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A New Genus of Fossil Freshwater Diatoms (Bacillariophyta: Stephanodiscaceae) from the sediments of Lake Baikal

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Three new species of diatoms are described from early Pliocene sediments of Lake Baikal, Russia. These species all possess circular valves, with areolae arranged in radial rows, with radiating fascicules at the valve margin. One to ten central fultoportulae are bounded by 3 satellite pores. The valve mantle is divided into distinct sections separated by hyaline strips. Marginal fultoportulae are located regularly around the mantle and are bounded by 3 satellite pores. A single, small, sessile rimoportula is placed on the mantle about half the distance between 2 marginal fultoportulae. The three species are distinguished by their size, pattern of areolation and number and placement of processes. These three species are not easily placed in any existing genus of freshwater centric diatoms, therefore a new genus, *Tertiariopsis*, is proposed. The new genus is compared with close allies, including *Tertiarius*, *Thalassiosira*, *Stephanodiscus* and *Stephanopsis*.

Lake Baikal has been well documented as a biodiversity hot-spot—containing many endemic taxa across the spectrum of biological diversity (Kozhov 1963), and the diatoms are no exception. In the recent flora, early workers such as Dorogostaisky (1904), Skvortzow & Meyer (1928), Jasnitzky (1936), Skvortzow (1937) and Skabitchevsky (1936, 1984) documented many new and unusual forms in living communities of this ancient and deep lake. And more recently, new taxa continue to be described from amongst Baikal's extent flora (e.g., Makarova & Pomazkina 1992; Genkal & Popovskaya 1990; Edlund et al. 1996).

The Baikal region, and the lake itself, have also been localities from which interesting taxa have been described from the fossil record. Cheremissinova (1971, 1973), Lupikina & Khursevich (1991), Khursevich (1994) and Likhoshway et al. (1997) described many new taxa from the Middle-Upper Miocene sediments of the Tunkin Hollow, a depression basin located 60 km west of the southern edge of Lake Baikal. More recently, Khursevich and colleagues (1989, 2000) have described endemic genera from the Neogene sediments of the Transbaikal area and Lake Baikal. New and apparently exinct

taxa of the genera *Stephanodiscus* and *Cyclotella* were described from Pleistocene sedimentary strata of Lake Baikal (Loginova & Khursevich 1986, 1990; Khursevich 1989, 2000; Likhoshway et al. 1997; Nikiteeva & Likhoshway 1994; Likhoshway 1996; Khursevich et al. 2001).

In an effort to document floristic elements and their relationship to climate change, the Baikal Drilling Project has extracted several cores from the lake. In a core taken in 1996, we have found some interesting centric taxa to which we cannot assign a genus name. Herein, we describe three species as new, and present them in a new genus, *Tertiariopsis*.

Materials and Methods

In 1996 two parallel drilling cores BDP 96-1 (200 m in length) and BDP 96-2 (100 m in length) were taken on top of the underwater Academician Ridge of Lake Baikal (53°41′48″N; 108°21′06″E, water depth 321 m). Sediments consist of alternating fine clay and diatom ooze intervals. The core was sampled every 2 cm to achieve a 500-year resolution. The magnetic polarity age model based on 13 magnetic reversal-event boundaries provides a robust chronology for BDP 96 sedimentary records for the last 5 Ma (BDP members 1997; Williams et al. 1997). Preparation of permanent slides is described in Grachev et al. (1997). Specimens were examined and photographed by oil immersion light microscopy (Ergaval brightfield, in Minsk; Leica DMRB in San Francisco) and by scanning electron microscopy (SEM) (JEOL JSM-35C in Minsk, Leo 1450VP in San Francisco).

Systematic Account

Genus *Tertiariopsis* Khursevich & Kociolek, gen. nov.

