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MICROALGAE OF MUD VOLCANO OF THE BULGANAK SOPOCHNOE FIELD ON THE CRIMEAN PENINSULA

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Mud volcanoes are one of unique natural phenomena widely spread around the world. They can be found in Crimea, including the Bulganak sopochnoe field – the largest cluster of active mud volcanoes on the peninsula (45°25′29.04″N, 36°27′51.64″E). Study of mud volcano microalgae in Crimea, as well as in other regions of Russia, has not been conducted so far. Therefore, scientific interest is caused by need and urgency of the study of these volcanoes. First data on microalgae species composition of active mud volcanoes are presented in this article. Samples collected by O. Yu. Eremin (03.08.2012 and 13.04.2013) in the upper 2–3-cm layer of suspension and in surface water were investigated. The ranges of salinity and water temperature were 27–32 g per L and +28…+31 °C, respectively. Microalgae species composition was determined in water preparations using Axioskop 40 (Carl Zeiss) light microscope at magnification of 10×40 with software AxioVision Rel. 4.6. Totally 16 taxa were found: Cyanobacteria (1), Dinophyta (2), Bacillariophyta (6), and Euglenophyta (7). Of these, cyanobacteria *Chamaecalyx swirenkoi* (Schirshov) Komárek et Anagnostidis, 1986 was found by us in the mud volcano in August 2012. Pennate species of diatoms were also identified – single living (of genera *Cylindrotheca* (Ehrenberg) Reimann & J. C. Lewin, *Lyrella* Karajeva, and *Nitzschia* Hassall) and colonial species (of genera *Berkeleya* Greville and *Pseudo-nitzschia* H. Peragallo). The brackish-water, benthic, boreal-tropical species *Nitzschia thermaloides* Hustedt was recorded for the algal flora of Crimea, the Black Sea, and the Sea of Azov for the first time. Euglenophytes were also found in the samples – 5 species of the genus *Trachelomonas* Ehrenberg and 2 species of the genus *Strombomonas* Deflandre. Of all the species found in the mud volcano ecotope, 7 species are common for the Black Sea, and 9 species, including 3 euglenophytes, are common for the Sea of Azov. It is shown that by characteristics of halobility, species found in the mud volcano belong to freshwater complex (53 %), with a significant share of marine (27 %) and brackish-water (20 %) species. Of the phytogeographic flora elements, boreal species make up 33 %, boreal-tropical – 47 %, and cosmopolites – 20 %. Three species of potentially toxic algae are recorded: diatom *Pseudo-nitzschia prolongatoides* (Hasle) Hasle, 1993, as well as dinophytes *Prorocentrum lima* (Ehrenberg) Dodge, 1975 and *Alexandrium tamiyavanichii* Balech, 1994. The last species is marine, boreal-tropical, and new to the algology of Crimea, the Black Sea, and the Sea of Azov. In the article, own and literary data on morphology, ecology, and phytogeography of species, as well as on their general distribution in different waterbodies of the world, are also presented. Some microalgae species are indicators of saprobity; they are able to participate in purification of water from organic substances. Photos of mud volcanoes and micrographs of some species are presented.

Keywords: microalgae, euglenophytes, diatoms, dinophytes, mud volcano, Crimean Peninsula

Mud volcanoes are one of unique natural phenomena widely spread around the world. They can be found on the Crimean Peninsula being part of the Bulganak sopochnoe field, which is the largest cluster of active mud volcanoes in Crimea [25]. The term "mud volcano" (in German, *Mudevulkan*) was proposed by G. Helmersen, who was involved in the studies of mud volcanoes, in particular, of Altai and oil fields of the Taman and Kerch peninsulas for 60 years. According to academician I. M. Gubkin, one of the founders and creators of oil geology in Russia, gas and oil manifestations and mud volcanism are functions of the same reasons, special forms of tectonics – of diapir structures (folds and domes arising due to extrusion from the lower horizons of highly plastic rocks, salt and clay). He was the first to establish their single genetic whole; it was used later in a program for the study of mud volcanoes of the Crimean-Caucasian geological province of Dzherelo [25].

Crimea is one of the areas of mud volcanism; there are 33 volcanoes on the territory of the peninsula [8]. Dirt pours out through craters and spreads along slopes in the form of streams. Volcano fields of Bulganak type belong to mud volcano formations with violent eruptions being not characteristic. They are natural monuments of regional significance, as well as tourist attractions.

So far, study of microalgae of mud volcanoes in Crimea has not been carried out. Moreover, there is no information available about similar research in other regions of Russia. Preliminary studies have shown presence of microalgae in the surface layer of mud volcano ejections. Relevance of the work is due to complete lack of data on the study of microalgae communities of Crimean mud volcanoes, which is of significant scientific interest.

Aim of the work is to describe the species composition of microalgae biotopes of the mud volcano located in the eastern part of the Crimean Peninsula.

MATERIAL AND METHODS

Material for the study was high-quality samples (sulfur-clay-silty substrate and water), taken by an employee of A. O. Kovalevsky Institute of Biology of the Southern Seas O. Yu. Eremin on the Crimean Peninsula from the area of active volcanoes of the Bulganak sopochnoe field. Volcanoes are scattered over a vast territory there, and their cones are almost flush with the ground or have relatively large sizes (Fig. 1).

Sampling was carried out on August 3, 2012 and April 13, 2013 in the upper 2–3-cm layer of silt suspension with surface water flowing from the mud volcano. Salinity (27–32 g per L) and water temperature (+28…+31 °C) were measured using a refractometer and digital thermometer, respectively [22].

