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NEW *THALASSIOSIRA* SPECIES (BACILLARIOPHYTA) FROM HOLOCENE SEDIMENTS OF THE BUNGER OASIS, EAST ANTARCTICA*

RINAT M. GOGOREV, ZINAIDA V. PUSHINA, MARTIN MELLES & SERGEY R. VERKULICH

Abstract. Studies of Holocene marine sediments from the Bunger Oasis (East Antarctica) collected during the joint Russian-German Expedition in 1993–1994 revealed several dominant diatom species. This paper focuses on the morphology of *Thalassiosira* species studied by light and scanning electron microscopy. One of them, *Thalassiosira longifultoportulata* Gogorev & Pushina *sp. nov*., characterized by relatively large valves, several central fultoportulae, one ring of marginal fultoportulae and a single rimoporula, is described here as new for science. The unique morphological feature of *T. longifultoportulata* are the very long external tubes of marginal fultoportulae. Based on some morphological features (especially number and location of subcentral fultoportulae clusters) another new species *Thalassiosira bungerensis* Gogorev & Pushina *sp. nov.* is described.

Key words: diatoms, morphology, new taxa, *Thalassiosira*, sediment cores, Holocene, Bunger Hills, East Antarctica

Rinat M. Gogorev, Department of Algology, Komarov Botanical Institute, Russian Academy of Sciences, Prof. Popov Street, 2, St. Petersburg 197376, Russia; e-mail: gogorev@mail.ru
Zinaida V. Pushina, Russian Research Institute for Oceanology and Mineral Resourses, Angliyskiy Street, 1, St. Petersburg 190121, Russia; e-mail: musatova@mail.ru
Martin Melles, Universität zu Köln, Mathematisch-Naturwissenschaftliche Fakultät, Institut für Geologie und Mineralogie, Zülpicher Str., 49a, D-50674, Köln, Germany; e-mail:mmelles@uni-koeln.de
Sergey R. Verkulich, Arctic and Antarctic Research Institute, Department of Polar Geography, Bering Street, 199226, St. Petersburg, Russia; e-mail: verkulich@mail.ru

INTRODUCTION

In 1993–1994, a joint Russian-German scientific expedition undertook coring of lacustrine and marine sediment in the Bunger Oasis. This paper considers two new taxa found in bottom sediments from the marine basins in the Bunger Oasis.

The Bunger Oasis (66°16′S, 100°45′E; Fig. 1) forms one of the largest ice-free areas in East Antarctica, located to the east of the Scott/Denman Glacier system. To the north the Oasis is bordered by the Shackleton Ice Shelf, to the east by the East Antarctic Ice Sheet, to the south by the Apfel Glacier, and to the west by the Edisto Glacier. The southern part of the Oasis (Southern Hills) is a large land area of *ca* 280 km^2 with a great number of freshwater lakes. To the north, numerous islands are separated from the Southern Hills by marine basin inlets (Edisto Channel, Kakapon Bay, Rybiy Khvost Bay), which have a hydraulic connection to the open ocean beneath the floating glaciers and the Shackleton Ice Shelf.

The climate in the Southern Hills is characterized by average monthly temperatures of up to 1.8°C in summer down to –20.6°C in winter, and by precipitation of *ca* 200 mm/yr and potential evaporation of 400–600 mm/yr (Rusin 1961). The waters of marine basins on the Bunger Oasis are NaCl type (Klokov *et al.* 1989), with Si content of 1–10 mg Si/l. Recently the waters of the Rybiy Khvost Bay show extremely high phytoplankton production. The chlorophyll *a* concentration is 1–10 mg/l in this bay. In Rybiy Khvost Bay, salinity varies from 9‰ under the ice cover to 18.6‰ at 20 m depth. The highly

* Dedicated to Dr. Kurt Krammer on the occasion of his 85th birthday

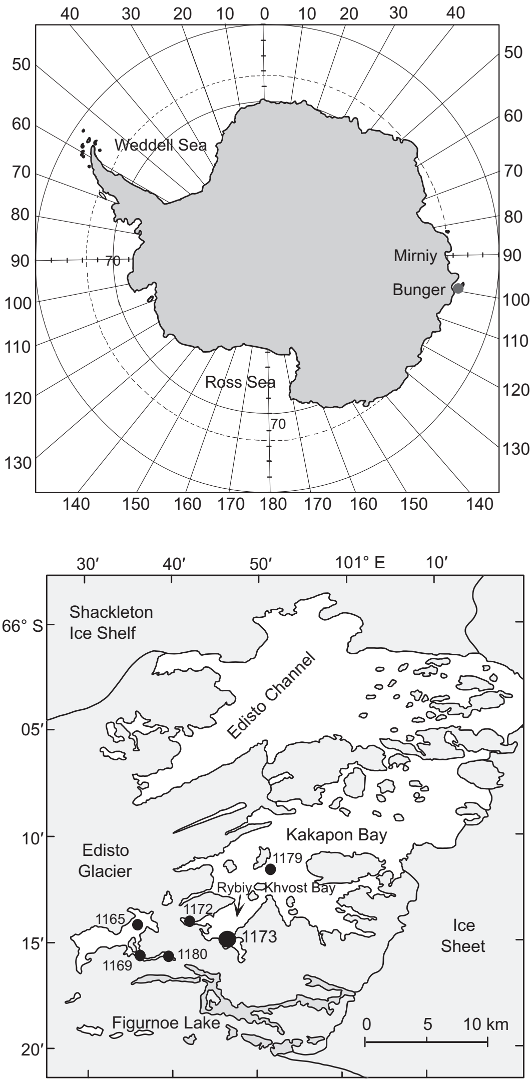


Fig. 1. Sampling sites and geographical setting of Bunger Oasis, East Antarctica.

mineralized water in Rybiy Khvost Bay is of marine origin.

Modern diatom assemblages in lakes of the Bunger Oasis were investigated by Gibson *et al.* (2006). There are no data on modern marine diatoms in this region. Fossil diatoms were studied and analyzed for diatom composition and abundance in sediment cores from the marine basins (Bolshiyanov *et al*. 1991; Melles *et al*. 1997; Kulbe *et al*. 2001; Pushina *et al*. 2004; Pushina 2008) and in sediment cores from the lakes (Roberts *et al*. 2000; Verkulich *et al*. 2002).

Material and methods

Marine and lacustrine sediment sequences were sampled by gravity and piston corers from a platform (3.5 × 2.7 m), which was run either with 4 inflatable rubber pontoons on open water or with 4 runners on lake ice. The gravity corer was employed for sampling undisturbed near-surface sediments. Long sediment sequences were recovered with the piston corer (Melles *et al*. 1994b). Sediment cores PG 1165 (246 cm), PG 1169 (190 cm), PG 1172 (265 cm), PG 1173 (1278 cm), PG 1179 (100 cm), PG 1180 (1202 cm) were sectioned on site at 0.2 cm intervals. Sampling locations are shown in Figure 1. The samples were processed for LM and SEM by standard procedures (Jousé *et al*. 1969); 300 diatom valves of each sample were counted at 1000×.