Type Species. — *Tertiariopsis imperseptus* Khursevich, Fedenya & Kociolek

Description. — Valves circular, diameter 5.0–15.3 μm. Valve face more or less flat, sometimes with slightly elevated center. Areolae arranged in radial rows of unequal length, sometimes forming radiating fascicles (in two to six rows) at the margin of the valve face. Center of the valve with an irregular pattern of areolae or structure is lacking. There is a distinct separation of the valve face and mantle areolae. On the valve face may be a single, slightly eccentric fultoportula or several (2–10) fultoportulae, with usually 3 (rarely 2) satellite pores. The valve mantle is divided into distinct sections (consisting of 6–10 vertical rows of small areolae) separated by hyaline strips. Marginal fultoportulae are located regularly around the valve mantle. Externally they appear as distinct rounded apertures at the base of hyaline strips. Internally they have 3 satellite pores and are covered by a marginal lamina. A single small sessile rimoportula is placed on the mantle approximately 1/2 the distance between 2 marginal fultoportulae. Spines may be present.

Etymology. — Named because the species of this genus resemble those in the genus *Tertiarius*.

***Tertiariopsis imperseptus* Khursevich, Fedenya & Kociolek, sp. nov.**
Figs. 1–4, 12–17. Figure 1 is the holotype.

Description. — Valves circular, flat or slightly convex, 5.0–14.6 μm in diameter. Areolae 15–20 in 10 μm along the radius, arranged in radial rows of unequal length. There is a distinct break between the valve face areolae and those of the mantle. Mantle areolae are smaller than those on the valve face, and arranged in linear rows. Cribra were not observed on any specimens. One slightly eccentric fultoportula with three or four satellite pores occurs on the valve face. Mantle fultoportulae are spaced regularly around the margin (4–6/10 μm). Internally, they have three satellite pores and are

