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New Species of the Family Heliodiscidae Haeckel (Radiolaria)

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Abstract—The family Heliodiscidae Haeckel, 1881, which includes five genera, is reviewed. New methods of investigation are applied to the inner structure of Cretaceous spherical radiolarian skeletons, which reveal numerous taxa with an eccentric microsphere. Three new species, *Astrophacus marinae* sp. nov., *Excentrosphaerella kovalenkovi* sp. nov., and *Excentrosphaerella kurilovi* sp. nov., are described. The eccentric position of the microsphere suggests that these forms are nontypical Mesozoic radiolarians or new representatives of the family Heliodiscidae Haeckel, 1881, which was previously recorded in the Cenozoic.

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Key words: Radiolaria, Heliodiscidae, new species, Cretaceous.

INTRODUCTION

The aim of the future of paleontology and biostratigraphy is to receive the maximum amount of information from the minimum sized piece of rock using different microfossils, such as foraminifers, nannoplankton, and radiolarians. This is very important especially for regions which are remote or difficult to access. Thus, 1 cm^2 of a section of siliceous rocks may contain up to 1000 or even more radiolarians of different taxa, while 1g of dry sediment occasionally contains 1 to 500 thousand specimens. Searching for macrofaunal groups, e.g., ammonites, inocerams or echinoids, usually takes several days in an outcrop of 10 m^2. The probability of finding macrofossils in core samples is even lower. Therefore, it is not surprising that the microfauna, especially radiolarians, is more applicable for both economic and practical purposes. For a long time, radiolarians were largely ignored in paleontological and biostratigraphical studies. They were considered as an auxiliary group even among microfossils. Now, it is realized that this group has great potential.

THE REVIEW OF THE POINTS OF VIEW ON THE SYSTEMATIC POSITION OF THE FAMILY HELIODISCIDAE HAECKEL

The family Heliodiscidae Haeckel, 1881 (De Wever *et al.*, 2001) represents the order Spumellaria Ehrenberg, 1875 of the class Radiolaria Müller, 1858. It was established by raising the rank of the subfamily proposed by Haeckel in 1881. The presence of two latticed shells and irregular arrangement of numerous radial spines was taken by Haeckel as the basis of his classification. Originally, the subfamily Heliodiscinae had been attributed to the family Phacodiscidae Haeckel, 1887. Subsequently, because of poor knowledge of details of the inner position of the shells, it was transferred to several different families, namely, to the Liosphaeridae Haeckel, 1887 because of the absence of the main spines (Lipman, 1967); to the Coccodiscidae Haeckel, 1962 because of the concentric position of the shells, giving the impression of cameral rings (Dumitrica, 1984); or to Lithocycliidae Ehrenberg, 1854 in view of the chambers positioned as concentric rings (Kozlova, 1999).

Dumitrica (1984) substantially amended the diagnosis of the subfamily Heliodiscinae and its content by attaching the primary significance to the position of the microsphere. The eccentric microsphere distinguishes Heliodiscinae from Mesozoic and the majority of Cenozoic radiolarians, which have the microsphere in the center. In the last classification of Phanerozoic radiolarians, Dumitrica raised this subfamily to the family rank and stipulated the presence of cortical and medullary shells, with the last always containing the eccentric microsphere (De Wever *et al.*, 2001). The family Heliodiscidae was assigned to group B of the superfamily Actinommacea Haeckel, 1862, which has two inner shells, although, according to the diagnosis, some members of this family have two, three, or even more

Fig. 1. *Astrophacus marinae* sp. nov., holotype ILRAN, no. 64/00m: (a) general view of the skeleton, two external spheres are coupled and form the cortical shell, ×160; (b) medullary shell (internal macrosphere) is connected with the cortical shell by beams, ×300; (c) internal microporous macrosphere, ×735; (d–f) general view of the interior of the medullary shell, microporous wall is partly disrupted, coarse polygonal structure is clearly visible inside the macrosphere, ×160, ×300, and ×735; western Kamchatka Peninsula, Tikhaya River basin; Upper Cretaceous, Coniacian–Lower Campanian.

