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Green Snow and Ice from the Antarctica

By E. KOL, Budapest

We are still far from knowing adequately the microorganisms of the Antarctic freshwaters, soil, snow and ice. As far as I know, the first substantial freshwater algae have been collected by HOOKER and HARVEY, on the occasion of "The Antarctic voyage of H. M. Discovery ships Erebus and Terror, in the year 1839–43". Since that time, freshwater algae have been brought home by several expeditions to the Antarctica. But the coloured snow of the Antartctica has been observed only by the end of the last century.

Until now, literature recorded red, yellow and green snows, and green ice from the Antartctica.

The Antarctic cryovegetation might be grouped as follows: 1. microvegetation of the snow, 2. microvegetation of the ice, 3. the facultative cryovegetation appearing on the seasonal ice of freshwaters, 4. cryoedaphon.

The microorganisms of the green snow and ice of Terre Adélie

Professor P. M. ARNAUD, Marseilles, has kindly sent me the most valuable and interesting green cryoseston material collected on the Antarctica in 1962. ("Prélévement de neige et glace vertes fait an Terre Adélie [Antarktique de l'Est] en 26. II. 1962. et conserve dans alcool. Dr. P. M. ARNAUD — Archipel de Polte Geologie.")

I am glad to have this opportunity to thank Professor ARNAUD for placing this interesting material at my disposal.

The green cryoseston sample contained the following Chlorophyta algae: *Bracteococcus minor* (CHOD.) PETROVÁ var. *glacialis* FLINT (Pl. I, Figs. 9—13);

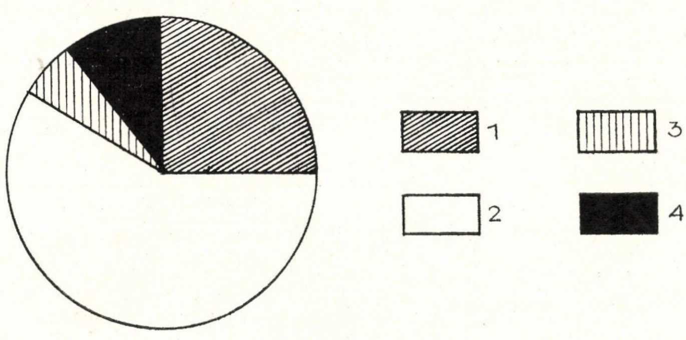

Fig. I. Mass proportions of the microorganisms of the green snow and ice: 1 = *Bracteococcus minor* (CHOD.) PETROVÁ var. *glacialis* FLINT = 25%; 2 = *Chlamydomonas ballenyana* KOL = 60%; 3 = *Cryocystis brevispina* (FRITSCH) KOL fo. *groenlandica* KOL, *Cryocystis granulosa* KOL = 5%; 4 = *Scotiella nivalis* (SHUTTLEW.) FRITSCH, *Scotiella polyptera* FRITSCH = 10%.

Chlamydomonas ballenyana var. *minor* nova var. (Pl. I, Figs. 1—6); *Cryocystis brevispina* Fritsch fo. *groenlandica* Kol (Pl. I, Fig. 14); *Cryocystis granulosa* Kol (Pl. I, Fig. 15); *Scotiella nivalis* (Shuttlew.) Fritsch (Pl. I, Figs. 7, 8); *Scotiella polyptera* Fritsch (Pl. I, Figs. 16—19).

The green cryoseston communities deriving from Terre Adélie and the Sabrina Island are similar to each other.

In the microorganism communities of green ice originating from Terre Adélie and the Sabrina Island, the predominating species are *Chlamydomonas ballenyana* Kol and *Bracteococcus minor* var. *glacialis* Flint. In the green snow of various areas from the Antarctica, the species *Cryocystis brevispina* (Fritsch) Kol, and *Raphidonema nivale* Lagerh. are frequent.