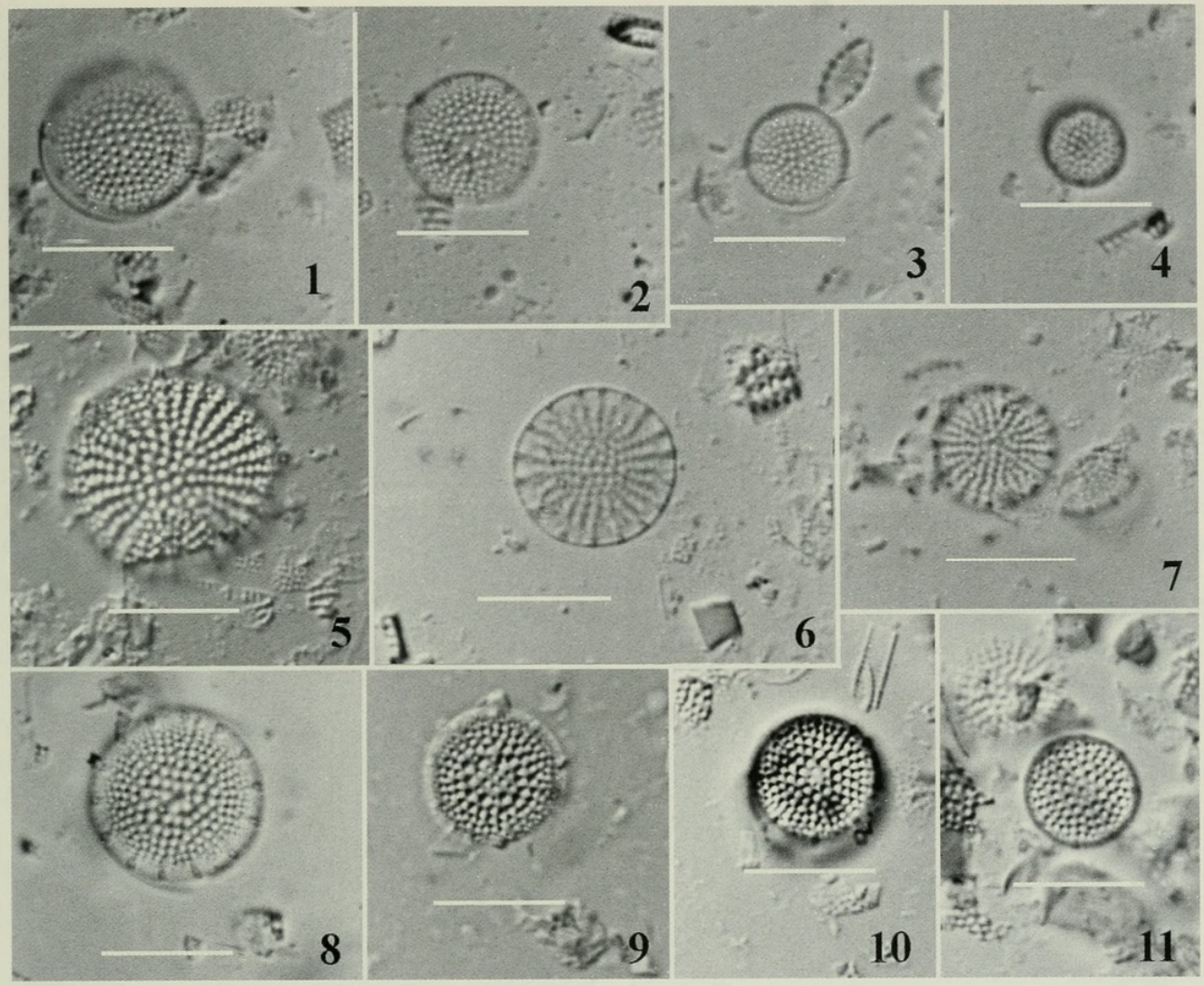

PLATE 1. Light microscopy, valve views. Figures 1–4. *Tertiariopsis imperseptus* Khursevich, Fedenya & Kociolek, sp. nov. Figures 5–7. *Tertiariopsis sibericus* Khursevich, Fedenya & Kociolek, sp. nov. Figures 8–11. *Tertiariopsis makarovae* Khursevich & Kociolek, sp. nov. Scale bar in figure 1 = 10 μm, same for all figures.

covered by a marginal lamina. External openings of mantle fultoportulae are found at the base of hyaline strips interrupting the pattern of mantle areolae. A sessile rimoportula is located on the mantle at the same level with marginal fultoportulae, approximately halfway between two marginal fultoportulae. Spines were observed on the valve face/mantle junction.

HOLOTYPE. — Slide number 3415a, BDP 96-1, core 94-1 (2–3 cm), deposited in the Khursevich Collection, Institute of Geological Sciences, National Academy of Sciences of Belarus, Minsk.

ISOTYPES. — Slide 3415b, BDP 96-1, core 94-1 (2–3 cm), deposited in the Baikal Drilling Project Collection, Institute of Geochemistry, Siberian Branch of Russian Academy of Sciences, Irkutsk, Russia. Type material has also been deposited in the Diatom Collection, California Academy of Sciences.

TYPE LOCALITY. — Underwater Academician Ridge of Lake Baikal, Russia, borehole BDP 96-1, depth 184–194 m from sediment surface.

GEOLOGICAL ERA. — Early Pliocene.

ETYMOLOGY. — From the Latin *imperseptus*, to mean imperceptible, referring to its ambiguous systematic position.

COMMENTS. — This species differs from *Thalassiosira dispar* (Peragallo & Héribaud) Serieyssol (Serieyssol et al. 1998:178–180, figs 1–10) by the finer areolation of the valve face surface (12–14, rarely 16 in 10 μm in *T. dispar* versus 15–20 in 10 μm in *Tertiariopsis imperseptus*), as well as