Stratigraphic information was obtained by radiocarbon dating of the total organic carbon of marine and lacustrine sediments (Melles *et al*. 1994a, b, 1997). Measurements were performed by accelerator mass spectrometry at the Research Laboratory for Archaeology and History of Art, Oxford. Full marine environments with biogenic sedimentation were established at 8540±80 BP (Bolshiyanov *et al*. 1991; Melles *et al*. 1994a, b, 1997; Kulbe *et al*. 2001). The lithology, radiocarbon chronology, granulometry, chemistry and distribution of diatoms were analyzed. Analyses of the sediment composition revealed the environmental history of the water basins, providing information about the evolution of the Hills.

Results

The deglaciation on the Bunger Oasis started close to the Pleistocene/Holocene boundary with rapid ice decay, at least in the Southern Hills. The diatom flora from sediments of the marine basins of the Bunger Oasis is here determined for the first time. About 100 diatom species and one silicoflagellate *Dictyocha speculum* were identified in marine diatom-rich sediments. The most species-rich genera are *Fragilariopsis* (11 species), *Navicula* (8; 4 undetermined), *Thalassiosira* (7), *Cocconeis* (5). The taxonomic composition of diatoms found is more or less similar to modern marine assemblages of near-shore Antarctic waters. *Chaetoceros* resting

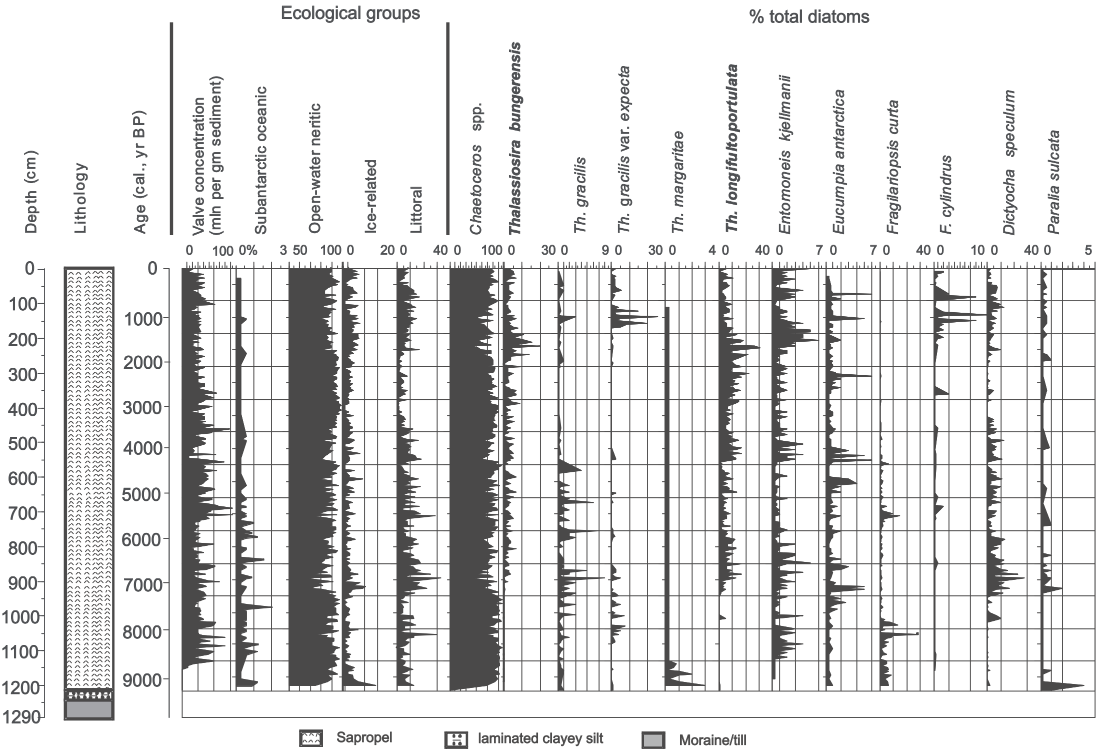


Fig. 2. Lithology and Holocene variations of diatoms in sediment core PG 1173 of Rybiy Khvost Bay (Bunger Oasis, East Antarctica).

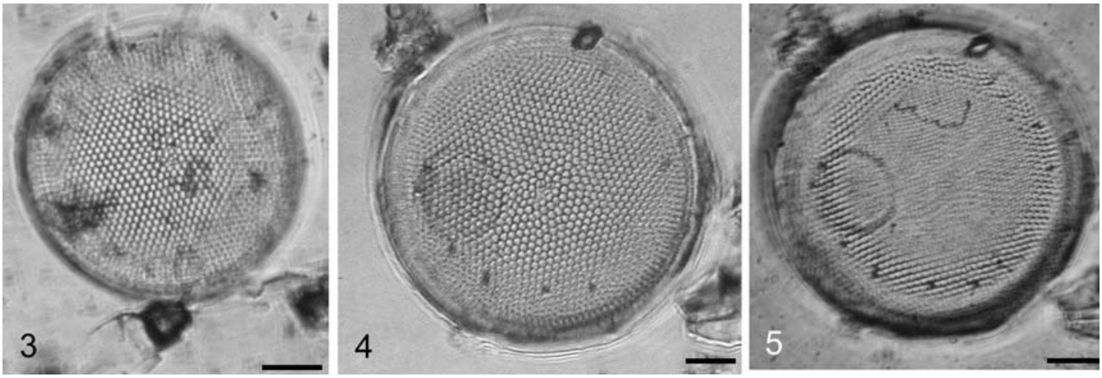
spores identified as *Chaetoceros neglectus* Karsten were the most abundant. Diatom assemblages are dominated by *Chaetoceros* spp., mostly from elsewhere in the sediments of marine bays (Pushina *et al*. 2004; Pushina 2008). The distribution and abundance of diatoms in core PG 1173 are shown in Figure 2. The study revealed 2 thalassiosiroid diatoms which could not be assigned to known taxa; these are described here.

In the distribution of these two abundant and interesting *Thalassiosira* species through the long sediment core PG 1173 (1290 cm, water depth 91 m), the first appearance of the species is recorded at 1205 cm depth, where only marine conditions were established. The abundance of these two species was very low in the basal part of the core and increased only at *ca* 7000 BP. The highest abundance (31% of total diatom assemblage abundance) of *Thalassiosira* new species was determined at 1000–2000 BP (Fig. 2). The most stable and warm Holocene paleoceanographic conditions in the Bunger Oasis were established at 4300–1800 BP.

The first data on the morphology and taxonomy of the new taxa were presented earlier in an abstract (Gogorev & Pushina 2006). Valid descriptions of these taxa are given below.

