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New Radiolarian Species from the Upper Cretaceous Naiba Reference Section (Southern Sakhalin)

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Abstract—A new study of the Late Cretaceous radiolarian assemblages of southern Sakhalin has revealed a large number of new taxa. The species *Cenosphaera robusta* sp. nov., *Hexapyramis* (?) *perforatum* sp. nov., *Patellula sakhalinica* sp. nov., *Spongodiscus sakhalinensis* sp. nov., *S. quasipersenex* sp. nov., *S. concentricus* sp. nov., *Spongurus cylindricus* sp. nov., *Stylodruppa ornata* sp. nov., and *Patulibracchium* (?) *quadroastrum* sp. nov. are described.

Key words: Radiolaria, Upper Cretaceous, Sakhalin, reference section.

INTRODUCTION

The Upper Cretaceous radiolarian fauna of the Naiba section has been studied since the 1970s. The results of these studies were presented by Kazintsova in her papers (1979, 1981) and in the sections of *Atlas of the Index Groups of the Cretaceous Fauna of Sakhalin* (Zonova *et al.*, 1993) dealing with radiolarians.

The Naiba section is the reference section for the Western Sakhalin Mountains (*Opornyi...*, 1987). Therefore, its fossils require additional study. From the 1990s onward, radiolarians received increasingly more study; hence, a large amount of new data exists. This paper focuses on the detailed study of the radiolarian assemblages of the Naiba reference section, which will be useful for subsequent wide correlations based on literature sources and original data on the radiolarians of different regions (Bragina, 1991a, 1991b, 1994, 1999a, 1999b; Bragina and Bragin, 1995, 1996; Bragina and Vitukhin, 1997).

In 1992, the Naiba reference section was sampled for radiolarians. The radiolarians discovered in the carbonate nodules allowed the following subdivision: (1) beds with *Cuboctostylus kasinzovae–Cuboctostylus sakhalinensis* (middle Cenomanian, Member V of the Naiba Formation), (2) beds with *Cuboctostylus trifurcatus–Cassideus yoloensis* (upper Cenomanian, Members I and II of the Bykovskaya Formation, and (3) beds with *Orbiculiforma monticelloensis–Cavaspongia contracta* (upper Turonian, lower part of Member VI of the Bykovskaya Formation). The study of the taxonomic composition of the above radiolarian assemblages allowed increased understanding of the morphological diversity of Late Cretaceous assemblages from the Western Sakhalin Mountains and produced records of new species for this region. The presence of the spicule-bearing *Entactinaria* (Bragina, 1999), bipilomate discoids (Bragina, 1999b), numerous Actinommidae, and late Cenomanian *Phaeodaria* is particularly interesting. The present paper contains descriptions of nine new radiolarian species discovered in the Cenomanian–Turonian part of the section. The test measurements are in μm.

MATERIAL

Collection no. 4850/4-28 is housed at the Geological Institute, Russian Academy of Sciences (GIN).

SYSTEMATIC PALEONTOLOGY

Order Spumellaria Ehrenberg, 1875

Family Liosphaeridae Haeckel, 1882

Genus *Cenosphaera* Ehrenberg, 1854

***Cenosphaera robusta* Bragina, sp. nov.**

Plate 4, figs. 1 and 4

Etymology. From Latin *robustus* (robust).

Holotype. GIN, no. 4850/4; southern Sakhalin, basin of the Naiba River; upper Cenomanian, Member I of the Bykovskaya Formation, beds with *Cuboctostylus trifurcatus–Cassideus yoloensis*.

Description. The test represents a large shell covered with irregularly spaced small pores with a shape varying from circular to oval-polygonal. At the junctions of several pores, the test possesses small spines, resulting in a rough surface. The test wall is very thick, and penetrated with pores. The arrangement of spines and pores on the internal side of the wall is the same as that on the external.

Measurements. Holotype GIN, no. 4850/4: test diameter, 150; pore diameter, 3–6; test wall thickness, 10–15.

Remarks. *Cenosphaera robusta* Bragina, sp. nov. is assigned to the genus *Cenosphaera* Ehrenberg because its skeleton consists of one shell. The internal surface of this shell lacks radial spines, thus suggesting that there was no internal shell (not presently preserved). It is possible that *Cenospaera robusta* Bragina sp. nov. is ancestral to *Cenosphaeran politepora* Lipman described from the upper Eocene of Western Siberia (Lipman *et al.*, 1960).

