation between the thorax and abdomen. Free continuations of the greater lateral horns (not connected to the shell wall) are undeveloped. A distinct narrow constriction is observed between the cephalis and thorax. The thorax is truncated conical, approximately 1.5 times as wide as the cephalis, slightly inflated, with three or four irregular transverse rows of pores. The abdomen is also truncated conical, slightly inflated, twice as wide as the cephalis, with three or four indistinct transverse rows of circular pores. Distinct superficial constrictions are observed between the thorax, abdomen, and postabdominal segments. From five to six postabdominal segments are present; the first two of which are wider than the preceding segments. Beginning from the third postabdominal segment, the shell gradually narrows. Each postabdominal segment has three or four indistinct transverse rows of circular pores, which are sometimes enclosed in thin hexagonal frames. The aperture is wide, open.

Measurements, μm. Length of the apical horn, 25–30; length of the ventral horn, 10–15; length of the greater lateral horns, up to 50; length of the cephalis without the apical horn, 20–25; greatest width of the cephalis, up to 35; length of the shell without the apical horn, 250–270; greatest width of the shell without the lateral horns, 110–115.

Comparison. The new species differs from *Nordvikella elegans* sp. nov. in the shorter apical and ventral horns, the development of transverse grooves on the articulations between the abdomen and subsequent segments, and in the smaller pores in the segments, which form indistinct transverse rows.

Material. Eighteen specimens from the Upper Volgian (*chetae* Zone) and Lower Berriasian (*sibiricus* Zone) substages of the Urdyuk-Khaya Cape, Nordvik Peninsula, Arctic Siberia.

Genus *Arctocapsula* Bragin, gen. nov.

Etymology. From the Latin *Arctus* (north, North Pole) and the Latin *capsula* (small box, envelope).

Type species. *Arctocapsula perforata* sp. nov.

Diagnosis. Horns in apical shell part short and massive, trihedral in cross section; shell wall without pronounced segmentation; shell having from three to six postabdominal segments.

Species composition. In addition to the type species, *A. incompta* sp. nov. and *A. magna* sp. nov.

Comparison. The new genus differs from *Nordvikella* gen. nov. in the short, massive trihedral horns in the apical part of the shell. It differs from *Echinocampe* gen. nov. in the absence of transverse ridges on the articulations between the segments.

Arctocapsula perforata Bragin, sp. nov.

"Anisicyrtis" sp.: Kozlova, 1994, pl. 7, figs. 4, 5, and 8.

Etymology. From the Latin *perforatus* (having an opening).

Holotype. GIN, no. 4850-9120, Arctic Siberia, Nordvik Peninsula, Urdyuk-Khaya Cape; Upper Jurassic, Volgian Stage, upper substage, *Chetaites chetae* Zone.

Description (Figs. 2c, 3a–3f). The cephalis is relatively large, hemispherical, thick-walled, with large, circular, irregularly arranged pores. The apical horn is relatively short, at most as long as the cephalis, massive, trihedral at the base, with a pointed end; it deviates from the apex of the cephalis and is distinctly inclined (at an angle of 30°) to the longitudinal axis of the shell. The ventral horn is much shorter than the apical horn, massive, trihedral, begins from the middle part of the cephalis and is inclined at an angle about 60° to the longitudinal axis of the shell in the direction opposite to the inclination of the apical horn. The lesser