Algae

Bracteococcus minor (Chod.) Petrová var. **glacialis** Flint
Plate I, Figs. 9—13

Sphaerical cells, 9—15 μ in diameter, with one or two chloroplastis, without pyrenoide (Pl. I, Fig. 13). Wall of young cells thin, that of older specimens with a local thickening or tuberculiform incrassation on one side (Pl. I, Fig. 11).

Propagation by forming aplanospores and zoospores (Pl. I, Figs. 9, 12). Zoosporangium sphaerical (Pl. I, Fig. 10), 21 μ in diameter. Zoospores 5 μ wide and 10 μ long, slightly larger than in the species deriving from the Balleny Island. Zoospores liberated by jellyfication of zoosporangial wall.

This microorganism was first described by Flint (Kol & Flint, 1968) from the green ice of the Sabrina Island in the Antarctica.

Chlamydomonas ballenyana Kol var. **minor** nova var.
Plate I, Figs. 1—6

Differt a typo in dimensione cellularum. Hab. in nivibus at glacie viride, Terre Adélie, Antarctica.

Elliptic cells, 6—8 μ wide, 12—14 μ long, with thin walls, one chloroplast, and a small round stigma in anterior part of cell (Pl. I, Fig. 5—6).

Propagation: cell-division (Pl. I, Figs. 1—3); formation of 4—8 daughter cells (Pl. I, Fig. 4).

The form differs from the nominate one of the Sabrina Island by its smaller measurements.

Cryocystis brevispina (Fritsch) Kol fo. **groenlandica** Kol
Plate I, Fig. 14

Oval cells, 20 μ long, 15 μ wide, wall covered with short spines.

The nominate form of this microorganism was first described by Fritsch (1912) from the yellow snow of the South Orkneys, Antarctica. Kol discovered the fo. *groenlandica* in the red snow of Greenland (1959). Only one specimen was found in the green cryoseston of Terra Adélie.

Cryocystis granulosa KOL
Plate I, Fig. 15

Oval cells, 15 μ wide, 18 μ long, wall ornamented by minute verrucosity.

KOL described (1959) the microorganism from the red snow of Greenland. Only a few specimens were found in the green cryoseston of Terre Adélie.

Scotiella nivalis (SHUTTLEW.) FRITSCH
Plate I, Fig. 7–8

Oval cells, 18 μ long, 12 μ wide, wall ornamented with longitudo-spirally decurrent ribbing.

Various developmental stages in greater numbers were found in the green cryoseston of Terre Adélie. The microorganism is known from several localities in the Antarctic snow. It is one of the most frequently occurring cryobionts both in the Northern and the Southern Hemispheres.

Scotiella polyptera FRITSCH
Plate I, Figs. 16–19

Wide oval cells, 18—24 μ long, 15—21 μ wide, with numerous longitudo-spirally decurrent sinuous ribbing.

The microorganism was first described by FRITSCH (1912) from the yellow snow of the Antarctica.

Comparison of the green cryosestons deriving from various areas of the Antarctica

The green cryoseston microorganisms, collected and observed in the Antarctica, may be summarily reviewed as follows.

Red and green snows in the Antarctica were for the first time collected by É. RAKOVITZA, biologist of the "Expedition antarctiqué de la 'Belgica' ", led by DE GERLACHE DE GOMERY in 1897–1899, in the area of the Détroit de Gerlache.

RAKOVITZA collected green snow in the above locality in January, 1898; it was worked up by DE WILDEMANN (1900, 1935). DE WILDEMANN (1935) published the following microorganisms from the green snow sample: *Oscillatoria* sp., *Hormiscia flaccida* (KG.) LAGERH. var. *nivalis* DE WILD., *Olpidium ulotrichicis* DE WILD., *Stichococcus bacillaris* NAEG., *Raphidonema nivale* LAGERH., *Conferva bombycina* AG., *Trochiscia nivalis* LAGERH., *Chlamydomonas sanguinea* LAGERH., *Menoidium incurvum* (FRES.) KLEBS var. *antarcticum* DE WILD., *Mesocarpus* sp., *Spirogyra* sp. Desmidiaceaea: *Hyalotheca dissiliens* (SMITH) BRÉB., *Closterium Malinvernianum* DE NOT., *Cosmarium Botrytis* (BORY) MENEGH., *Cosmarium subspeciosum* NORDST., *Staurastrum muticum* BRÉB., *Staurastrum* sp.

