



The epipsammon diatoms of Kruglaya Bay (the Black Sea). I. Centric, araphid and monoraphid

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ABSTRACT

This paper focuses on study of benthic diatoms of the sand beach of Kruglaya (Omega) Bay of the Black Sea. For the first time, diatom algae of epipsammon were studied in an electron scanning microscope. 14 Bacillariophyta taxa representing 8 genera were found, of which 6 species of the genus *Cocconeis* Ehrenberg (*C. guttata*, *C. pinnata*, *C. placentula*, *C. pseudodebesii*, *C. scutellum*, *Cocconeis* sp.) prevailed. Of the diatoms, 6 species, *Anorthoneis arthus-bertrandi*, *A. dulcis*, *Cocconeis guttata*, *Coscinodiscus concinnus*, *Diplomenora cocconeiformis* and *Pseudostaurosira medliniae* were found in Black Sea coastal waters for the first time. Original and literature data on species morphology, variability of shell and shell size, occurrence, ecology and geography of distribution in different areas of the World Ocean are presented. 55 SEM-microphotographs of all diatom species from different angles are presented.

Keywords: diatoms, taxonomy, epipsammon, electronic scanning microscope, Black Sea

РЕЗЮМЕ

Рябушко, Л., Бегун, А. Баринова, С., Бальчева, Д. Диатомовые водоросли эпипсаммона бухты Круглая (Черное море). I. Центрические, арафидные и монорафидные. Статья посвящена донным диатомовым водорослям песчаного пляжа бухты Круглая (Омега) Черного моря. Впервые изучены диатомовые водоросли эпипсаммона в электронном сканирующем микроскопе. Обнаружено 14 таксонов Bacillariophyta, представляющих 8 родов, из которых 6 видов рода *Cocconeis* Ehrenberg преобладали: *C. guttata*, *C. pinnata*, *C. placentula*, *C. pseudodebesii*, *C. scutellum*, *Cocconeis* sp. Из диатомей 6 видов *Anorthoneis arthus-bertrandi*, *A. dulcis*, *Cocconeis guttata*, *Coscinodiscus concinnus*, *Diplomenora cocconeiformis* и *Pseudostaurosira medliniae* обнаружены для прибрежных вод Черного моря впервые. Приведены оригинальные и литературные данные о морфологии видов, изменчивости размеров створок и панцирей, встречаемости, экологии и географии распространения в разных акваториях Мирового океана. Представлено 55 микрофотографий, полученных в СЭМ всех видов диатомовых в разных ракурсах.

Ключевые слова: диатомовые водоросли, таксономия, эпипсаммон, электронный сканирующий микроскоп, Черное море

Kruglaya Bay (Omega) is located at 5 km southwest of the entrance to the Sevastopol harbor. This bay is named because of its configuration, which is circular in the form of the corresponding sign of Ω . The bottom and shores of the bay are sandflats, so it was previously called of Peschanaya Bay. In the past, because of the healing mud that was mined here, the bay was used for recreational purposes for the “Omega” children’s resort. In the innermost part of the shallow bay, under the influence of winds and the abundance of *Zostera marina* L., the rapidly warming waters contribute to the accumulation of debris and rotting macrophytes.

In the biomonitoring system of marine coastal ecosystems of Crimean region, the need to study the taxonomy and ecology of benthic diatoms increases with the accumulation of data on their species diversity in the different ecotopes. The study of the benthic diatoms of the Black Sea in a scanning electron microscopy (SEM) lag significantly compared to a light microscopy (LM).

Besides of the same time, the analysis of morphological characteristics: shape, size, ultrastructure features of the diatom frustules, performed using electron microscopy,

has a number of advantages for their species identification. Here, additional morphological elements of the fine ultrastructure of the outer and inner area of the valves and frustules are revealed, which in the LM at high magnification in permanent preparations using an immersion refractive medium are very weakly or not at all visible. It should be noted that the morphological data of diatoms well complement ecological and phytogeographical characteristics. The diatoms epipsammon in shallow coastal waters of Kruglaya Bay are still poorly studied (Ryabushko 1996, 2013), including in SEM.

The aim of this work is to study the epipsammon species belonging to the centric, araphid and monoraphid diatoms in Kruglaya Bay of the Black Sea, their morphology in SEM, size structure, ecology and phytogeography.

MATERIAL AND METHODS

Sampling was carried out on October 30, 2016 on sand beach in Kruglaya Bay, the Crimean coastal waters of the Black Sea, at a depth of 0.3 m near the city Sevastopol beach at a water temperature of 13°C and water salinity of

17.89 ‰. Sample processing and preparation for operation in a scanning electron microscopy (SEM) of the type “Sigma 300 VP” (Great Britain) was carried out at the A.V. Zhirmunsky National Scientific Center for Marine Biology FEB RAS, Vladivostok, Russia.

Cleaned material diatoms preparation was carried out using a technique by Hasle & Fryxell (1970): burning organic matter in concentrated sulfuric acid at high temperature, and then washing the suspension with purified diatom valves from organic material, with repeated centrifugation in distilled water. An electrically conductive chromium coating was applied to the surface of the samples in an Edwards, AUTO 306 vacuum station.

The species of diatoms were examined in scanning electron microscopy (SEM). When determining taxa of diatoms, we used morphological characters that are specific for every species. The taxonomy has based upon morphological features of the frustules and valves characteristics: shape, size, symmetry, structure and density of striae, nature of raphe and its position on the valves. Biometry of valves: length (L), μm ; width (W), μm ; striae density in 10 μm is a diagnostic feature in determining of the diatom species. The SEM examination of material from Kruglaya Bay, diatom cell sizes according to our data and in LM – own and literature data. It should be noted that ecology and phylogeography characteristics are important for assessing the quality of floristic work and depend on the correct identification of the species.

We used the classification of benthic diatom taxa based on “The Diatoms. Morphology and Biology of the Genera” (Round et al. 1990) with some later additions. The morphometric (dimensions in SEM and LM), ecological (the relation of species to water salinity) and phylogeographical characteristics of diatoms were from the literary sources used.

RESULTS AND DISCUSSION

The taxonomic composition and the fine structure of epipsammon diatoms of centric, araphid and monoraphid of Bacillariophyta of Kruglaya Bay near Sevastopol of the Crimean coastal waters of the Black Sea are studied. Total of 14 taxa representing to 9 genera with previed 6 species belong to the genus *Cocconeis* Ehrenberg: *C. guttata*, *C. pinnata*, *C. placentula*, *C. pseudodebesii*, *C. scutellum*, *Cocconeis* sp. (Table 1 and Figs 1–7).

From all diatoms of 6 new species *Anorthoneis arthus-bertrandi*, *A. dulcis*, *Cocconeis guttata*, *Coscinodiscus concinnus*, *Diplomenora cocconeiformis* and *Pseudostaurosira medliniae* for the coastal waters of the Crimean and the Black Sea were found. Marine species (7) and cosmopolites (4) predominated.

The taxonomic characteristic of epipsammon diatoms of Kruglaya Bay of the Black Sea, their morphology and morphometric, ecology and phylogeography information is below.

Centric diatoms

Class Coscinodiscophyceae

Order Coscinodiscales

Family Coscinodiscaceae

Genus *Coscinodiscus* Ehrenberg 1839

Coscinodiscus concinnus W. Smith 1856 (Fig. 1 A)

Dimensions in light microscopy (LM): frustules 380–465 μm diameter (Smith 1856, p. 85; Hendey 1964, p. 79); frustules 150–450 μm diameter (Lebour 1930).