Thalassiosira longifultoportulata Gogorev & Pushina, ***sp. nov.*** Figs 3–17

Valvae circulares, subconvexae, margine planae, 32–80 µm in diametro, limbus valvae nanus. Areolae in seriebus radialibus, fasciculatae, (6)7–8 in 10 µm in faciei valvae et 10–12 in 10 µm in limbui valvae, foraminis circularia. Fultoportulae centrales 3–7, raro usque ad 9, earum tubuli externi ad 2 µm alt. Fultoportulae marginales in anulo singulari, 6–9(10) in 10 µm, earum tubuli externi praecelsi, 2–6 µm alt., per 1 areola inter se separati. Rimoportula singularis, tubulo magno (quam fultoportulis grandior) pervio externo, 2.7–3.5 µm alt.



Figs 3–5. Valves of *Thalassiosira longifultoportulata* Gogorev & Pushina *sp. nov*. Figs 4 and 5 are same specimen viewed at different focal planes – on center (4), on valve margin (5). All LM. Scale bars = 10 μm.

et 0.7–1.4 μm in diametro, et interno labiato, ad 2.6 μm alt., anulo fultoportularum marginalium juxtapositus.

TYPE: ANTARCTICA, Rybiy Khvost Bay, Bunger Oasis, in Holocene sediments (1290 cm) at 91 m depth, 66°15′S, 100°46′E, core PG1173-2, 238–240 cm, 22 February 1994, *leg. M. Melles* [HOLOTYPE: Slide no. A1173-2 (238–240), Diatom Collection (LE), Department of Algology, Komarov Botanical Institute, Russian Academy of Sciences, St. Petersburg (Figs 6 & 7); ISOTYPE: Slide no. B1173-2 (238–240), Diatom Collection, Russian Research Institute for Oceanology and Mineral Resources, St. Petersburg].

ETYMOLOGY: The Latin epithet is translated ‘long marginal strutted processes’.

Valves circular, almost slightly convex, flat on margin, 32–80 μm in diameter, mantle shallow (Fig. 7). Areolae pattern radial, fasciculated (Fig. 6), foraminae circular (Figs 13 & 16). Areolae (6–)7–8 in 10 μm on valve face and 10–12 on valve mantle. Fultoportulae with 4 satellite pores (Fig. 17). Central fultoportulae 3–7 or rarely up to 9, external tubes up to 2 μm long (Figs 16 & 17). One ring of densely packed marginal fultoportulae, 6–9(–10) in 10 μm (usually 7–8), with very long external tubes, 2–6 (usually 3.5–5.0) μm long, 1 process for each areola (Figs 6, 7, 11 & 12). Single rimoportula with large external tube, 2.7–3.5 μm long and 0.7–1.4 μm in diameter, usually longer than those of marginal fultoportulae, and large internal labiate tube, up to 2.6 μm long, located very nearly in ring of marginal fultoportulae (Figs 12 & 13). Slit of rimoportula nearly radial (Figs 14 & 15).

ECOLOGY. Marine, probably, cold-water neritic species.

DISTRIBUTION. Fossil species, recorded only in the Holocene from the Bunger Oasis. Antarctic endemic.

NOTES. In all samples observed, *T. longifultoportulata* was relatively abundant (0.3–31.0% of the diatom assemblages). From the data available, no similar species was noted in Holocene deposits of other areas (e.g., Cremer *et al*. 2003) or in modern plankton of the Antarctic.

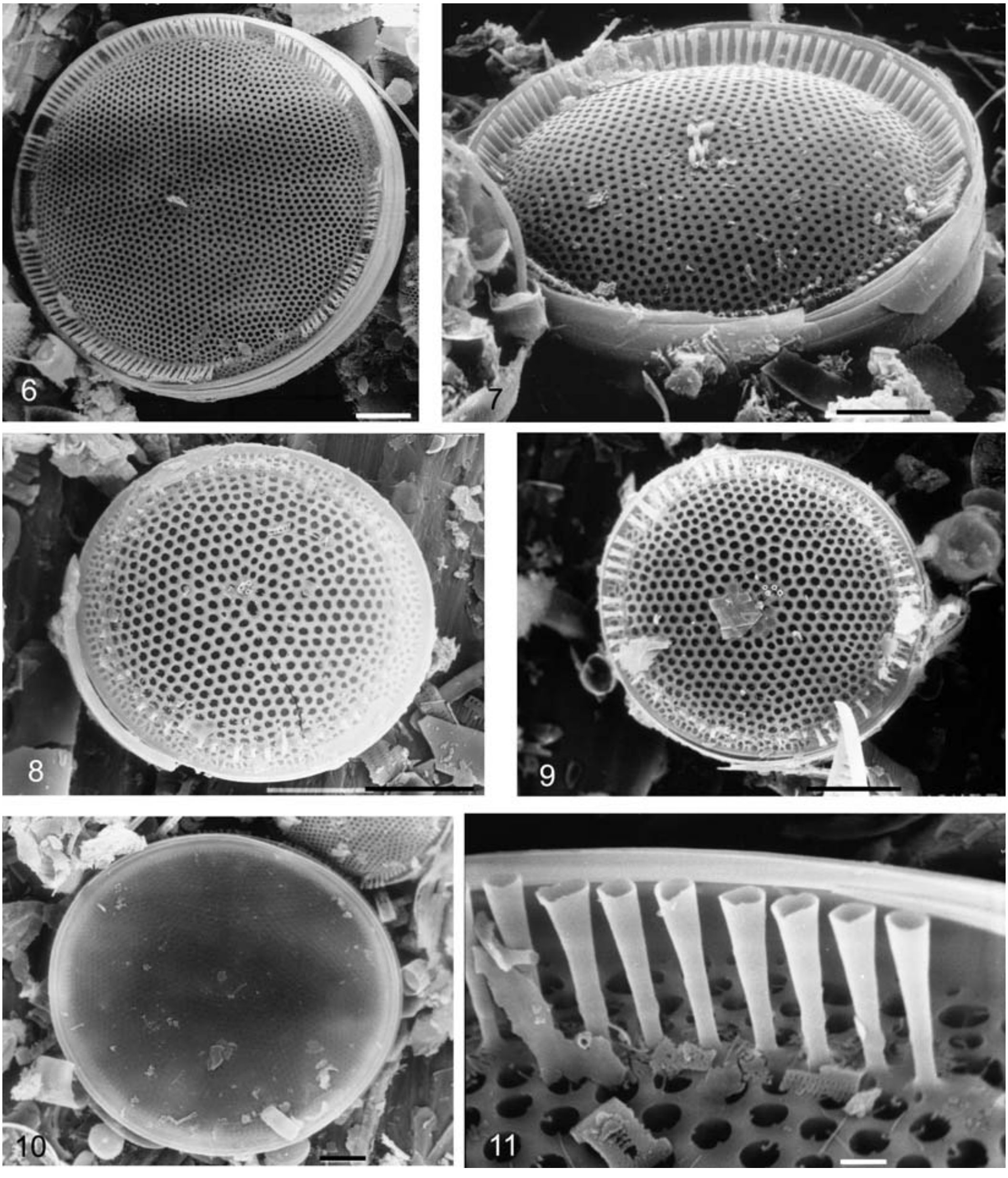
A peculiar morphological feature of the new species is its very long and beautiful marginal fultoportulae, 2–6 μm long. The marginal ring of the long fultoportulae is difficult to see on the mantle in LM (Figs 3–5). Extensions of the marginal fultoportulae can be seen in detailed SEM micrographs nearly at any angle if they are not broken (Fig. 8).