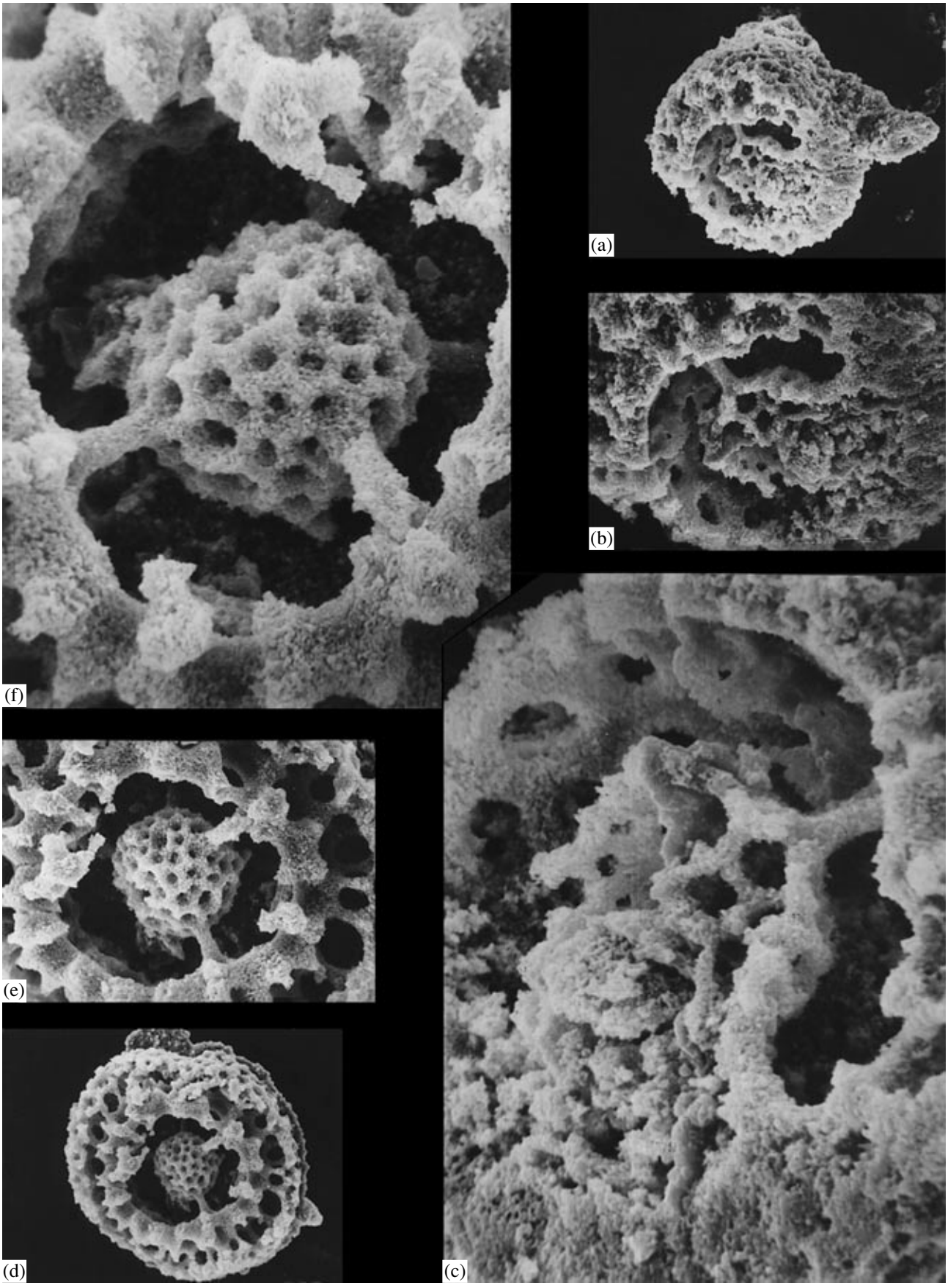
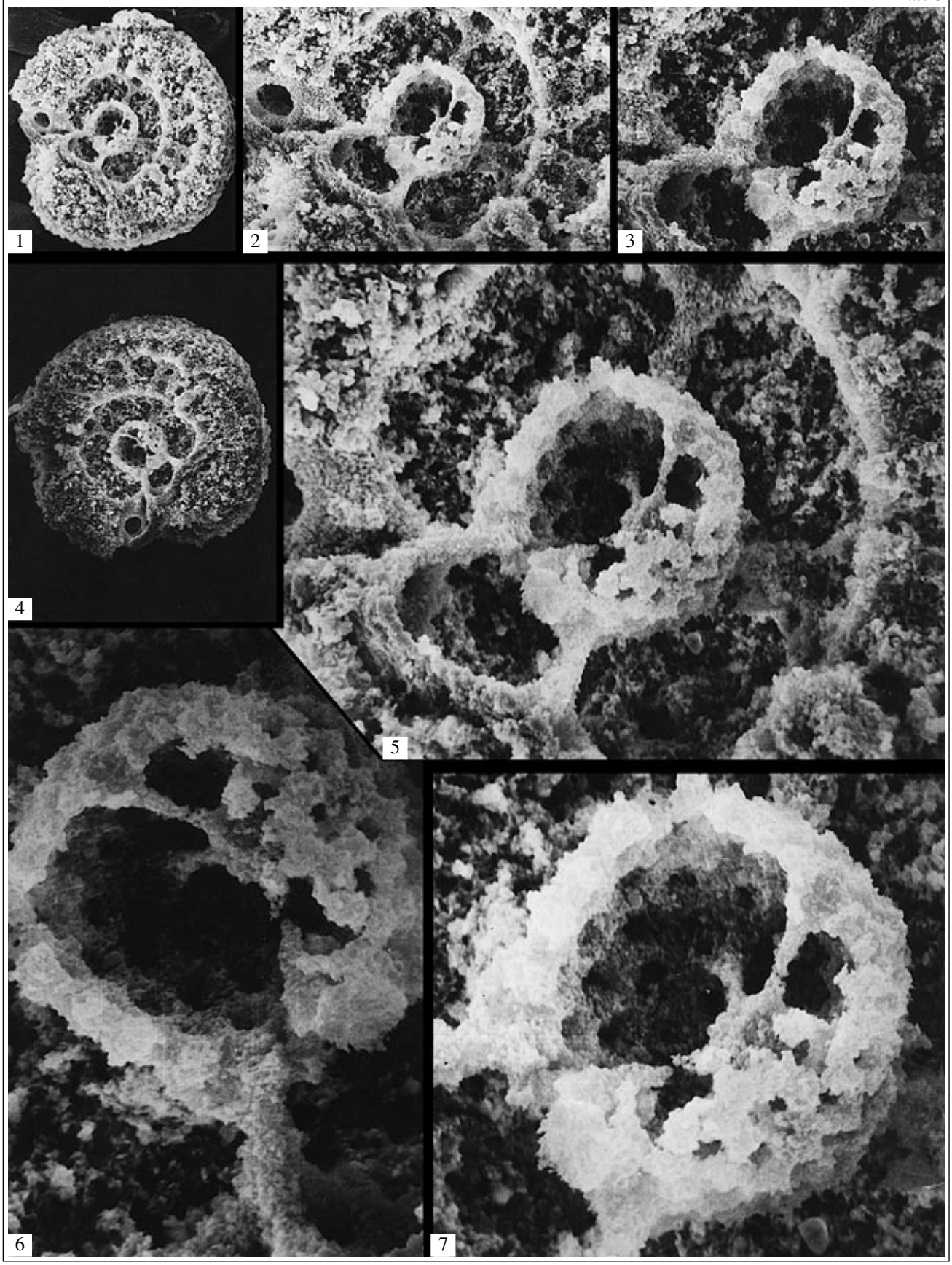