Ecology, distribution and phylogeography: benthoplanktonic, widespread in the benthos and plankton of the seas, marine, boreal, harmful species. Occures in the Ireland (O'Meara 1875), British coastal waters (Hendey 1964), abundant in the North Sea (Hoppenrath et al. 2009), North Atlantic coastline, very common, English Channel, the Balthic Sea (Plinski & Witkowski 2020).

Class Mediophyceae

Order Eupodiscales

Family Odontellaceae P.A. Sims, D.M. Williams et Ashworth 2018

Genus *Odontella* C.A. Agardh 1832

Odontella aurita (Lyngbye) C.A. Agardh 1832 (Basionym: *Diatoma aurita* Lyngbye 1819; Synonyms: *Candollella aurita* (Lyngbye) Gaillon 1833, *Biddulphia aurita* (Lyngbye) Brébisson 1838, *Denticella aurita* (Lyngbye) Ehrenberg 1838) (Fig. 1 B)

Dimensions in SEM images: frustule 59.4 μm length, 33–34 μm wide, 10 rows of areolae in 10 μm .

Dimensions in LM images: valves 35–77 μm length, 12–39.6 μm wide; frustule 35–56 μm wide, 7–11 rows of areolae in 10 μm (Ryabushko & Begun 2016).

Ecology, distribution and phylogeography: marine, benthoplanktonic, sublittoral, β -mesosaprobies species, cosmopolite, widespread in the benthos and plankton of the seas from the Arctic to the Antarctic, including Atlantic and Pacific Oceans, Baltic, Barents, White, Norwegian, Pechora, Kara, Bering, Caribbean, North, Yellow, Mediterranean, Black Sea, the Sea of Japan, East and China seas; off the coast of the United State, Spain, England, Latvia, Kuwait, India, China, Japan, the Philippines, Greenland, Australia and the Bahamas (Ryabushko, Begun, 2016), Faroe Island Fjords, Northern Atlantic Ocean (Witon & Witkowski 2006), Poland (Plinski & Witkowski 2020). Also of Kraternaya Bight in the area of underwater gas-hydrothermal activity of the marine volcano Ushishir (Yankicha Island, Kuril Islands) in the microphytobenthos of rocky and sand substrates at a depth of 3 to 15 m at a water temperature from 4 to 25 °C (Ryabushko & Tarasov 1989, Ryabushko & 2020).

Table 1. The diatoms occurrence, their ecological (RS) and phylogeographical (PhG) characteristics of epipsammon on Kruglaya Bay of the Black Sea

Taxa	RS	PhG	Figs number
<i>Anorthoneis arthus-bertrandi</i> De Stefano, Pennesi 2016 *	M/FW	BT	4 A-G
<i>Anorthoneis dulcis</i> M.K. Hein 1991 *	M/FW	B	3 F-H
<i>Cocconeis guttata</i> Hustedt et Aleem 1951 *	M	ABT	4 H-K
<i>Cocconeis pinnata</i> W. Gregory ex Greville 1859	M	C	5 A-C
<i>Cocconeis placentula</i> Ehrenberg 1838	ind	C	5 D-H
<i>Cocconeis pseudodebesii</i> Proshkina-Lavrenko 1963	MB	B	6 A-G
<i>Cocconeis scutellum</i> Ehrenberg 1838	MB	C	7 A-D
<i>Cocconeis</i> sp. *	–	–	7 E-G
<i>Coscinodiscus concinnus</i> W. Smith 1856 *	M	B	1 A
<i>Diplomenora cocconeiformis</i> (Schmidt) Blazé 1984 *	M	BT	3 A-C
<i>Hyalosira delicatula</i> Kützing 1844	MB	ABT	2 A-K
<i>Licmophora abbreviata</i> C.A. Agardh 1831	M	ABT, not	1 C-E
<i>Odontella aurita</i> (Lyngbye) C.A. Agardh 1832	M	C	1 B
<i>Pseudostaurosira medliniae</i> D.M. Williams et E.A Morales 2010	M/FW	B	3 D, E

Note. * – a new species for the Crimean coastal waters and the Black Sea; new genera are indicated bold; RS – the relation of species to the water salinity: M – marine species, FW – freshwater, MB – marine-brackish; ind – indifferent; PhG – phylogeographic elements: B – boreal species, BT – boreal-tropical, ABT – arctic-boreal-tropical, C – cosmopolite, not – notal species, found in the southern hemisphere.

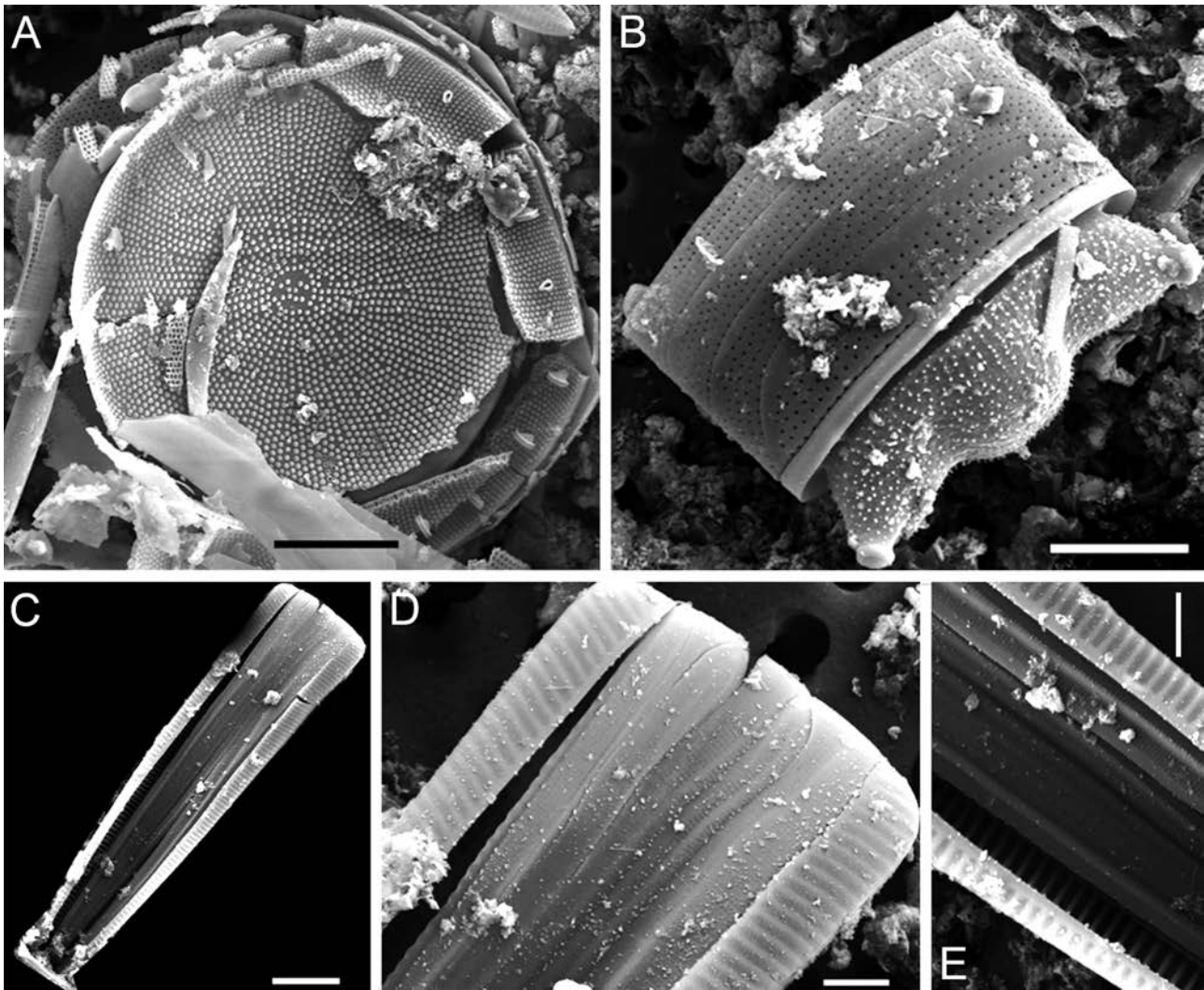


Figure 1. The internal damaged frustule of *Coscinodiscus concinnus* W. Smith 1856: A – general view with structure; the internal general frustule of *Odontella aurita* (Lyngbye) C.A. Agardh 1832: B – in girdle view; the internal general frustule (with the girdle view) of *Licmophora abbreviata* C.A. Agardh 1831: C – D – view, its fragments and structure. Scale bar: 10 μm (A – C), 2 μm , (D, E)