Interesting data have been obtained on the morphology of another *Thalassiosira* taxon closely related to *T. australis*. Based on some morphological features a new species is proposed.

Thalassiosira bungerensis Gogorev & Pushina, ***sp. nov.*** Figs 18–32

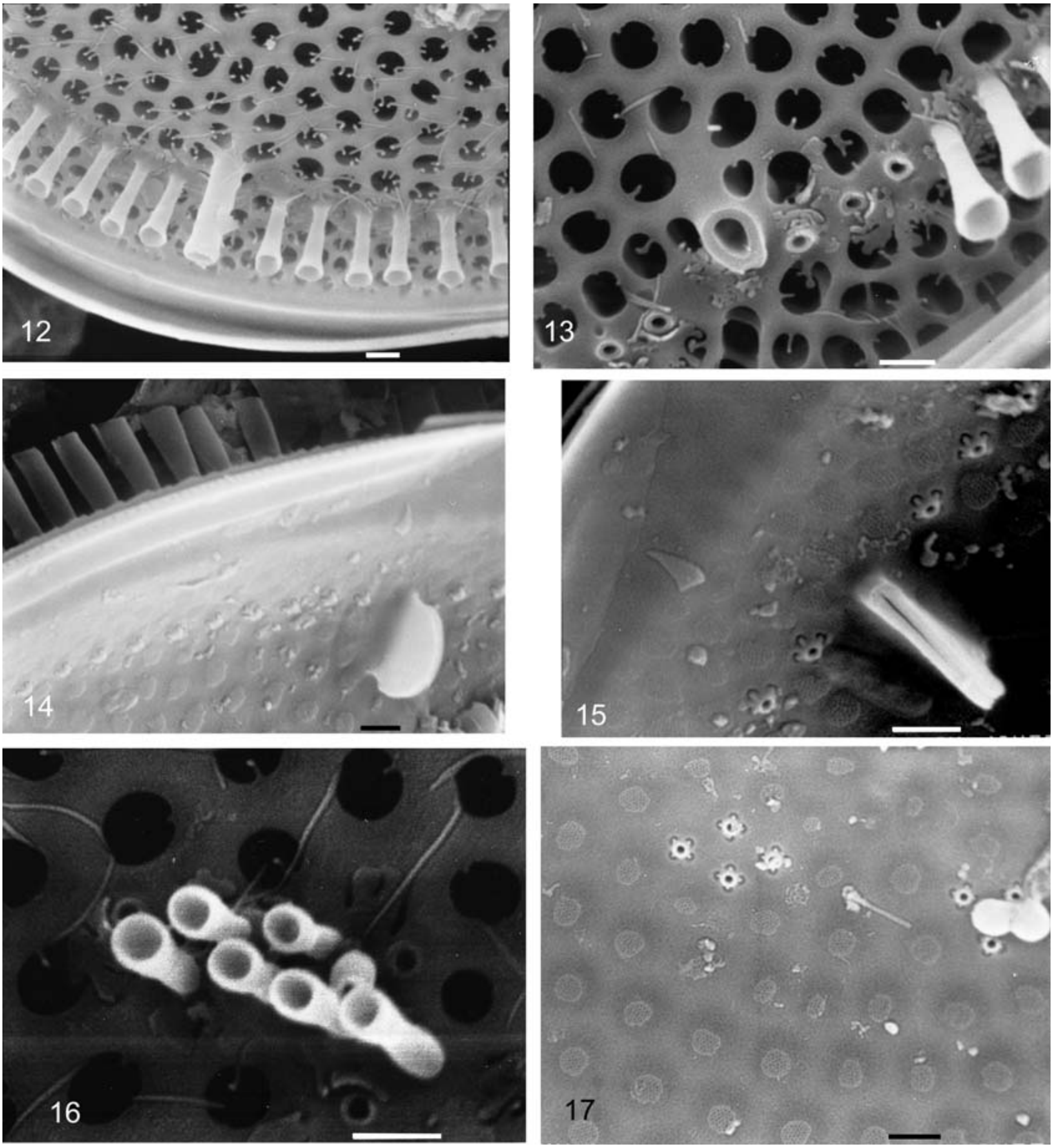
Thalassiosira australis sensu McMinn & Hodgson 1993, Fig. 9.

Frustulae tympaniforme, plus minusve aequale in altitudini et diametro. Valvae convexae, 26–47 μm in diametro,



Figs 6–11. Valve of *Thalassiosira longifultoportulata* Gogorev & Pushina *sp. nov*. 6–9 – exterior (8 & 9 – well visible central fultoportulae), 10 – interior, 11 – marginal fultoportulae. All SEM. Scale bars: 6–10 = 10 µm; 11 = 1 µm.

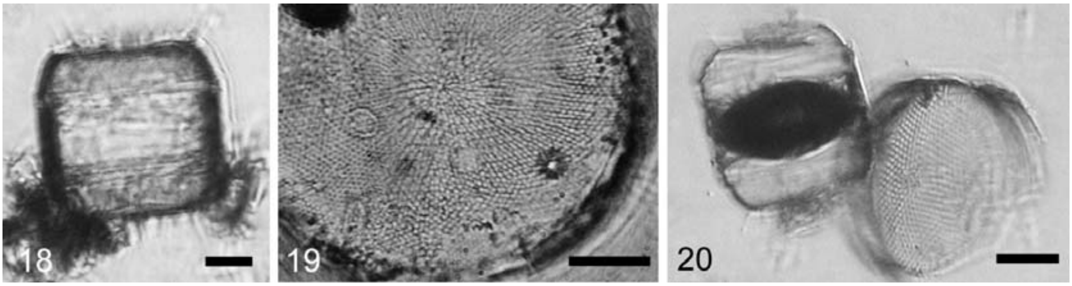
limbus valvae altus. Areolae in seriebus radialibus, 12–13 in 10 µm in faciei valvae et 11–20 in 10 µm in limbui valvae, foraminis circularia in faciei valvae, elongata elliptica prope centrum valvae. Fultoportulae subcentrales numerosae, in 4–8 gregibus, 9–20(*28*) *in gregi quovis. Fultoportulae marginales in anulo singulari, 3–4 in 10 µm, earum tubuli externi breves, minus 1 µm alt. Rimoportula singularis, in anulo processibus occlusis positus, rima tubuli interni radiatum versa. Processus occlusi aut desunt aut in anulo singulari, 2–3 in 10 µm, earum tubuli externi praecelsi, 4–15 µm alt., angustati et curvati ad centrum valvae.*



Figs 12–17. Valvar structure of *Thalassiosira longifultoportulata* Gogorev & Pushina *sp. nov*. 12–15 – marginal fultoportulae and rimoportula (12 & 13 – exterior, 14 & 15 – interior), 16 & 17 – central fultoportulae (16 – exterior, 17 – interior, showing satellite pores). All SEM. Scale bars: 6–10 = 10 μm; 11 = 1 μm.