Comparison. *Cenosphaera robusta* Bragina, sp. nov., like *C. minor* Lipman, 1952, has only a cortical shell, and the medullary shells are absent. *Cenosphaera robusta* Bragina, sp. nov. is distinguished from *C. minor* Lipman by the shape and arrangement of the pores and by the considerably thicker test wall.

Occurrence. Southern Sakhalin, basin of the Naiba River, Members I and II of the Bykovskaya Formation; upper Cenomanian, beds with *Cuboctostylus trifurcatus–Cassideus yoloensis*.

Material. Four complete and eight incomplete specimens.

Family Actinommidae Haeckel 1862, emend. Riedel 1967

Genus *Hexapyramis* Squinabol, 1903

***Hexapyramis* (?) *perforatum* Bragina, sp. nov.**

Plate 3, figs. 5, 7–14

Hexacontium (?) sp. A: Empson-Morin, 1984, p. 100, pl. 1, figs. 10–13.

Crucella cachensis Pessagno: Kazintsova in Zonova *et al.*, 1993, pl. 11, figs. 3 and 4.

Etymology. From Latin *perforatum* (perforated).

Holotype. GIN, no. 4850/5; southern Sakhalin, basin of the Naiba River; middle Cenomanian, Member V of the Naiba Formation, beds with *Cuboctostylus kasinzovae–Cuboctostylus sakhalinensis*.

Description. The test is large. The cortical shell is octagonal. Six spines extend from the angles of the octagon. The proximal part of these spines (one-half to three-quarters of their length) is covered with rounded-polygonal pores, which are more uniform in size and more regularly shaped (Pl. 3, figs. 5, 11) than those on the surface of the cortical shell. The pores are arranged in loose linear rows directed from the proximal to the distal end of the spines. These spines terminate in three- or four-sided pyramidal spines. The test surface is covered with variously sized rounded-angular pores, which are somewhat larger than the pores on the spines. The pores are arranged in pentagonal-hexagonal patterns. The spaces between the pores are slightly smaller than their diameter. At the junctions of several pores, the test possesses smaller spines, which are wider at the base and rapidly narrowing toward the top. The test surface is rough because of these spines. The second medullary shell is covered with circular pores, slightly varying in size. Its diameter is about one-half the diameter of the cortical shell, to which this medullary shell is connected by numerous radial beams extending regularly from its surface. The second medullary shell is connected to the first by thin, randomly arranged spines. The third medullary shell is irregularly shaped, with a diameter about one-quarter the diameter of the cortical shell. Its surface is covered with variously sized pores.

Measurements. Holotype GIN, no. 4850/5: cortical shell diameter, 35; spine length, 30–50.

Comparison. The new species is distinguished from *Hexapyramis pantanelli* Squinabol, 1903 by the longer, more regularly shaped spines, by the different types of pores on the cortical shell (which is covered with small spines at the junctions of several pores), by the arrangement of pores on the spines, and by the greater size of the spines.

Remarks. The new species is tentatively assigned to the genus *Hexapyramis*. Unlike typical representatives of this genus, in the new species the pores tend to form linear rows extending from the proximal to the distal part of the spine.

Occurrence. Southern Sakhalin, basin of the Naiba River; middle Cenomanian, Member V of the Naiba Formation, beds with *Cuboctostylus kasinzovae–Cuboctostylus sakhalinensis*; upper Cenomanian, Members I and II of the Bykovskaya Formation, beds with *Cuboctostylus trifurcatus–Cassideus yoloensis*; Campanian, Member X of the Bykovskaya Formation. Campanian of Cyprus, *Amphipyndax pseudoconulus* Zone.

Material. Three complete and seven incomplete specimens.