Araphid diatoms

Class Fragilariophyceae Round 1990

Order Licmophorales Round 1990

Family Licmophoraceae Kützing 1844

Genus *Licmophora* C.A. Agardh 1827

Licmophora abbreviata C.A. Agardh 1831 (Basionym: *Podosphenia abbreviata* Ehrenberg 1838; Synonyms: *Podosphenia lyngbyei* Kützing 1844; *Rhipidophora abbreviata* Kützing 1844; *Licmophora lyngbyei* Grunow 1867; *Licmophora lyngbyei* var. *abbreviata*, var. *elongata*, var. *minuta* Grunow 1880; *Licmophora rostrata* Mereschkowsky 1902; *Licmophora abbreviata* f. *rostrata* (Mereschkowsky) Proshkina-Lavrenko 1963) (Fig. 1 C–E)

Dimensions in SEM images: frustule 50 μm length, 12 μm width of head end, 17 striae in 10 μm of the end basal.

Dimensions in LM images: valves 11.2–140 μm length, 2–9 μm width the head end of the valve, 1.5 μm width, 11–18 striae in 10 μm at the upper end of the valve basal (Proshkina-Lavrenko 1963, p. 110, table II, figs 9–11).

Ecology, distribution and phytogeography: marine, littoral and sublittoral, eurythermal, euryhaline, β -mesosaprobies, found in epilithon, epiphyton of benthic vegetation, epiphyton of invertebrates, arctic-boreal-tropical, notal species, common along the shores of all European seas, as well as the Caribbean, Mediterranean, Baltic, Barents, Black, Azov, Caspian, White, Japan and East China seas, off the

coast of America, Norwegian, Sweden, Kuwait, China, India (Ryabushko & Begun 2016), it found in epiphyton *Zostera*, epilithon rock substrates, in fouling test plates and fish stomachs in the Australia and New Zealand (Crosby & Wood 1959), Kuwait's coastal waters frequently intertidal sand beach (Al-Yamani & Saburova 2011, p. 190, pl. 22, figs f–j).

Order Rhabdonematales Round 1990

Family Rhabdonemataceae F.E. Round &

R.M. Crawford

Genus *Hyalosira* Kützing 1844

Hyalosira delicatula Kützing 1844 (Basionym: *Striatella delicatula* (Kützing) Grunow ex Van Heurck 1881; Synonym: *Microtabella delicatula* (Kützing) Round 1990) (Fig. 2 A–K)

Dimensions in SEM images: valve 36.5 μm length, 2.5–3.0 μm width, 24 striae in 10 μm ; valve 6.3–13.3 μm length, 3–4 μm width, 30 striae in 10 μm (Kuylenstierna 1989, pl. 11, figs 117–119).

Dimensions in LM images: valves 5–30 μm length, 2.5–3 μm width 26–30 striae in 10 μm (Proshkina-Lavrenko 1955, p. 171, figs 74, 1–8; 1963, p. 104), indicated in plankton and benthos of the Black Sea; valves 18–22 μm length, 3–4 μm width, 33–35 striae in 10 μm (Ryabushko 1986) – in the Russian waters of the Sea of Japan.

Ecology, distribution and phytogeography: marine and brackish water, littoral, sublittoral, arctic-boreal species.

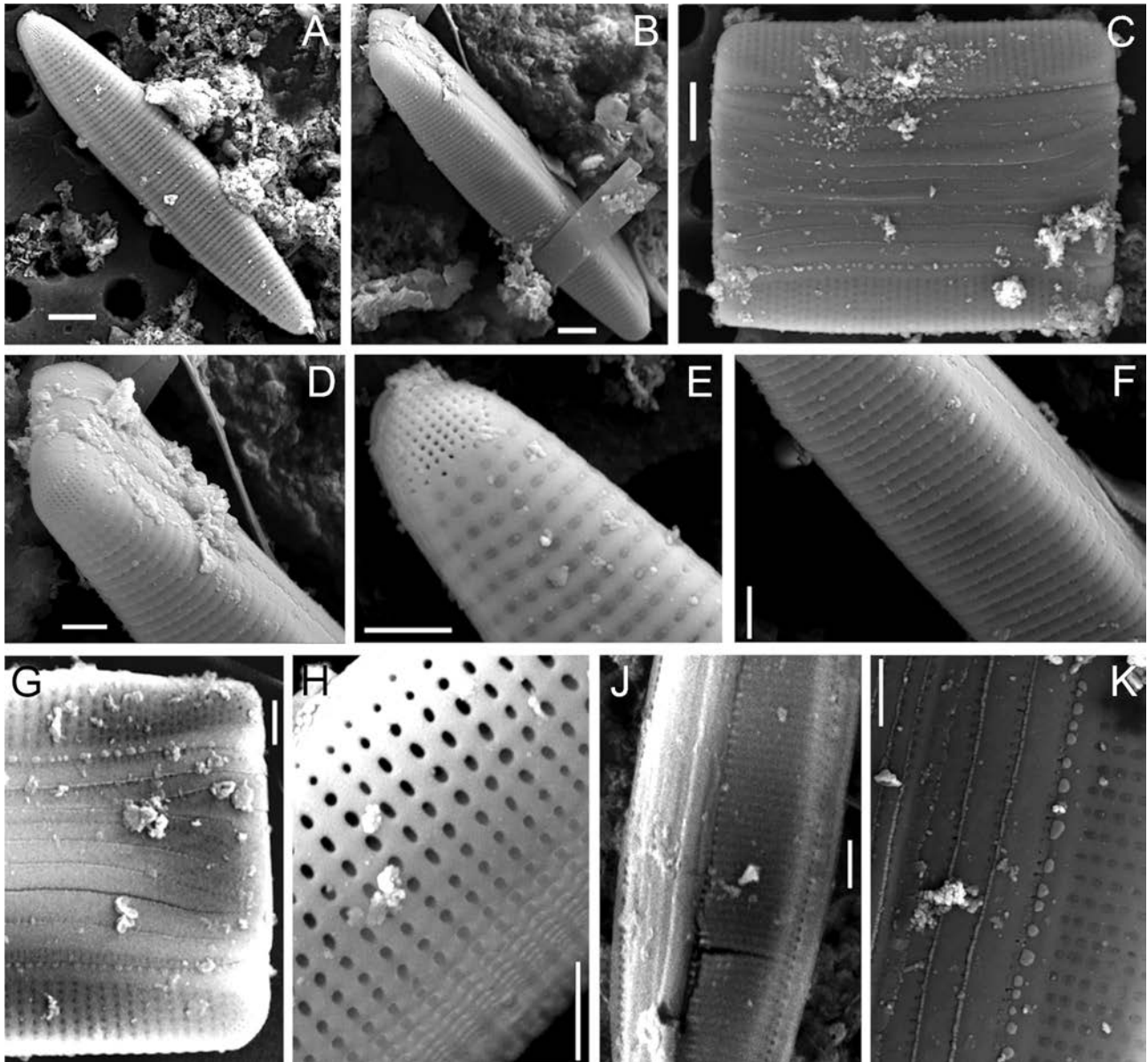


Figure 2. The valves of *Hyalosira delicatula* Kützing 1844: A, B – frustules, C, G – their structure, and D – K – fragments. Scale bar: 2 μ m (A – C), 1 μ m (D – K)