(a)
(b)
(c)
(d)
(e)
(f)

Plate 3



shells. Moreover, some of these shells can be discoidal in shape.

The new diagnosis of the family Heliodiscidae (De Wever *et al.*, 2001, text-fig. 69) embraces three- and multispherical discoidal, ellipsoidal, and spherical Spumellaria with a double medullary shell and an eccentrical inner microsphere. The cortical shell is connected to the medullary one by numerous radial beams. The eccentric position of the microsphere is the major difference between the Heliodiscidae and Coccodiscidae. The family includes both discoidal (*Heliodiscus* Haeckel = *Astrophacus* Haeckel) and spherical forms with single (*Excentrodiscus* Hollande et Enjumet) or double (*Excentrosphaerella* Dumitrica) cortical shell, or radiolarians with the cortical shell built of the equatorial ring with two or more concentric rows of chambers (*Excentrococcus* Dumitrica). Unfortunately, the inner microsphere is infrequently preserved in fossil condition, thus, hampering the accurate diagnosis of the family. Perhaps, this family can be taken as an independent group based on the eccentric microsphere position (Afanasieva *et al.*, 2004).

The first SEM observations of the interior of the Cretaceous spherical radiolarians from the eastern areas of Russian have revealed numerous spherical radiolarians with an eccentric microsphere in the Coniacian–Santonian of the Kamchatka Peninsula (Vishnevskaya, 2003; Vishnevskaya *et al.*, 2003). The same forms had been described earlier as *Cromyosphaera vivenkensis* Lipman (Lipman, 1967, pp. 92, 93, pl. 1, figs. 1–5, pl. 2, figs. 1–4; Vishnevskaya, 2001, pl. 7, figs. 1, 2) or *Cromyosphaera tschurini* Lipman (Lipman, 1967, p. 94, pl. 1, figs. 10–12; Zhamoida, 1972, p. 103, pl. 17, fig. 6) because of the unknown composition of their interior. These forms had been placed in the family Liosphaeridae Haeckel, 1887.

