Phenotypic and ecological diversity of freshwater coccoid cyanobacteria from maritime Antarctica and Islands of NW Weddell Sea. II.

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Abstract

The article contains the second part of the review of natural populations of coccoid (unicellular, colonial) cyanobacteria from the coastal, maritime Antarctica and the vicinity of Antarctic Peninsula, mainly from its north-eastern region. The samples were collected from several localities with terrestrial and freshwater habitats of the deglaciated parts of South Shetland Islands, and from the northern part of James Ross Island. The material was identified according to the modern system (Komárek et al. 2014b). This second part contains 16 species (from 12 genera) from the cytologically more complicated orders Chroococcales, Pleurocapsales and Chroococcidiopsidales, characterized also by more irregular thylakoidal system. Similarly as in types from the order Synechococcales, all species are connected with special habitats and their cultivation is difficult. They are adapted to the special biotopes and in spite of their relatively wide diversity, only few occurred rarely in massive populations. Several species are evidently endemic for Antarctica, 8 species are described as new recognized taxa.

Key words: coastal Antarctica, coccoid cyanobacteria, complicated thylakoidal system, South Shetland Islands, James Ross Island, taxonomy, ecology

Abbreviations: D - description of morphology, E - ecology, L - locality, N - notes, JRI - James Ross Island, KGI - King George Island

DOI: 10.5817/CPR2014-1-3

Received March 17, 2014, *accepted* July 28, 2014.
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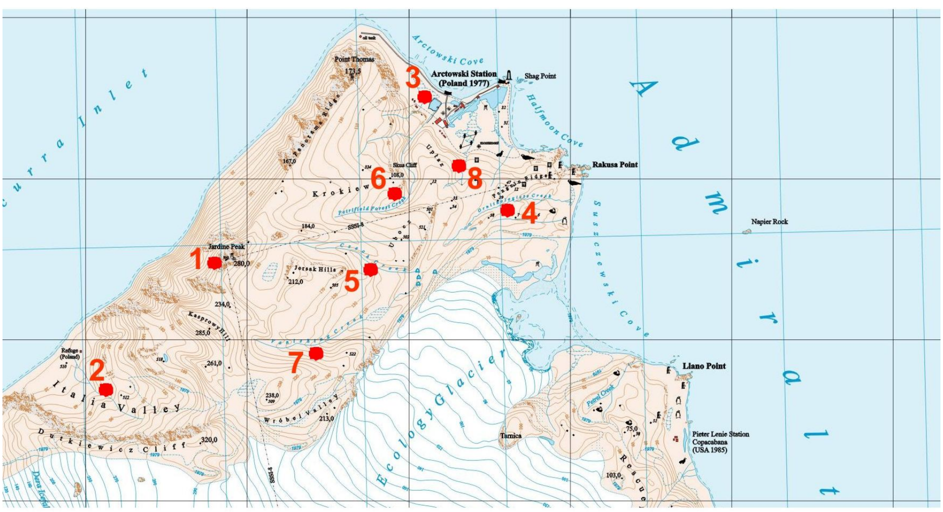
Acknowledgement: The study was supported by grants GA CR 206/08/0318 and RVO67985939. The author thanks to chiefs of Antarctic expeditions in King George Island (Prof. Barcikowski, Toruń – H. Arctowski Station, Prof. Batista, Montevideo – Artigas Station) and James Ross Island (Prof. Barták, Brno – J.G.Mendel Station) and for the collaboration in terrain and laboratory work to Doc. J. Elster, Dr. O. Komárek, Dr. L. Nedbalová and D. Švehlová.

Introduction

This article contains the second part of the review of nature populations of coccoid cyanobacteria from maritime Antarctica, from the cytologically more complicated orders. The unicellular and colonial cyanobacteria were traditionally (during the morphological period of botanical classification) classified only in one order, but modern polyphasic approach, using commonly the ultrastructure and molecular methods, identified at least two main phylogenetic clades of coccoid genera, resulting to filamentous cyanobacteria (Synechococcales → Pseudanabaenales; Chroococcales → Oscillatoriales). The members of Synechococcales, identified from the region of maritime Antarctica are included in the previous, first part of this article (Komárek 2013). The second part contains the species, classified now to the more complicated orders Chroococcales, Pleurocapsales and Chroococcidiopsidales, characterized by the morphologically more diversified thallus and reproducing often by combined binary fission and nanocytes or baeocytes. The data from the introduction of the first part are valid also for this second part, particularly the common information and description of localities and habitats, from which were collected materials for our studies.

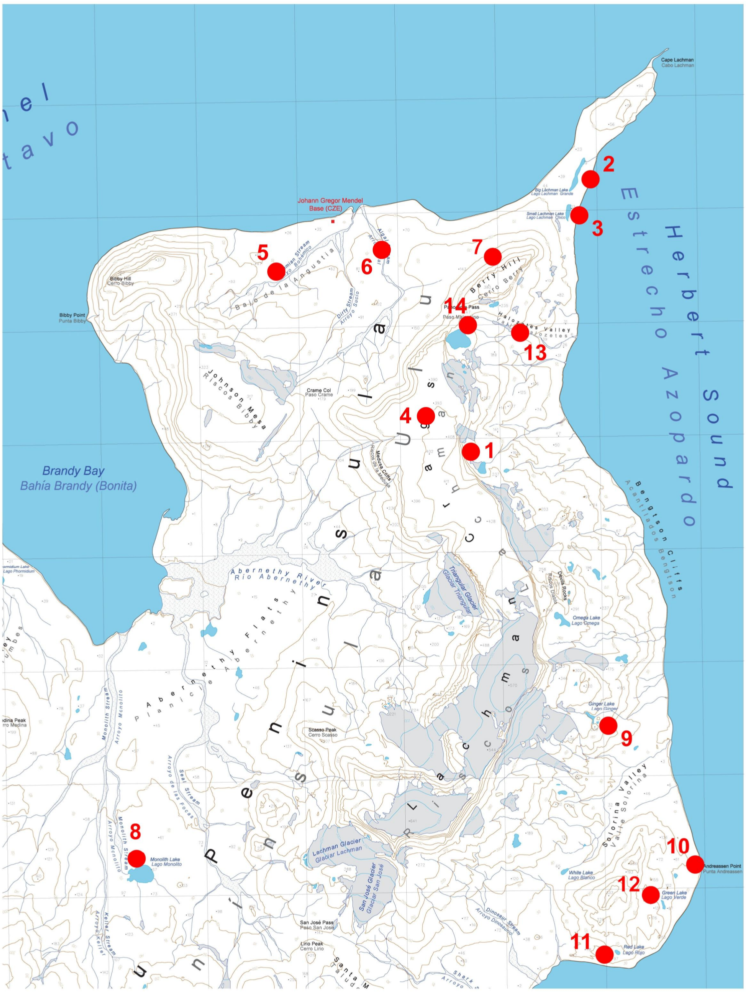
The cyanobacterial microflora of Antarctica is little known with regard of the modern taxonomy. It is also the reason, why several morphotypes were not exactly classified on the species level. The unicellular cyanobacteria occur in all main habitats of the coastal Antarctica, but grow only sporadically and massive populations develop rarely. In spite of it, they often appear in special morphotypes. This article is focused on description of coccoid morphotypes from the mentioned phylogenetically more complicated orders, found in the studied areas. The filamentous cyanobacterial types from the same region will be included in special articles, with frequent use of cultures, which are easier in these types (Strunecký et al. 2012, Komárek et al. 2014a).



Map 1. Main localities of sample collections at the King George Island near Arctowski station: 1- Jardine Peak, 2 - Italian Valley, 3 - Polish Antarctic H. Arctowski Station, 4 - Ornithologist Creek, 5 - Czech Creek, 6 - Petrified Forest Creek, 7 - Vanishing Creek, 8 - Moss Creek. *Source*: Map of SSSI - 8, Department of Antarctic Biology, PAS, IUNG Pulawy, Rafal Pudełko 2002.

Material and Methods

The description of the area, data and locations of sampling and methods of laboratory studies are described in the introductory chapter of the first part (Komárek 2013) and are identical with the second part. The respective differences are mentioned in various species. In this review, as well as in the first part, all registered taxa are described and their characteristics (with respective diagnoses) are included in the paragraph „D“. Other data are contained in the paragraphs „E“ (ecology), „L“ (localities) and „N“ (taxonomical notes to individual taxa).



Map 2. Main localities of sample collections at the James Ross Island: 1 - Devil Rocks, 2 - Lake Lachman I, 3 - Lake Lachman II, 4 - Lachman Crags, 5 - Water Supply Creek, 6 - Algal Creek, 7 - Northern slopes of Berry Hill, 8 - Monolith Lake, 9 - Ginger Lake, 10 - Andreassen Point (Santa Marta Cove), 11 - Red Lake, 12 - Green Lake (Solorina Valley), 13 - Tern Creek (Halozetes Valley), 14 - Dulánek. *Source:* Topographic base of Czech Geological Survey (2009).