Found in all seas of Europe to the North seas, Arctic Ocean inclusive. Indicated in the Adriatic, Black, Azov seas and of the microphytobenthos of the stones of Vostok Bay at a depth of 0.5 m and in autumn in the epiphyton of macrophytes in Reefovaya Bay of the Sea of Japan, on the Canary Islands, off the coast of Britain, Romania, China (Ryabushko & Begun 2016) and Sweden (Kuylenstierna 1989).

Monoraphid diatoms

Class Fragilariophyceae Round 1990

Order Rhaphoneidales Round 1990

Family Rhaphoneidaceae Forti 1912

Genus *Diplomenora* Blaze 1984

Diplomenora cocconeiformis (Schmidt) Blazé 1984
(Basionym: *Coccinodiscus cocconeiformis* Schmidt 1878;
Synonym: *Raphoneis superba* (Janish) Grunow 1862)
(Fig. 3 A–C)

Dimensions in SEM images: valve 11.2–12.6 μ m in diameter.

Dimensions in LM images: valves 18–25 μ m in diameter. Valve surface areolated, areolae arranged in concentric arcs radiating from sternum, 14–15 rows in 10 μ m (Al-Yamani & Saburova 2011, p. 62, Pl. 24, figs a–f); valves 18–50 μ m

in diameter, 4 areolae in 10 μ m (Witkowski et al. 2000, p. 46–47, pl. 22, figs 1, 2; pl. 23, figs 8–11).

Ecology, distribution and phytogeography: marine, epipsammic form, boreal-tropical, common species on Indian Ocean, Mediterranean Sea and Kuwait's coastal waters frequently intertidal sandflats (Witkowski et al. 2000, Al-Kandari et al. 2009, Al-Yamani & Saburova 2011). The species was first recorded on the sand beach of Kruglaya Bay, new species for the Crimean region and the Black Sea.

Remark. In our samples, only the lower raphe valves and only the upper (rapheless) valves were found from the authors mentioned above.

Class Bacillariophyceae Haeckel 1878 emend. D.G.

Mann in Round et al. 1990

Order Fragilariales

Family Staurosiraceae

Genus *Pseudostaurosira* D.M. Williams et Round 1988

Pseudostaurosira medliniae D.M. Williams et E.A. Morales 2010 (Basionym: *Fragilaria elliptica* Schumann 1867; Synonyms: *Fragilaria zeileri* var. *elliptica* F. Gasse 1980; *Pseudostaurosira elliptica* (F. Gasse) I. Jung

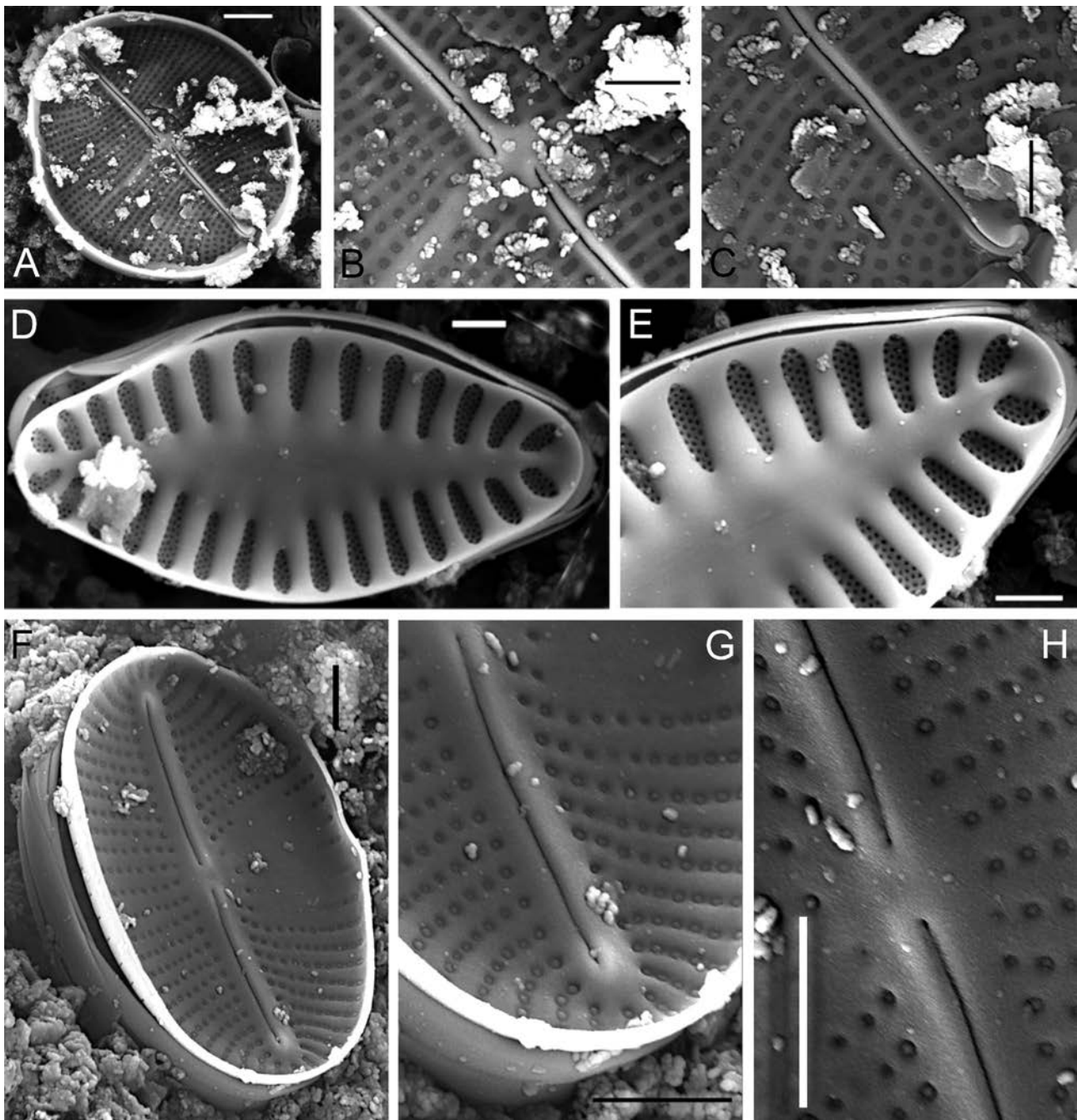


Figure 3. The internal valve of *Diplomenora cocconeiformis* (Schmidt) Blazé 1984 (A) general view and its structure: details of the central raphe nodule (B) and apical raphe nodule (C); the valve (D) and structure (E) of *Pseudostaurosira medliniae* D.M. Williams et E.A Morales 2010 view; the internal valve of *Anorthoneis dulcis* M.K. Hein 1991 general view (F), and its fragments and structure (G, H). Scale bar: 2 μ m (A), 1 μ m (B–H)

et L.K. Medlin 2008; *Pseudostaurosira zeileri* var. *elliptica* (F. Gasse) Kulikovskiy 2008) (Fig. 3 D, E)

Dimensions in SEM images: valve 9.6 μ m length, 4.5 μ m width, 18 striae in 10 μ m (for authors this paper).