Family Spongodiscidae Haeckel, 1862

Genus *Patellula* Kozlova, 1972

***Patellula sakhalinica* Bragina, sp. nov.**

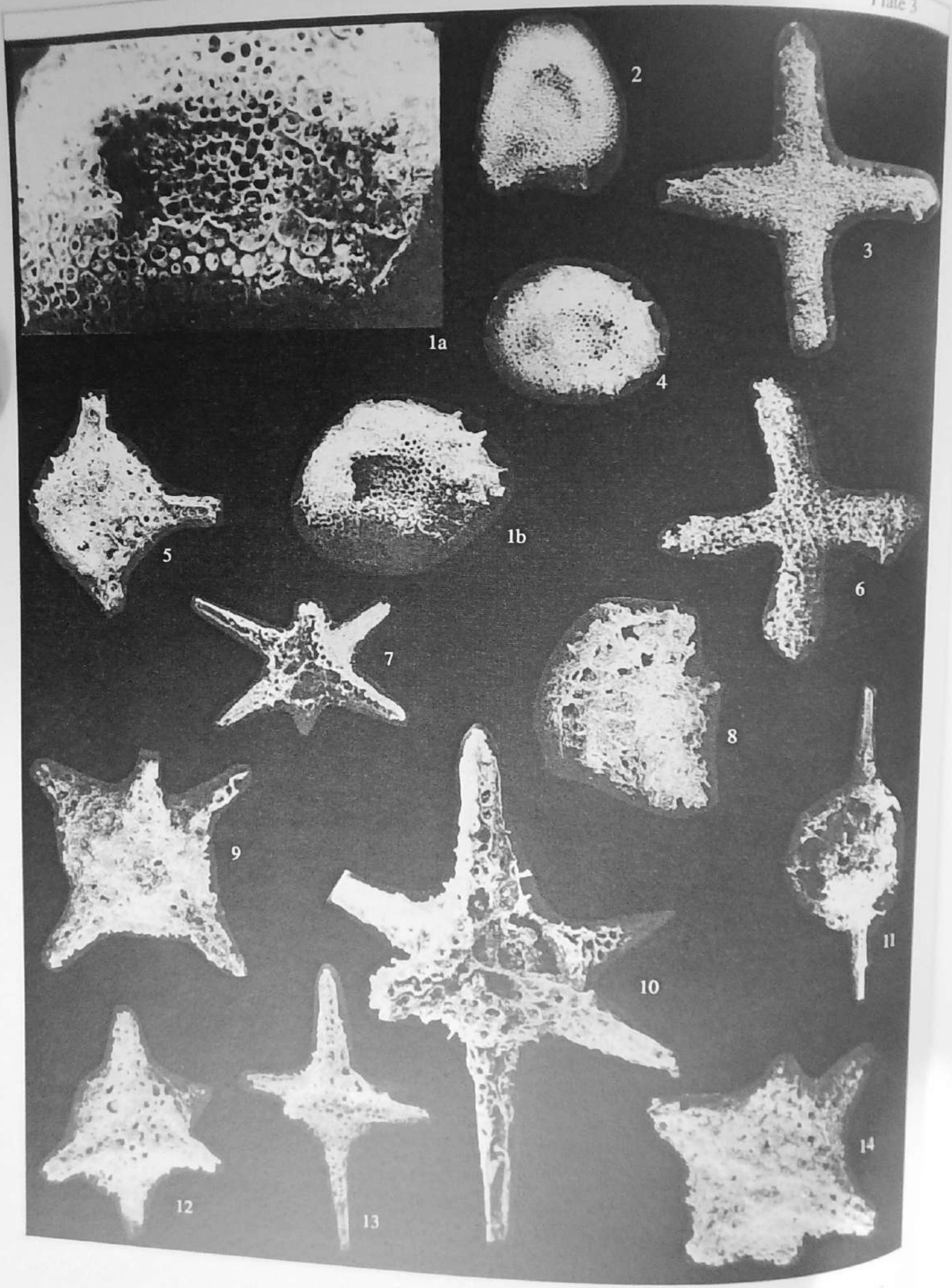
Plate 4, fig. 8

Etymology. After Sakhalin, where it was discovered.

Holotype. GIN, no. 4850/6; southern Sakhalin, basin of the Naiba River; upper Turonian, Member VI of the Bykovskaya Formation, beds with *Orbiculiforma monticelloensis–Cavaspongia contracta*.

Description. The skeleton is large, spongy, discoidal, with a weak keel. The tolus is low, about one-third of the diameter of the skeleton, surrounded by a narrow ridge consisting of tubercles. The structure of these tubercles resembles the pseudoalophacoid structure characteristic of this genus (Petrushevskaya and Kozlova, 1972). The keel possesses a small depression (one-sixth to one-eighth of the diameter of the skeleton). From the opposite side, the keel is extended, giving the test a heart-shaped appearance.

Plate 3



Measurements. Holotype GIN, no. 4850/6: skeleton diameter, 130; tolus diameter, 50; tolus height, 10.