Results

***Aphanothece* sp. (Fig. 1) – Chroococcales, Aphanothecaceae**

D: Small colonies with colourless, not structured slime (sometimes with few cells only), rarely forming larger (but yet microscopical) colonies with many, irregularly localized cells. Cells oval, greyish-blue, usually with 1-2 distinct ± polar granules, 2.4-4.2 x ± 2.6 µm.
E: In seepages, in assemblages of other cyanoprokaryotes, rarely forming up to macroscopically visible, irregular colonies.
L: Found only in JRI.
N: *Aphanothece* occurs in few slightly different morphological types in seepages, sporadically. Its relations to other known *Aphanothece*-species and also between various populations in other Antarctic localities are unclear.

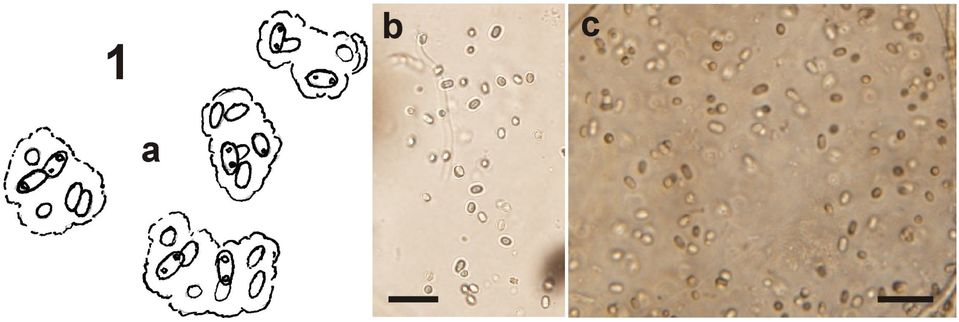


Fig. 1. *Aphanothece* sp. (bars = 20 µm).

***Asterocapsa* sp. (div.?) (Fig. 2) – Chroococcales, Chroococcaceae**

D: Solitary cells or their small agglomerations among other algal and cyanobacterial assemblages, rarely enveloped by mucilaginous sheaths. Cells irregularly spherical or subspherical, usually solitary or in free irregular groups, later in twos or several in one sheath, with pale blue-green or greyish, ± homogeneous content, enveloped by thin, smooth, firm, dark violet up blackish (or orange?) sheaths with smooth surface. Diameter of single cells with sheaths 7.2-8.5 µm. The sheath opens or splits after cell division and the daughter cells escape and synthetize their individual envelopes.
E: Subaerophytically, sporadically on wet rocks, stones and in emerged rocks in old seepages, rarely also submersely.
L: Known from wet rocks (subaerophytic) in maritime Antarctica (KGI: Fildes Peninsula, Jardine Peak) and from JRI (Devil Rocks, seepages near Lake Lachman II), locally quite common (several localities).
N: In KGI occurs two types with differently coloured sheaths, violet and orange (two genotypes ?), but no transient forms between both these *Asterocapsa* types were found. – The taxonomy and position of this type of cyanobacteria is still unclear. In European and American populations of cyanobacteria from wet rocks occur similar types of cells, considered as stages of various *Gloeocapsa* or *Gloeocapsopsis* species (*cf.* Nováček 1934, Jaag 1945, Hauer pers. comm.; *cf.* Fig. 12d). However, larger, irregular cells, dividing within envelopes (rarely forming 2- or more-celled irregular colonies), differ from *Gloeocapsa,* often with firm, not stratified sheaths. Our types are without tran-

sitions to other species, occurring on various aerophytic localities. – The Antarctic specimens are probably members of simple „unicellular“ types within the genus „*Asterocapsa*“, which possibly represent a different generic entity in comparison with „typical *Asterocapsa*“ with more cells and with complicated life cycle (which never occurred in our samples). We never have found the transient types to *Gloeocapsa* or *Gloeocapsopsis* stages.

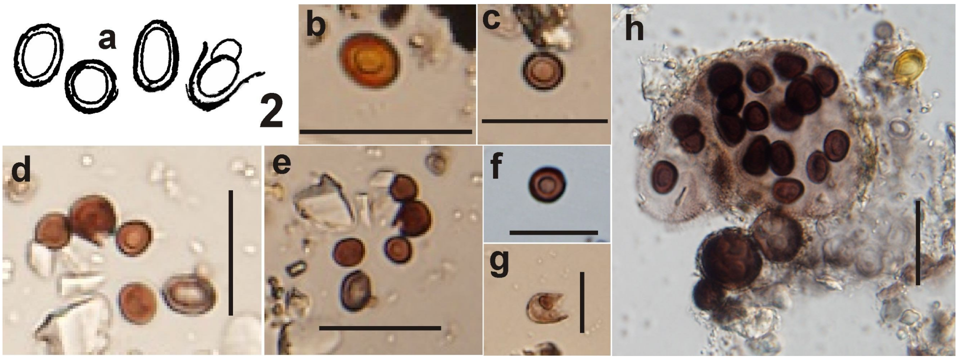


Fig. 2. *Asterocapsa* sp.: Solitary ensheated cells, **h** = group of cells in mucilaginous colony (bars = 20 μm).

***Chamaesiphon arctowskii* sp. nova (Fig. 3) – Chroococcales, Stichosiphonaceae**

D: Cells ± pear-shaped, arranged ± parallelly and vertically on the substrate (usually plant substrate), in dense layers or forming irregular clusters, with one (very rarely with two) exocytes, ± 5-8 x 3-6.5 μm. Cell content pale grey-blue, pseudovaginae relatively thin, colorless, brownish or yellow-brown. – Type: Fig. 3.

E: Epiphytic on filamentous algae (*Klebsormidium*), other filamentous cyanoprokaryotes and mosses in small creeks in streaming water. Known from small streams with intense vegetation of mosses.

L: Type locality: Moss Creek (Polish Antarctic H. Arctowski Station, KGI). - Originally found only near the station „Henryk Arctowski“, with the best population in the Moss Creek. However, small other populations occur also in other creeks in KGI in Admiralty Bay: Fildes Peninsula, Ornithologist Creek, Vanishing Creek, Czech Creek, and in JRI: Ulu Peninsula.

N: *C. arctowskii* belongs evidently to the subg. *Godlewskia,* but it is clearly morphologically and ecologically different from other species of this cluster. This section belongs in another order and family as the typical *Chamaesiphon* and will be surely reclassified on the level of genus in future. Another morphologically and ecologically similar species from the subgenus *Godlewskia* occur commonly in central part of King George Island (vicinity of Admiralty Bay), forming blackish spots on stones in streaming waters (*see* next species). Similar cells (two slightly different populations), occur also among other cyanobacterial assemblages on stony substrates very sporadically in JRI, but the determination was impossible for the rare material. – *C. arctowskii* is possibly genetically similar to the next species.

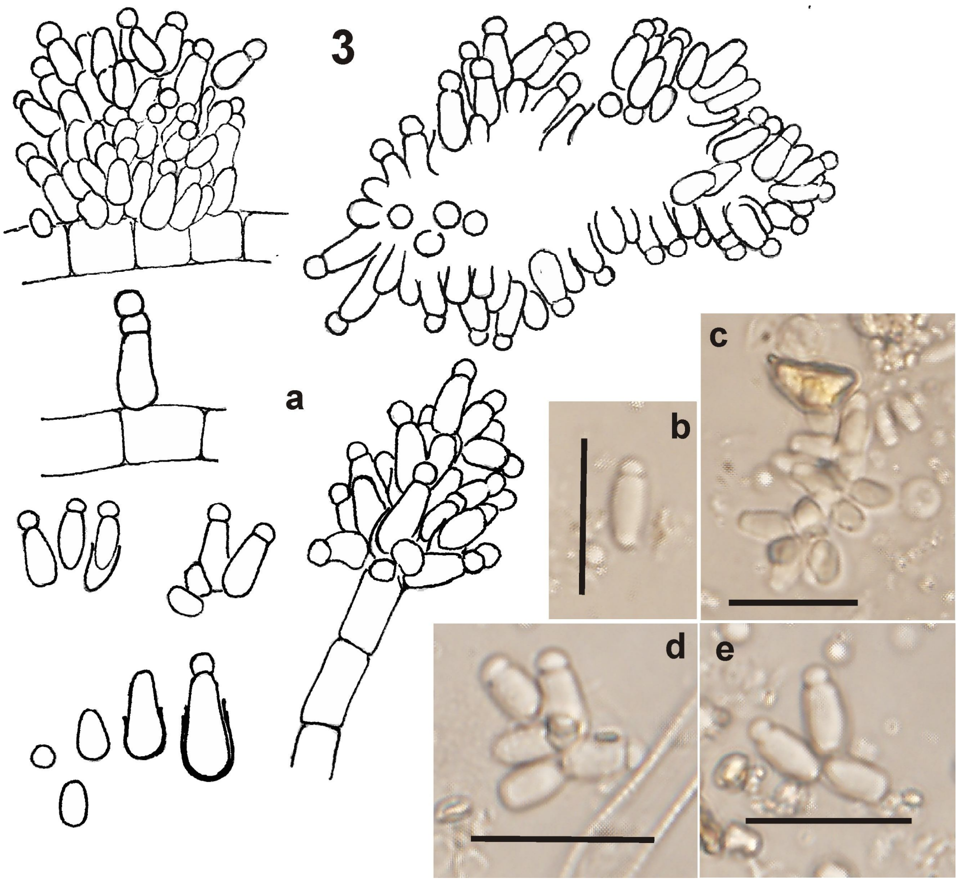


Fig. 3. *Chamaesiphon arctowskii* (bars = 20 µm).