Dimensions in LM images: valve 21 μ m length, 4 μ m width, 13 striae in 10 μ m (Kulikovskiy 2008).

Ecology, distribution and phytogeography: freshwater and boreal species which found in sphagnous bogs of the Russian Plain (Kulikovskiy 2008).

Remark. The species is similar to the *Achnanthes delicatula* of internal view of valve (Kuylenstierna 1989, pl. 35, fig. 347): valve 5.85 μ m length, 3.3 μ m width from brackish waters off the coast of Sweden. This species a rare and first found on the sand beach of Kruglaya Bay and for the Black Sea.

Class Bacillariophyceae

Order Achnanthes P.S. Silva 1962

Family Cocconeidaceae Kützing 1844

Genus *Anorthoneis* A. Grunow 1868

Anorthoneis arthus-bertrandii De Stefano et Pennesi 2018 (Fig. 4 A–G)

Dimensions in SEM images: valves 16.5–19.8 μ m length, 12.6–12.8 μ m width, 17–25 striae and 20 areolae in 10 μ m (sizes of authors). Valves 16–22 μ m length, 13–18 μ m wide, 14–18 striae and 10–14 areolae in 10 μ m (Pennesi et al. 2018).

Ecology, distribution and phytogeography: benthic, marine, boreal-tropical species. Occures on the seagrass of the Siladen Island and Sulawesi in the Indonesia. The species was first recorded on sand beach of Kruglaya Bay, new species for the Crimean region and the Black Sea.

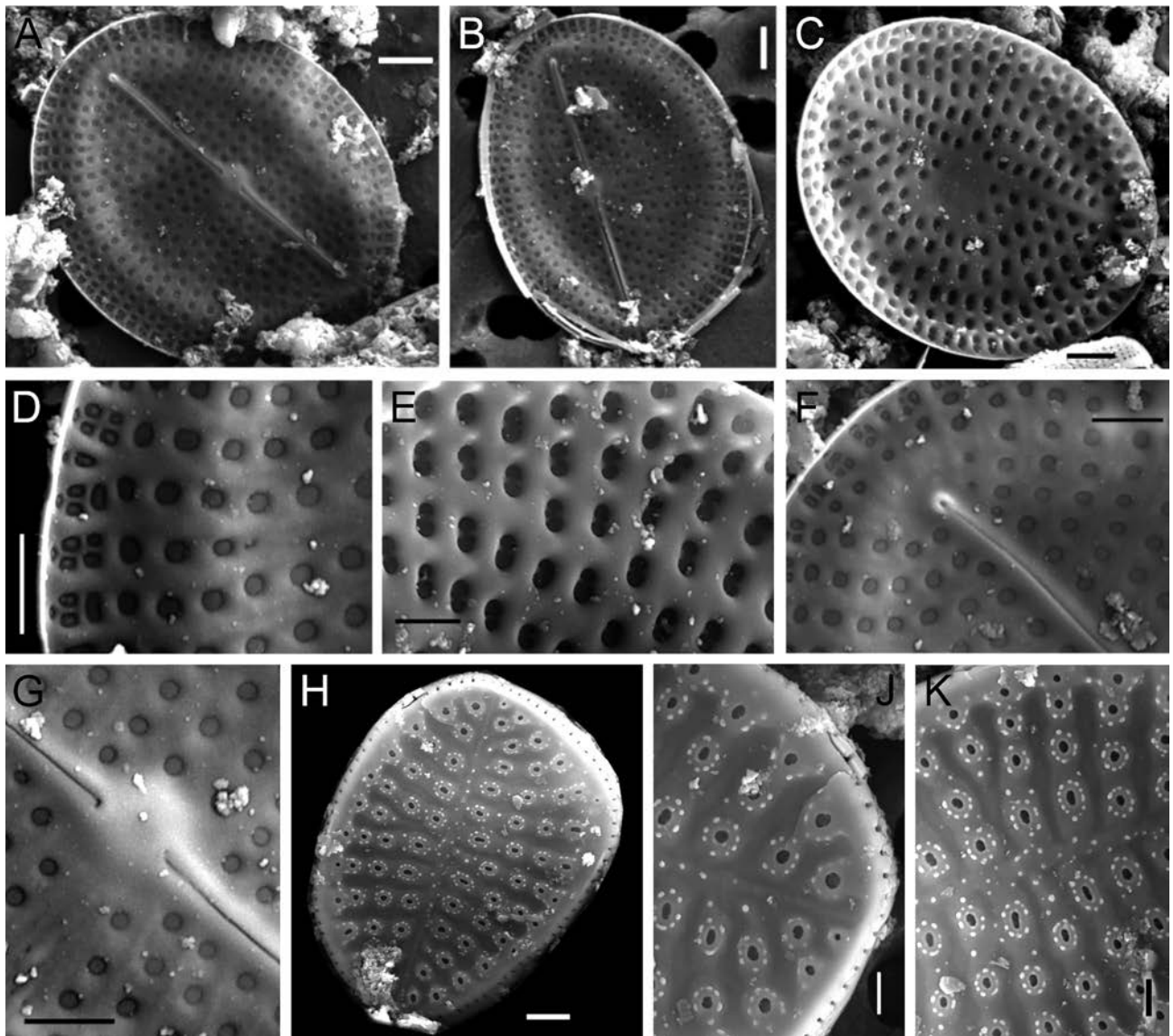


Figure 4. The external lower raphe (A, B) and upper rapheless (C) valves an eccentric raphe of *Anorthoneis arthus-bertrandii* De Stefano et Pennesi 2018 view with different their fragments and structure (A – G); the internal general upper valve of *Cocconeis guttata* Hustedt et Aleem 1951 view, its fragments and the structure (H – K). Scale bar: 2 μm (A – C, H), 1 μm (D – G, J, K)

Remark. Currently, the genus *Anorthoneis* has 13 different species, which found in marine and freshwaters (Van Heurck 1899, Proschkina-Lavrenko 1950, Navarro 1982, Witkowski et al. 2000, Marinines & Marciana 2008, Lópes et al. 2010, Taylor & Cocquyt 2016, Pennesi et al. 2018, Guiry & Guiry 2021). Three from all species of the *Anorthoneis*, *A. hummii* (Guslyakov et al. 1992), *A. arthus-bertrandii*, and *A. dulcis*, were first recorded in the Black Sea.. Cells of *A. arthus-bertrandii* monoraphid, heterovalvar, different valves of the same species are the raphe and rapheless, solitary, free living or attached on substrate, neritic species.

***Anorthoneis dulcis* M.K. Hein 1991** (Fig. 3 F–H)

Cells of *A. dulcis* monoraphid, heterovalvar, flat-convex, different valves of the same species are the raphe and rapheless, solitary, free living or attached on substrate, neritic species. The central area is asymmetric.

Dimensions in SEM images: valves 7 μm length, 4.2 μm width, 20 striae and 30 areolae in 10 μm (size of authors).

Dimensions in LM images: valves 14–16 μm length, 9.2–12 μm wide and 20–22 striae in 10 μm (Pennesi et al. 2018).

Ecology, distribution and phylogeography: marine and freshwater species, littoral, boreal-tropical, listed in the Withlacoochee River northern Florida U.S.A. (Hein 1991) and

South America (Tremarin & Ludwig 2008). The first found on the sand beach of Kruglaya Bay and for the Black Sea.