Among the recorded algal species few are true cyrobionts, namely: *Raphidonema nivale* LAGERH., *Stichococcus bacillaris* NAEG., *Trochiscia nivalis* LAGERH., *Chlamydomonas sanguinea* LAGERH., *Menoidium incurvum* (FRES.) KLEBS. var. *antarcticum* DE WILD. Most of them are cryoxenous species, members of probably facultative cryosestons.

In general, the members of the facultative cryosestons occur concomitantly with the microorganisms of the true cryoseston in the snow flora of the Antarctica.

R. N. Rudmose Brown collected, with the Scottish Natural Expedition (1902—04), red and yellow snows in the South Orkneys; the material was worked up by F. E. Fritsch (1911, 1912).

L. Gain, biologist of the "Deuxième Expedition Antartique Française du Dr. J. Charcot (1908—10)", ship "Pourquoi Pas?", collected red and green snows on the Islands Peterman, Boothe, Handel, and Wienkes, in the territory of Terre de Graham; the samples were elaborated by N. Wille and published by Gain (Gain, 1911, 1912; Wille, 1912).

Gain (1912) published several species from Wille's identification. The following algae were found (p. 183—185) in the green snow collected on the Peterman Island in March, 1909: *Chlorella ellipsoidea* Gerneck f. *antarctica* Wille., *Stichococcus bacillaris* Näg., *Stichococcus bacillaris* var. *genuinum* Kirchn., *Stichococcus bacillaris* var. *minor* Näg., *Stichococcus bacillaris* var. *major* (Nägel) Roth., *Mycacanthococcus antarcticus* Wille., *Ulothrix subtilis* Kg. var. *tenerrima* (Kg.) Kirchn. f. *antarctica* Wille.

The algal species found in the green snow of the Wienke Island, March, 1908, were as follows (p. 185—187): *Ulothrix subtilis* Kg. var. *tenerrima* Kg. f. *antarctica* Wille, *Mycacanthococcus cellaris* Hansg. f. *antarctica* Wille., *Mycacanthococcus ovalis* Wille., *Pseudotetraspora Gainii* Wille., *Raphidonema nivale* Lagerh. f. *minor* Wille.

The algae of the green snow collected in the Boothe-Wandel Islands (p. 189—190), in February, 1909, were: *Stichococcus bacillaris* Näg., *Chlamydomonas antarcticus* Wille., *Pseudotetraspora Gainii* Wille., *Pleurococcus vulgaris* Menegh. var. *cochaerens* Wittr., *Mycacanthococcus ovalis* Wille.

Recently G. Llano (1962) observed green snow near the Wilkes Station in the Antarctica.

In March, 1964, E. Schofield gathered green ice in the smallest island of the Balleny Islands, Sabrina; of the sample E. A. Flint succeeded to derive pure cultures of the following algal species: *Phormidium pristleyi* Fritsch, *Chlamydomonas ballenyana* Kol, *Bracteococcus minor* (Chod.) Petrová var. *glacialis* Flint, *Ankistrodesmus antarcticus* Kol & Flint, *Ellipsoidion perminium* Pascher var. *cryophila* Kol, *Chloridella glacialis* Kol, *Nitzschia* sp.

It was Flint who first succeeded to produce pure cultures of the microorganisms in the green ice of Antarctica (Kol & Flint, 1968).