The eccentric position of the microsphere in Cretaceous radiolarians from eastern Russia (western Kamchatka Peninsula) and other regions suggests that these forms are either nontypical Mesozoic radiolarians or new representatives of the family Heliodiscidae Haeckel, 1881, the group so far known from the middle of the Cenozoic. New species markedly extend the family volume and the knowledge of radiolarian faunas of the world. They are also useful in the biostratigraphy of Russia and the world. Some inner morphological characteristics supplement the family diagnosis.

The material studied is housed at the Russian Center of Micropaleontological Reference Collections, no. 2001-1(R).

SYSTEMATIC PALEONTOLOGY

CLASS RADIOLARIA

Order Spumellaria

Family Heliodiscidae Haeckel, 1881

D i a g n o s i s. Sphaerellaria with subspherical porous test and eccentrically or centrally (?) placed microsphere. Two, three, or more shells. More than 20 radial, randomly arranged spines varying in length may present.

C o m p o s i t i o n. Five genera: *Astrophacus* Haeckel, 1881; *Heliodiscus* Haeckel, 1862; *Excentrococcus* Dumitrica, 1978; *Excentrodiscus* Hollande et Enjumet, 1960; *Excentrosphaerella* Dumitrica, 1978.

O c c u r r e n c e. Upper Cretaceous (Santonian)–Recent, subtropical and temperate latitudes.

Genus *Astrophacus* Haeckel, 1881

T y p e s p e c i e s. *Astrophacus asteriscus* Haeckel, 1887; Recent; Pacific Ocean.

D i a g n o s i s. Test lenticular–spherical, irregularly porous, with three latticed shells. Medullary shells coupled, forming double internal shell; internal sphere polyhedral. Microsphere not described. Test with numerous simple radial spines in equatorial area.

S p e c i e s c o m p o s i t i o n. In addition to the type species, 12 species: *A. solaster* (Haeckel, 1887) from Recent sediments; *A. testatus* Kozlova, 1966, *A. testatus testata* Kozlova, 1966, *A. testatus quadrispina* Kozlova, 1966, *A. duplus* Kozlova, 1966, *A. duplus dupla* Kozlova, 1966, *A. duplus expolita* Kozlova, 1966, *A. pictus* Kozlova, 1966 (Kozlova and Gorbovets, 1966), *A. hexaspinus* Tochilina, 1966, *A. stellatus* Tochilina, 1966, *A. tetraradialis* Tochilina, 1966, and *A. hexasteriscus intricatus* Kozlova, 1979 from Eocene.

C o m p a r i s o n. *Astrophacus* differs from other genera of the family in the polyhedral microsphere.

R e m a r k s. Judging from the original description, *Astrophacus asteriscus* Haeckel, 1887 is a synonym of *Heliodiscus asteriscus* Haeckel, 1862. Therefore, many researchers regarded *Astrophacus* Haeckel, 1881 as a synonym of *Heliodiscus* Haeckel, 1862, which was indicated by M.G. Petrushevskaya and G.E. Kozlova (*History of Microplankton...*, 1979; Kozlova, 1999). The type species of the genus *Heliodiscus* has been changed several times. Therefore, radiolarian workers preferred using the genus *Astrophacus* sensu lato, and many new species and subspecies were described under this generic name. Surprisingly, the last classification of Phanerozoic radiolarians (De Wever *et al.*, 2001)

Explanation of Plate 3

Internal structural details of the new radiolarian species of the genus *Excentrosphaerella* Dumitrica (family Heliodiscidae Haeckel, 1881) from the Upper Cretaceous (Coniacian–Lower Campanian) of the Tikhaya River basin, western Kamchatka Peninsula.

Figs. 1–7. *Excentrosphaerella kamchatica* Vishnevskaya et Dumitrica, sp. nov.; holotype ILRAN, no. 64/00-1; the eccentric microsphere is clearly visible at high magnification, ×120, ×250, ×600, ×150, ×600, ×960, and ×960.

places *Astrophacus* in either the family Heliodiscidae Haeckel, 1881 or Coccodiscidae Haeckel, 1962. Therefore, additional examination of the internal structure will be crucial in refining the diagnosis of *Astrophacus*.

***Astrophacus marinae* Vishnevskaya, sp. nov.**

Etymology. In honor of the eminent radiolarian worker Marina Spartakovna Afanasieva.

Holotype. ILRAN (Institute of the Lithosphere of Marginal Seas, Russian Academy of Sciences), no. 64/00m; western Kamchatka Peninsula, Tikhaya River basin; Upper Cretaceous, Coniacian–Lower Campanian.