Comparison. *P. sakhalinica* Bragina, sp. nov. differs from *P. planoconvexa* (Pessagno, 1963) in the heart-shaped test.

Occurrence. Southern Sakhalin, basin of the Naiba River, upper Turonian, Member VI of the Bykovskaya Formation, beds with *Orbiculiforma monticelloensis–Cavaspongia contracta*.

Genus *Spongodiscus* Ehrenberg, 1854

Spongodiscus sakhalinensis Bragina, sp. nov.

Plate 4, figs. 10 and 11

Etymology. After Sakhalin, where this species was discovered.

Holotype. GIN, no. 4850/7; southern Sakhalin, basin of the Naiba River; upper Turonian, Member VI of the Bykovskaya Formation, beds with *Orbiculiforma monticelloensis–Cavaspongia contracta*.

Description. The test is large, discoidal, and biconvex. The keel is relatively well developed. Numerous (14–18) thin spines extend from the center of the test, radiating toward the keel, and stretch outward to the distance of about one-third of its radius. In places where these spines extend outward, the test has weakly developed, extending edges, giving it a rounded-polygonal shape in cross section. The internal filling represents a very weakly developed spongy lattice with large pores. The thin-walled test is covered with pores. The diameter of these pores usually exceeds the distance between them, resulting in a latticed appearance of the test. The size of the pores varies, as does their shape, from angular to almost completely round. The pores are arranged in a pentagonal-hexagonal pattern. Where several pores are connected, the test surface has very small spines, triangular at the base and sharply narrowing at the top.

Measurements. Holotype GIN, no. 4850/7: test diameter, 300; test thickness, 70.

Comparison. This species is distinguished from *S. quasipersenex* Bragina sp. nov. by the absence of an incision in the keel and by the shape and arrangement of the pores.

Occurrence. Southern Sakhalin, basin of the Naiba River, Member VI of the Bykovskaya Formation; upper Turonian, beds with *Orbiculiforma monticelloensis–Cavaspongia contracta*.

Material. Four complete and numerous incomplete specimens from the type locality.

Spongodiscus concentricus Bragina, sp. nov.

Plate 3, figs. 1a, 1b, 2, and 4

Etymology. From Latin *concentricus* (concentric).

Holotype. GIN, no. 4850/8; southern Sakhalin, basin of the Naiba River, upper Turonian, Member VI of the Bykovskaya Formation, beds with *Orbiculiforma monticelloensis–Cavaspongia contracta*.

Description. The test is discoidal varying from the irregularly oval to the subtriangular. The test surface is covered with circular pores radiating from the center. The pores are similar in size. The distance between the pores is approximately half of their diameter. Where pores are connected, the test has small spines of various sizes. The keel is very distinct. Along the entire periphery, the keel possesses variously developed, irregularly arranged, short, thin spines. In regions where the keel is extended, the spines are spaced more densely and are better developed. The test has a secondary shell, giving the skeleton a biconvex, irregular shape. This is because some parts of the secondary shell are somewhat depressed. The distance from the secondary shell to the interior cortical shell in the area of the tolus is about one-third of the radius of the test, and gradually decreases until they fuse in the region of the keel. The pores on the secondary shell are arranged irregularly and vary in size. The inner cavity of the test is filled with a spongy lattice.

Measurements. Holotype GIN, no. 4850/8: length of the test in cross section, 90; width in cross section, 80; diameter of the pores on the cortical shell, 2–4; diameter of the pores on the secondary shell, 3–8.

Comparison. The new species is distinguished from *Spongodiscus impressus* Lipman, 1952 by the oval-subtriangular shape of the test, the presence of the keel and spines on the keel, and by the presence of a secondary shell obscuring the biconvex cortical shell.