The species composition of microalgae was determined in water preparations using Axioskop 40 (Carl Zeiss) light microscope at magnification of 10×40 with software AxioVision Rel. 4.6. For species identification, modern guides and atlases were used [4, 12, 14, 15, 16, 20, 24, 36, 39, 40, 41].

RESULTS AND DISCUSSION

A preliminary study of two samples of silty suspension of the mud volcanoes showed the presence of microscopic algae in these habitats belonging to different high rank taxonomic groups. Totally 16 species of different genera were identified: cyanobacteria (*Chamaecalyx swirenkoi* (Shirshov) Komárek et Anagnostidis), 2 dinophyte species (*Alexandrium* Halim and *Prorocentrum* Ehrenberg), 6 pennate diatom species (1 species of *Lyrella* Karajeva, *Nitzschia* Hassall, *Cylindrotheca* (Ehrenberg) Reimann et J. C. Lewin, and *Pseudo-nitzschia* H. Peragallo; 2 colonial species of *Berkeleya* Greville). Euglenophytes lodges were often found in samples; we identified 5 species of *Trachelomonas* Ehrenberg and 2 species of *Strombomonas* Deflandre.

Classification of the species identified, their size, ecology, phytogeography, and general distribution are given below.

Fig. 1. General view of the mud volcano of the Crimean Peninsula and its crater vents (photos from O. Yu. Eremin personal archive)

Phylum Cyanobacteria (Cyanoprokaryota), class Cyanophyceae, order Pleurocapsales, family Hyellaceae, genus *Chamaecalyx* J. Komárek et K. Anagnostidis, 1986. ***Chamaecalyx swirenkoi* (Schirshov*) Komárek et Anagnostidis, 1986** (basionym: *Dermocarpa swirenkoi* Shirshov, 1929; synonyms: *Dermocarpa clavata* Geitler, 1932; *D. clavata* var. *aquaedulcis* Geitler, 1932; *Dermocarpella clavata* (Geitler) J. Feldmann et Feldmann, 1953; *Cyanocystis swirenkoi* (Sirsov*) G. Hällfors et R. Munsterhjelm, 1982) [32]. Found in the mud volcano on August 03, 2012 (Fig. 2). Met often, singly. Sizes: 41.8 μm long, 13.4 μm wide. Cell sizes [according to: 5, 48]: 20–30 μm (less often up to 40 μm) long, 6.0–10.5 μm wide. This species was first described by P. P. Shirshov from the Kodyma River, a tributary of the Bug River (Ukraine) [47]. Ecology, phytogeography, and general distribution. Freshwater and brackish-water species, found in stagnant freshwater bodies, as well as in seas; boreal-tropical species. It is recorded in supralittoral [23] and microphytobenthos of the Kazantip Nature Reserve of the Sea of Azov [21], in cystoseira

* The author's spelling of the surname Schirshov (Shirshov) [5, 47] is specified in contrast to Širšov used in Komárek et Anagnostidis, 1986 [32, 38].

epiphyton, and on other substrates of the Black and Aegean seas [17], as well as on algae and higher aquatic plants in Dniester River mouth and the Dniester Estuary in Odessa region [7], in epiphyton of green algae and higher aquatic plants near water edge in water bodies of Leningrad Region, in the Chikhachev Bay of the Sea of Japan [1], in a lagoon of the Gulf of Finland of the Baltic Sea [34], in Austria, Japan, Mexico, and Western Slovakia, on the Java Island [38].

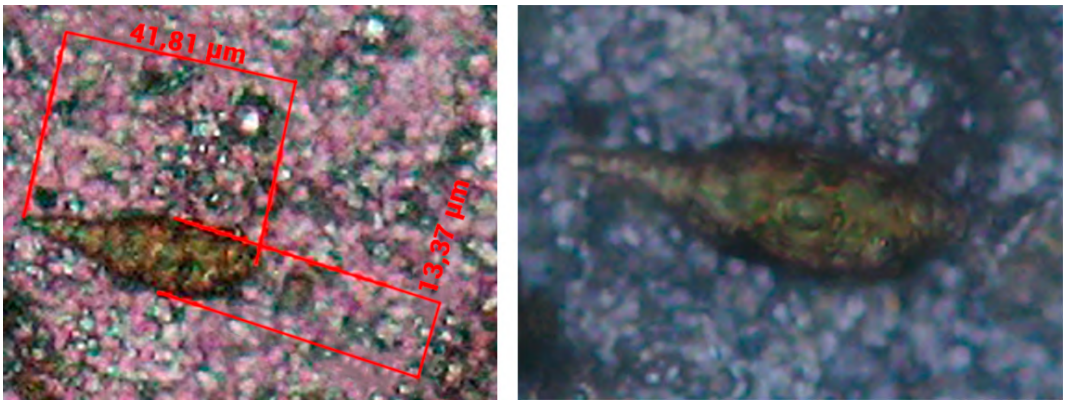

Fig. 2. Cyanobacteria *Chamaecalyx swirenkoi* in the mud volcano in the eastern part of the Crimean Peninsula

Phylum Bacillariophyta, order Naviculales Bessey, family Berkeleyaceae D. G. Mann, 1990, genus *Berkeleya* Greville, 1827. ***Berkeleya micans* (Lyngbye) Grunow, 1868** (basionym: *Bangia micans* Lyngbye, 1819; synonym: *Amphipleura micans* (Lyngbye) P. Cleve, 1894). The benthic species of diatom was found in the mud volcano on August 03, 2012. Sizes: 35 µm long, 3.5 µm wide. Sizes of valves: 39–81 µm long, 4–5 µm wide [17]. Ecology, phytogeography, and general distribution. Marine and brackish-water, boreal and natal species inhabiting mainly the southern European seas, including shallow waters near southern Crimea and the Caucasian coast of the Black Sea, on stones, rocks, and invertebrates' shells [17, 21]. The species was first described from phytoplankton and microphytobenthos of the Sea of Azov [3, 13].