G. E. Fogg was the first to make biological observations—in situ—on the microorganisms causing the red, green, and yellow snows of the Antarctica.

Little was known of the physiology of algae in snow and ice until Fogg (1967) published the results of his preliminary investigations on the snow algae of Signy Island.

Fogg (1967, p. 281) found the following microorganisms in the green snow of the South Orkney Islands: *Chlamydomonas nivalis, Chlorosphaera antarctica, Raphidonema nivale, Hormidium subtile, Trochiscia antarctica, Chodatella brevispina, Ochromonas* (?) sp., and also published their quantitative occurrence.

M. Hirano (1965) and H. Fukusima (1959) also published valuable data on the snows of the Antarctica.

As is to be seen, the green cryosestons are widely different in the various regions of the Antarctica; many diverse communities of the mass vegetation of various microorganisms stain green the surface of the cryobiotopes.

Green snow was hitherto seen in the Antarctica only at the margins of the continent, or in the neighbouring islands. No mass vegetation was as yet observed on the snow or ice deep in the mainland. The severe snow storms raging frequently in the continent greatly obstruct the settling of the microorganisms and their mass proliferation on the snow fields. At the coastal areas and on the islands the climate is milder, the summer warmer, and the locally thawing snow renders suitable conditions also for the nivicolous microorganisms. Among the cryobiont microorganisms of the cryoseston, the algae of the facultative cryovegetations are also frequently encountered.

The community of microorganisms constituting the green cryoseston of the

Antarctica wholly differs—as is to be seen from the summaries given above—from the green cryoseston of the Northern Hemisphere.

Whereas in the Northern Hemisphere masses of the various *Raphidonema—Koliella* species, *Chlaymdomonas yellowstonensis*, and diverse *Carteria* species stain green the surface of the snow fields, the species *Chlorella ellipsoidea* f. *antarctica* WILL., *Stichococcus bacillaris* NÄG. and its various forms, *Chlamydomonas ballenyana* KOL, *Bracteococcus minor* var. *glacialis* FLINT, *Ankistrodesmus antarcticus* KOL et FLINT appear in great numbers in the green snow and ice of Antarctica.

It is an interesting phenomenon also from an aerobiological point of view that there are very few bipolar cryobiont microorganisms, and in most cases they, too, exhibit some difference between the species inhabiting the Northern and the Southern Hemispheres.

Summary

Six green algal species, deriving from green snow and ice samples collected by Professor P. M. ARNAUD on Terre Adélie, Antarctica, are discussed; the predominating taxa are *Bracteococcus minor* var. *glacialis* FLINT, and *Chlamydomonas ballenyana* var. *minor* var. nova. An algal diagram shows also the quantitative occurrence of the microorganisms of the cryoseston. A review and comparison of the green cryosestons hitherto published from the Antarctica are also given.

Explanation of Plate I.

Figs. 1—6: *Chlamydomonas ballenyana* KOL, ×1500: 1. cell division, 2. start of cell division, 3. cell without flagellum, 4. formation of daughter cells, ×1000, 5, 6. vegetative cells. — Figs. 7—8: *Scotiella nivalis* (SHUTTLEW.) FRITSCH, ×1500: 7. young cell, 8. young cell with thick strata of gelatinous cover. — Figs. 9—13: *Bracteococcus minor* (CHOD.) PETROVÁ var. *glacialis* FLINT, ×1500: 9, 12. zoospores, 10. zoosporangium, ×1000, 11. local thickening or bubble on wall of old cell, 13. young cell. — Fig. 14: *Cryocystis brevispina* fo. *groenlandica* KOL, ×1000. — Fig. 15: *Cryocystis granulosa* KOL, ×1500. — Figs. 16—19: *Scotiella polyptera* FRITSCH, ×1000: 16, 18, 19. formation of spores, 17. top-view of cell.