***Chamaesiphon austro-polonicus* sp. nova (Fig. 4) – Chroococcales, Stichosiphonaceae**

D: Cells pear-shaped to oval, 3-10.6 x ± 5 µm, agglomerated in colonies, forming macroscopic and blackish spots on stony substrates, sometimes with one to several layers or forming irregular clusters, with pale grey-blue-green cell content. Sheaths thin to slightly thickened, yellow-brown, exocytes solitary up to in short (up to 3) rows. Exocytes ± 2-2.6 µm in diameter. – Type: Fig. 4.

E: Epilithic, living submersely and forming chocolate dark brown to blackish irregular and macroscopically visible spots on the surface of stones in streaming water. Very intense development on the surface of stones in creeks, usually influenced by near penguin rookeries (*Spheniscus adeliae*). Occurs also on the bottom part of stones, but with cells more intensely blue-green and colorless sheaths.

L: Up to now found only in KGI, in the vicinity of Polish Antarctic station "Henryk Arctowski". The largest population (type locality) was found in lower stream of the Ornithologist`s Creek near the station, on the plane below the first rock step, locally very common; very rarely occurred in the lower part of the Petrified Forest Creek.

N: Colonies macroscopical, resembling *Ch. geitleri;* morphologically similar also to *Ch. polonicus*. Probably a special morphospecies of *Chamaesiphon* subg. *Godlewskia.* A little similar morphotype forms very rarely blackish biofilms in JRI, on stony substrate (in the spray-zone) of the lower part of the Devil Rocks (E walls of Lachman Crags).

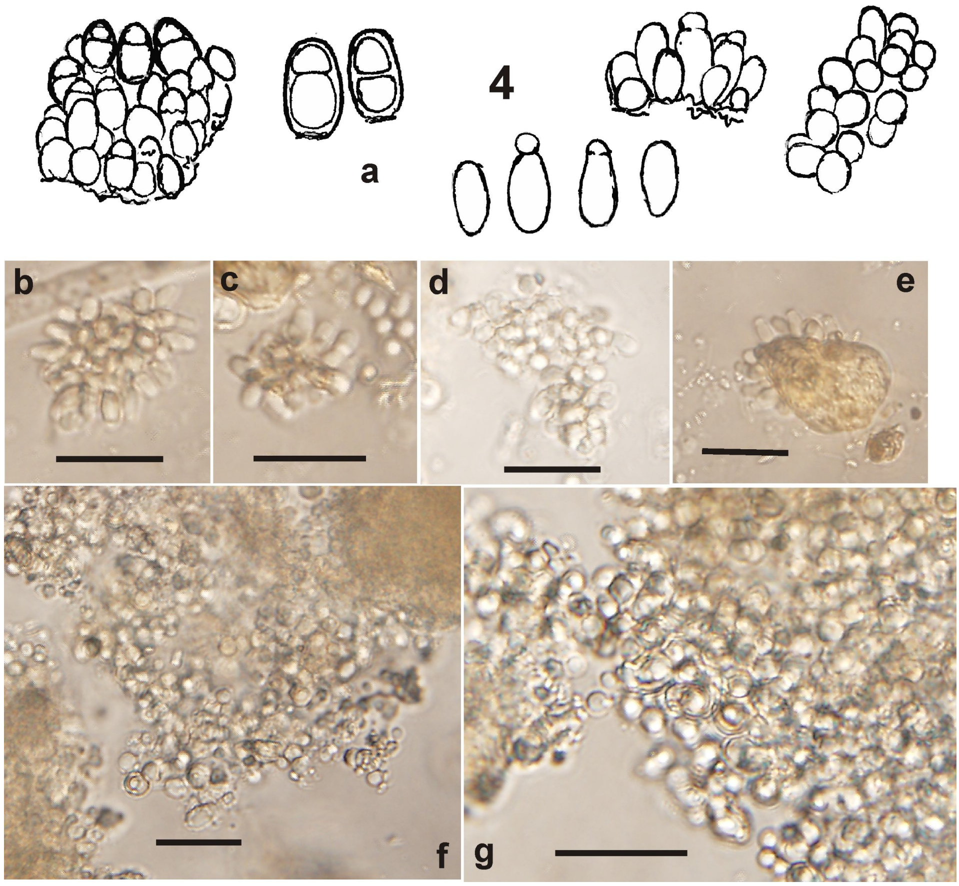


Fig. 4. *Chamaesiphon austro-polonicus* (bars = 20 µm).

***Chamaesiphon* sp. – Chroococcales, Stichosiphonaceae**

D: Cells short cylindrical, irregularly oval or ovoid, with pale greyish blue-green content. Cells solitary or irregularly, ± parallel arranged and forming rusty brownish spots on stony substrates. The cells grow in one narrow monolayer, they are widely oval with pale greyish blue-green, ± homogeneous protoplast; 2.2-4.8 x ± 2.4 µm, enveloped by firm, thin, narrow, brownish sheath. At the top divides one exocyte, which separate occasionally from protoplast or remains attached to the empty sheath. Cells grow solitary or ± parallel in a monolayer, without firm envelopes (possibly from the subg. *Chamaesiphon*; *see* part 1, Komárek 2013).

E: This type occurs sporadically on wet rocks near the small streams and small waterfalls.

L: One population from JRI was found in creeks below Devil Rocks and it is known also from Water Supply Creek and Algal Creak (Ulu Peninsula), also from wetted rocks.
N: Occurs in various morphotypes, but never was found in wide populations and the morphological and ecological variability is still unclear. It needs further study.

Chlorogloea antarctica **sp. nova (Fig. 5) – Chroococcales, Entophysalidaceae**
D: Colonies gelatinous, relatively small, micro-, less frequently up to macroscopic, intensely yellow-brown at the margin, in the middle is the mucilage only slightly yellowish or brownish, up to almost colorless. Cells irregularly situated, more aggregated on the margins, sometimes gathered 4 together or ± in irregular or cubic formations, enveloped by individual sheaths, or arranged in short, indistinct rows, ± spherical, subspherical or oval before division, 2.2 – 4 µm in diameter, bright blue-green. Common colonial mucilage is colorless or slightly yellowish-brownish inside the colonies, yellow-brownish or orange-brownish near the colonial surface. – Type: Fig. 5.
E: Colonies mixed with other cyanoprokaryotes in mats in seepages, usually on the upper surface of stones, slightly covered by slowly streaming, shallow water layer.
L: Repeatedly found in JRI, in shallow seepages on northern slopes below Berry Hill, near Monolith Lake and in mats in Ginger Lake.

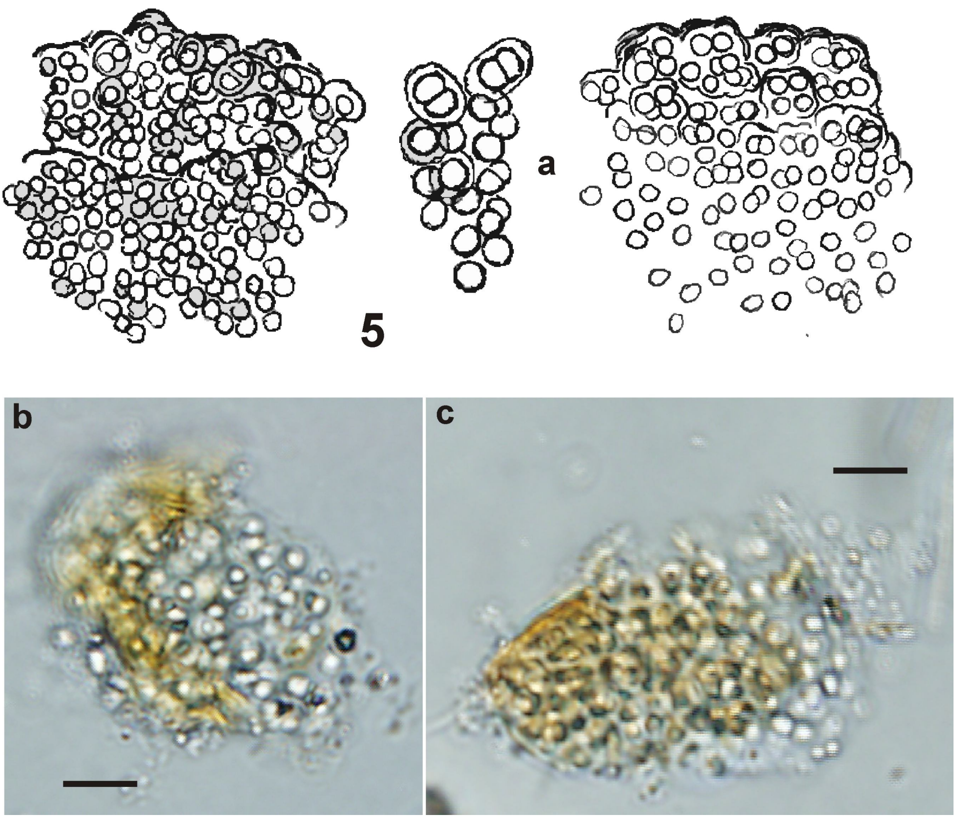


Fig. 5. *Chlorogloea antarctica* (bars = 10 µm).