***Berkeleya rutilans* (Trentepohl) Grunow, 1880** (basionym: *Conferva rutilans* Trentepohl ex Roth, 1806; synonym: *Amphipleura rutilans* (Trentepohl) Cleve, 1894). The benthic species of diatom algae was first found in the mud volcano on August 03, 2012. Sizes of valves: 35.1 µm long, 3.5 µm wide. Sizes [according to: 9, 21]: 6–38 long, 2.5–5.0 wide; 26–30 striae and 16–20 rims in 10 µm. Ecology, phytogeography, and general distribution. Marine and brackish-water, littoral and sublittoral, eurythermal species, cosmopolitan. Known in the North, White, Baltic, Barents, Kara, Mediterranean, Black, Caspian, Japanese, and East China seas, as well as in the Sea of Azov, off the coast of Romania, England, North America, Greenland, Iceland, Sweden, China, Kuwait, Japan, New Zealand, and Antarctic Australia [20].

Phylum Bacillariophyta, order Bacillariales Hendey, family Bacillariaceae Ehrenb., genus *Cylindrotheca* L. Rabenhorst, 1859. ***Cylindrotheca closterium* (Ehrenberg) Reimann et J. Lewin, 1964** [45] (basionym: *Ceratoneis closterium* Ehrenb. 1839; synonyms: *Nitzschia closterium* (Ehrenb.) W. Smith, 1853; *N. reversa* W. Smith, 1853; *N. closterium* var. *reversa* (W. Smith) Hauck, 1872; *Nitzschiella closterium* Rabenhorst, 1864; *Nitzschia rostratum* Grunow, 1880; *N. longissima* var. *closterium* (Ehrenb.) Van Heurck, 1885; *N. curvirostris* var. *closterium* (Ehrenb.) De Toni, 1892; *Nitzschiella longissima* var. *closterium* (Ehrenb.) Peragallo et Peragallo, 1897; *Homoeocladia closterium* (Ehrenb.) Kuntze, 1898; *Nitzschiella tenuirostris* Mereschk., 1901; *Nitzschia longissima* Gran, 1930; *N. closterium* var. *recta* Gran, 1931). Found in the mud volcano on August 03, 2012 (Fig. 3). Sizes: 25–260 µm long, 1.5–8.0 µm wide, 12–16 striae

in 10 μm [46]. Ecology, phytogeography, and general distribution. The species is eurythermic, euryhaline, marine and brackish-water, benthic-planktonic. It can be found in plankton of neritic waters, littoral, and sublittoral of seas; cosmopolite; identified in all geographical zones of the World Ocean [20, 35].

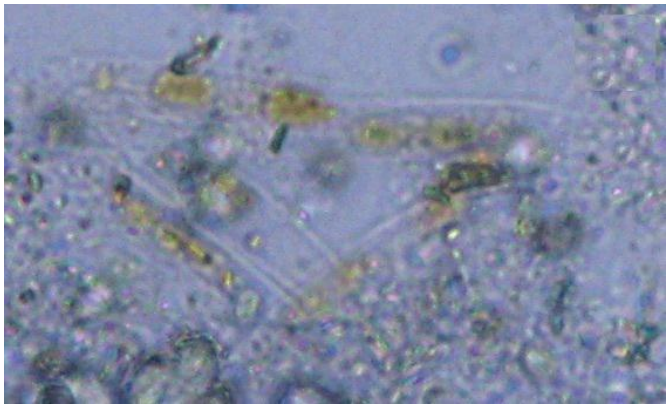

Fig. 3. *Cylindrotheca closterium* cells with chloroplasts in the mud volcano

Phylum Bacillariophyta, order Lyrellales D. G. Mann, 1990, family Lyrellaceae D. G. Mann, 1990, genus *Lyrella* N. I. Karajeva, 1978. ***Lyrella atlantica* (Gregory) D. G. Mann, 1990** (basionym: *Navicula atlantica* A. W. F. Schmidt, 1874; synonyms: *Navicula lyra* var. *atlantica* A. Schmidt, 1874; *Lyrella lyra* var. *atlantica* (Schmidt) Karajeva, 1988). Found in the mud volcano on August 03, 2012 (Fig. 4). Sizes: frustules of 60–100 μm long, 26–32 μm wide, 9–11 striae in 10 μm [4]; 59–65 μm long, 29–35 μm wide, 10 striae in 10 μm [16]. Ecology, phytogeography, and general distribution. Marine, sublittoral species, boreal and natal. Found in the coastal waters of Britain [36] and Australia, as well as in the Black and North seas [16].