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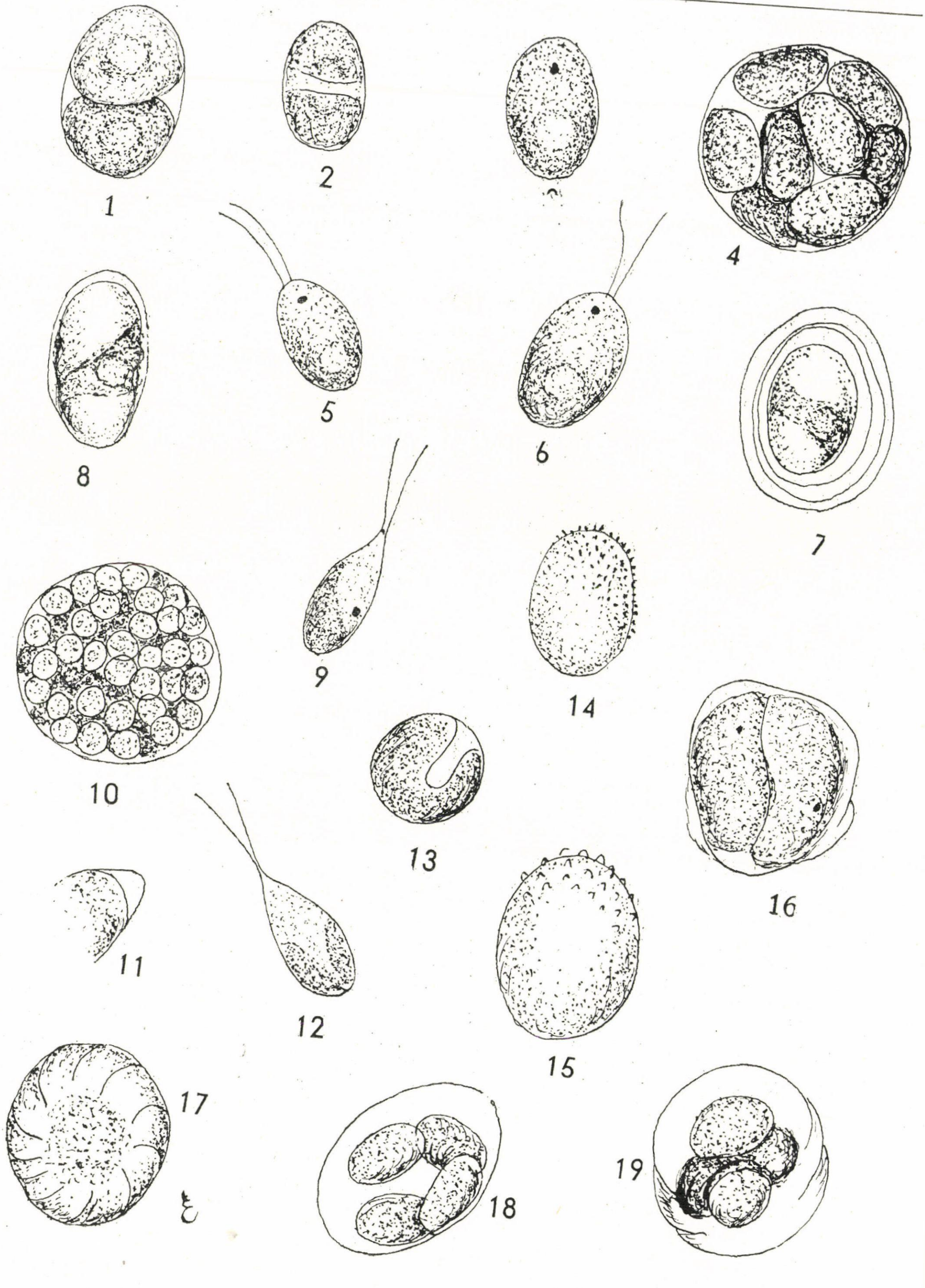
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