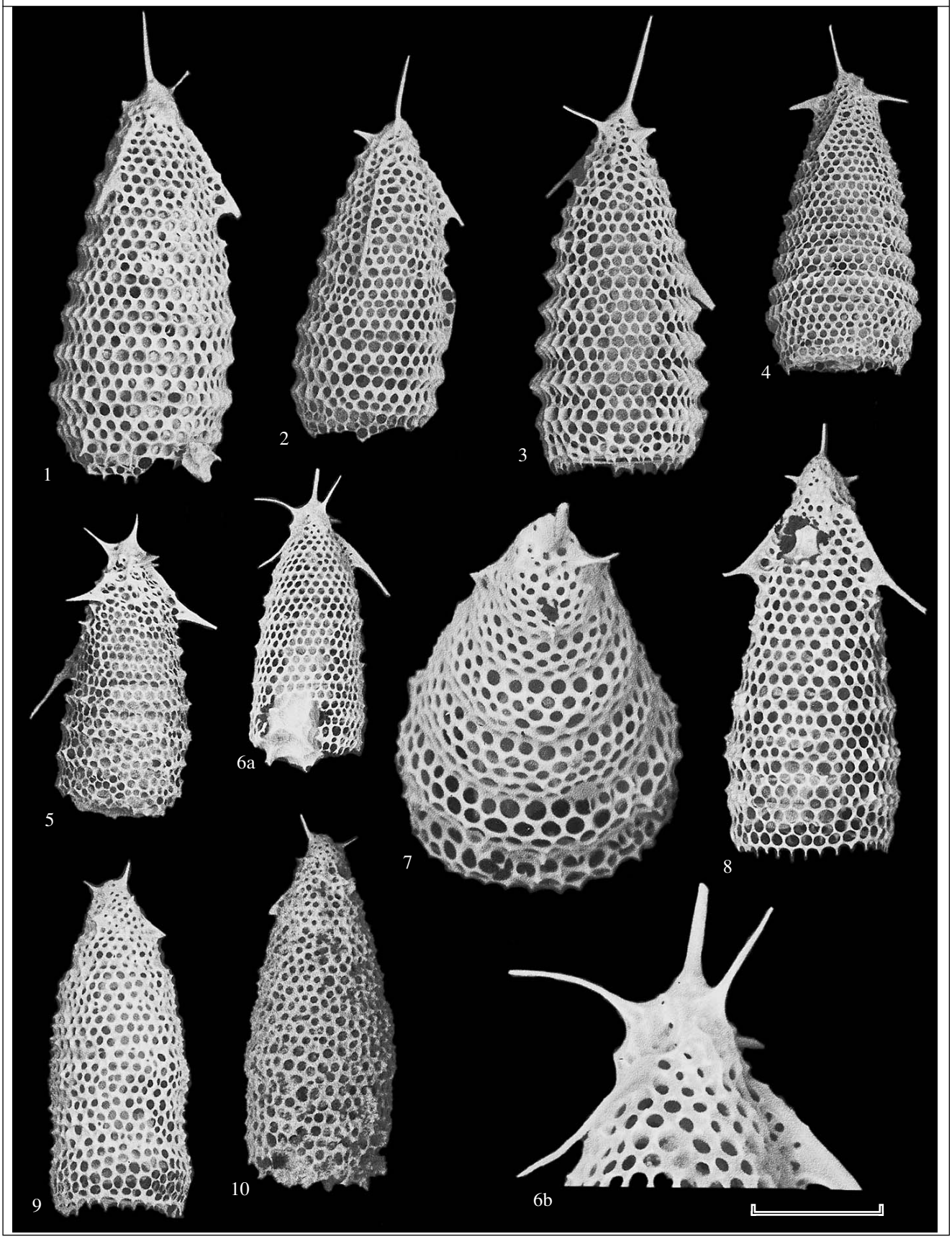
Explanation of Plate 2

Radiolarians of the genus *Nordvikella* gen. nov. All specimens come from the Nordvik section, Volgian Stage, upper substage. Scale bar: (Figs. 1, 2, 3, 8) 100 μm; (Figs. 4, 5, 6a) 120 μm; (Figs. 6b, 7) 40 μm; and (Figs. 9, 10) 80 μm.

Figs. 1–6 and 8. *Nordvikella elegans* sp. nov.: (1) holotype GIN, no. 4850-9109; (2–6, 8) paratypes: (2) GIN, no. 4850-9110; (3) GIN, no. 4850-9111; (4) GIN, no. 4850-9112; (5) GIN, no. 4850-9113; (6) GIN, no. 4850-9114: (6a) general appearance and (6b) apical region; (8) GIN, no. 4850-9115.