Fig. 4. Benthic diatom *Lyrella atlantica* from the mud volcano

Phylum Bacillariophyta, order Bacillariales Hendey, family Bacillariaceae Ehrenb., genus *Nitzschia* Hassall, 1845. ***Nitzschia thermaloides* Hustedt, 1955** (= *Nitzschia translucida* Hustedt, 1959) (Fig. 44: 1–7 [39]). Found in the mud volcano on August 03, 2012 (Fig. 5). Sizes: 34.7–49.7 μm long, 3–7 μm wide, 1 fibula, 14–16 striae in 10 μm. Sizes: 20–73 μm long, 4–6 μm wide, 16–20 fibulae in 10 μm [39]; 43.2–59.5 μm long, 3.8–5.9 μm wide (light microscope); 52 μm long, 6 μm wide, 1 fibula, 21 striae in 10 μm (scanning electronic microscope) [41]. Ecology, phytogeography, and general distribution. Brackish-water, benthic, and boreal-tropical species. Identified for Crimea, the Black Sea, and the Sea of Azov for the first time. Species marked as halophilic one

in Kuril Islands thermal waters, recorded at water temperature of +50…+60 °C [11]. It is common in river estuaries and in the northern fjords of the Sweden coast in winter, spring, and autumn in the supralittoral up to 1.5 m in different ecotopes (silty sand, silt, and sand), as well as on the surface of *Phormidium* and *Mytilus* [40].

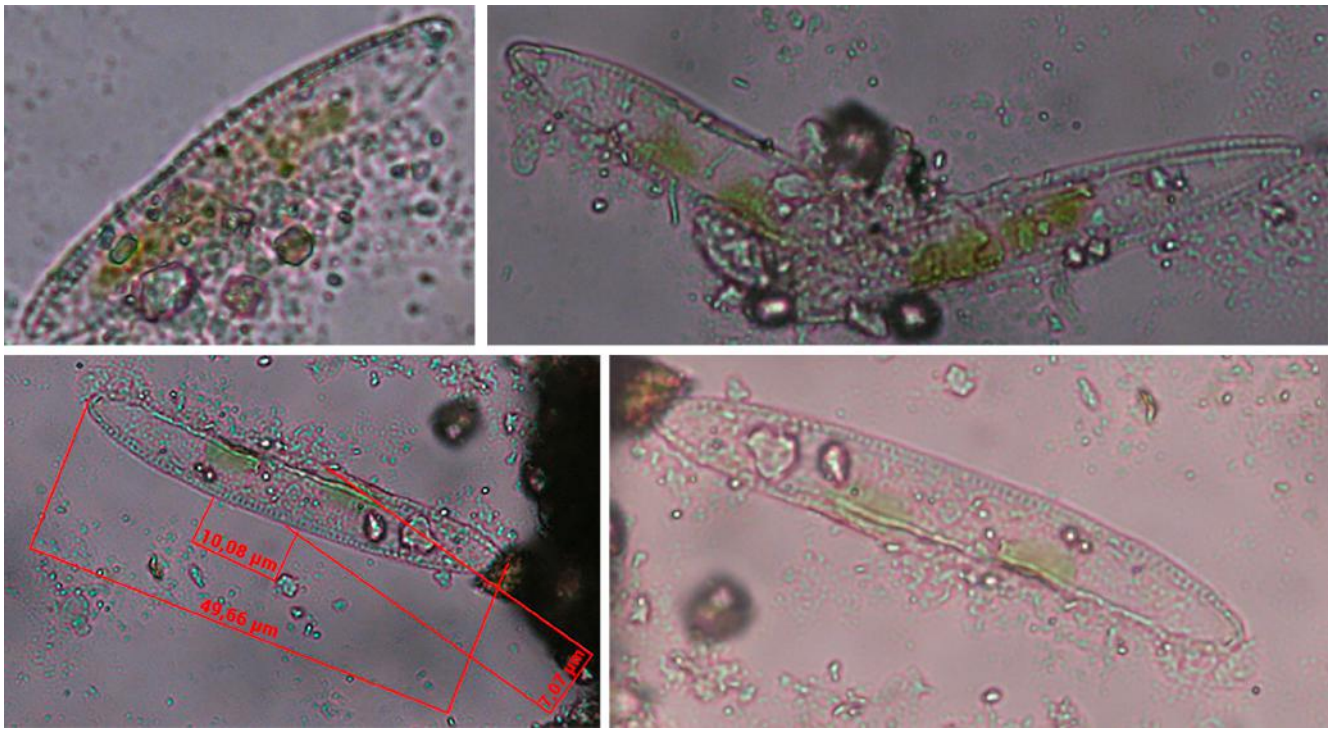

Fig. 5. Benthic diatom *Nitzschia thermaloides* with chloroplasts from the mud volcano

Phylum Bacillariophyta, order Bacillariales Hendey, family Bacillariaceae Ehrenb., genus *Pseudo-nitzschia* H. Peragallo, 1900. ***Pseudo-nitzschia prolongatoides* (Hasle) Hasle, 1993** (basionym: *Nitzschia prolongatoides* Hasle, 1965; synonym: *Nitzschia prolongata* Manguin, 1957). Found in the mud volcano on August 03, 2012. Sizes: 18.5 µm long, 3.3 µm wide. Sizes [according to: 35]: 60 µm long, 16 fibulae and 28 striae at 10 µm. It was recorded relatively recently in the Sea of Azov and in the Black Sea [2, 17]. In Kazantip nature reserve coast (depth up to 1 m) of the Sea of Azov, the species was found on: April 9, 2006 (in the epiphyton of *Enteromorpha* sp., a colony of 2 cells, 123.2 µm long, 2.8 µm wide); October 28, 2011 (in sand ground, a colony of 2 cells was identified being of 117.7 µm long and of 2.2 µm wide, as well as individual cells of 55 µm long, 2.5 µm wide); August 07, 2014 (in the epiphyton of the red alga *Ceramium rubrum*). Ecology, phytogeography, and general distribution. Marine, planktonic, belongs to potentially toxic algae. Due to poor knowledge, the species can still be attributed to boreal and natal. The species is recorded in Antarctic waters [19].