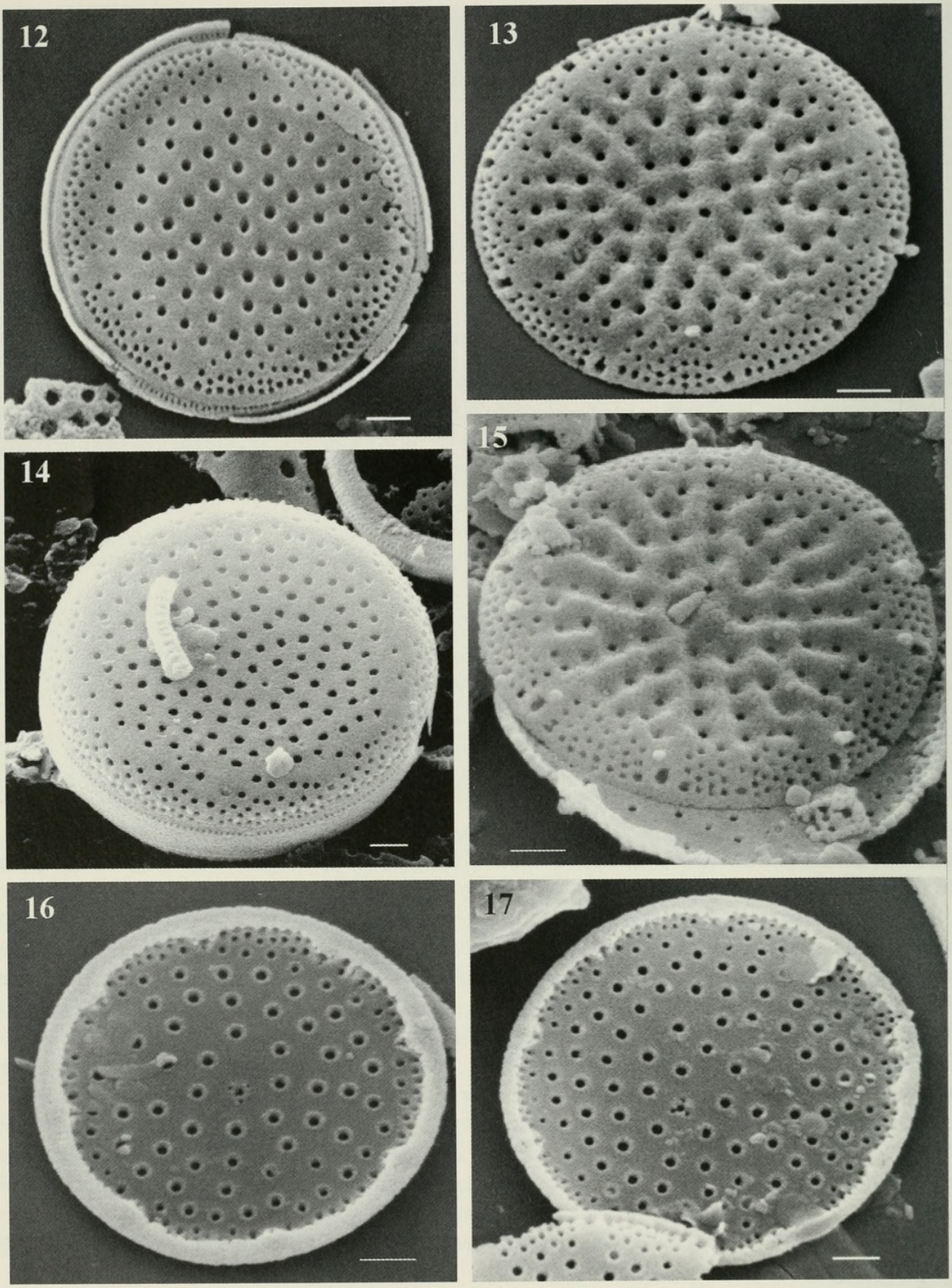

PLATE 2. SEM. *Tertiariopsis imperseptus* Khursevich, Fedenya & Kociolek, sp. nov. Figures 12–15. Valve exterior, showing range of surface from smooth to small ridges and undulations. Fasciculated mantle is evident, as are openings of mantle fultoportules. Spines may be few or lacking. Figures 16, 17. Internal views showing larger central areolae and smaller marginal openings. Few central fultoportulae with three satellite pores are present. Scale bars = 1 μm.

by the placement of the rimoportula (on the face-mantle border in *Thalassiosira dispar*, on the mantle in *Tertiariopsis imperseptus*).