N: *Chlorogloea* is classified traditionally into the family Entophysalidaceae, with the following generic diacritical characters: unicellular, colonial, spherical and subspherical cells are arranged irregularly in mucilaginous colonies, which have more or less heteropolar orientation. They grow and divide intensely in peripheral parts of the whole colony and from this process follows the partly radial orientation of cells in short, irregular and indistinct rows. The peripheral cells and sometimes also all cells in colonies are enveloped by individual sheaths. The common mucilage is often colored by sheath pigments, particularly in peripheral parts. – The final position of individual taxa of the genus in the modern system is yet unclear, particularly because it contains evidently heterogeneous complex of species. It seems that the different species are distinctly connected with special ecology. In seepages and in the littoral of lakes of the northern coastal areas of JRI occurs this special type, which does not correspond both morphologically and ecologically to any up to now known species. – The genus *Chlorogloea* contains now more than 20 species. It is very diversified and probably heterogeneous. Numerous types from ecologically restricted and distinct habitats exist especially in tropical and extreme biotopes. *C. antarctica* is a little similar to the type species *C. microcystoides,* but from all other species of this genus differs by details in colony structure and mainly by quite specific ecology. Probably belong to the same species samples with colorless to slightly orange brown small colonies, sporadically registered from seepages.

***Chroococcidiopsis friedmannii* sp. nova (Fig. 6) – Chroococcidiopsidales, Chroococcidiopsidaceae**

D: Cells ± spherical or subspherical, less frequently irregularly rounded, agglomerated quite irregularly in groups and clusters, without slime, but enveloped by distinct, thin and firm sheaths. Cell content blue-green to olive-green, homogeneous or slightly keritomized, without visible chromatoplasma. Mother cells up to 15 μm in diameter, the largest baeocyte-producing mother cells up to 28 μm in diameter. Reproduction by baeocytes with blue-green, homogeneous content, 2.5-3 μm in diameter, developing successively already during the growth of cells. The groups of baeocytes remain sometimes connected for longer time in compact clusters. – Type: Fig. 6.

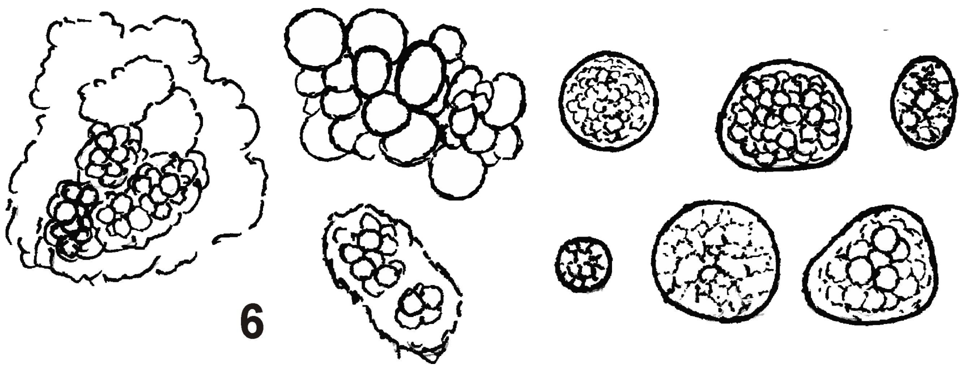


Fig. 6. *Chroococcidiopsis friedmannii.*

E: Narrow mats from lower and bottom parts of stones in littoral of lakes (above water level); less frequently submersely on the upper side of benthic stones.
L: Found only in JRI, Ulu Peninsula, chasmoendolithic and on the bottom of periodically flooded littoral stones of Green Lakes (Solorina Valley), in the massif of Andreassen Point in the vicinity of Santa Marta Cove (heavy population).
N: Members of this genus were found in Antarctica particularly in very extreme conditions of continental, arid and very cold areas, as prominent species of endolithic microbial communities. Several very interesting endolithic *Chroococcidiopsis* types are known from arid continental parts of Antarctica (Friedmann 1980, Friedmann et al. 1988), which were not yet described taxonomically. The relation of our populations with these endolithic types is possible to recognize only after molecular analyses.

Chroococcus polaris **sp. nova (Fig. 7) – Chroococcales, Chroococcaceae**
D: Cells solitary or in small, up to 4-celled groups, spherical, hemispherical or in a form of sphere-section, irregularly rounded, with pale or bright blue-green or greyish olive-green, slightly granular content, with distinct or sometimes slightly visible chromatoplasma, (8.5)10-13(14) µm in diameter; gelatinous envelopes with or without distinct marginal line, colorless, but slightly refractive, homogeneous and in some specimens very finely and densely lamellated. – Type: Fig. 7.
E: In littoral of creeks, in seepages, on rocky shores of lakes and pools. This unique, most common morphotype of *Chroococcus* occurs always dispersedly and solitary in well developed cyanobacterial assemblages, but it is characteristic for this habitat. Less frequently and sporadically occurs in wet soils (two localities). It grows sporadically also in more dried localities, in drying seepages and soils.
L: Studied from eight localities in JRI, several localities are known also from KGI. Occurs probably sporadically in corresponding localities over the whole maritime Antarctica, and probably is distributed more in the all coastal regions.
N: From the widely diversified and variable genus *Chroococcus* more morphotypes occur in JRI, but only this one morphospecies is satisfactorily definable. The certain morphological resemblance with *Eucapsis* follows from old colonies, in which the cells are arranged in ± cubic formations.

Chroococcus **cf.** ***helveticus*** **(Fig. 8) – Chroococcales, Chroococcaceae**
D: The colonies are solitary, mostly four-celled, maximally 8-celled, cells are 4.6-8.5(12.8) µm in diameter. Cells with olive-greyish-brown, finely irregularly granular content, with small granules in the centre of cells. Mucilaginous envelopes colorless, diffluent, narrow, mostly not delimited but refractive, often indistinct (occasionally very finely and indistinctly lamellated). The color of protoplasts is more variable, from pale greyish blue-green to brownish or brown-violet.
E: Mostly in stabilized seepages and in littoral of lakes.
L: Known sporadically from JRI.
N: Clearly smaller, but morphologically similar to the previous morphotype; both they occur almost always together and only in well developed communities in seepages. Relation between both described types is possible, in spite of the clear average size difference between them. The similar case of variation and ecological similarity within *Chroococcus* was described recently (Komárková et al. 2009), where both similar types were found genetically diverse.