Phylum Dinophyta, class Dinophyceae, order Prorocentrales Lemmermann, family Prorocentraceae F. Stein, genus *Prorocentrum* Ehrenberg, 1834. ***Prorocentrum lima* (Ehrenberg) Dodge, 1975** (basionym: *Cryptomonas lima* Ehrenberg, 1860; synonyms: *Exuviaella marina* Cienkowski, 1881; *Dinopyxis laevis* Stein, 1883; *E. lima* (Ehrenberg) Bütschli, 1885; *E. laevis* (Stein) Schröder, 1900; *E. chathamensis* Lemmermann, 1907; *E. cincta* Schiller, 1918; *E. caspica* I. Kisselev, 1927; *E. marina* var. *lima* (Ehrenberg) Schiller, 1931; *E. ostenfeldii* Schiller, 1933; *Prorocentrum marinum* Dodge et Bibby, 1973; *P. marinum* (Cienkowski) Abé in Bodeanu, 1987–1988; *P. marinum* var. *lima* (Schiller) Krachmalny, 1994).

Found in the mud volcano on April 13, 2013 (Fig. 6). Sizes: 25 μm long, 14.7 μm wide. Sizes [according to: 18]: 30–50 μm long, 18–45 wide; Black Sea specimens: 36–44 μm long, 21–30 μm wide. Ecology, phytogeography, and general distribution. Marine, benthic species, cosmopolitan. Recorded in the Mediterranean, Adriatic, Black, Caspian seas, as well as in the Sea of Azov and in the Indian Ocean. The species is toxic and produces okadaic acid [18, 40, 47].

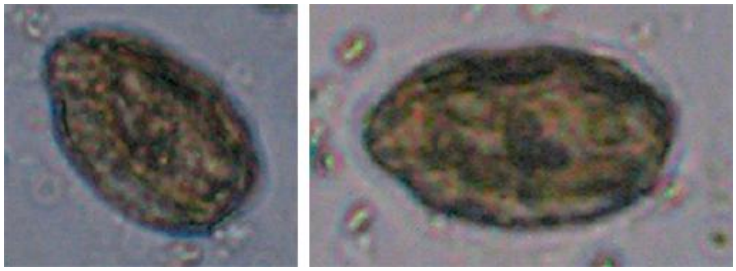

Fig. 6. Different views of dinoflagellate *Prorocentrum lima* (Ehrenberg) Dodge shells from the mud volcano

Phylum Dinophyta, class Dinophyceae, order Gonyaulacales F. J. R. Taylor, family Ostreopsidaceae Lindemann, genus *Alexandrium* Halim, 1960. ***Alexandrium tamiyavanichii* Balech, 1994.** Found in the mud volcano on April 13, 2013 (Fig. 7). Sizes: 32.3 μm long, 29.5 μm wide. Sizes [according to: 29]: 40.8–41.7 μm long, 37.5–43.8 μm wide. Ecology, phytogeography, and general distribution. Marine, planktonic, boreal-tropical, and potentially toxic species [47]. Found in water bodies in Thailand and the Philippines [29]. This is a new species for algal flora of Crimea and the Black Sea.

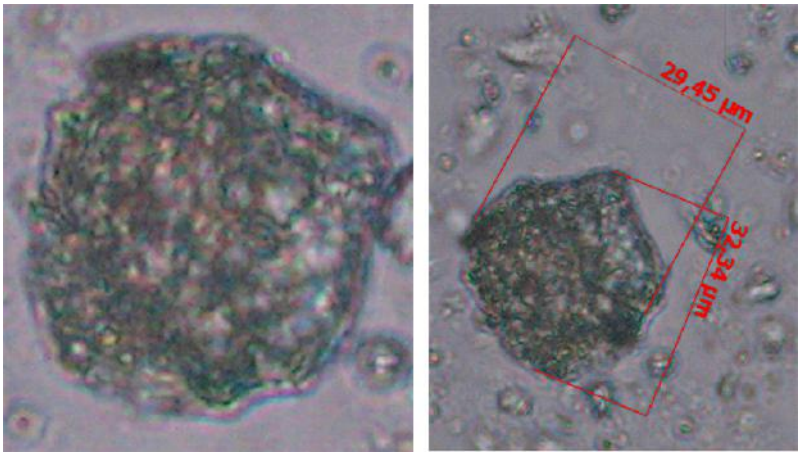

Fig. 7. Dinoflagellate *Alexandrium tamiyavanichii* Balech from the mud volcano

Euglenophytes species, first identified in the mud volcano in the eastern part of the Crimean Peninsula, their ecology, phytogeography, and general distribution [22] are given below.

Phylum Euglenophyta, class Euglenophyceae, order Euglenales, family Euglenaceae, genus *Trachelomonas* Ehrenberg, 1838. ***T. armata* (Ehrenberg) Stein, 1878** (basionym: *Pantotrichum armatum* Ehrenberg; synonym: *Chaetotyphla armata* Ehrenberg, 1833). Found in the mud volcano on April 13, 2013. Sizes: 32.4 μm long, 22.3 μm wide. Sizes [according to: 14]: 30–39 μm long, 25–28.5 μm wide. Ecology, phytogeography, and general distribution. Freshwater, boreal-tropical, natal species. Recorded in Russia [14, 15], Romania [31], China [37], Singapore [43], North and South America [49], Australia and New Zealand [33], Turkey [27], the Netherlands, Slovakia, Sweden, Brazil, Caribbean Islands, Britain, Germany, Spain, Bangladesh, in Africa [32], as well as in the Baltic Sea [34].