Description (Figs. 1a–1f). The skeleton is subspherical, porous, consists of three concentric macrospheres. Two closely spaced external shells are coupled and connected to the medullary shell by beams. The central macrospheral pores are circular, with polygonal frames. The pores become larger toward the external sphere. They are persistently circular and retain their polygonal frames. The microsphere is a polyhedron with a large rounded pore on each edge. Radial beams diverge from the vertices of the polyhedron and connect it to the medullary shell (macrosphere) enclosing it. The exact position of the microsphere relative to the macrosphere is uncertain because it is very fragile. Both the beams forming the internal polyhedron and the beams connecting the micro- and macrospheres are thick and massive.

Dimensions, μm. Diameters of the internal microsphere, 35–40, macrosphere, 80; mean diameter of pores, 9; diameter of the external sphere, 460; and thickness of the external sphere, 20–40.

Comparison. The large size, subspherical shape, and large pores of the internal sphere distinguish this species from all known species of this genus.

Material. Three specimens.

Genus *Heliodiscus* Haeckel, 1862

Heliodiscus: Haeckel 1862, p. 436; Haeckel, 1887, p. 444; Clark and Campbell, 1945, p. 21; Nigrini, 1967, p. 32; Kozur and Mostler, 1972, p. 22; De Wever *et al.*, 2001, p. 181.

Type species. *Heliodiscus asteriscus* Haeckel, 1862; Mediterranean Sea, Recent.

Diagnosis. Test subspherical, finely porous, consisting of two shells: rough spiny external shell with 6–8 or more radial spines in the equatorial area and coarsely cellular internal shell with the eccentric microsphere.

Species composition. In addition to the type species, 15 species: *H. asteriscoides* Haeckel, 1908, *H. asteriscus* Nigrini, 1967, *H. echiniscus* Haeckel, 1887, *H. sol* Ehrenberg, 1844, *H. polymorphus* Haeckel, 1887, *H. solaster* Haeckel, 1887, *H. phacodiscus* (Haeckel, 1887), and *H. viminalis* (Hollande et Enjume, 1960) from Recent sediments; *H. lentis* Lipman, 1952 from the Eocene–Miocene; *H. heliasteriscus* Clark et Campbell, 1942, *H. hexasteriscus* Clark et Campbell, 1942, *H. linckiaformis* Clark et Campbell, 1942, *H. quadratus* Clark et Campbell, 1942, and *H. inca* Clark et Campbell, 1942 from the Eocene (Clark and Campbell, 1942); *H. borealis* Vishnevskaya, 2002 from the Santonian–Lower Campanian.

Comparison. The subspherical skeleton, slender and short spines, and eccentric microsphere distinguish *Heliodiscus* from all known genera of the family.

Remarks. Kozlova (1999) studied boreal representatives of the genus and concluded that *Heliodiscus* appeared in the Paleocene. The finding of *Heliodiscus borealis* suggests that the genus appeared in the latest Santonian or the earliest Campanian (Late Cretaceous). New finds of *Heliodiscus* in the Cretaceous expand its geographical and geological ranges. *H. inchoatus* Rust (Kozur and Mostler, 1972) is excluded from the genus because it lacks a microsphere, which is replaced by a spicule.

Genus *Excentrococcus* Dumitrica, 1978

Type species. *Excentrococcus annulatus* Dumitrica, 1978; Neogene of Romania (Dumitrica, 1978).

Diagnosis. Test discoidal to spherical, finely porous, consisting of cortical shell formed by equatorial ring with one or more concentric rows of chambers and medullary shell with eccentric microsphere.

Species composition. Type species.

Comparison. The ellipsoidal shape of the test and the eccentric microsphere distinguish *Excentrococcus* from all known genera of this family.

Genus *Excentrodiscus* Hollande et Enjumet, 1960

Type species. *Excentrodiscus echinatus* Hollande et Enjumet, 1960; Recent of the Mediterranean.

Diagnosis. Test discoidal to spherical, finely porous, consisting of two shells: spherical cortical and single medullary shells with eccentric microsphere.

Species composition. Type species.

Comparison. The discoidal test and the eccentric microsphere distinguish this genus from the other genera of this family.

Genus *Excentrosphaerella* Dumitrica, 1978

Type species. *Excentrosphaerella sphaeroconha* Dumitrica, 1978; Neogene of Rumania.

Diagnosis. Test spherical, with double cortical shell and eccentric internal microsphere located inside macrosphere.