TYPE: ANTARCTICA, Rybiy Khvost Bay, Bunger Oasis, in Holocene sediments (1290 cm) at 91 m depth, 66°15′S, 100°46′E, core PG1173-2, 238–240 cm, 22 February 1994, *leg. M. Melles* [HOLOTYPE: Slide no. A1173-2 (238–240), Diatom Collection (LE), Department of Algology, Komarov Botanical Institute, Russian Academy of Sciences, St. Petersburg (Figs 21 & 23); ISOTYPE: Slide no. B1173-2 (238–240), Diatom Collection, Russian Research Institute for Oceanology and Mineral Resources, St. Petersburg].

Frustule drum-shaped in girdle view, with pervalvar axis length less than or equal to diameter (Figs 18 & 21). Valves convex, 26–47 μm in



Figs 18–20. *Thalassiosira bungerensis* Gogorev & Pushina *sp. nov*. 18 – mantle view of frustule, 19 – valve face, 20 – frustule with putative endogenous resting spore. All LM. Scale bars: 18 & 20 = 10 µm; 19 = 5 µm.

diameter, with high mantle (Fig. 21). Areolae in radial rows, 12–13 in 10 µm on valve face, 11–20 in 10 µm on mantle, foraminae circular and elongated elliptical at valvar center (Figs 22 & 25). 4–8 clusters of numerous subcentral fultoportulae, in cluster 9–20(–28) fultoportulae (Figs 23, 27, 30 & 31). Single ring of marginal fultoportulae, 3–4 in 10 µm, with short external extensions less than 1 µm (Fig. 29). Fultoportulae with 4 satellite pores. One rimortula with radially located slit of labiate tube outside (Fig. 32). Occluded processes 2–3 in 10 µm when present, arranged in single ring that includes the rimoportula, external tubes of processes very long (4–15 µm), curved to valve center and narrowed on their distal part (Figs 21, 24, 27 & 30).

Etymology: The new species is named after its type locality.

Ecology. Marine, probably, cold-water neritic species.

Distribution. The new species is recorded in Holocene sediments from the Bunger Oasis and in modern phytoplankton from the Vestfold Hills. Antarctic endemic.

Notes. *Thalassiosira bungerensis* seems to be a spore-forming taxon. We observed frequently resting spores inside frustules only in LM (Fig. 20), but we could not study them in SEM.

Discussion

The genus *Thalassiosira* is represented at least by 19 species in Antarctic waters (Johansen & Fryxell 1985). Some species were described in fossil materials or surface sediments.

Comparisons are drawn between *Thalassiosira longifultoportulata* and species having several central fultoportulae (CF), one ring of marginal fulotoportulae (MF) and one rimoportula (Table 1). Similar characteristics are seen in 22 species; 6 of them are chosen for comparison here.

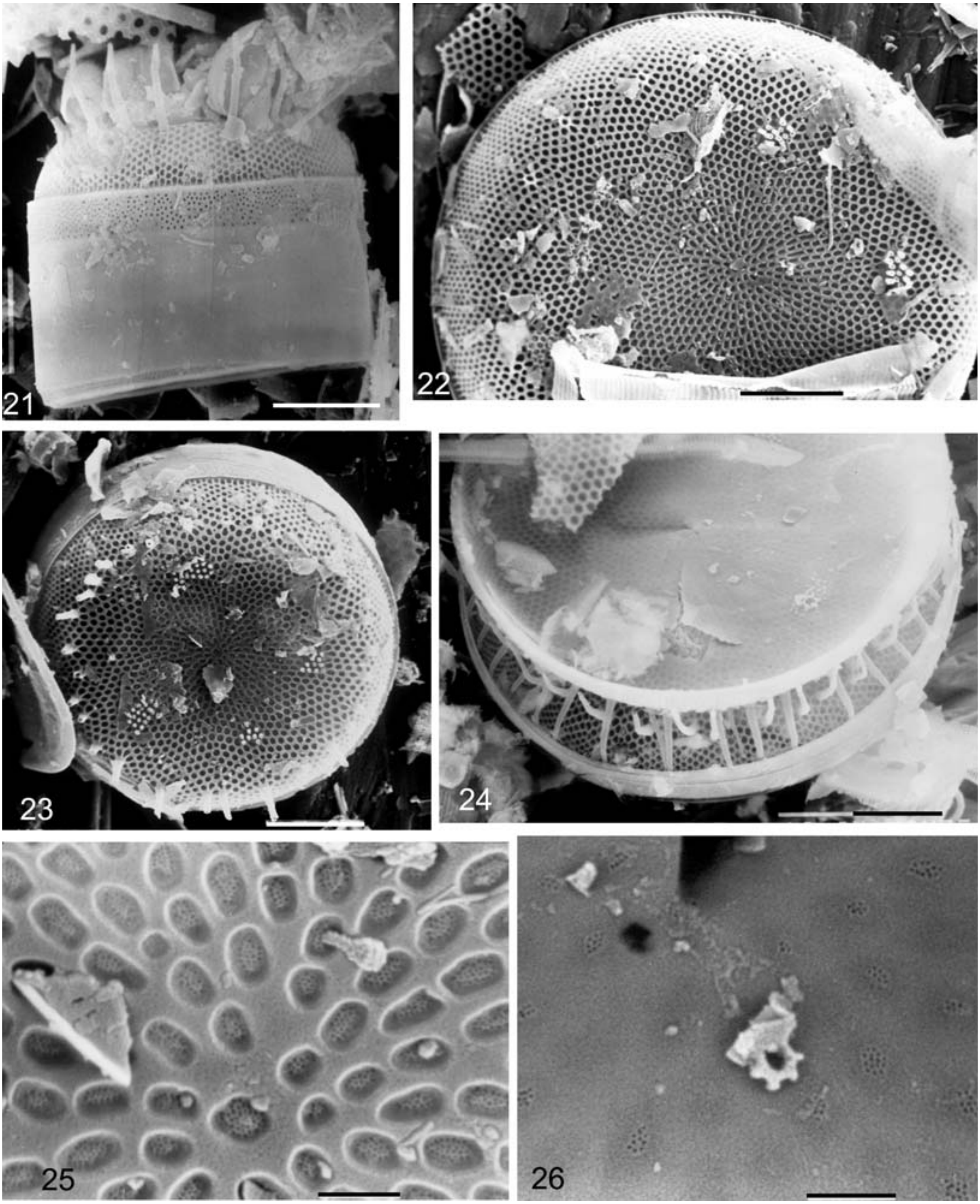
The new species is externally similar and seems to be closely related to *Thalassiosira densannula*. Many morphological features of the two species, including MF density (one per areola), are very similar. The main distinctions are in the arrangement of areolae on the valve (linear in *T. densannula* and radial in *T. longifultoportulata*) and MF length.