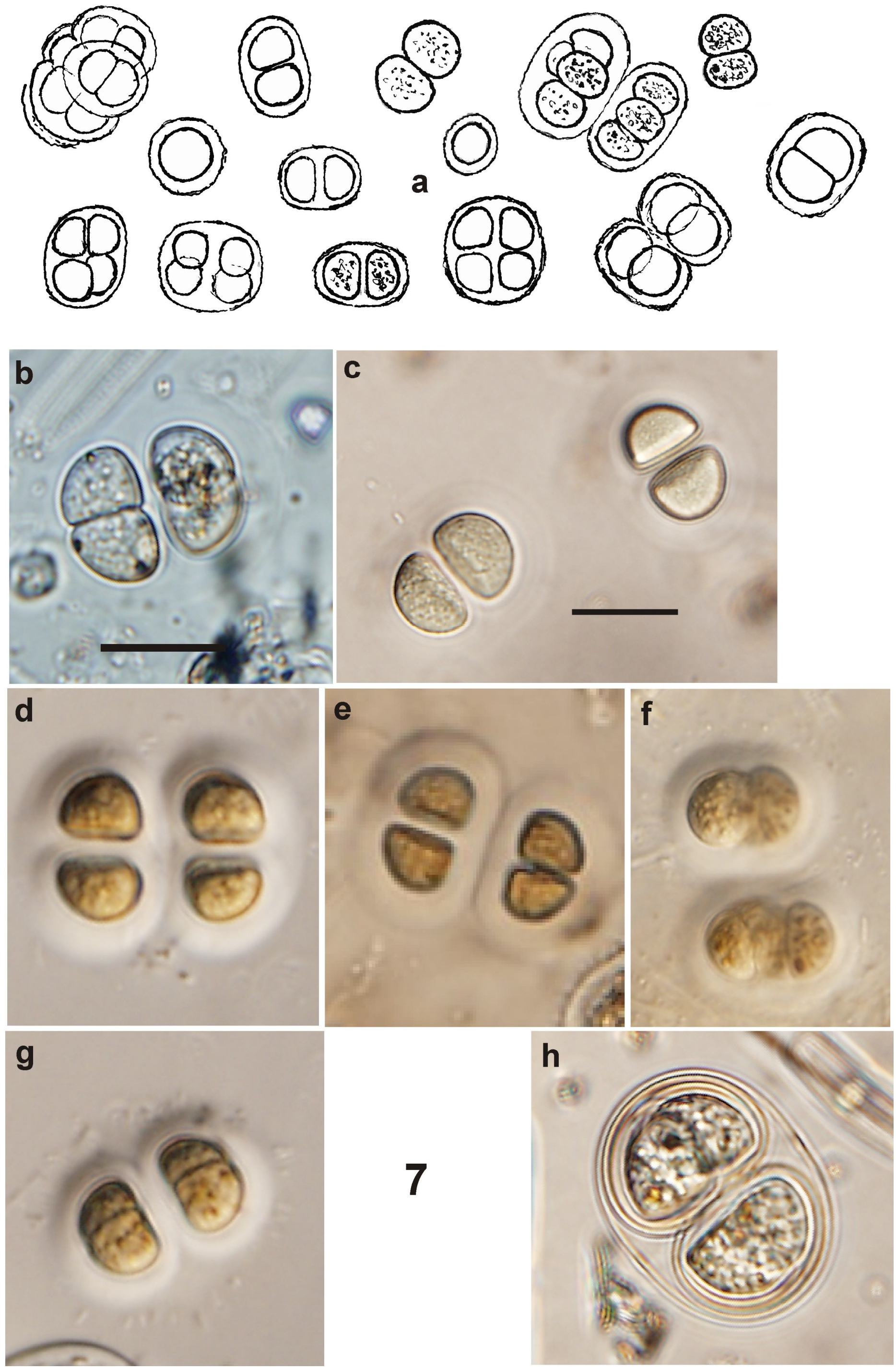


Fig. 7. *Chroococcus polaris;* **h** = *Chroococcus* sp., very solitary, not identified colonies (bars = 20 µm).

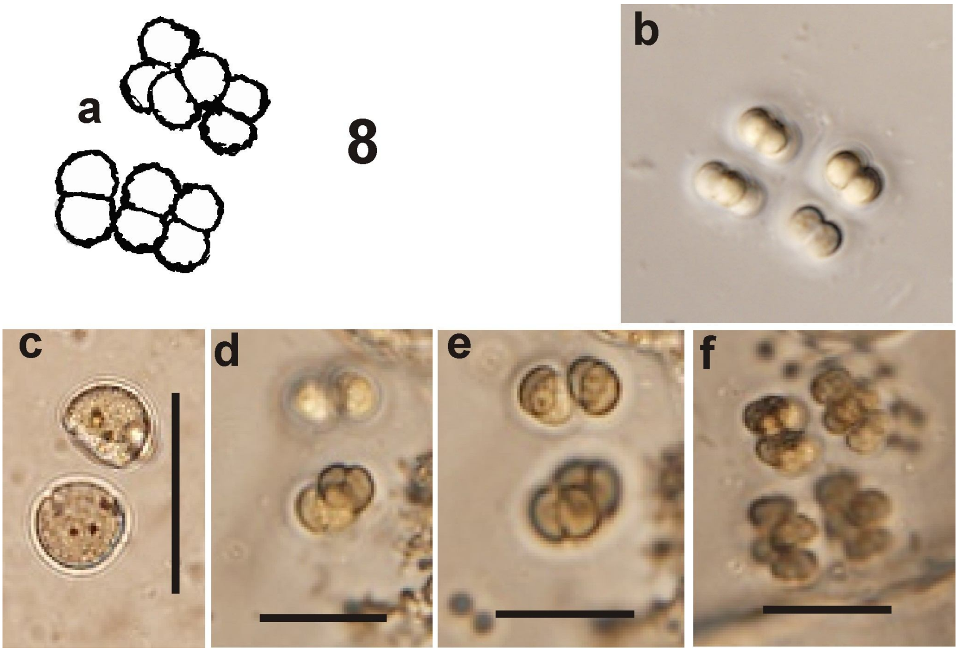


Fig. 8. *Chroococcus* cf. *helveticus* (bars = 20 µm).

***Cyanosarcina* ? sp. (Fig. 9) – Chroococcales, Chroococcaceae**

D: Numerous small, spherical or subspherical, solitary cells, sometimes growing in small clusters, without own mucilaginous, individual envelopes, with pale blue-green content, dividing irregularly in various planes (like *Chroococcus*, but later packet-like). Cells of very similar character grow sometimes more or less sessile in rows on trichomes of *Microcoleus* sp. Less frequently occur also microscopic colonies with ± irregularly spherical cells with colorless, not structured, ± diffluent mucilage, 3-4.5 µm in diameter, bright blue-green, dividing in different planes, gathered in small, separated aggregates. Grows in irregular, spheroidal, microscopic colonies with colorless, unstructured, diffluent mucilage with irregularly agglomerated cells.

E: This morphotype occurs only sporadically in seepages among other cyanobacterial assemblages, without morphological transitional stages to other types.

L: Found in KGI and JRI, but always solitary in stabilized seepages.

N: Identity of all morphological deviations is probable. In one sample occur colonies with dark blue-green cells, densely gathered packet-like together. This population was recognized only in this one sample, but its taxonomic existence is problematic. The Antarctic populations do not correspond exactly to the generic diagnosis, however, they do not exist any data about the genetic position and diversity of this genus up to now. The agglomeration of cells in colonies is more free in Antarctic specimens and relations to *Aphanocapsa* or *Coelomoron* are also possible.

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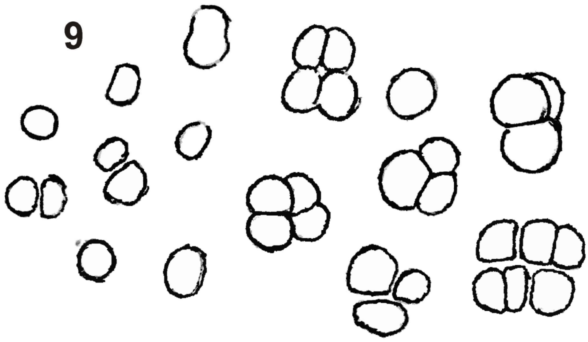

Fig. 9. *Cyanosacrina ?* sp.

Cyanothece ohtanii **spec. nova (Fig. 10) – Oscillatoriales, Cyanothecaceae**
Cyanothece aeruginosa sensu auct. (Akyiama 1968, Hirano 1979, 1983, Ohtani 1986, Pankow et al. 1987)

D: The cells are always solitary (in twos only after division), oval, bright blue-green without any visible mucilaginous envelopes, (17)20-36(41) x (11)12.5-17.5(20) µm; only rarely occurs in few-celled short rows under culture conditions. The content seems to be homogeneous, intensely blue-green, with slight, ± lengthwise striation (keritomy). Division always perpendicularly to the longer axis, in two ± identical daughter cells. Sometimes in solitary populations occurs a great diversity in cell size. They are also found involution cells of irregular shape. – Type: Fig. 10.

E: In seepages and marshes among other algae, rarely, often solitary; probably only on localities with pH ‹ 7. Commonly distributed in moss tundra and in seepages, but never in large quantities. Well developed populations are always connected with old, wet communities of mosses in seepages, less frequently on the edge of stabilized lakes and moraine lakes. Solitary cells occur in similar habitats near creeks.

L: In KGI was *Cyanothece* found in numerous localities in coastal wetlands, and it is evidently distributed in seepages as additional species in well developed cyanobacterial assemblages, probably in the whole coastal Antarctica (Komárek & Anagnostidis 1998). It was recorded especially from Japanese authors (Akyiama 1968, Hirano 1979, Ohtani 1986) from mosses in the vicinity of Syowa station, but with a little wider size range of cells (17-41 x 11-16 µm; the population from JRI 2006 has cells ± 30 x 20 µm). Numerous localities were recorded from maritime Antarctica (Nelson Island, Fildes Peninsula and Admiralty Bay in KGI), or from Lachman Lakes I, II, Monolith Lake and Green Lake in Ulu Peninsula in JRI.