***T. hexangulata* Svirenko, 1914** [48]. Found on April 13, 2013 in the surface water of the mud volcano. Sizes: 32.2–34 μm long, 12.6–14 μm wide; neck: 4.2 μm high, 2.8 μm wide. Sizes [according to: 14]: 27–34 μm long, 12–16 μm wide. Ecology, phytogeography, and general distribution. Freshwater, boreal species. Found among cyanobacteria communities in lakes plankton, in the swampy sedge hummock, in forest ditches, puddles along channels of dried forest streams, at the edges of sedge marshes, in sphagnum swamps of the forest-tundra [14]. It is recorded in the marsh waters of European Russia, Western Siberia [14, 15], Far East [10], and Chelyabinsk region [26], in waters of Great Lakes of the USA [42], in water bodies of Romania [30], Turkey [27], the Netherlands, Poland, Romania, Slovakia, Sweden, Britain, Spain, India, Brazil, Argentina, North America, Cuba, Tajikistan, Thailand, Taiwan, Bangladesh, Mexico, and Iraq [32], as well as in the Sea of Azov [6] and the Baltic Sea [34].

***T. planctonica* Svirenko, 1914.** Found in the mud volcano on April 13, 2013. Lodge sizes: 23–27 μm long, 18–21 μm wide. Sizes [according to: 14]: 21–31 μm long, 17–22 μm wide. Ecology, phytogeography, and general distribution. Freshwater, boreal-tropical. Can be found in small water bodies with fresh stagnant water, occasionally in rivers, mainly in plankton of rivers in Tomsk and Chelyabinsk regions, Western Siberia [14, 26], Russian Far East [10], in water bodies of the Netherlands, Poland, Romania, Slovakia, Sweden, Britain, Spain, India, Brazil, Argentina, North America, Cuba, Tajikistan, Thailand, Taiwan, and Bangladesh [32], as well as in the Baltic Sea [34] and the Sea of Azov [6].

***T. scabra* Playfair, 1915** (= *Trachelomonas scabra* var. *latior* Skwortzow, 1925). Found in the mud volcano on August 03, 2012. Sizes: 23–27 μm long, 18–21 μm wide. Sizes [according to: 14]: 18–33 μm long, 15–20 μm wide. Ecology, phytogeography, and general distribution. Freshwater species, boreal-tropical and natal. Found in the coastal lakes of Georgia and Chelyabinsk region [26], Britain, North America [50], Romania [31], Spain [27], Turkey [28], and China [37], as well as in Australia and New Zealand [32]. Recorded in the Sea of Azov [6].

***T. volvocina* (Ehrenberg) Ehrenberg, 1834** (= *Microglena volvocina* Ehrenb.). Found in the mud volcano on April 13, 2013 with cell diameter of 8–9 μm (Fig. 8). Lodges are spherical, with diameter of (4)–8–23–(32) μm [14]. Ecology, phytogeography, and general distribution. It is a freshwater species, mainly inhabiting stagnant water, less commonly found in weakly brackish water at pH of (4.4)–5.5–8.4. It is characterized as β-mesosaprob-oligosaprob, has mixotrophic nutrition. Boreal species. It is recorded in Odessa Region and Crimea [14].

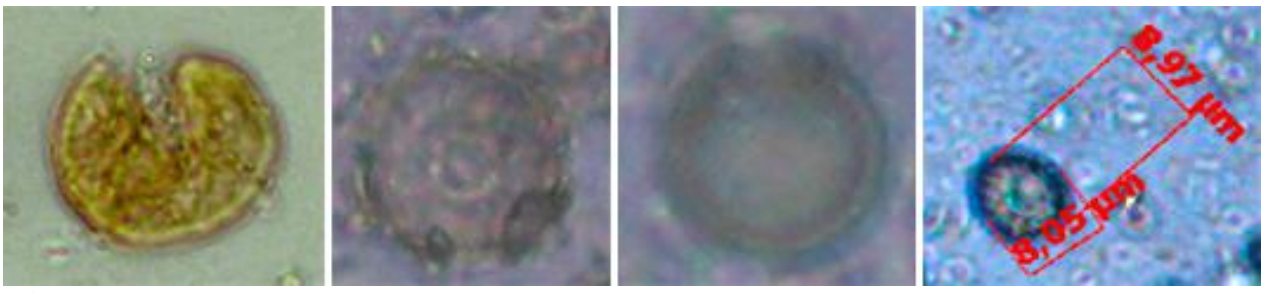

Fig. 8. *Trachelomonas volvocina* from the mud volcano, view from different angles

Phylum Euglenophyta, class Euglenophyceae, order Euglenales, family Euglenaceae, genus *Strombomonas* Deflandre, 1930 (= *Trachelomonas* Ehrenberg). Lodge sizes of species of this genus are larger and more variable in shape compared to those of the genus *Trachelomonas* [14]. *Strombomonas* were found in the intravital state in the mud volcano. Representatives of this genus were often recorded in samples, but it was difficult to identify them to species. Micrographs of some of them are given below.

