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Soil algae from northern Victoria Land (Antarctica)

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Abstract: Samples of dry mineral soil with no apparent algal vegetation were collected from 20 locations of northern Victoria Land (Antarctica) to determine their microalgal content. Direct microscopic examination and cultures revealed the presence of 63 taxa, mostly represented by Chlorophyta (29 taxa) and Cyanobacteria (22 taxa). Other components observed included Xanthophyta (9 taxa) and Bacillariophyta (3 taxa).

Descriptions of the 15 species newly recorded for Continental Antarctica or the whole of Antarctica are given. A comparison among other studies shows that northern Victoria Land edaphic microflora only partially corresponds with the microflora present in other locations of Victoria Land or in other areas of Antarctica.

key words: algae, cyanobacteria, soil, floristic, Antarctica

Introduction

The particular climatic and environmental conditions of the Antarctic continent provide little possibility for the growth of biologic communities, in particular, microalgal communities. In fact, the richest ecosystems in terms of biodiversity are those where the conditions are relatively stable, with a constant supply of water, such as lakes, where algal mats can thrive (Fumanti *et al.*, 1995, 1997).

One of the more interesting non-aquatic Antarctic environments is that consisting of ahumic mineral soil which favours the growth of edaphic algal communities (Broady, 1996) and which is formed by glacial action or weathering *in situ* of rocks present in that environment (Broady, 1979a). It has practically no organic component, and it lacks visible vegetation with algae forming only on or close to the surface of the soil.

From an ecological standpoint, the localization of algal species is particularly important, considering that conditions such as the availability of water, light, and the action of wind are markedly different when comparing the surface of the soil to the underlying substrata (Davey and Clarke, 1991).

Soils lacking in macroscopically visible microalgal cover exist throughout Antarctica and have been examined by numerous studies, but very few have focussed on the floristic component. In northern Victoria Land, floristic studies have been carried out by Broady (1985, 1987a) and Broady *et al.* (1987). In the adjacent area of southern Victoria Land Seaburg *et al.* (1979) and Holm-Hansen (1964) obtained pure algal

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cultures from samples collected in different zones of the Dry-Valleys.

This paper is a contribution to the knowledge and distribution of soil algae from northern Victoria Land with a comparison with soil algal flora of Antarctica.

Material and methods

During the Antarctic Expeditions of 1989-90, 1990–91, and 1995–96 (the latter carried out by the author as a member of the BIOTAS Project-Biological Investigation of Terrestrial Antarctic Systems), samples of mineral soils lacking macroscopically evident algal growth were collected from 20 locations in northern Victoria Land between 72°36′S and 75°46′S (Table 1, Fig. 1); the substrata of the soil appeared to be principally made up of granite or lava products (Simeoni *et al.*, 1989).

Three soil samples of the upper 2 cm were collected from each of the locations using a 4 cm diameter corer; collection sites were located at least 10 m from running water, snowfields, and lakes spaced more than 100 m one another.

All samples were collected in sterile bags, frozen at −20° C, and sent to Italy. Part of each sample was used for examining the flora with a light microscope (ZEISS AXIOSCOP, with 10×, 40×, 100× objectives), while 1 g was used, after dilution-suspension in 100 m*l* of distilled water, for performing algal cultures on liquid and solid (the latter with 5 g/*l* of agar-agar) BBM medium (Chantanachat and Bold, 1962) and BG11 medium (Stanier and Cohen-Bazire, 1977). Cultures were incubated at 20°C to promote the growth of the greatest number of algae (Broady, 1982, 1992) with dark/light cycles of 12 h; they were examined every 10 days and microalgae were isolated to obtain pure cultures. Most taxa were not sufficiently abundant for detection with the

Table 1. Physical and chemical characteristics of a single sample from each of 20 locations. C org.: organic carbon; O.M.: organic matter; N tot.: total nitrogen.

N°	Localities	Coordinates	pH	C org. %	O.M. %	N tot. %
1	Adelie Cove	74°46' S; 164°03' E	7.7	0.189	0.325	0.067
2	Baker Rocks	74°14' S; 164°47' E	6.8	0.215	0.369	0.041
3	Base surroundings	74°41' S; 164°07' E	7.8	0.192	0.330	0.075
4	Cape King	73°35' S; 166°37' E	-	-	-	-
5	Cape Sastrugi	74°37' S; 163°43' E	7.3	0.112	0.192	0.07
6	Carezza Lake surroundings	74°42' S; 164°03' E	7.7	0.076	0.130	0.054
7	Crater Cirque	72°36' S; 169°17' E	5.1	1.152	1.981	0.140
8	Edmonson Point	74°34' S; 165°08' E	6.3	0.819	1.408	0.140
9	Gondwana	74°37' S; 164°13' E	7.3	1.660	2.855	0.350
10	Harrow Peaks	74°06' S; 164°51' E	5.8	2.288	3.950	0.544
11	Inexpressible Island	74°53' S; 163°43' E	7.6	0.246	0.423	0.047
12	Kay Island	74°04' S; 165°18' E	4.9	2.995	5.151	0.730
13	Markham Island	74°35' S; 164°56' E	7.7	0.176	0.302	0.032
14	Mt. Crummer	75°08' S; 162°40' E	6.8	0.135	0.234	0.025
15	Mt. McGee	74°03' S; 164°33' E	8.0	0.220	0.383	0.110
16	Mt. Melbourne	74°21' S; 164°42' E	7.0	0.389	0.670	0.108
17	Prior Island	75°41' S; 162°53' E	6.1	2.381	4.095	0.280
18	Skua Lake surroundings	74°42' S; 164°07' E	7.9	0.320	0.550	0.052
19	Tarn Flat	74°58' S; 162°30' E	8.9	0.376	0.646	0.140
20	Withmer Peninsula	75°46' S; 162°52' E	6.6	0.779	1.339	0.088