Remark. The valve is similar to *Anorthoneis excentrica* (Donkin) Grunow (Witkowski et al. 2000, p. 97, pl. 54, fig. 9), but differs in the nature of the seam and the inner node.

Genus *Cocconeis* Ehrenberg

***Cocconeis guttata* Hustedt et Aleem 1951** (Fig. 4 H–K)

Dimensions in SEM images: valve 9–16 μm length, 4.5–11.8 μm width, 20 striae and 40 punctae in 10 μm .

Dimensions in LM images: valves elliptical to lanceolate, somewhat asymmetrical to both apical and transapical axes, 20–31 μm length, 10–18 μm width (Sar et al. 2003); valve 15 μm length, 9 μm width, striae radiate, 8–8.5 in 10 μm (Al-Yamani & Saburova 2011, p. 82, pl. 53, figs d–f).

Ecology, distribution and phylogeography: marine, benthic, arctic-boeal-tropical species. Occurrence in the coastal waters of England (Hustedt & Aleem 1951, Hendey 1964) and France (Riaux-Gobin 1991), Kuwait's marine sediments (Al-Kandari et al. 2009, Al-Yamani & Saburova 2011), for the first time from marine coasts of the southwestern Atlantic Ocean (Sar et al. 2003) and Faroe Island Fjords, Northern Atlantic Ocean (Witon & Witkowski 2006). This

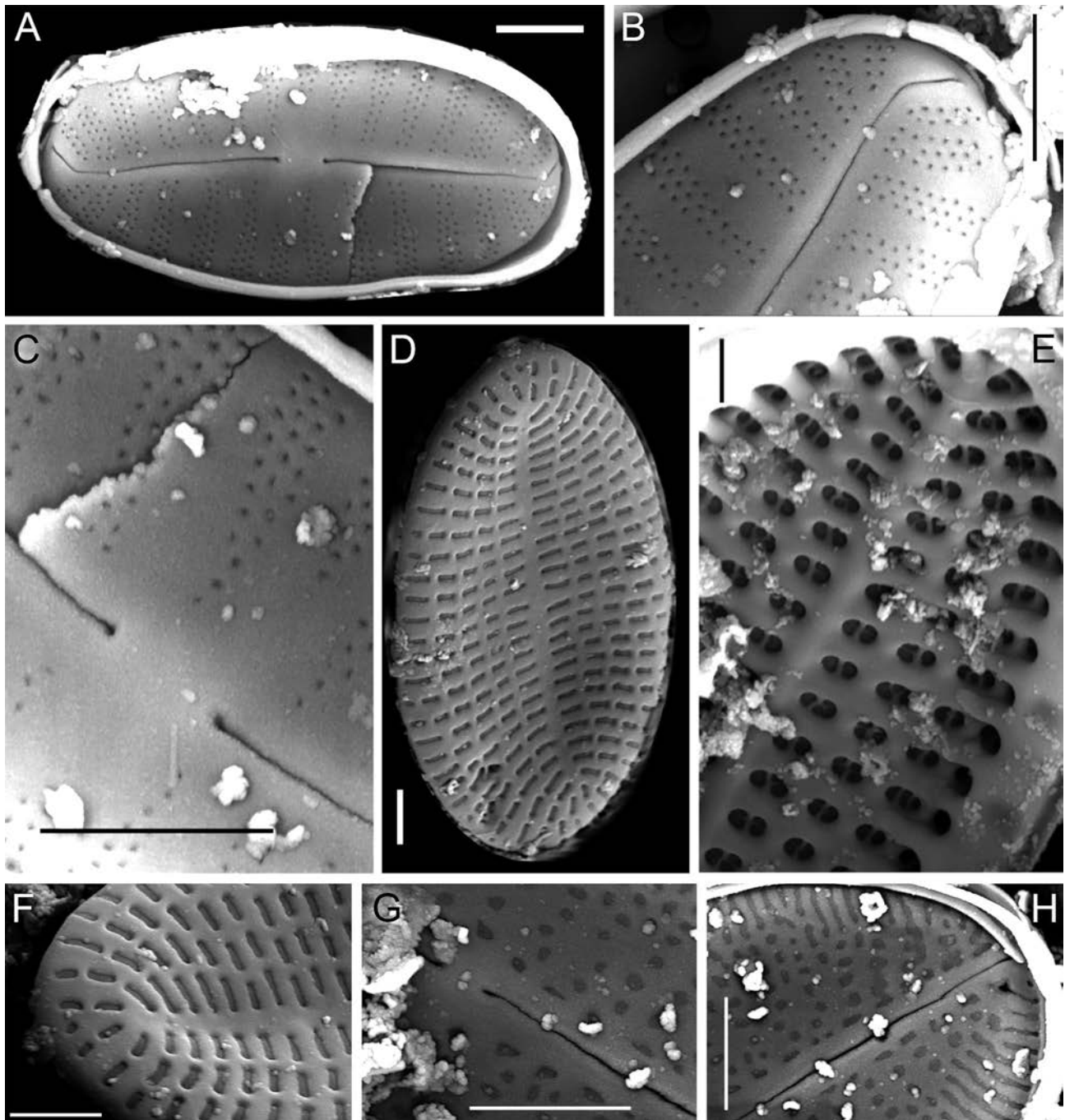


Figure 5. The lower raphe valve with valvacopula (A) of *Cocconeis pinnata* Gregory ex Greville 1859 view and its fragments and structure (B, C); the upper raphe valves of *Cocconeis placentula* Ehrenberg 1838 view (D – F) with the lower raphe (G, H), their fragments and structure. Scale bar: 1 μm

species was found for the first in Kruglaya Bay and for the Crimean coastal waters of the Black Sea.

Remark. Initially, this species was identified by us as *Cocconeis distans* Gregory, thanks to the authors' article, we came to the conclusion that our only specimen bears more similarity with the species *C. guttata*. Along with this (Hustedt & Aleem 1951) pointed out that *C. guttata* resembles *C. distans* in the shape and structure of valves, but they differ mainly in the density of striae, which is clearly seen in SEM.

Cocconeis pinnata Gregory ex Greville 1859 (Fig. 5 A–C)

Dimensions in SEM images: valve 25.3 μm length, 6.7 μm width.

Dimensions in LM images: valves 20–45 μm length, 18–30 μm width, 4–5 striae in 10 μm (Diatom ... 1950, p. 81, tabl., 28, figs 7a, b).

Ecology, distribution and phytogeography: marine, littoral and sublittoral species, cosmopolite. Occurrence from the Arctic to the Antarctic. Recorded in water bodies of Turkey (Aysel 2005), in North, Baltic, Mediterranean, Adriatic seas, off the coast of Spitsbergen, Iceland, Greenland, Finnmarken, Norwegian, French Polynesia (South Pacific), as well as in the Seychelles, Tahiti, Singapore, in the Antarctic waters about King George. In the Sea of Japan it was first found in the summer in epilithon of Vostok Bay at a depth of 0.5 m (Ryabushko & Begun 2016). The first found on the sand beach of Kruglaya Bay and for the Black Sea.