Figs. 7, 9, and 10. *Nordvikella improcera* sp. nov.: (7) paratype GIN, no. 4850-9117, dorsal view; (9) holotype GIN, no. 4850-9116; (10) paratype GIN, no. 4850-9118.

Plate 2



lateral horns are short, massive, deviate from the articulation between the cephalis and thorax at an almost right angle to the longitudinal axis of the shell. The greater lateral horns and dorsal horn extend to the middle of the shell, their proximal parts are included in the shell wall, while the ends are free, pointed, flattened trihedral. The thorax, abdomen, and three postabdominal segments are truncated conical or subcylindrical; constrictions, ridges, or other borders between them are absent. All of these segments are pierced by circular pores, which widely vary in size and are enclosed in irregular hexagonal and pentagonal frames. The shell reaches the greatest width within the first and second postabdominal segments; then, it rapidly narrows. In some specimens, the aperture is narrow but open; in others, the aperture is completely closed. In the region of the abdomen and the first postabdominal segment, there is the lateral pseudoforamen, a large rounded opening bordered by a ring band, which is lowered in the relief relative to adjacent area of the shell and pierced by small circular pores.

Measurements, μm. Length of the apical horn, 25–30; length of the ventral horn, 15–20; length of the greater lateral horns, 90–120; length of the cephalis without the apical horn, 50; greatest width of the cephalis, up to 80; length of the shell without the apical horn, 200–270; greatest width of the shell without the greater lateral horns, 140–145.

Comparison. The new species differs from *Arctocapsula incompta* sp. nov. in the more massive apical and ventral horns, the long and massive greater lateral horns, the large randomly scattered pores, and in the development of the lateral pseudoforamen. It differs from *Arctocapsula magna* sp. nov. in the smaller shell and randomly scattered pores over the entire extent of the shell.

Material. More than 100 specimens from the Upper Volgian (*chetae* Zone) and Lower Berriasian (*sibiricus* Zone) substages of the Urdyuk-Khaya Cape, Nordvik Peninsula, Arctic Siberia.

Arctocapsula incompta Bragin, sp. nov.

Etymology. From the Latin *incomptus* (unaffected, unvarnished, simple).

Holotype. GIN, no. 4850-9126, Arctic Siberia, Nordvik Peninsula, Urdyuk-Khaya Cape; Upper Jurassic, Volgian Stage, upper substage, *Chetaites chetae* Zone.

Description (Figs. 3i, 3j). The cephalis is relatively large, hemispherical, with many small circular randomly arranged pores. The apical horn is relatively short, as long as the cephalis, narrow, trihedral at the base, with a pointed end; it deviates from the apex of the cephalis at an angle of 10°–15° to the longitudinal axis of the shell. The ventral horn is slightly shorter than the apical horn, narrow, trihedral at the base, deviating from the middle part of the cephalis and inclined at an angle about 60° to the longitudinal axis of the shell in the direction opposite to the inclination of the apical horn. The lesser lateral horns are completely included in the shell wall and are not seen externally. The greater lateral horns and dorsal horn are relatively short, terminating within the thorax and abdomen; they are usually completely included in the shell wall, although occasionally their pointed ends are seen. Constrictions or ridges between segments are undeveloped. The thorax is truncated conical, pierced by small circular randomly scattered pores. The abdomen and three postabdominal segments are truncated conical or subcylindrical; the shell gradually increases in thickness from the cephalis to the second postabdominal segment; the ultimate segment is narrower. The abdomen and postabdominal segments are pierced by circular pores, which vary in size, randomly scattered within the abdomen and first two postabdominal segments, and form indistinct transverse rows in the ultimate segment. The aperture is wide, rounded.