The new species is closely related to *Thalassiosira gerloffii* but has less dense areolae on the valve face (7–8 instead of 13–18 in 10 µm) and a more variable areolae pattern. In general, *Thalassiosira longifultoportulata* seems similar to several taxa of the genus and differs in having longer strutted processes extending.

Occluded processes are known for 13 species of *Thalassiosira*. Morphological data for some taxa are summarized in Table 2.

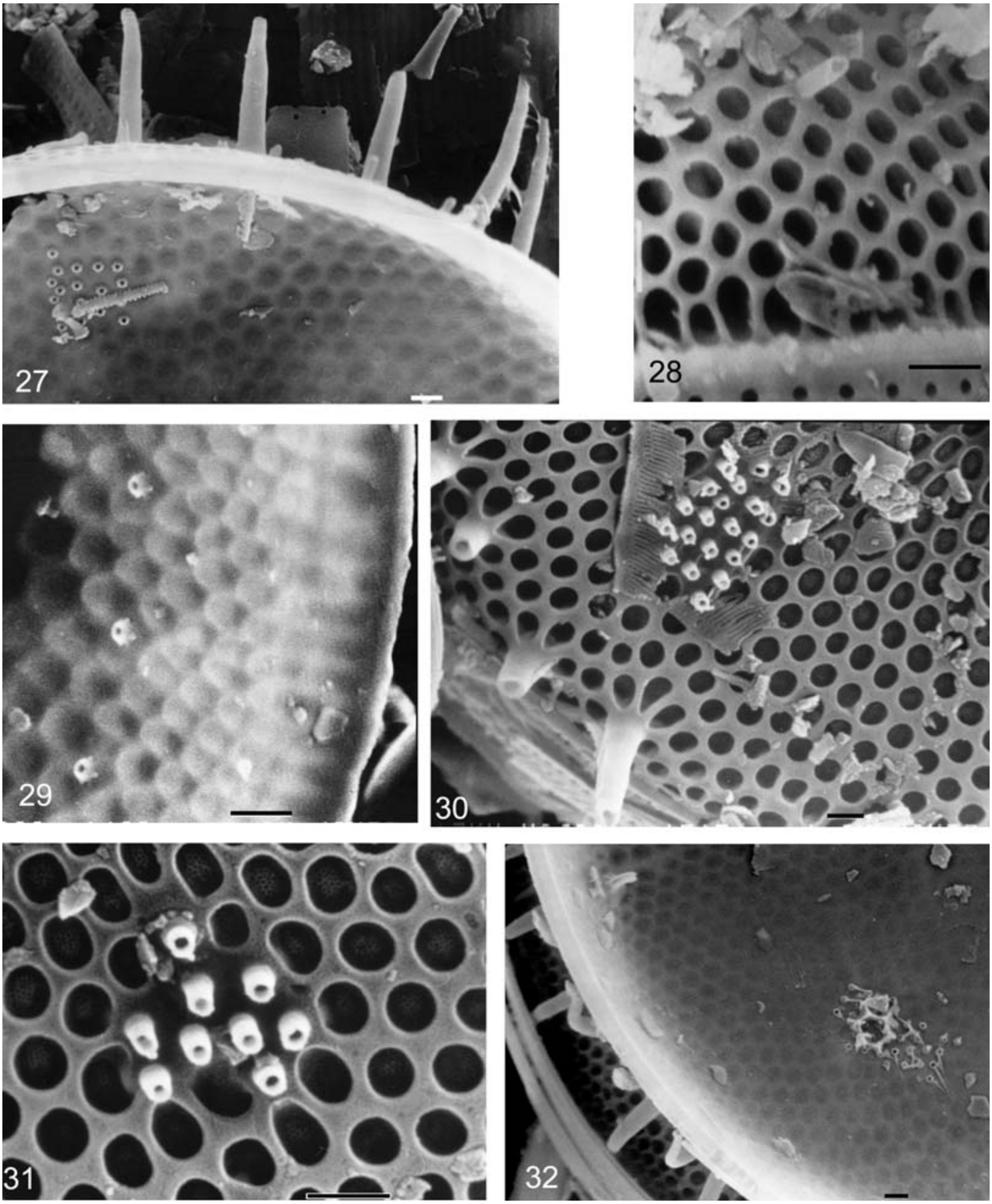
Thalassiosira bungerensis, like *T. australis*, has a combination of characters such as clusters of subcentral fultoportulae and occluded processes which are not recorded for any other *Thalassiosira* species.

Thalassiosira bungerensis can be distinguished from *T. australis* by the following: (*i*) there are more numerous clusters of subcentral fultoportulae (4–8 rather than 2–4); (*ii*) the location of these clusters is closer to the valve margin than the valve



Figs 21–26. *Thalassiosira bungerensis* Gogorev & Pushina *sp. nov*. 21 – valve mantle with occluded processes, 22, 23 – valve exterior, 24 – adjacent valves, 25, 26 – valve center (25 – outside, 26 – interior with velum occluding the areolae). All SEM. Scale bars: 21–24 = 10 μm; 25 & 26 = 1 μm.

center, and so should be deemed submarginal; (*iii*) the number of fultoportulae per cluster is smaller (9–28 rather than 11–46); (*iv*) the shape and size of occluded processes; (*v*) the distance between occluded processes; and (*vi*) the probable presence of resting spores (Table 2).



Figs 27–32. Valve structure of *Thalassiosira bungerensis* Gogorev & Pushina *sp. nov*. 27 & 30 – occluded processes and cluster of 'submarginal' fultoportulae, 28 & 29 – marginal fultoportula(e) (28 – exterior, 29 – interior with satellite pores), 31 – cluster of 'submarginal' fultoportulae outside, 32 – adjacent valves showing cluster of 'submarginal' fultoportulae (white arrow) and rimoportula (black arrow) inside. All SEM. Scale bars = 1 µm.