N: A special morphotype, similar to the typical „*Cyanothece aeruginosa*“, occurring commonly, but solitary in coastal deglaciated parts of Antarctica. It is evidently a special species, uniform morphologically and ecologically (mostly in seepages). I never have seen also the typical form of *Cyanothece major*. Study of the taxonomic relations with European specimens is desirable. The content of cells resembles in optical microscope also the genus *Cyanobacterium*. – The populations of *C. aeruginosa* are known from slightly acidic, unpolluted and oligotrophic wetlands and peaty bogs in temperate and nordic zones, and from high mountains. It is considered to be cosmopolitan species, but our Antarctic populations are different morphologically (structure of cell content), and slightly ecologically. This type evidently forms in Antarctica a different morphotype and a geographic race, the cells are always less keritomized than the usual European populations. The keritomy occurs in form of irregular, lengthwise stripes, in comparison with European populations, which have more or less net-like intracellular structure. Therefore, the Antarctic populations can belong evidently to a unique genotype and morphotype (*see* description), which must be, however, confirmed by molecular analysis.

Fig. 10. *Cyanothece ohtanii* (bars = 20 µm).

Gloeocapsa cf. _sanguinea_ (Agardh) Kützing 1843 (Fig. 11) – Chroococcales, Chroococcaceae

D: The colonies are micro- to macroscopic, irregular, composed from small clusters of ensheathed cells. The cells are spherical or subspherical with pale greyish-blue, slightly and irregularly granular content, 3-3.5 µm in diameter. Envelopes (sheaths) are widened, colorless or intensely reddish, delimited and layered.

E: Only on wet rocks (subaerophytically).

L: On wet rocks of JRI were found very rarely *Gloeocapsa* populations with reddish sheaths, however, a small similar populations were found also in seepages. Rarely occurring also near coastal shallow lakes on Lachman Peninsula.

N: Numerous *Gloeocapsa*-types, usually with coloured envelopes by reddish or yellow sheath-pigments, are cited in floristic lists from Antarctica. They are identified usually as *G. sanguinea* (Pankow et al. 1987; three morphotypes from our localities), *G. ralfsiana* or *G. (= Gloeocapsopsis) magma* (Ohtani 1986). In KGI were found few other stages, resembling particularly *G. sanguinea.* However, the identity of these specimens with populations from mountains and wetted rocks of temperate and tropical zones is still very questionable and should be proved by molecular sequencing. The morphological deviations are distinct and indicate rather or the wider genetic variability, or another genetic position. The better developed and rich populations are necessary to the final taxonomic evaluation. It is interesting from phytogeographic point of view that various *Gloeocapsa* population are evidently more common in coastal areas of eastern Antarctica then in western part of the continent (Ohtani, pers. comm.) . The transfer of typical members of *Gloeocapsa* in cultures is commonly difficult and the identification of majority of isolated strains is problematic.

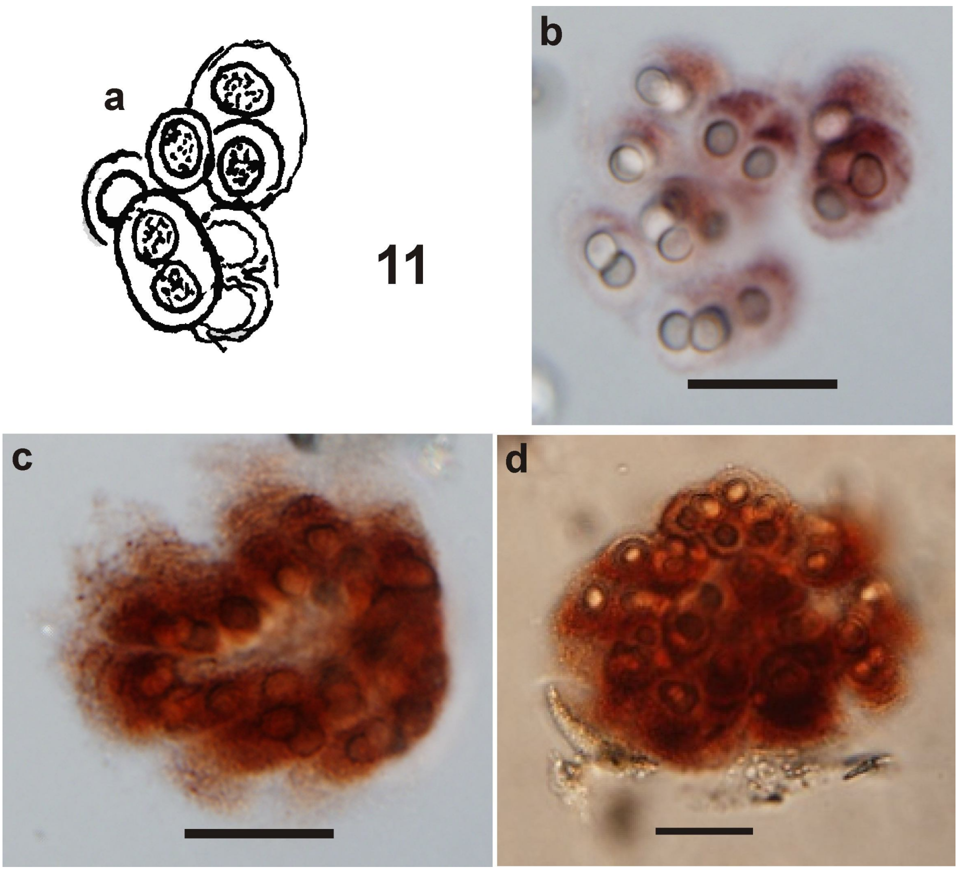

Fig. 11. *Gloeocapsa* cf. *sanguinea* (bars = 20 µm).

***Gloeocapsa* sp. (Fig. 12) – Chroococcales, Chroococcaceae**

D: Typical epilithic *Gloeocapsa* species with violet, lamellated sheaths and not widened envelopes. In old populations is tendency to form „chlorogloeoid“ type of colonies.

E: Subaerophytic on wetted rocky walls (only!, typical ecology).

L: Sporadically collected in KGI.

N: This type does not belong surely to *G. kuetzingiana* with yellow sheaths, which forms different stages during the vegetation cycle. Compare also with *Gloeocapsopsis*, but material from several samples indicates rather the „*Chlorogloea*-type“, *e.g.* the same character have specimens (in small quantity) from wet rocks in the Italian Valley (Admiralty Bay).

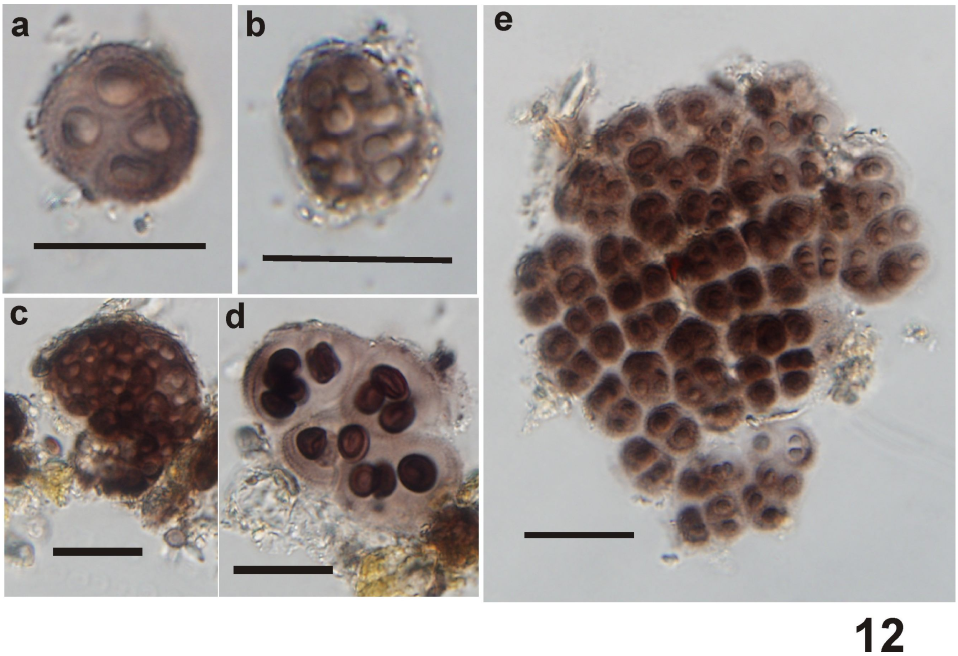

Fig. 12. *Gloeocapsa* sp. (bars = 20 µm).

***Gloeocapsopsis aurea* Mataloni & Komárek 2004 (Fig. 13) – Chroococcales, Chroococcaceae**

D: Irregularly clusters of irregularly-rounded cells, which are aggregated, with yellowish or rusty brown envelopes, with pale greyish or grey-blue cell content. In mass development, it forms blackish, mucilaginous, flat mats. Cells are irregular-spherical, 2-5(8) µm in diameter, enveloped by thick, firm, sometimes orange-brown sheaths, smooth on the surface. The gelatinous envelopes are colorless to yellow, sometimes a little reddish.