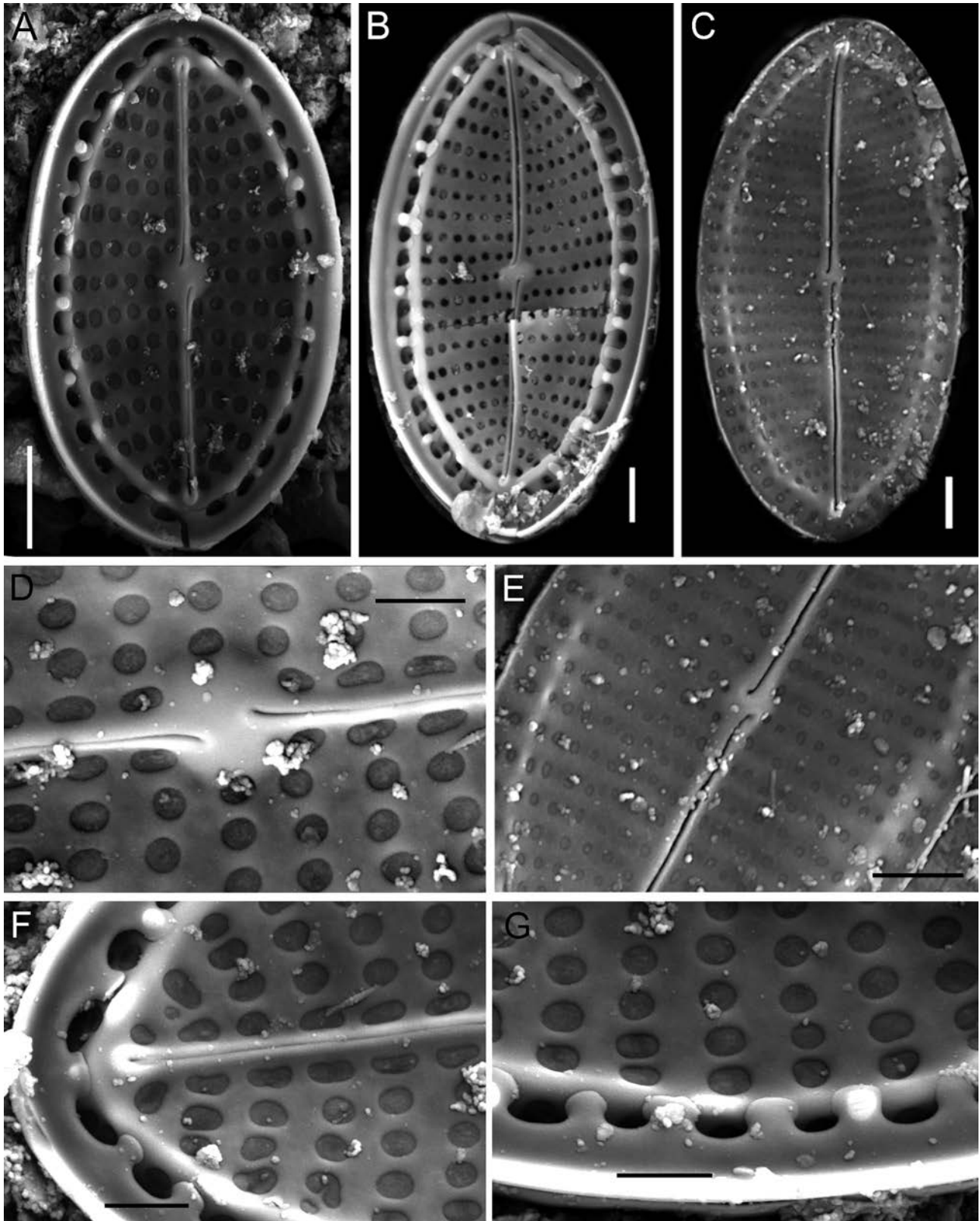


Figure 6. The lower raphe sternum valves of *Cocconeis pseudodebesii* Proshkina-Lavrenko 1963 view (A – C) and their fragments and structure (D – G), of the central part valves with central nodule (D, E), the apical raphe nodule (F) and the valve rim from the side (G). Scale bar: 2 μ m (A, B), 1 μ m (C – G)

***Cocconeis placentula* Ehrenberg 1838** (Fig. 5 D–H)

Cells monoraphid, heterovalvar, different valves of the same species are the raphe and rapheless.

Dimensions in SEM images: valves 12.2–17.3 μ m length, 6–9.7 μ m width, 8 areolae and 6–9 chambers in 10 μ m.

Dimensions in LM images: valves 12.5–35 μ m length, 8–20 μ m width, 25 striae in 10 μ m (Cleve 1895); valves 22–45 μ m length, 8–16 μ m width, 23–25 striae in 10 μ m (Proshkina-Lavrenko 1963); 18–32 μ m length, 7–25 μ m width, 18–24 striae in 10 μ m (Karayeva 1972); 18–29 μ m length, 11–15 μ m width, 20–25 striae in 10 μ m (Wu & Wang 2002); 18–35 μ m length, 9–23 μ m width, 18–22 striae in 10 μ m (Ryabushko & Begun 2016).