***Tertiariopsis sibericus* Khursevich, Fedenya & Kociolek, sp. nov.**
Figs. 8–11, 18–23. Figure 8 is the holotype.

DESCRIPTION. — Valves circular, flat or slightly convex, 7.5–15.3 μm in diameter. Areolae 12–15/10 μm along a radius, arranged in radial rows of unequal length. Areolae decrease in size towards the valve margin, where mantle areolae are distinctly separated from those on the valve face. The valve mantle is divided into distinct sections separated by hyaline strips. These sections have 7–8 vertical rows of small areolae. The center of the valve has either an irregular pattern of areolae or the center is structureless. Valve face fultoportulae, 2–10, occur in radial areolar rows near the center of the valve and occupy the place of areolae. They have three (rarely two) satellite pores. Externally, they may have small projections. A single sessile rimoportule is placed on the valve mantle. External expression of marginal fultoportulae (6 in 10 μm) appear as distinct, rounded pores close to the edge of the valve mantle at the base of hyaline strips. Internally they have three satellite pores.

HOLOTYPE. — Slide 3407a, BDP 96-1, core 93-1 (38–39 cm), deposited in the Khursevich Collection, Institute of Geological Sciences, National Academy of Sciences of Belarus, Minsk.

ISOTYPES. — Slide 3407b, BDP 96-1, core 93-1 (38–39 cm), deposited in the Baikal Drilling Project Collection, Institute of Geochemistry, Siberian Branch of Russian Academy of Sciences, Irkutsk, Russia. Type material has also been deposited in the Diatom Collection, California Academy of Sciences.

TYPE LOCALITY. — Underwater Academician Ridge of Lake Baikal, Russia, borehole BDP 96-1, depth 188.0–194.0 m from sediment surface.

GEOLOGICAL ERA. — Early Pliocene.

ETYMOLOGY. — Named for Siberia, the region of Russia where Lake Baikal is situated.

COMMENTS. — This species differs from *Thalassiosira cuitzeonensis* Israde, Serieyssol & Gasse (Serieyssol et al. 1998:180–182, figs 11–20) by the finer areolation of the valve face surface (10–12/10 μm in *T. cuitzeonensis* versus 12–15/10 μm in *Tertiariopsis sibericus*) and the position of the rimoportula (in *Thalassiosira cuitzeonensis* it is placed near one side and closest to the base of a marginal fultoportula, whereas in *Tertiariopsis sibericus* it is placed approximately one-half the distance between two marginal fultoportulae).

***Tertiariopsis makarovae* Khursevich & Kociolek, sp. nov.**
Figs. 5–7, 24–27. Figure 5 is the holotype.

DESCRIPTION. — Valves are circular with slightly convex or concave surfaces, 8.5–14.2 μm in diameter. Areolae, up to 15 in 10 μm along the radius, are arranged in radial rows of unequal length forming radiating fascicles. The latter are separated by interfascicles, continuing to the end of the valve mantle. The fascicles are biseriate to quadriseriate (rarely up to six rows) at the valve margin of the valve face, becoming uniseriate towards the center. The mantle areolae are smaller in size and are grouped in linear rows (4–5 small areolae in each row). One fultoportula with three satellite pores can be seen near the center. Valve mantle with more or less a regular ring of marginal fultoportulae, 4–6/10 μm. They have three satellite pores on the internal valve surface and open by small apertures at the base of interfascicles externally. A single sessile rimoportula is located on the mantle halfway between two marginal fultoportulae.

HOLOTYPE. — Slide 3379a, BDP 96-1, core 92-1 (76–77 cm), deposited in the Khursevich Collection, Institute of Geological Sciences, National Academy of Sciences of Belarus, Minsk.