E: Occurs epilithic, mostly in seepages, among other algae, and in pools and marshes. Very commonly was found subaerophytic, epilithic on pretty wetted rocks and stones (also with slightly streaming water), with continual supply of water during the summer season, where it forms blackish, thin mucilaginous layers. Similar habitat is in the spray

zone along the margins of waterfalls, on emerged stones in streams, subaerophytic in littoral of creeks, on wet rocks of shores of lakes and pools.
L: In KGI registered from many localities, mainly in seepages distant from the shore. Occurs also commonly in JRI, where it is known from several localities: wet stones in the creek between Green and Red Lakes (massif of Andreassen Point), in seepages below Berry Hill, on emersed stones in Tern Creek (Halozetes Valley), on surface of stones and rocks (Devil Rocks), on the surface of emerged stones in littoral and in seepages near Monolith Lake, in seepages near Lake Lachman II and on stones near morain pool Dulánek.

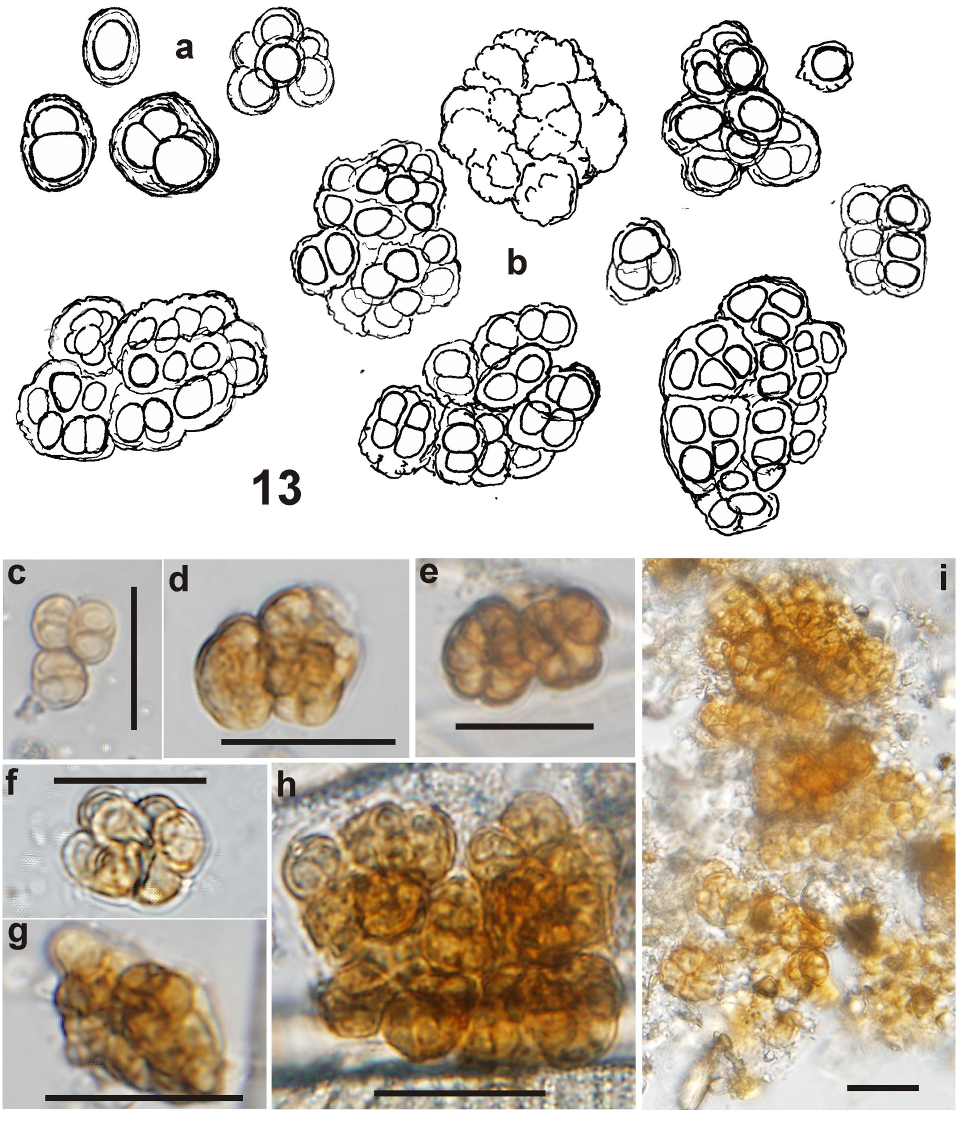

Fig. 13. *Gloeocapsopsis aurea* (bars = 20 µm).

N: In the middle of summer occurs commonly the single pale blue-green cells without sheaths, liberating from packet-like colonies. From 13 populations in the northern part of JRI were not distinct differences one from another. The localities are spread over the whole region. It forms irregular clusters of cells and grows among other cyanobacteria and algae, or in macroscopic monocultures in form of black layers. The blackish biofilms on stones, composed from distinct subcolonies, are macroscopically recognizable. – It is probably one from the common and ecologically distinct species in deglaciated areas of the whole maritime Antarctica (probably endemic). – The reproduction by baeocytes was sporadically recognized. It must be solved, if it is common character of this species, or if different similar types exist in various Antarctic localities. In few populations was found commonly liberation of daughter cells and formation of nanocytes (another species?). – The species is therefore pretty variable in several characters, but well distinguishable. In some localities occurs with more reddish mucilaginous envelopes and the relation of these populations to the type is not clear (it grows on stones in seepages near the Lake Lachman II). In spite of the almost common distribution in Antarctic habitats and unique character, the biology of this species is not yet exactly known. – In JRI 2006 were found following similar, but different populations: (i) with orange brownish agglomerations among other cyanobacteria, irregularly spherical cells with firm, delimited orange-brownish envelopes, composed from smaller subcolonies; cells were pale grey, irregular, (2)2.5-7.5(8) µm in diameter; very probably reproducing also by baeocytes, maybe rather *Chroococcidiopsis;* (ii) type reproducing by baeocytes, rather *Chroococcidiopsis;* in seepages, with orange-brownish envelopes, cells irregular, 2-5 µm in diameter, baeocytes ± 2 µm in diameter; (iii) irregular, microscopical groups of pale greyish-blue cells, 2-5 µm, with envelopes 3.5-5.6 µm in diameter, with orange envelopes.

***Gomphosphaeria barcikowskii* spec. nova (Fig. 14) – Chroococcales, Gomphosphaeriaceae**

D: Microscopic, ± spheroidal colonies with radially and ± peripherally oriented polarized small cells, up to 80 µm in diameter. Cells are densely agglomerated ± on the colonial surface, intensely blue-green, relatively small, obovoid. They remain for longer time in relatively "cordiform" state after division, ± 5-8(11.5) µm long. – Type: Fig. 14.

E: Submersely among other algae, in marshes covered by mosses. Rarely, and only in few places occur more commonly, probably in localities influenced by sea water (particularly after strong wind).

L: Found only in KGI, on the plain of Arctowski station in Admiralty Bay, in shallow water biotopes connected with rich moss vegetation (in two samples common); (up to now the single locality).

N: A small, characteristic and very unique morphospecies, occurring in cold bogs and seepages. The cells are small in comparison with other *Gomphosphaeria* species and resemble a little some *Woronichinia* or *Snowella* species without aerotopes, but they possess the typical morphology and life cycle of *Gomphosphaeria.* However, the colony structure is not yet quite clear. The species differs from other members of *Gomphosphaeria* distinctly by smaller cells, by ecology and distribution.

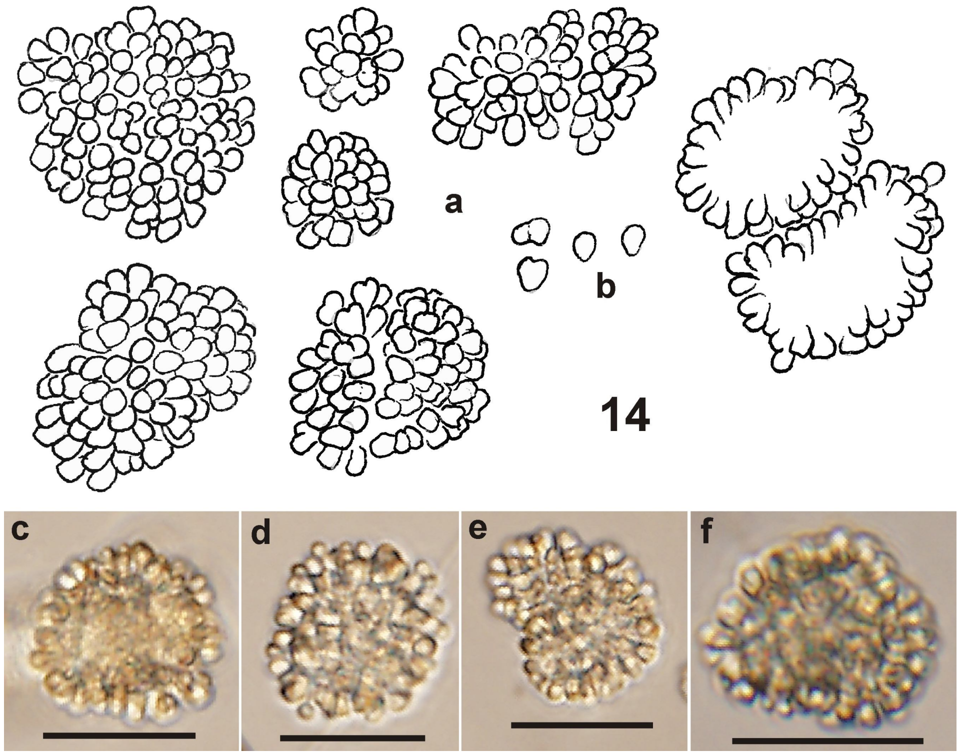

Fig. 14. *Gomphosphaeria barcikowskii* (bars = 20 µm).