Measurements, μm. Length of the apical horn, 25–30; length of the ventral horn, 20–25; length of the greater lateral horns, up to 50; length of the cephalis without the apical horn, 30; greatest width of the cephalis, up to 55; length of the shell without the apical horn, 180–210; greatest width of the shell without the greater lateral horns, 120–130.

Comparison. The new species differs from *Arctocapsula perforata* sp. nov. in the narrow apical and ventral horns, the weakly developed lateral horns, and in the presence of transverse rows of pores.

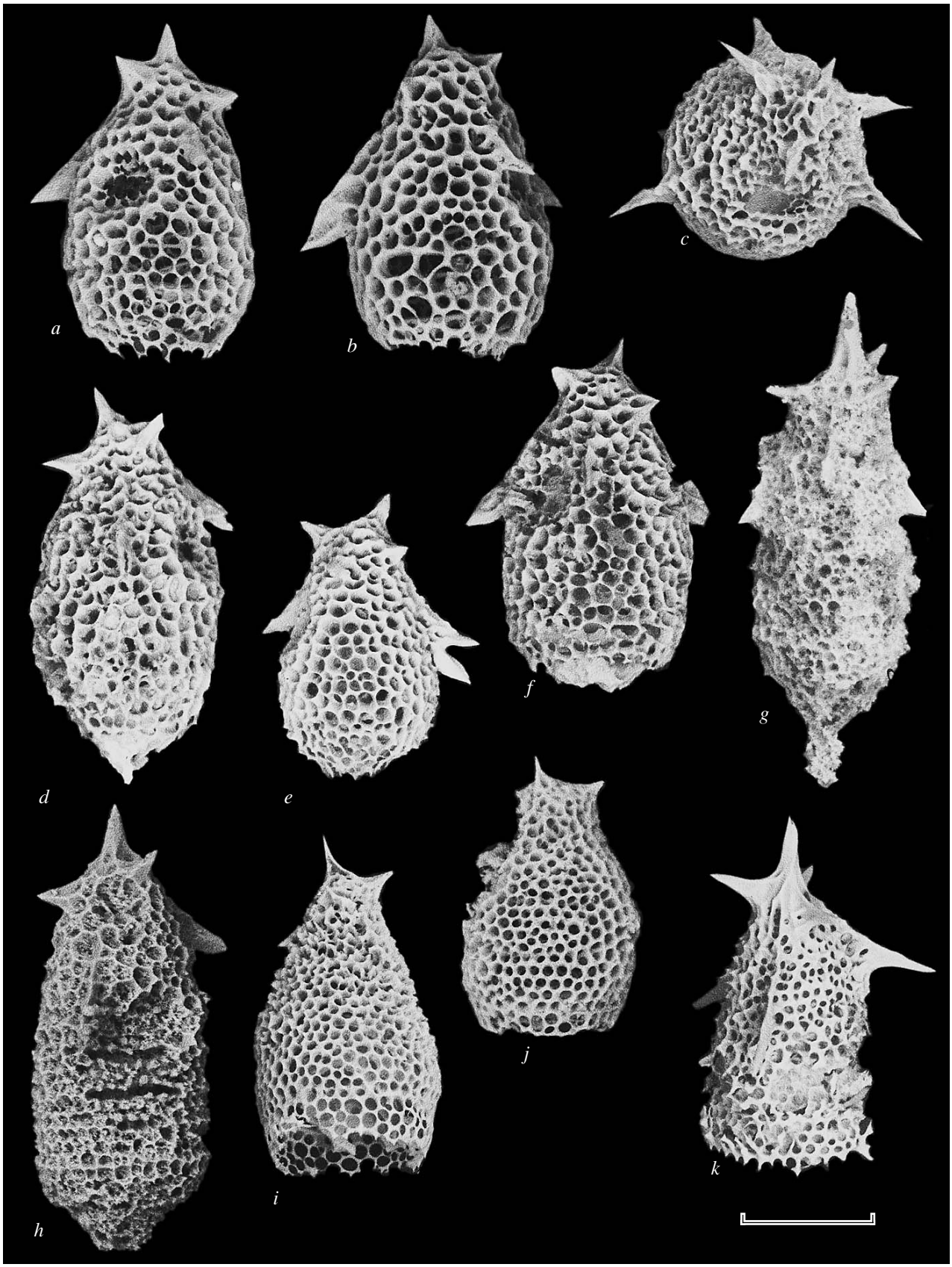
Material. Twelve specimens from the Upper Volgian (*chetae* Zone) and Lower Berriasian (*sibiricus* Zone) substages of the Urdyuk-Khaya Cape, Nordvik Peninsula, Arctic Siberia.