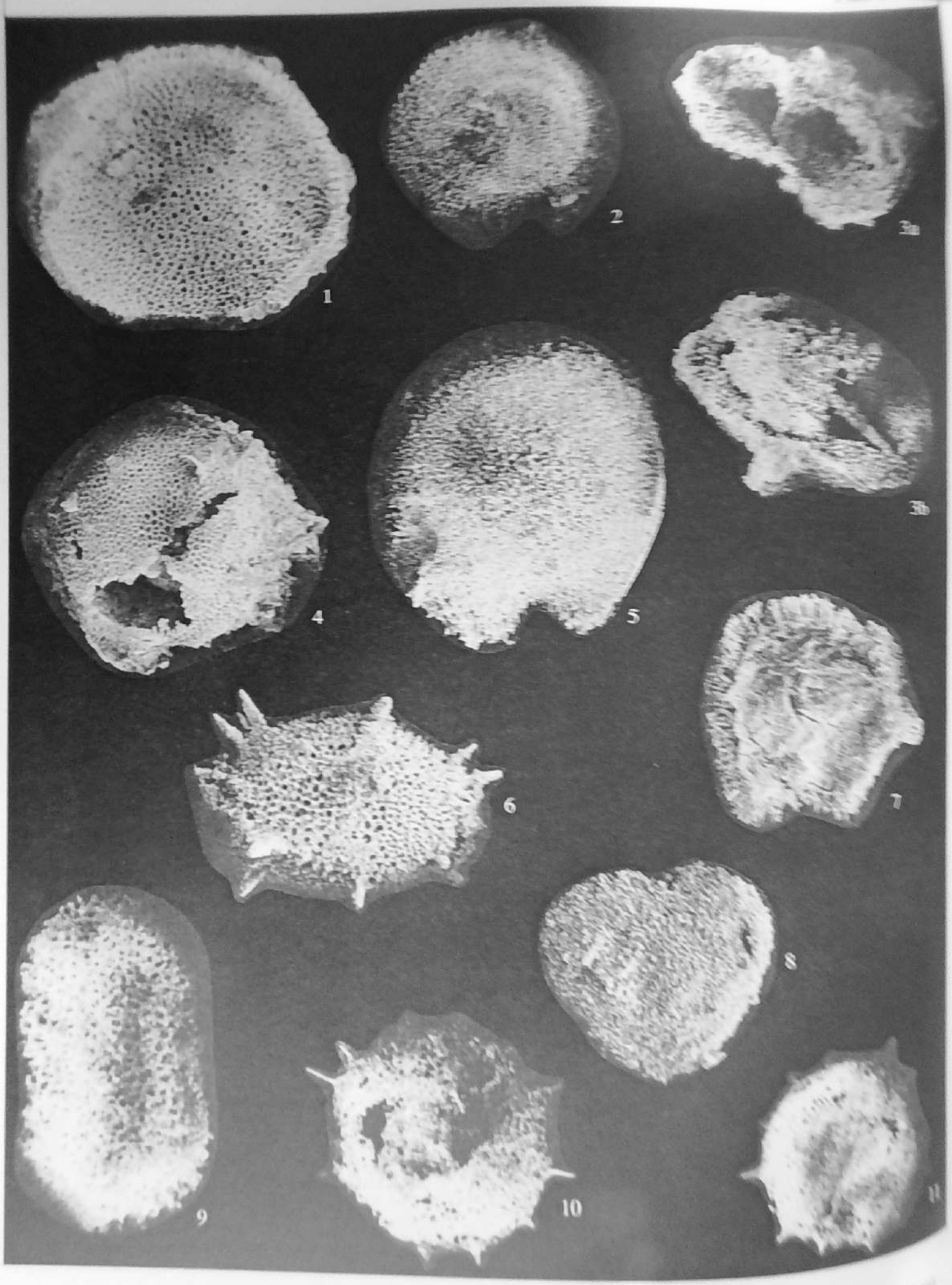
Occurrence. Southern Sakhalin, basin of the Naiba River, Member VI of the Bykovskaya Formation; upper Turonian, beds with *Orbiculiforma monticelloensis–Cavaspongia contracta*.

Explanation of Plate 3

Figs. 1a, 1b, 2, and 4. *Spongodiscus concentricus* sp. nov.: (1) holotype GIN, no. 4850/8; (1a) fragment of a skeleton showing the development of the secondary medullary shell, ×500; (1b) ×100; (2) paratype GIN, no. 4850/13, ×100; (4) paratype GIN, no. 4850/14, ×100.

Figs. 3 and 6. *Patulibracchium* (?) *quadroastrum* sp. nov., ×120: (3) holotype GIN, no. 4850/12; (6) paratype GIN, no. 4850/28.

Figs. 5, 7–14. *Hexapyramis* (?) *perforatum* sp. nov.: (5) paratype GIN, no. 4850/16; (7) paratype GIN, no. 4850/17; (8) paratype GIN, no. 4850/21 showing the inner structure of the test; (9) paratype GIN, no. 4850/18; (10) paratype GIN, no. 4850/15; (11) paratype GIN, no. 4850/22; (12) paratype GIN, no. 4850/19; (13) holotype GIN, no. 4850/5; (14) paratype GIN, no. 4850/20; (7, 13) ×100; (8) ×250; (5, 9, 10, 11, 12, 14) ×200.