***Pleurocapsa antarctica* sp. nova (Fig. 15) – Pleurocapsales, Pleurocapsaceae**

D: Pseudofilamentous formations, sometimes pseudodichotomously divaricated. Cells irregular, 2-8 µm in diameter, pale greyish blue-green, forming irregular rows, the terminal cells are slightly claviform. Pseudofilaments enveloped by thin, colorless or slightly brownish sheaths, attached to cells. Baeocyte formation not found. – Type: Fig. 15.

E: Various similar *Pleurocapsa*-morphotypes were found rarely on stones in streaming water in seepages and creeks (often in lower parts of stones), but their identification was difficult, with exception of the described type.

L: Little known cyanobacterial morphotype, collected sporadically only in few localities in JRI (2009). Important samples are known from seepages near Monolith Lake and from submersed stones in frozen Bedrich Lake.

N: The taxonomic position of this morphospecies, which occurs only solitary, is not quite clear; it never was found in rich population and never was found the baeocyte formation. The generic classification is based only on the structure (morphology) of pseudofilaments. Therefore, up to now, is this species little known both taxonomically and ecologically. The knowledge of life cycle and of variability from more rich material is necessary to the better taxonomic evaluation. However, the morphology of pseudo-filaments corresponds well to freshwater *Pleurocapsa* species, but the identification with any known species is impossible. The relationships to the type of the genus *Pleurocapsa* must be confirmed by cultivation and by molecular analyses.

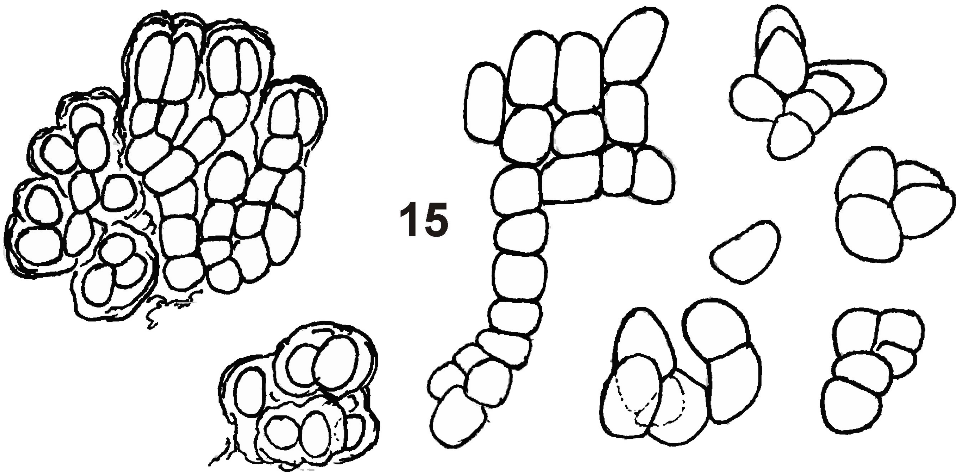

Fig. 15. *Pleurocapsa amtarctica.*

Discussion

We have studied the microflora of cyanobacteria in a part of coastal western Antarctica, particularly in several islands near the northern end of Antarctic Peninsula, during several summer seasons from 1989 to 2009. Our main task was to present the review of the diversity of natural populations of this important group of phototrophic microorganisms according to the modern, revised system of cyanoprokaryotes. The common ecological situations of our studied areas and lists of main taxa are presented in preliminary studies (Komárek 1999, Komárek et Elster 2008). The detailed review of cyanobacterial morphotaxa is divided in four separated presentations, containing (i-ii) coccoid (unicellular and colonial) species (in two parts, Komárek 2013, this study), (iii) filamentous cyanobacteria without heterocytes (in preparation), and (iv) heterocytous species (Komárek et al. 2014a). This division does not correspond exactly with the modern system of cyanobacteria (*cf.* Hoffmann et al. 2005, Komárek et al. 2014b), but still enables the first approach to the field determination of various populations.

The morphological (phenotype) diversity is presented in this paper without molecular support, but it is important for the recognition of Antarctic cyanobacterial flora, and it must be more characterized, described and recognized in future. The diversity will be found also surely richer in cultures. However, the molecular sequencing of coccal cyanobacteria was very rare up to now and the taxonomic review of such populations from nature is not yet solved. The precise morphological characteristics, is necessary especially for their ecological characterization. The review of morphospecies from natural habitats should serve as the basis for ecological studies, for which the purely molecular evaluation without correct binomial taxonomic designation is problematic. It was also the reason, why several clearly distinct morphotypes (morphospecies), which do not correspond to any up to date described cyanobacterial species in literature, are described as „new species“.

We consider the binomial nomenclature, representing the exactly defined morpho- and ecotypes, as the best connecting link between the phenotypic, ecological and genetic evaluation method of the cyanobacterial diversity (polyphasic approach).

The diversity of coccoid cyanobacteria from different, mainly aquatic habitats of South Shetlands and of the JRI is distinct, if we study the natural populations, but their isolation in cultures is not easy. It is interesting that in the recent studies, which evaluate the Antarctic cyanobacterial microflora mainly according to molecular, phylogenetic analyses, occurs the identified coccoid types only sporadically and appear too many designations like "undefined Antarctic cyanobacterium" or "*Cyanobacterium* sp." (*cf.* Jungblut et al. 2005, Fritsen et Priscu 1998, Taton et al. 2003, 2006 and others). The probable reason is that the Antarctic coccoid species need probably the special care with the isolation and transfer of such populations in monospecific strains. They form also very rarely the massive populations. In spite of it, their diversity in various microhabitats is not negligible and they occur distinct morphotypes. To their better knowledge must be studied the combined detailed morphology of natural populations, combined with molecular approach from different microbiotopes.

The cyanobacterial microflora seems to be similar in the whole coastal West Antarctica, *e.g.*, in Antarctic Peninsula, in James Ross Island and also up to the vicinity of McMurdo Station (coasts of Ross Sea). However, they seem to be some differences in subaerophytic cyanobacterial communities between coasts of West and East Antarctica, where dominate, *e.g.*, numerous *Gloeocapsa* types on wet rocky walls and which correspond morphologically more to the known species from high mountains in lower geographic widths (*e.g.*, *G. sanguinea* and others). This situation follows mainly from previous investigations of West et West (1911), Ohtani (1986), Broady (1989), Ohtani et al. (1991); Ohtani, pers. comm.; *cf.* also Pankow et al. (1987). These interesting differences will be surely the objects of next studies.

However, several up to now identifications of Antarctic coccoid cyanobacteria selected from literature are very improbable (*see* papers of Pankow et al. 1987, Vinocur et Pizarro 1995 and others). Ecology and distribution of the type material of these species is very different from Antarctic habitats and we never met similar taxa. Their occurrence in Antarctica is problematic and must be confirmed by exact molecular methods.

Few examples:
- *Aphanocapsa elachista, A. endolithica, A. roeseana:* All these species have quite different and special ecology, different from Antarctic habitats. Their occurrence on Antarctic continent is improbable.
- *Chlorogloea fritschii* (must be *Chlorogloeopsis fritschii*) is a tropical species with heterocytes. From other *Chlorogloea* species - *C. microcystoides* occurs only in calcareous Alpine creeks in Europe, *C. purpurea* is known only from deep benthos of lakes in European Alps with limestone substrate. All three "*Chlorogloea*" species are therefore ecologically and geographically very specific and differ also in taxonomic and morphological characters; never were confirmed and documented from Antarctica.
- *Gloeocapsa* (should be probably *Chondrogloea*) *dermochroa* grows only in Alpine creeks on limestone substrate, up to now proved only from European mountains; its occurrence in Antarctica should be precisely documented and confirmed.
- *Myxosarcina burmensis, M. concinna*; both species are exclusively tropical, differences are in ecology and also in morphology.

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