Species composition. Four species in addition to the type species: *Excentrosphaerella teuria* (Hollis, 1997), Maastrichtian–Early Paleocene, New Zealand; *E. kamchatica* Vishnevskaya et Dumitrica, 2003, Santonian–Campanian, Kamchatka Peninsula (Vishnevskaya and Dumitrica, 2003); *Excentrosphaer-*

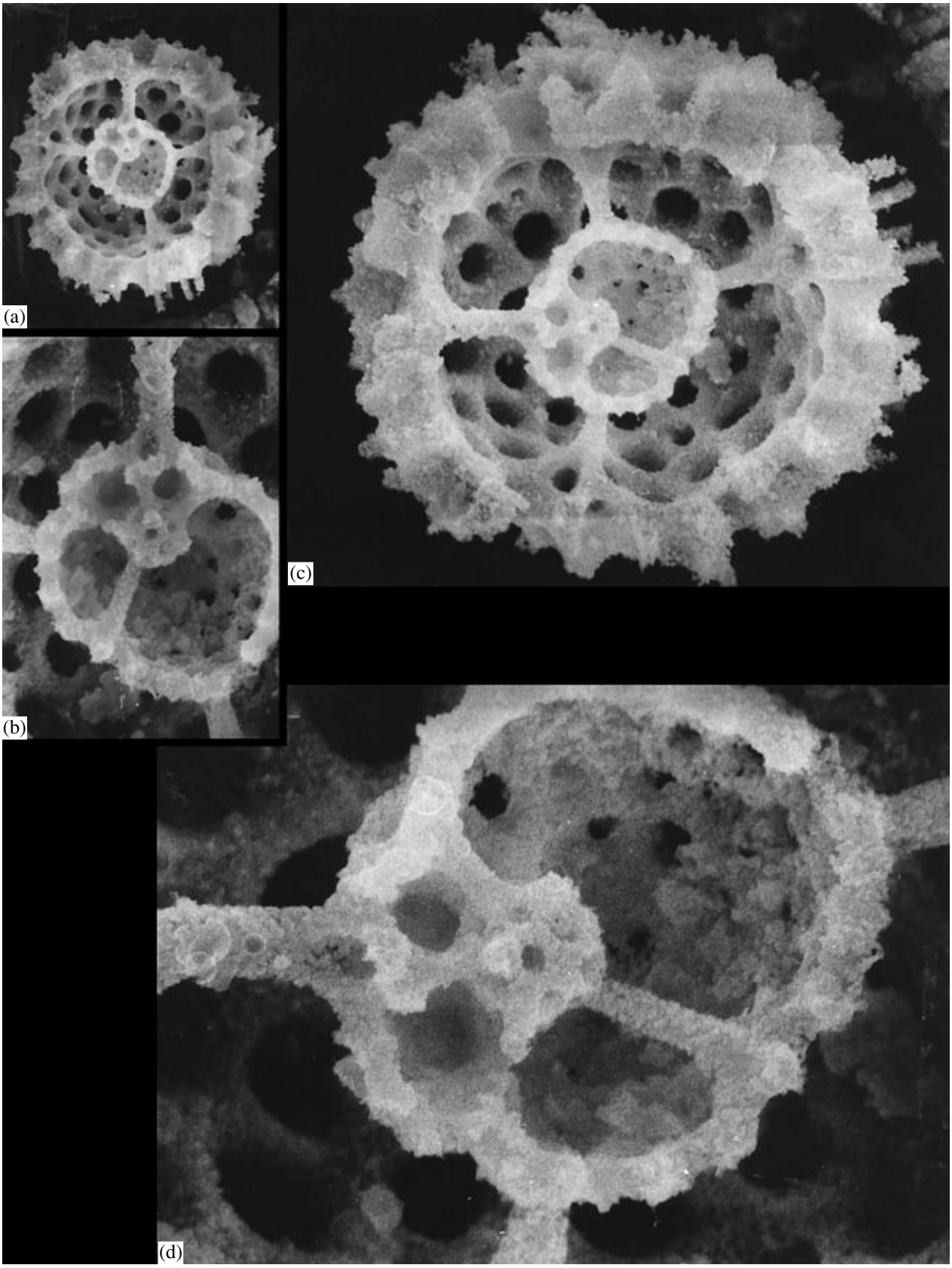
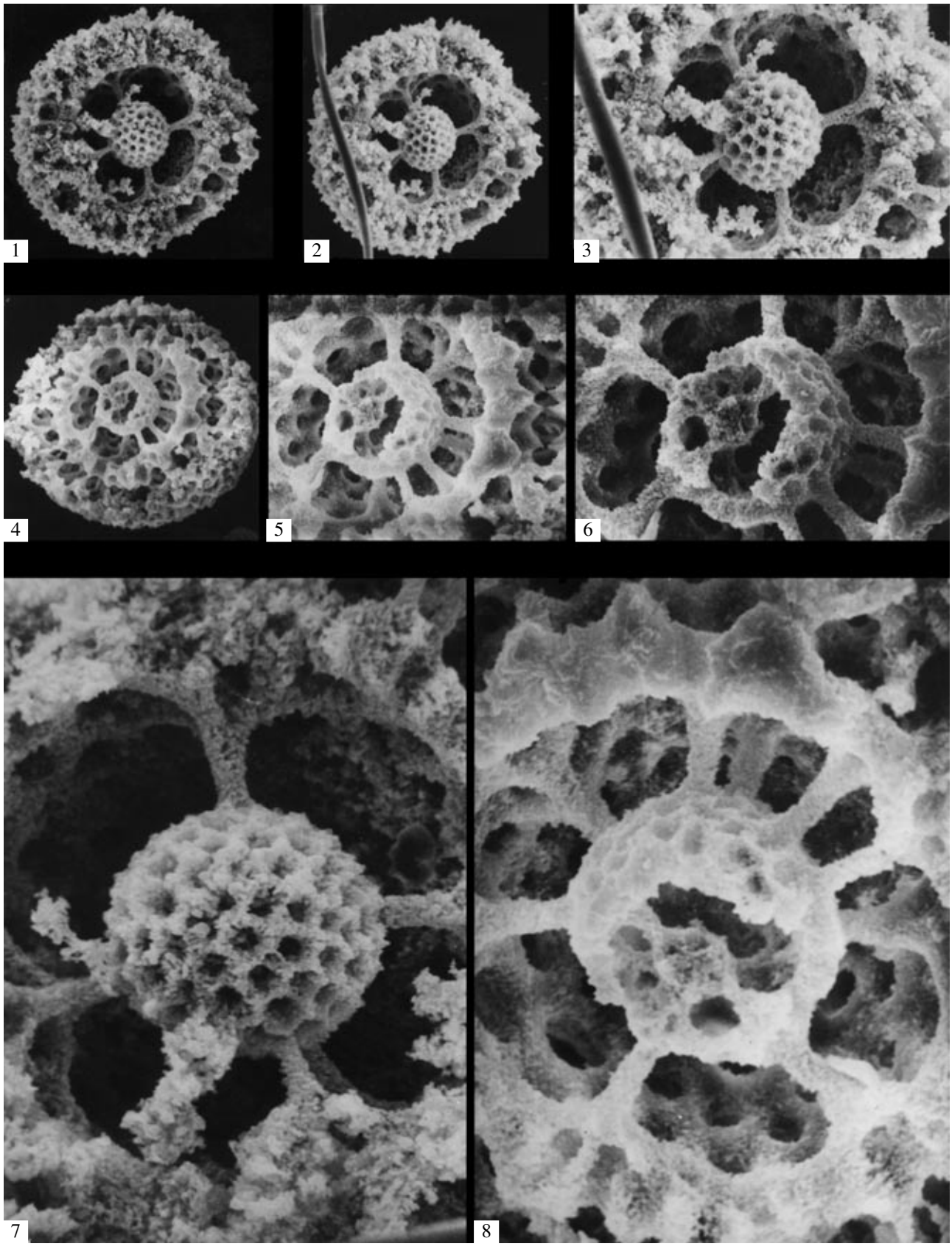