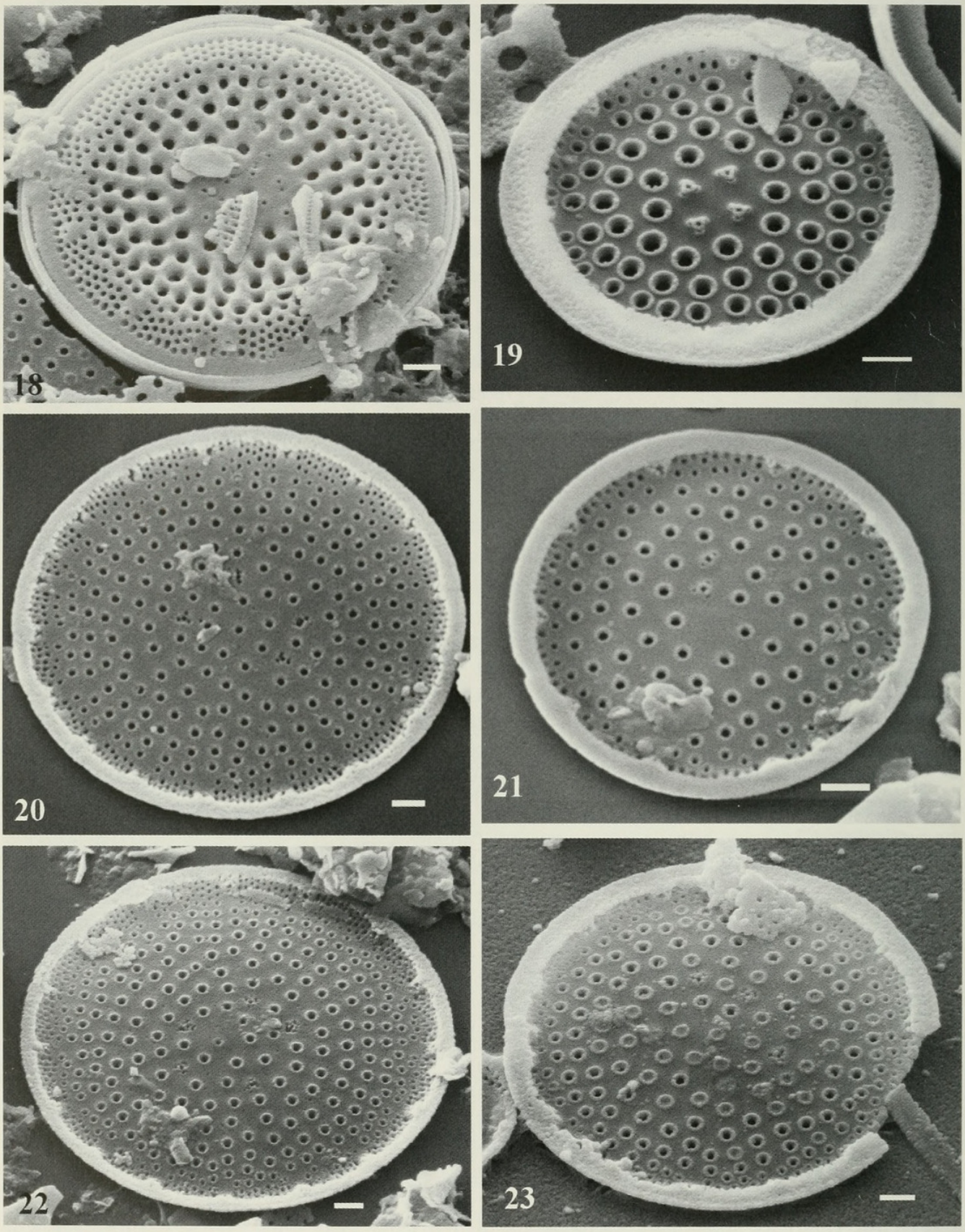

PLATE 3. SEM. *Tertiariopsis sibericus* Khursevich, Fedenya & Kociolek, sp. nov. Figure 18. Valve exterior. Note numerous openings of central fultoportulae and sectors of smaller areolae on mantle separated by hyaline strips. Figures 19–23. Internal views. An alveolus is present, though its development is narrow to wide. Central fultoportulae have three satellite pores. Scale bars = 1 μm.