Thalassiosira australis has been observed in benthic habitats in the Antarctic sector of the southwestern Atlantic (Johansen & Fryxell 1985), southern Argentina and South Orkney Islands (Fryxell 1977), rarely in plankton of eastern Antarctic waters (Gogorev 2009), so

Table 1. Comparison of *Thalassiosira* species with several central fultoportulae (CF), one ring of marginal fultoportulae (MF) and one rimoportula.

Taxon	Diameter, µm	Areola pattern	Areolae in 10 µm	Number of CF	MF in 10 µm	MF length, µm	Satellite pores	Distribution	Reference
Thalassiosira longifultoportulata Gogorev & Pushina *sp. nov.*	32–80	radial, fasciculated	(6)7–8 (10–12)	3–7(9), <2 mk	6–9(10)	2–6	4	Bunger Oasis (East Antarctica)	This paper
Thalassiosira densannula Hasle & Fryxell	27–52	linear	6–7	5–6	7–8	1.2–1.5*	3–4	Indian Ocean	Hasle & Fryxell 1977
Thalassiosira dichotomica (Kozl.) Fryxell & Hasle	15–22	radial	*ca* 30	1–6	3–7			SW Atlantic, Indian & SW Pacific sectors of Antarctica	Fryxell & Hasle 1983; Johansen & Fryxell 1985; Fryxell & Johansen 1990
Thalassiosira gerloffii Rivera	16–77	fasciculated	13–18	2–9	6–9 (5–11)			SW Atlantic sector of Antarctica	Johansen & Fryxell 1985; Fryxell & Johansen 1990
Thalassiosira latimarginata Makarova	21.5–53	radial-linear	6–7, 8–10	3–5	2.5–3	1.5 inside	3	NE Pacific, Indian & Pacific sectors of Antarctica	Makarova 1988
Thalassiosira poro-irregulata Hasle & Heimdal	17–40.5	fasciculated	10–15	1–8	4–6	flared skirt		Coastal waters of Chile & Peru	Johansen & Fryxell 1985; Fryxell & Johansen 1990
Thalassiosira poroseriata (Ramsf.) Hasle	14–38	fasciculated	11–16	1–8 (2–5)	1–2	easily visible in LM		North Atlantic, Antarctic	Fryxell & Hasle 1979; Johansen & Fryxell 1985; Fryxell & Johansen 1990

* – data obtained from illustrations only.

Table 2. Comparison of *Thalassiosira* species with central or sub-central fultoportulae (sCF) and occluded processes (OP).

Species	Diameter, µm	Areolae pattern	Areolae in 10 µm	sCF	MF in 10 µm / length, µm	Satellite pores	Rimo-portulae	OP in 10 µm / length, µm	Distribution	Reference
Thalassiosira australis Perag.	23–56	radial, fascicu-lated, bifur-cating*	10–13	2–4(3) clusters, 11(21)–(24)46 in cluster	1 ring, 4–5 (9) / 1.4–2.4	3–4	1	3–4 (0–5) / 3.0–4.1	South Orkney Islands, South Argentina, SW Atlantic sector of Southern Ocean	Fryxell 1977; Fryxell *et al.* 1979; Johansen & Fryxell 1985; Fryxell & Johansen 1990*; Semina & Fryxell 1994
Thalassiosira bun-gerensis Gogorev & Pushina *sp. nov.*	26–47	radial	12–13	4–6(7–8**) clusters, 9–20(28) in cluster	1 ring, 3–4 / <1	4	1	2–3 / 4–15	Bunger Oasis, Vestfold Hills** (Prydz Bay) – East Antarctica	McMinn & Hodgson 1993
Thalassiosira anguste-lineata (A.S.) Fryxell & Hasle	14–60	linear, radial, fascicu-lated	8–12	4–7 clusters, 2–5	1 ring, 3–4 / -	4	1	-	Cold to tem-perate waters	Hasle 1968; Ma-karova 1988
Thalassiosira delicatula Ostf.	9–30	radial*, fascicu-lated	22–26, [25–30(35)*]	1 central + scattered	2–3 rings, 4–5 / <1	3?–5	1	3–4 / 1.8–4.0	North Atlantic	Hasle 1980; Semina & Fryxell 1994
Thalassiosira lundiana Fryxell	13–43		24–30	central + scattered	2 rings (<2), 5–10 / -		1	Several / -	Subtropical to temperate waters	Fryxell 1975; Semina & Fryxell 1994
Thalassiosira scotia Fryxell & Hoban	15–56	radial, fascicu-lated	9–16	8–25	2 rings: 6–8 & 2–3(4) / 0.5–1.1		1	2–5 / 2.1–5.0	Subpolar; Scotia Sea, SW Atlantic sector of Southern Ocean	Fryxell *et al.* 1979; Fryxell & Johansen 1990; Semina & Fryxell 1994
Thalassiosira scotia *resting spores*	18–46	radial	5–8	7–12	3–7 / -		1	3–5 / -		Fryxell & Johansen 1990
Thalassiosira symmetrica Fryxell & Hasle	30–88	eccentric	5–9	ring (7)	1 ring, 4–6 + submarginal, 10–11 / reduced	4–5	2	spines (3–6) / -	Temperate to tropical waters	Ake-Castillo *et al.* 1999
Thalassiosira tubifera Fryxell	19–33		~20	central + clusters	3–4 / -		1	several (3) / -	Warm waters	Fryxell 1975; Semina & Fryxell 1994

* – obtained from illustrations and the literature; ** – after McMinn & Hodgson (1993).

biogeographically this species can be regarded as subantarctic.

Thalassiosira bungerensis has been noted in this study and perhaps in the literature (McMinn & Hodgson 1993, fig. 9, subcentral fultoportulae in 7–8 clusters). This means that the new species may be distributed in East Antarctica in the Vestfold Hills (71°S, 78°E) as recent and in the Bunger Oasis (66°S, 101°E) as fossil.

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REFERENCES

AKE-CASTILLO J. A., HERNÁNDEZ-BECERRIL D. U. & MEAVE DEL CASTILLO M. E. 1999. Species of the genus *Thalassiosira* (Bacillariophyceae) from the Gulf of Tehuantepec, Mexico. *Bot. Mar.* **42**: 487–503.

BOLSHIYANOV D., VERKULICH S., PUSHINA Z. & KIRIENKO E. 1991. Some features of the Late Pleistocene and Holocene history of the Bunger Hills (East Antarctica). In: *Abstract volume: 6th International Symposium on Antarctic Earth Science* (*Saitama, Japan, 9–13 September*), pp. 66–71. National Institute of Polar Research, Tokyo, Japan.

CREMER H., ROBERTS D., MCMINN A., GORE D. & MELLES M. 2003. The Holocene diatom flora of marine bays in the Windmill Islands, East Antarctica. *Bot. Mar.* **46**: 82–106.

FRYXELL G. A. 1975. Three new species of *Thalassiosira*, with observations on the occluded process, a newly observed structure of diatom valves. *Nova Hedwigia* **53**: 57–82.