Arctocapsula magna Bragin, sp. nov.

Etymology. From the Latin *magnus* (large).

Holotype. GIN, no. 4850-9001, Arctic Siberia, Nordvik Peninsula, Urdyuk-Khaya Cape; Upper Jurassic, Volgian Stage, middle substage, *Epivirgatites variabilis* Zone.

Fig. 3. Radiolarians of the genera *Arctocapsula* gen. nov. and *Echinocampe* gen. nov.: (a–f) *Arctocapsula perforata* sp. nov.: (a) holotype GIN, no. 4850-9120; (b–f) paratypes: (b) GIN, no. 4850–9121; (c) GIN, no. 4850-9122, view from above; (d) GIN, no. 4850-9123; (e) GIN, no. 4850-9124; (f) GIN, no. 4850-9125; (g, h) *Arctocapsula magna* sp. nov.: (g) holotype GIN, no. 4850-9001 and (h) paratype GIN, no. 4850-9002; (i, j) *Arctocapsula incompta* sp. nov.: (i) holotype GIN, no. 4850-9126 and (j) paratype GIN, no. 4850-9127; and (k) *Echinocampe aculeatum* sp. nov., paratype GIN, no. 4850-9119. All specimens, except for (g) and (h), come from the Nordvik section, Volgian Stage, upper substage; (g, h) Volgian Stage, middle substage. Scale bar, 100 μm.


a
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D e s c r i p t i o n (Figs. 3g, 3h). The cephalis is relatively small, hemispherical, with large cellular randomly arranged pores. The apical horn is relatively short, as long as the cephalis, massive, trihedral at the base, deviates from the apex of the cephalis strictly vertically, without inclination. The ventral horn is half as long as the apical horn, massive, trihedral, deviates from the middle of the cephalis and is inclined to the longitudinal axis of the shell at an angle of 45°. The lesser lateral horns are short, massive, trihedral, deviate from the lower part of the cephalis perpendicular to the longitudinal axis of the shell. The greater lateral horns and dorsal horn are massive, partially included in the shell wall; the greater lateral horns extend to the first postabdominal segments, the dorsal horn terminates in line with the articulation between the thorax and abdomen. Constrictions or ridges between the cephalis, thorax, and other segments are indiscernible. The thorax and abdomen are truncated conical, pierced by large randomly scattered pores enclosed in cellular polygonal frames varying in size and shape. Five or six subcylindrical postabdominal segments are present; they are pierced by relatively small pores enclosed in polygonal frames and forming indistinct transverse rows. The shell increases in width to the penultimate segment; the last segment is somewhat narrower, its end tapers in a narrow apertural tube. The aperture is narrow, almost closed.

M e a s u r e m e n t s, μm. Length of the apical horn, 50–60; length of the ventral horn, 25–30; length of the greater lateral horns, up to 100–130; length of the cephalis without the apical horn, 50–60; greatest width of the cephalis, up to 90; length of the shell without the apical horn, 300–350; greatest width of the shell without the greater lateral horns, 150.

C o m p a r i s o n. The new species differs from *A. perforata* sp. nov. in the longer shell and in the presence of transverse rows of pores in the middle and apertural parts of the shell.

M a t e r i a l. More than 100 specimens from the Middle Volgian Substage (*variabilis* Zone) of the Urdyuk-Khaya Cape, Nordvik Peninsula, Arctic Siberia.

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