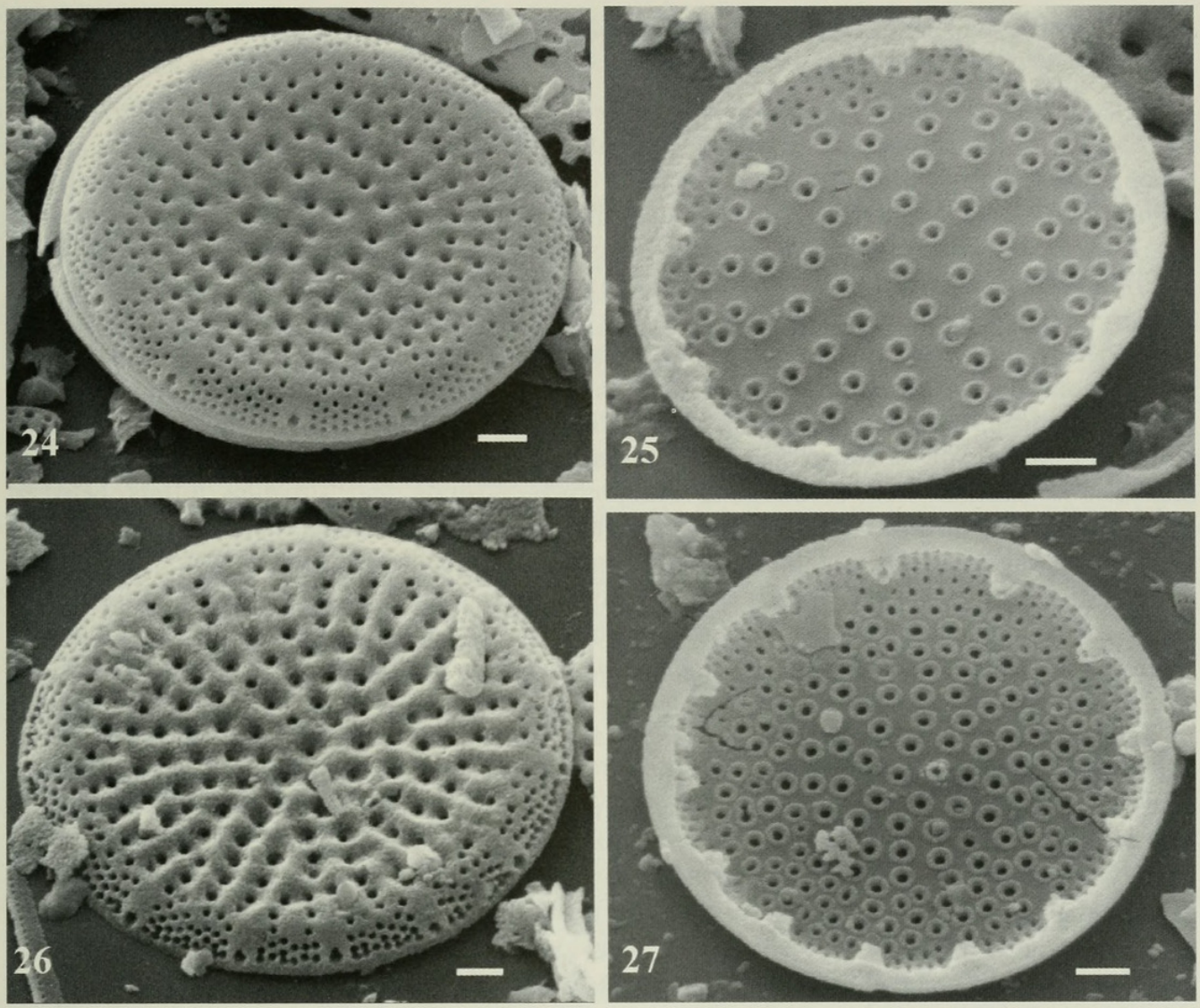

PLATE 4. SEM. *Tertiariopsis makarovae* Khursevich & Kociolek, sp. nov. Figures 24 and 26. External views. Surface is smooth to having elevated siliceous ridges. Groups of fine areolae are positioned on the mantle, separated by hyaline strips. Figures 25 and 27. Internal views. Central fultoportulae have 3 satellite pores. Marginal fultoportulae are prominent. A rimoportule is positioned on the valve face:mantle junction. Scale bars = 1 μm.

ISOTYPE. — Slide 3379b, BDP 96-1, core 92-1 (76–77 cm), deposited in the Baikal Drilling Project Collection, Institute of Geochemistry, Siberian Branch of Russian Academy of Sciences, Irkutsk, Russia. Type material has also been deposited in the Diatom Collection, California Academy of Sciences.