FRYXELL G. A. 1977. *Thalassiosira australis* Peragallo and *T. lentiginosa* (Janisch) G. Fryxell, comb. nov. two Antarctic diatoms (Bacillariophyceae). *Phycologia* **16**: 95–104.

FRYXELL G. A. & HASLE G. R. 1979. The genus *Thalassiosira*: *T. trifulta* sp. nova and other species with tricolumnar supports on strutted processes. *Nova Hedwigia* **64**: 13–40.

FRYXELL G. A. & HASLE G. R. 1983. The antarctic diatoms: *Thalassiosira dichotomica* (Kozlova) comb. nov. and *T. ambigua* Kozlova. *Polar Biol.* **2**: 53–62.

FRYXELL G. A. & JOHANSEN J. R. 1990. Family *Thalassiosiraceae.* Section 2: The genus *Thalassiosira* from the Antarctic. In: L. K. MEDLIN & J. PRIDDLE (eds), *Polar Marine Diatoms*, pp. 98–103. British Antarctic Survey, Cambridge.

FRYXELL G. A., VILLAREAL T. A. & HOBAN M. A. 1979. *Thalassiosira scotia,* sp. nov.: observations on a phytoplankton increase in early austral spring north of the Scotia Ridge. *Journal of Plankton Research* **1**: 355–370.

GIBSON J. A. E., DONNA R. & VAN DE VIJVER B. 2006. Salinity control of the distribution of diatoms in lakes of the Bunger Hills, East Antarctica. *Polar Biol.* **29**(8): 694–704.

GOGOREV R. M. 2009. Taxonomic composition of planktonic and ice algae in Antarctic waters (2006–2007 studies). *Novosti Sist. Nizsh. Rast.* **43**: 36–49 (in Russian).

GOGOREV R. M. & PUSHINA Z. V. 2006. A new *Thalassiosira* species (*Bacillariophyta*) in Holocene sediments from the Bunger Oasis (Antarctic). In: Y. V. LIKHOSHWAY & R. M. CRAWFORD (eds), *The 19th International Diatom Symposium: Abstracts* (*Listvyanka, 28 August – 2 September, 2006*), p. 51. Institute of Geography SB RAS, Irkutsk.

HASLE G. R. 1968. The valve processes of the centric diatom genus *Thalassiosira*. *Nytt Mag. Bot.* **15**: 193–201.

HASLE G. R. 1980. Examination of *Thalassiosira* type material: *T. minima* and *T. delicatula* (Bacillariophyceae). *Norweg. J. Bot.* **27**: 167–173.

HASLE G. R. & FRYXELL G. A. 1977. The genus *Thalassiosira*: some species with a linear areola array. *Nova Hedwigia* **54**: 15–66.

JOHANSEN J. R. & FRYXELL G. A. 1985. The genus *Thalassiosira* (Bacillariophyceae): studies on species occurring south of the Antarctic Convergence Zone. *Phycologia* **24**(2): 155–179.

JOUSÉ A. P., MUKHINA V. V. & KOZLOVA O. G. 1969. Diatoms and silicoflagellates of the Pacific surface bottom sediments. In: V. G. BOGOROV, S. V. BRUEVICH, P. L. BEZRUKOV *ET AL.* (eds), *The Pacific Ocean, Microflora and microfauna in the recent sediments of Pacific Ocean*, **8**: 7–47. Nauka, Moscow (in Russian).

KLOKOV V. D., KAUP E. B., HAENDEL D. & ZIERATH R. 1989. Hydrochemical composition and ecological description of waters in the Bunger Oasis lakes. *Information Bulletin Soviet Antarctic Expedition* **111**: 91–104 (in Russian).

KULBE T., MELLES M., VERKULICH S. R. & PUSHINA Z. V. 2001. East Antarctic climate and environmental variability over the last 9400 years inferred from marine sediments of the Bunger Hills. *Arctic, Antarctic and Alpine Research* **33**(2): 223–230.

MAKAROVA I. V. 1988. Diatoms of the seas of USSR: the genus *Thalassiosira* Cl. Nauka, Leningrad (in Russian).

MCMINN A. & HODGSON D. 1993. Summer phytoplankton succession in Ellis Fjord, eastern Antarctica. *Journal of Plankton Research* **15**(8): 925–938.

MELLES M., VERKULICH S. R. & HERMICHEN W.-D. 1994a. Radiocarbon dating of lacustrine and marine sediments from the Bunger Hills, East Antarctica. *Antarctic Science* **6**(3): 375–378.

MELLES M., KULBE T., OVERDUIN P.-P. & VERKULICH S. 1994b. The Expedition Bunger Oasis 1993/94 of the AWI Research Unit Potsdam. The Expeditions Norilsk/Taymyr 1993 and Bunger Oasis 1993/94 of the AWI Research Unit Potsdam. *Berichte zur Polarforschung* **148**: 27–80.

MELLES M., KULBE T., VERKULICH S. R., PUSHINA Z. V. & HUBBERTEN H.-W. 1997. Late Pleistocene and Holocene Environmental history of Bunger Hills, East Antarctica, as revealed by fresh-water and epishelf lake sediments. In: C. A. RICCI (ed.), *The Antarctic Region: Geological Evolution and Processes*, pp. 809–820. Terra Antarctica Publication, Siena.

PUSHINA Z. V. 2008. Late Quaternary diatoms and the paleoenvironments in the Central part of the Eastern Antarctica. PhD Thesis, Russian Research Institute for Oceanology and Mineral Resources, St. Petersburg (in Russian).

PUSHINA Z. V., VERKULICH S. R., MELLES M. & HUBBERTEN H.-W. 2004. Holocene palaeoenvironments and climatic changes in Bunger Hills (Eastern Antarctica) reflected by the diatom assemblages from the sediment cores. In: A. WITKOWSKI, T. RADZIEJEWSKA, B. WAWRZYNIAK-WYDROWSKA *ET AL.* (eds), *Abstracts of the 18th International Diatom Symposium*, p. 204. Międzyzdroje, Poland.

ROBERTS D., MCMINN A. & ZWARTZ D. 2000. An initial palaeosalinity history of Jaw Lake, Bunger Hills based on a diatom-salinity transfer function applied to sediment cores. *Antarctic Science* **12**(2): 172–176.

RUSIN N. P. 1961. The meteorological and radiation regime of the Antarctic. Gydrometeoizdat, Leningrad (in Russian).

SEMINA H. I. & FRYXELL G. A. 1994. *Thalassiosira echinata* Semina, a new diatom species from the Equatorial Pacific. *Diatom Res.* **9**(2): 377–385.

VERKULICH S., MELLES M., HUBBERTEN H.-W. & PUSHINA Z. 2002. Holocene environmental changes and development of Figurnoye Lake in the southern Bunger Hills, East Antarctica. *Journal of Paleolimnology* **28**: 253–267.

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