***Strombomonas acuminata* (Schmarda) Deflandre, 1930** (basionym: *Lagenella acuminata* Schmarda; synonym: *Strombomonas acuminata* var. *verricosa* Teodoresco). Found in the mud volcano on April 13, 2013 (Fig. 9). Lodge sizes: 21.5–27.6 μm long, 20.7–32 μm wide; neck: 14×9.8 μm. Sizes [according to: 14]: 38.0–55.5 μm long, 28–33 μm wide. Ecology, phytogeography, and general distribution. The species is freshwater, boreal. It is recorded in the water bodies of Romania [31], Crimea, the Caucasus, Central Asia, and Western Siberia [14].

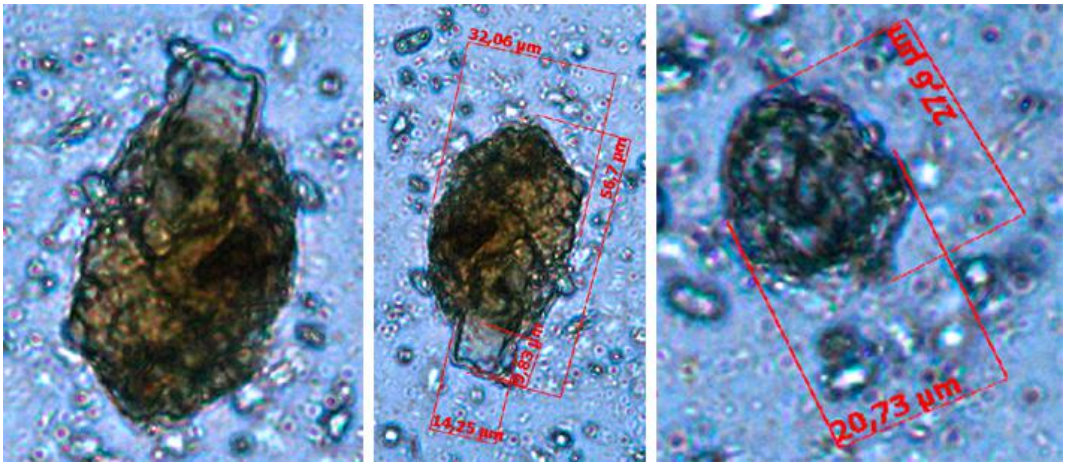

Fig. 9. View of lodges of *Strombomonas acuminata* from the mud volcano

***St. tambowica* (Swirenko) Deflandre, 1930** (synonyms: *Trachelomonas zmiewica* Swirenko; *Tr. tambowica* var. *granulata* Skvortzov; *Strombomonas verrucosa* var. *zmiewica* (Swirenko) Deflandre, 1930). Found in the mud volcano on April 13, 2013 (Fig. 10). Lodge sizes: 38–55.5 μm long, 28–34 μm wide. Sizes [according to: 14]: 47.5–56 μm long, 26.6–32 μm wide. Ecology, phytogeography, and general distribution. The species is freshwater, boreal. Recorded in the plankton of freshwater bodies of Ukraine, as well as Tambov, Rostov and Tomsk regions of Russia [14].

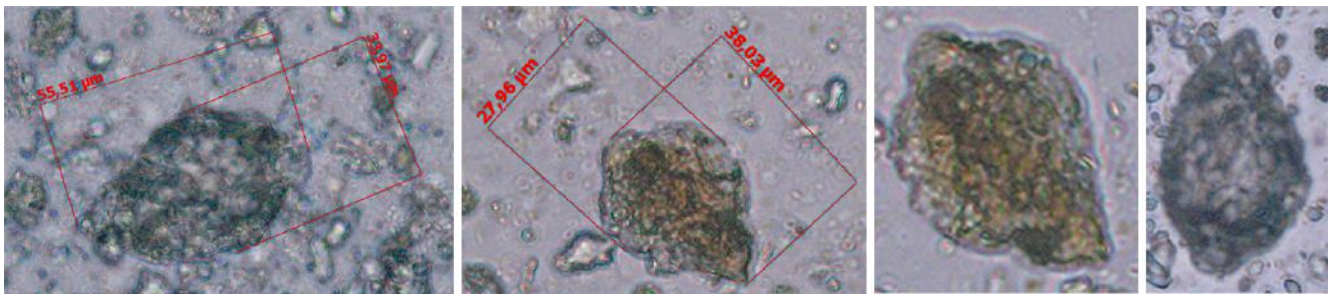

Fig. 10. Lodges of *Strombomonas tambowica* from the mud volcano, view from different angles

Euglenophytes, uniting unicellular, less often colonial microscopic algae, inhabit freshwater bodies throughout the world. A small number of them are confined to brackish and sea waters. These are representatives of the genera *Eutreptia* Perty, *Eutreptiella* da Cunha, *Klebsina* P. C. Silva, *Trachelomonas* Ehrenberg, and *Strombomonas* Deflandre. They can be found in plankton, in thickets of coastal algae and interstitial of sandy beaches, in rivers and lakes, and at sea coasts with low salinity. *Trachelomonas caudata* (Ehrenberg) F Stein, *T. volvocina* (Ehrenberg) Ehrenberg, and *T. volvocina* var. *papillata* Lemmermann species

were identified in the Black Sea [17]. Totally 24 species were found in the Sea of Azov, 7 of them (*Trachelomonas borodiniana* Swirenko, *T. globularis* (Averintsev) Lemmermann, *T. hispida* (Perty) F. Stein, *T. planctonica* Svirenko, *T. scabra* Playfair, *T. verrucosa* A. C. Stokes, and *T. volvocina* (Ehrenberg) Ehrenberg) were mainly recorded in summer and autumn [6, 21]. Most species of microalgae from the mud volcano having a mixotrophic or totally saprophytic type of nutrition are actively involved in self-cleaning of habitats.