Fig. 2. *Excentrosphaerella kovalenkovi* sp. nov.; holotype ILRAN, no. 177/01: (a, c) general view of the skeleton ×225 and ×450; (b, d) internal macro- and microspheres ×500 and ×1100; western Kamchatka Peninsula, Ust'-Palana River; Upper Cretaceous, Santonian–Lower Campanian.

Plate 4



ella kovalenkovi Vishnevskaya, sp. nov., and *Excentrosphaerella sukhovi* Vishnevskaya et Kurilov, sp. nov.

Comparison. This genus differs in its spherical test from other genera of the family.

Excentrosphaerella kamchatica Vishnevskaya et Dumitrica, 2003

Plate 3, figs. 1–7

Holotype. ILRAN, no. 64/00-1; western Kamchatka Peninsula, Tikhaya River basin; Upper Cretaceous, Coniacian–Lower Campanian.

Description. The skeleton is spherical, porous, consists of three visible concentric shells and a hardly discernible microsphere connected to each other by radial beams. Radial rods connect the coupled external shell with the centrically placed internal macrosphere. The internal microsphere is eccentric. Sometimes, the external test surface has small thornlike spines. The internal surface of the external shell is pierced by rows of small rounded pores with polygonal frames. Toward the external sphere, the pores become larger, with better defined polygonal frames.