1
2
3a
3b
4
5
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7
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9
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11

Material. Four complete and numerous incomplete specimens from the type locality.

***Spongodiscus quasipersenex* Bragina, sp. nov.**

Plate 4, figs. 2, 3a, 3b, 5, and 7

(?) *Orbiculiforma renillaeformis* sensu stricto (Campbell et Clark): Hollis, 1997, p. 20, pl. 9, figs. 4 and 5.

Etymology. From Latin *quasi* (as though) and *persenex* (very aged).

Holotype. GIN, no. 4850/9; southern Sakhalin, basin of the Naiba River; upper Cenomanian, Member I of the Bykovskaya Formation, beds with *Cuboctostylus trifurcatus–Cassideus yoloensis*.

Description. The skeleton is large, with two small, extended processes, which are located in the keel part of the test and sometimes terminate in small spines. A small incision between the processes is subtriangular in shape and gradually wedges out within the skeleton at a distance of one-fifth of the diameter. The test surface is spiny and is covered with very small, variously sized, randomly spaced pores of irregular outline. The keel is absent. Occasionally, the test is slightly flattened near the tolus. The flattened zone is one-third of the diameter of the test (Pl. 4, fig. 2). The thickness of the disc is quite significant (one-fifth of its diameter). The test wall is thick and spongy. The pores in the test wall are arranged in loose radial rows from the supposed center of the test. The test interior is filled with a spongy lattice. In the very center of the skeleton, the spongy lattice is slightly denser. Occasionally, several spines extend from this lattice. These spines do not extend beyond the test and are oriented toward the keel zone.

Measurements. Holotype GIN, 4850/9: test diameter, 130; test wall thickness, 50; process length, 15–25.

Comparison. *S. quasipersenex* Bragina, sp. nov. is distinguished from *S. volgensis* Lipman, 1952 by the thicker test wall, by the larger and more evenly shaped incision, and by the presence of processes with small spines on their ends surrounding the incision.

Occurrence. Southern Sakhalin, basin of the Naiba River; upper Cenomanian, Member I of the Bykovskaya Formation, beds with *Cuboctostylus trifurcatus–Cassideus yoloensis*.

Material. Five complete and numerous incomplete specimens from the type locality.

Family Druppulidae Haeckel, 1882

Genus *Spongurus* Haeckel, 1862

***Spongurus cylindricus* Bragina, sp. nov.**

Plate 4, fig. 9

Spongurus (?) sp. Zonova *et al.*, 1993, pl. 10, fig. 1.

Etymology. From Latin *cylindricus* (cylindrical).

Holotype. GIN, no. 4850/10; southern Sakhalin, basin of the Naiba River; upper Cenomanian, Member I of the Bykovskaya Formation, beds with *Cuboctostylus trifurcatus–Cassideus yoloensis*.

Description. The test is large, elongate, cylindrical, lacelike, consisting of three parts separated by slight constrictions. The polar parts are slightly increased in diameter and have slightly rounded terminations. The polar parts are higher than the cylindrical central part. The lacelike surface of the test is relatively porous and not dense. The total length of the test is 1.7–2 times greater than its width.

Measurements. Holotype GIN, no. 4850/10: test length, 360; width of the polar part, 180; width at the constriction, 165.

Comparison. The new species is distinguished from *Spongurus porrectum* Kasinzova, 1993 (in Zonova *et al.*, 1993) by the greater width of all parts and the looser lattice.

Occurrence. Southern Sakhalin, Basin of the Naiba River; upper Cenomanian, Member I of the Bykovskaya Formation, beds with *Cuboctostylus trifurcatus–Cassideus yoloensis*.

Material. Two complete and numerous incomplete specimens from the type locality.

Genus *Stylodruppa* Kazintsova, 1979

***Stylodruppa ornata* Bragina, sp. nov.**

Plate 4, fig. 6

Etymology. From Latin *ornata* (ornate).

Holotype. GIN, no. 4850/11; southern Sakhalin, basin of the Naiba River; middle Cenomanian, Member V of the Naiba Formation.