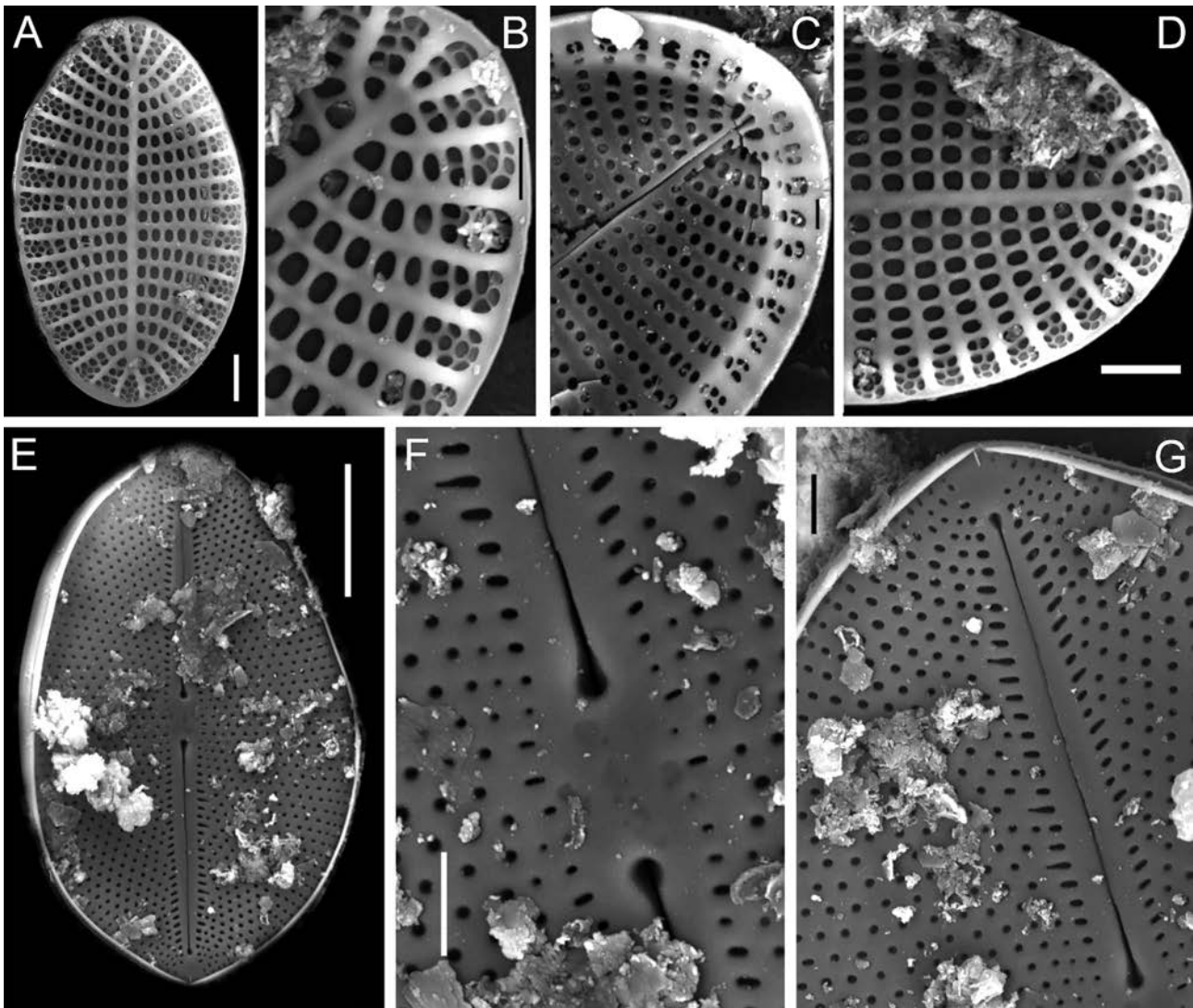


Figure 7. The external upper rapheless valves of *Cocconeis scutellum* Ehrenberg 1838 view (A, B, D) and its structure; the structure; the internal part of the raphe valve *Cocconeis* sp. (E), its fragments and structure (F, G). Scale bar: 1 µm (B, C), 2 µm (A, D, F, G) and 10 µm (E)

Ecology, distribution and phytogeography: littoral and sublittoral, eurythermal and indifferent, widely noted in fresh and brackish waters and in freshened areas of the seas and river estuaries, cosmopolite. Occurrence in phytoplankton of the Amur River estuary, in the ice of Franz Josef Land, in the Laptev, Kara, Barents, Caribbean, North, Baltic, Aegean, Black, Azov, Caspian, East China seas, off the coast of the Europe, Northern America, Kuwait, Australia and New Zealand (in the sandflat at a depth of 200 m), in reservoirs of the USA, Brazil, Mexico, England, Denmark, Romania, Germany, Bulgaria, Spain, China, Sweden, Turkey, Israel, Singapore, Taiwan, Tasmania, Ecuador, the Galapagos and the Canary Islands.

Remark. In the Sea of Japan, this species is recorded in the microphytobenthos of Bays: Expedition, Novgorodskaya, Trinity and Posiet, as well as Gulfs: Amurskiy, Ussurijskiy, Slayvanka, Nakhodka and Boisman (Ryabushko & Begun 2016).

***Cocconeis pseudodebesii* Proshkina-Lavrenko 1963**
(Fig. 6 A–G)

Cells monoraphid, heterovalvar, different valves of the same species are the raphe and rapheless.

Dimensions in SEM images: 13.3–17.3 µm length, 8.4–12.2 µm width, 11–14 areoles and 3 chambers in 10 µm on lower valve.

Dimensions in LM images: valves 35–37 µm length, 23–24 µm width, the upper rapheless valves 6–6.5 costae in 10 µm, 11–12 punctae in 10 µm on the lower raphe valve (Proshkina-Lavrenko 1963, p. 116, table IV, figs 11, 12).

Ecology, distribution and phytogeography: brackish waters, possibly also marine species, boreal (Table 1). The species is known in the southern coast of the Crimea of the Black Sea in the fouling of macrophytes at the end of summer. Rarely (Proshkina-Lavrenko 1963). This taxon was found of the first time in Kruglaya Bay of the Black Sea.

***Cocconeis scutellum* Ehrenberg 1838** (Basionym: *Cocconeis scutellum* var. *dilatata* A. Schmidt; *C. scutellum* var. *genuina* A. Cleve-Euler 1953; *C. scutellum* var. *ampliata* Grunow; *C. scutellum* var. *baldjikiana* Grunow; *C. scutellum* var. *morrisii* Peragallo; *C. scutellum* var. *adjuncta* Peragallo) (Fig. 7 A–D)

Cells monoraphid, heterovalvar, different valves of the same species are the raphe and rapheless.

Dimensions in SEM images: valve 16 µm length, 9.6 µm width, 15 striae and 20 areolae in 10 µm.

Dimensions in LM images: valves 20–68 µm length, 12–48 µm width, 5–9 striae and 9–12 areolae in 10 µm (Proshkina-Lavrenko 1963, c. 114, table XIII, figs 1, 2); 20.8–46.2 µm length, 14.2–22 µm width, 8–9 striae and 8–10 areolae in 10 µm (Karayeva 1972); 19.7–65 µm length,

13.2–46 µm width, 6–8 areolae and 10–11 striae in 10 µm (Ryabushko 1986); 24–50 µm length, 16.5–33.5 µm width, 7–8 areolae in 10 µm (Ryabushko & Begun 2016).

Ecology, distribution and phylogeography: marine and brackish waters, euryhaline and eurythermic, littoral and sublittoral species, cosmopolite and ubiquitous (Table 1). Occurrence in the plankton of the Amur River estuary, the Black, Azov, Caspian, Aral, Baltic, Barents, White, North, Kara, Caribbean, Mediterranean, Adriatic, Tyrrhenian, Aegean, East China seas; off the coastal waters of Greenland, Brazil, Mexico; Scotland, Ireland, England, Sweden, Romania, Germany, Finland, Italy, Spain, Croatia, Turkey, Japan, China, India, South Africa, Kuwait, North and South America, Japan, Southern Sakhalin, Kurile, Canary, Hawaiian, Galapagos and Sri Lanka Islands. In the Russian waters this species is indicated in all substrates, including of the red alga *Mastocarpus stellatus* epiphyton in the Posyet Bay at the beginning of March 2014 at a depth of 3–6 m at a water temperature of about minus 1.5 °C and in the Vostok Bay at a depth of 0.5–10 m, year-round (Ryabushko & Begun 2016).

***Cocconeis* sp.** (Fig. 7 E–G)

Dimensions in SEM images: lower raphe valve 30.8 µm length, 18.8 µm wide. This species was found of the first in Kruglaya Bay and the Crimean coastal waters and the Black Sea.

The first studies of the epiphyton diatoms of 15 species of macrophytes: Rhodophyta (9 species), Phaeophyta (4) and Chlorophyta (2), sampling in May and August 1994 at a depth of 0–20 m near Omega Cape, showed a high diversity of diatoms living forms depending on the shape of macroalgae thalli (Ryabushko 1996, 2013). When comparing epipsammon and epiphyton, a weak similarity in the species composition of diatoms was revealed. Only two species are common, *Cocconeis scutellum* and *Licmophora abbreviata*, which are widely found in the sea on different substrates.

Generally, it should be noted that the shallow water of sandy beaches has a peculiar species diversity of benthic forms diatoms, which are food objects for many species of aquatic organisms.

CONCLUSION

For the first time, electron microscopic studies of the benthic diatoms of the sand beach of Kruglaya (Omega) Bay were carried out. We found 14 taxa of Bacillariophyta representing to eight genera with previed six species belong to the genus *Cocconeis* Ehrenberg: *C. guttata*, *C. pinnata*, *C. placentula*, *C. pseudodebesii*, *C. scutellum* and *Cocconeis* sp. From all diatoms 6 species, *Anorthoneis arbus-bertrandi*, *A. dulcis*, *Cocconeis guttata*, *Coscinodiscus concinnus*, *Diplomenora cocconeiformis* and *Pseudostaurisira medliniae*, were found first discovered for the coastal waters of the Crimea and the Black Sea. Centric and araphid diatoms are represented by 2 species each, and monoraphid diatoms – by 10 species. In the flora was dominated by marine species (6), cosmopolites and boreal 4 species each.

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