The beams branch and broaden at the points of attachment to the test walls. The beam size remains almost constant. The thin wall of the internal medullary shell has subhexagonal pores on the external side and small ovoid and circular pores on the internal sides. The wall becomes thicker where internal radial beams are attached. The beams become notably thinner toward the microsphere.

Dimensions, μm. The diameter the central microsphere is 40, that of the macrosphere, 120; average diameter of macrosphere pores, 8–10; diameter of the intermediate sphere, 280; intermediate sphere wall, 40 μm thick; diameter of the external cortical shell, 400, and its the wall thickness 20–40.

Comparison. This species differs from all known representatives of the genus in the large ovoid pore on the extension of the radial beam, where the cortical shells are attached to the macrosphere. It differs from *E. teuria* (Hollis, 1997, p. 36, pl. 3, fig. 6) from the Maastrichtian–Early Paleocene of New Zealand in the thicker walls of its cortical shells and in the absence of pyramidal tubercles.

Material. Three specimens.

Excentrosphaerella kovalenkovi Vishnevskaya, sp. nov.

Etymology. In honor of the expert in paleomagnetics Dmitrii Kovalenko, who collected radiolarian samples.

Holotype. ILRAN, no. 177/01; western Kamchatka Peninsula, Ust'-Palana River; Upper Cretaceous, Santonian–Lower Campanian.

Description (Figs. 2a–2d). The skeleton is spherical, porous, consists of two concentric spheres. The shells are connected by radial beams. The macrosphere is subspherical. The pores of the central microsphere (cortical shell) are circular, with polygonal frames. The external test surface is covered with relatively small, thin spines. The pores of the external sphere are large, circular on the internal side and have a polygon frame on the external side. They are closely spaced on the external sphere, while the pores on the internal surface look isolated. The microsphere is eccentric, porous. The pores are circular, with hexagonal frames. The beams between macro- and microspheres differ in length and approximately equal in width.

Dimensions, μm. The diameter of the internal microsphere is 40–45, that of the central microsphere, 130–150; average diameter of pores, 10; diameter of the external sphere, 440–460; thickness of the external sphere, 50–60; spine length, 40–80; and spine diameter, 10–20.

Comparison. The new species differs from Cenozoic radiolarians in the larger size and in the subspherical shape of the medullary shell.

Occurrence. Western Kamchatka Peninsula; Upper Cretaceous, Coniacian–Lower Campanian.

Material. Four specimens.

Excentrosphaerella sukhovi Vishnevskaya et Kurilov, sp. nov.

Plate 4, figs. 1–8

Etymology. In honor of the lithologist Aleksei Nikolaevich Sukhov, who assisted in the collection of radiolarian samples.

Holotype. ILRAN, no. 298/2001-1, 59(1)/99; western Kamchatka Peninsula, Irunei Mountain, Pansheteyam Mountain Ridge; Coniacian–Lower Campanian.

Description. The skeleton is spherical, porous, consists of three concentric spheres. The internal microsphere (fourth shell) is eccentric. The shells are connected by closely positioned beams. The pores of the central macrosphere are circular, with polygonal frames. Pores substantially increase in size toward the external sphere, while their frames become hexagonal and have polygonal rims with pointed vertices forming small spines (4–6 around each pore) and, hence, a rough scalloped surface of the test. The shells are connected by radial beams, which are circular or oval in section. The

Explanation of Plate 4

The internal structure of spherical radiolarians of the new species of the genus *Excentrosphaerella* Dumitrica from the Upper Cretaceous (Santonian–Lower Campanian) of Irunei Mountain of the western Kamchatka Peninsula.

Figs. 1–8. *Excentrosphaerella sukhovi* Vishnevskaya et Kurilov, sp. nov.; holotype of ILRAN, no. 59; (1–3) the external bispherical shell connected by four radial beams with the centric internal microsphere, ×130, ×130, and ×250; (4–6) specimens with clearly visible internal eccentric microsphere due to the fact that the macrosphere is broken, ×130, ×250, and ×490; (7, 8) the broken eccentric microsphere; four large pores are observed, ×600 and ×600.

pores are often double at the points where the internal radial rods are attached. The beams branch and broaden at the points of attachment to the test walls. The rods become sharply thinner toward the microsphere.

D i m e n s i o n s, μm. The diameter of the microsphere is 40, that of the central internal macrosphere, 120; pore diameter, 10; length of the beams deviating from the central sphere, 40; diameter of the middle sphere, 250; wall thickness, 40; diameter of the external sphere, 420–440; wall thickness 20–40; length of the beams between external sphere and the first internal sphere, 20.

C o m p a r i s o n. This species differs from other representatives of the genus by the presence of four large pores, which are clearly visible in the microsphere section.

M a t e r i a l. Five specimens.

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