Explanation of Plate 4

Figs. 1 and 4. *Cenosphaera robusta* sp. nov., (1) paratype GIN, no. 4850/23, interior of the test, ×200; (4) holotype GIN, no. 4850/4, ×120.

Figs. 2, 3a, 3b, 5, and 7. *Spongodiscus quasipersenex* sp. nov., (2) paratype GIN, no. 4850/24, ×100; (3a, 3b) paratype GIN, no. 4850/25, two halves of the same test, ×200, (5) holotype GIN, no. 4850/9, ×200; (7) paratype GIN, no. 4850/26, fragment of the test, ×200.

Fig. 6. *Stylodruppa ornata* sp. nov., holotype GIN, no. 4850/11, ×200.

Fig. 8. *Patellula sakhalinica* sp. nov., holotype GIN, no. 4850/6, ×120.

Fig. 9. *Spongurus cylindricus* sp. nov., holotype GIN, no. 4850/10, ×250.

Figs. 10 and 11. *Spongodiscus sakhalinensis* sp. nov., ×120; (10) holotype GIN, no. 4850/7; (11) paratype GIN, no. 4850/27.

Description. The skeleton is ellipsoidal, consisting of seven or eight closely spaced concentric shells (a characteristic feature of the genus). The external shell is penetrated by small oval-polygonal pores. Where the pores connect, the test has small spines, giving it a rough surface. Both poles of the skeleton are surrounded by five to eight relatively massive spines. The central part of the test has another five to eight spines, which lie in the equatorial plane and are of the same length and size as those on the poles of the test.

Measurements. Holotype GIN, no. 4850/11: skeleton height, 230; transverse diameter, 170; spine length, 25–40; pore diameter, 4–6.

Comparison. The new species is distinguished from *Stylodruppa bifascicula* Kazintsova, 1979 by the smaller pores, by the arrangement of the spines in both polar zones of the skeleton, and by the presence of spines in the central zone of the skeleton surrounding the test in the equatorial plane.

Occurrence. Southern Sakhalin, basin of the Naiba River, middle–upper Cenomanian, Member V of the Naiba Formation, beds with *Cuboctostylus kasinzovae–Cuboctostylus sakhalinensis*, Member I of the Bykovskaya Formation, beds with *Cuboctostylus trifurcatus–Cassideus yoloensis*.

Material. Three complete and six incomplete specimens from the type region.

Family Hagiastridae Riedel, 1971

Subfamily Patulibracchiinae Pessagno, 1971

Genus *Patulibracchium* Pessagno, 1971

***Patulibracchium* (?) *quadroastrum* Bragina, sp. nov.**

Plate 3, figs. 3 and 6

Hagiastrum sp. Zinkevich *et al.*, 1988, pl. 1, fig. 9

(?) Hagiastridae gen. et sp. indet.: Bragina and Vitukhin, 1997, pl. 1, fig. 1.

Etymology. From Latin *quadroastrum* (four-rayed star).

Holotype. GIN, no. 4850/12, southern Sakhalin, basin of the Naiba River; upper Turonian, Member VI of the Bykovskaya Formation, beds with *Orbiculiforma monticelloensis–Cavaspongia contracta*.

Description. A large test with four spines. The tolus is not raised. The diameter of the tolus is approximately one-third of the length of a spine. The width of each spine at the base and in the middle is approximately equal to the diameter of the tolus. The terminations of the spines are acute but irregularly shaped. One of the spines has a tubular bracchiopyle (characteristic of this genus), with a periphery with smaller spines. The test surface is covered with randomly arranged polygonal pores, flanked by irregularly shaped pore frames. The test surface is covered with irregularly arranged small spines. The diameter of the pores is approximately equal to, or slightly smaller than, the distance between the neighboring pores.

Measurements. Holotype GIN, no. 4850/12: spine length, 100; spine width, 35; pore size, 3–6.

Comparison. The new species is distinguished from *Patulibracchium inaequalum* Pessagno, 1971 in that all four spines are of similar length. It differs from all known *Patulibracchium* species in the presence of a fourth spine. Because of this feature, the new species is only tentatively assigned to the genus *Patulibracchium*.

Occurrence. Sakhalin, basin of the Naiba River; upper Turonian, Member VI of the Bykovskaya Formation, beds with *Orbiculiforma monticelloensis–Cavaspongia contracta*.

Material. Three complete and numerous incomplete specimens from the type locality.

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