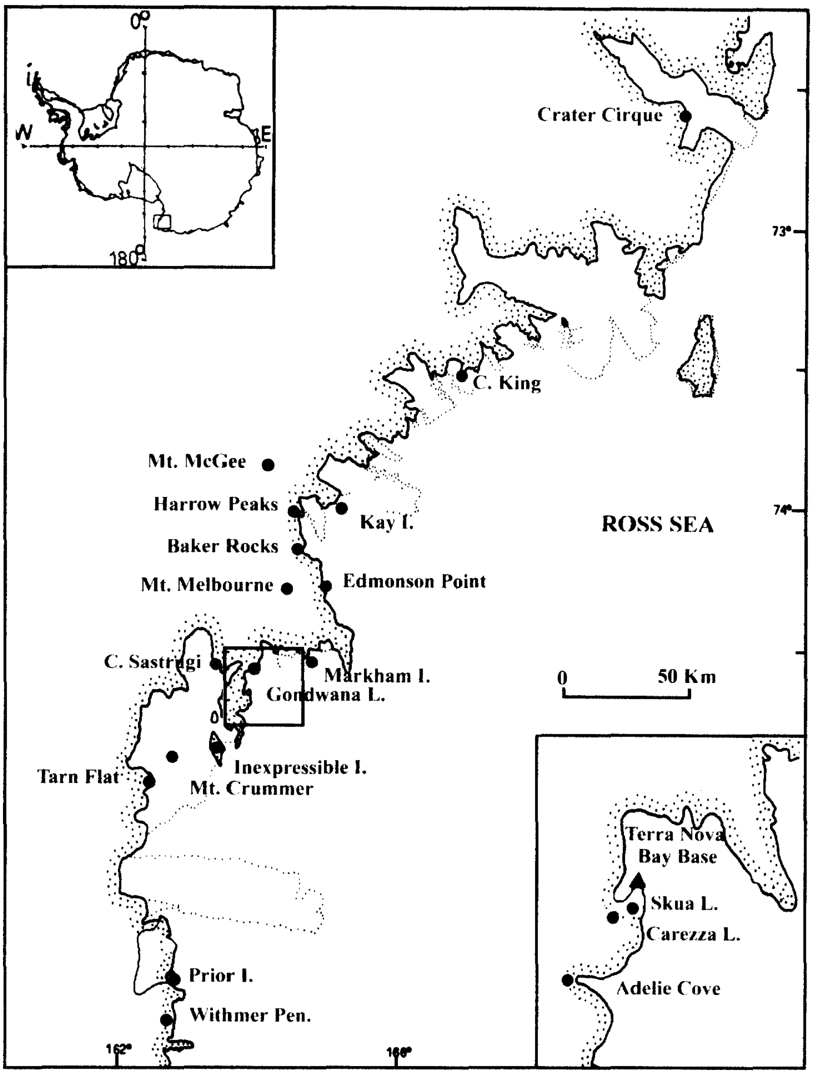


Fig. 1. Locations of sampling sites in northern Victoria Land.

light microscope using living material and were only revealed through culture. The use of culture media allows recognition of algae present in very low quantities probably resulting in an overestimate of the abundance of algae normally active in the soil. Nonetheless, the culture techniques adopted, which have been used by numerous authors (Broady, 1996), still represent some of the few techniques, together with direct observation, that provide a close to complete and detailed description of the flora.

When the quantity of material permitted, an aliquot from one sample of each location was air-dried in a protected environment and passed through a sieve (2 mm mesh) to determine pH and the percent concentration in total carbon, total nitrogen, and organic matter, following the standard methods of the Italian Society of Soil Science (Società Italiana della Scienza del Suolo, 1985).

The identifications of algal taxa were principally accomplished with the aid of the following systematics works: Geitler (1932), Anagnostidis and Komárek (1988); Komárek and Anagnostidis (1999); Krammer and Lange-Bertalot (1986); Komárek and Fott (1983); Ettl and Gärtner (1995). Previous records from Continental and Maritime Antarctica (as defined in Smith, 1984) were obtained from the literature.

Results and discussion

The samples contained 63 taxa belonging to 4 divisions (Table 2). Chlorophyta (46% of taxa) were the most diverse followed by Cyanobacteria (34.9%), Xanthophyta (14.3%) and Bacillariophyta (4.8%).