Conclusion. A preliminary study of microalgae of the mud volcano in the region of the Bulganak sopochnoe field on the Crimean Peninsula showed the diversity of their species composition in watered habitats.

We found cyanobacteria *Chamaecalyx swirenkoi* and 15 species of eukaryotic microalgae: 2 dinoflagellate species (of genera *Prorocentrum* and *Alexandrium*), 6 diatom species (1 of genera *Lyrella*, *Pseudonitzschia*, *Nitzschia*, and *Cylindrotheca*; 2 of genus *Berkeleya*), as well as 7 species of euglenophytes (5 of genus *Trachelomonas*; 2 of genus *Strombomonas*). Some of them are widespread in the microphytobenthos of the Sea of Azov and the Black Sea. Of all the types of algae found in the mud volcano, 7 species are common for the Black Sea, while 9 species, including 3 species of euglenophytes, are common for the Sea of Azov.

Three species considered to be potentially toxic were identified: diatom *P. prolongatoides*, as well as dinophytes *Pr. lima* and *A. tamiyavanichii*. The last species is marine, boreal-tropical, and new to Crimean flora. By characteristics of halobility, species found in the mud volcano belong to freshwater complex (53 %), with a significant share of marine (27 %) and brackish-water (20 %) species. Taking into account phytogeographic features, it can be concluded that boreal species make up 33 %, boreal-tropical species – 47 %, and cosmopolite – 20 %.

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МИКРОВОДОРОСЛИ ГРЯЗЕВОГО ВУЛКАНА БУЛГАНАКСКОГО СОПОЧНОГО ПОЛЯ КРЫМСКОГО ПОЛУОСТРОВА

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Грязевые вулканы — одно из уникальных явлений природы. Они широко распространены по всему миру. Грязевые вулканы встречаются и на территории Крыма, в том числе на Булганакском сопочном поле — крупнейшем скоплении действующих вулканов на полуострове (45°25′29.04″ с. ш.,

36°27′51.64″ в. д.). Изучение одноклеточных водорослей грязевых вулканов в Крыму, как и в других регионах России, до настоящего времени не проводили. Необходимость и актуальность исследований продиктована отсутствием сведений о видовом составе микроводорослей грязевых вулканов. Пробы собраны О. Ю. Ерёминым 03.08.2012 и 13.04.2013 в верхнем 2–3-сантиметровом слое суспензии вместе с приповерхностной водой, вытекающей из него. Диапазон солёности и температуры воды составлял 27–32 г·л$^{-1}$ и +28…+31 °С. Видовой состав микроводорослей определяли в водных препаратах в прижизненном состоянии водорослей с помощью светового микроскопа Axioskop 40 (Carl Zeiss) при увеличении 10×40, используя программное обеспечение AxioVision Rel. 4.6. Обнаружено 16 видов, принадлежащих к высшим таксономическим группам: Cyanobacteria (1 вид), Dinophyta (2), Bacillariophyta (6) и Euglenophyta (7). Из них цианобактерия *Chamaecalyx swirenkoi* (Schirshov) Komárek et Anagnostidis, 1986 найдена нами в августе 2012 г. В пробах отмечены пеннатные диатомовые водоросли — как одиночно живущие (родов *Cylindrotheca* (Ehrenberg) Reimann & J. C. Lewin, *Lyrella* Karajeva и *Nitzschia* Hassall), так и колониальные (родов *Berkeleya* Greville и *Pseudo-nitzschia* H. Peragallo). Солоноватоводный, бентосный, бореально-тропический вид *Nitzschia thermaloides* Hustedt впервые отмечен для альгофлоры Крыма, Чёрного и Азовского морей. Также обнаружены эвгленовые водоросли — 5 видов рода *Trachelomonas* Ehrenberg и 2 вида *Strombomonas* Deflandre. Из всех видов, найденных в экотопе грязевого вулкана, 7 являются общими с Чёрным морем, а 9, включая 3 вида эвгленовых водорослей, — с Азовским. Показано, что по характеру галобности в грязевых вулканах преобладают виды, типичные для пресноводного комплекса (53 %), при существенной доле морских (27 %) и солоноватоводных видов (20 %). Из фитогеографических элементов флоры бореальные виды составляют 33 %, бореально-тропические — 47 %, космополиты — 20 %. Отмечено три вида потенциально токсичных водорослей — диатомея *Pseudo-nitzschia prolongatoides* (Hasle) Hasle, 1993 и динофитовые *Prorocentrum lima* (Ehrenberg) Dodge, 1975 и *Alexandrium tamiyavanichii* Balech, 1994. Последний вид является морским, бореально-тропическим и новым для альгофлоры Крыма и Чёрного моря. В статье также представлены собственные и литературные данные по морфологии, экологии, фитогеографии видов и их общему распространению в разных водоёмах мира. Некоторые виды микроводорослей относятся к индикаторам сапробности; они способны участвовать в очищении вод от избытка растворённых органических веществ. Приведены фотоснимки грязевых вулканов и микрофотоснимки некоторых видов.

Ключевые слова: микроводоросли, эвгленовые, диатомовые, динофитовые, грязевой вулкан, Крымский полуостров