TYPE LOCALITY. — Underwater Academician Ridge of Lake Baikal, Russia, borehole BDP 96-1, depth 188.0–192.0 m from sediment surface.

GEOLOGICAL ERA. — Early Pliocene.

ETYMOLOGY. — Named in honor of our late colleague Prof. I. V. Makarova of Komarov Botanical Institute, Russian Academy of Sciences, St. Petersburg, Russia.

COMMENTS. — This species differs from *T. imperseptus* by the presence of distinct areolar fascicles separated by hyaline strips on the valve surface. *Tertiariopsis makarovae* differs from *T. sibericus* in the position and number of valve face fultoportulae.

DISCUSSION

The new genus *Tertiariopsis* differs from *Tertiarius* Håkansson & Khursevich (1997:21–22, figs. 5–33) by the absence of alveoli on the valve mantle and by the different position of the rimoportula (present near the base of costae or within a chamber of the alveolus internally in *Tertiarius* versus at the same level as marginal fultoportulae on the valve mantle in *Tertiariopsis*).

Tertiariopsis differs from *Thalassiosira* Cleve (Hasle 1978; Makarova 1981, 1988; Round et al. 1990) in several important ways. First, the two genera differ in the structure of the valve face. In *Tertiariopsis* areolae in uniseriate striae near the center frequently become multiseriate towards the margin. In *Thalassiosira* areolae are arranged in more-or-less dense, radial, tangential or eccentric rows. Second, the two genera differ by the structure of the valve mantle. In *Tertiariopsis*, the mantle is divided into distinct sections, consisting of 6–10 vertical rows of small areolae separated by hyaline strips. In *Thalassiosira*, small areolae are in vertical, diagonal or crossed rows that are not arranged into distinct sections. Third, marginal fultoportulae position and structure differs between *Thalassiosira* and *Tertiariopsis*. In *Tertiariopsis* a ring of marginal fultoportulae is placed near the edge of the valve and covered internally by a marginal lamina. In *Thalassiosira* marginal fultoportulae are positioned at the valve face/mantle junction and lack laminae coverings. Fourth, the two genera are distinguished by structure of rimportula. External rimportula opening lacks a tubulus in *Tertiariopsis*, but a tubulus is present in *Thalassiosira* (except a small group of freshwater, fossil species-see Kociolek and Khursevich 2001).

Some similarities exist between *Tertiariopsis* and *Stephanodiscus* Ehrenb. (Round 1981; Theriot et al. 1987; Khursevich 1989; Round & Håkansson 1992), including the valve face with fasciculate radial areolae, marginal fultoportulae with 3 satellite pores around the mantle and the absence of alveoli. The two genera differ in terms of internal cribra (domed in *Stephanodiscus*, apparently flat or raised slightly in *Tertiariopsis*), structure of rimoportulae (external openings usually tubules in *Stephanodiscus*; tubules are absent in *Tertiariopsis*), and the relationship of marginal fultoportulae on the external valve surface and spines (they are usually found together in *Stephanodiscus*, but this relationship between spines and external fultoportulae openings is not consistent in *Tertiariopsis*; in fact in most cases spines and fultoportulae openings are not positioned together in this new genus).

Tertiariopsis may also be compared with *Stephanopsis* Khursevich & Fedenya, another genus described from the sediments of Lake Baikal (Khursevich et al. 2000). Both genera lack alveolar striae, have marginal fultoportulae with 3 satellite pores, have external marginal fultoportulae openings lacking tubules, and may have or lack spines. The two genera differ, however, by the presence of thin, radial costae crossing the mantle internally in *Stephanopsis* and in the placement of rimoportulae (occurring at the end of one to several costae at the margin, or near the center of the valve face in *Stephanopsis*, but on the mantle exclusively in *Tertiariopsis*).

The genus may include French and Mexican species described by Serieyssol et al. (1998) from fossil localities. These species, originally placed in *Thalassiosira*, lack alveolae and appear to have a valve mantle dissected by hyaline strips. Transfer of these species to *Tertiariopsis* awaits review of type material and further detailed SEM study.

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