Chlorophyta were present in all locations except on Mt. McGee. The number of specimens present is always very low and they were mostly obtained in culture. Sometimes small groups of individuals were observed directly in vivo (*Prasiola crispa* in Adelie Cove samples or *Pleurococcus antarcticus* in Baker Rocks, Edmonson Point and Inexpressible Island ones).

Cyanobacteria were present in 80% of the samples collected; this division is absent only in the samples collected from Cape King, Markham Island, Mt. Crummer, and near Skua Lake (which have also low diversity). Filamentous Cyanobacteria were greatly represented, specifically, by *Phormidium* spp. and *Leptolyngbya frigida* which were present in the majority of the samples examined.

Xanthophyta were present in samples from seven locations and were always obtained in culture.

Bacillariophyta were rare. Of the three species present, two (*Luticola muticopsis* and *Pinnularia borealis*) are widespread in other environments of northern Victoria Land (Fumanti *et al*., 1995, 1997), while the third (*Navicula atomus*) is a typically edaphic species and was obtained in culture.

The number of species observed in the sampled areas varies greatly, from 22 at Inexpressible Island to 1 at Mt. Crummer and near Skua Lake, probably as a result of different moisture content in samples.

Although representative of Chlorophyta were observed most frequently in eight locations there is a greater number of Cyanobacteria, and in one case this group represents the only component of edaphic microflora (Mt. McGee, Table 2).

The most widespread species are: *Leptolyngbya frigida* (12 samples), *Phormidium attenuatum* (10 samples) among Cyanobacteria, *Xanthonema exile* (Xanthophyta, 5 samples), and *Stichococcus bacillaris* (Chlorophyta, 12 samples).

The location richest in species (Inexpressible Island) has a very high number of Cyanobacteria, principally represented by *Leptolyngbya frigida, Phormidium* spp., and *Calothrix* spp.. Some of the species, especially *Leptolyngbya frigida*, were observed directly in vivo and probably represent a mature colonization of these species which bind the soil particles of the substrata (Wynn-Williams, 1988; Davey *et al*., 1991) and which can resist extensive periods of desiccation during summer (Davey, 1989, 1991a).

Samples from Edmonson Point were particularly rich in species; in the lava soil, 18 taxa were detected and are probably favoured by the great availability of water present during the summer period, due to the presence of numerous transient streams. Two-thirds of the flora consists of Chlorophyta, including all of *Chlorella* species detected in this study, as well as *Pseudococcomyxa simplex*, previously observed by Broady (1987b) in many areas of Antarctica, and *Planktosphaerella terrestris*, observed in mineral soils by Broady (1979a), Davey (1991a, b), and Davey and Clarke (1991).

Among the samples collected in the areas of mountain peaks, there is a marked difference in the number of taxa when comparing Mt. Melbourne (12) and Mt. Crummer and Mt. McGee (1 and 4, respectively), probably due to the diverse microclimatic conditions and nature of substrata, which is of the lava type for the first location and granitic for the latter two.

The physical and chemical characteristics of the soils studied are reported in Table 1, revealing various pH levels, which were used to divide the soils into two groups: alkaline and acid. Most of the soils have an alkaline pH, regardless of the type of rocky substrata and especially in the zone close to Terra Nova Bay Station (Fig. 1). These pH values probably depend on the concentration of salts related to the sublimation of water during the summer and by the influence of marine spray.

Among the soils with an acid pH, that of Kay Island has the lowest value (pH=4.9) while Tarn Flat has the highest (pH=8.9) among basic pH soils.

The content of nitrogen, carbon, and organic substance of the samples is generally very low. With respect to all other samples, Kay Island presents the highest values for all of the analyses performed. The values for nitrogen are also high for Harrow Peaks (0.54%) and Gondwana (0.35%) perhaps influenced by bird guano. For organic matter and organic carbon, the values for Harrow Peaks and Prior Island are high. Mt. Crummer also presents the lowest value in total nitrogen, while a soil adjacent to Carezza Lake has the lowest percentage of organic carbon and organic substance. Overall, the extreme values of physical-chemical parameters recorded are found in the presence of a rather scarce edaphic flora.

The entire territory of northern Victoria Land has, to date, not been studied in-depth in terms of its flora, and, in particular, its ahumic mineral soils have been studied only by Broady (1985, 1987a), Broady *et al.* (1987) and Bargagli *et al.* (1996), always using soil samples with surface algal growth.

In his 1985 study, Broady, in a preliminary report, illustrates the microalgae present in five locations in northern Victoria Land, including Inexpressible Island, where he observed evident growth of *Microcoleus vaginatus* W. West et G.S. West and *Nostoc commune*, while when scratching the surface, he detected small colonies of *Prasiola crispa, Achnanthes brevipes* Agardh, and *Navicula muticopsis* Van Heurck (=*Luticola muticopsis*).

In a later, more in-depth study, Broady (1987a) described the flora present in samples of raw mineral soils from Inexpressible Island and Edmonson Point, reporting nine taxa in the former location and two in the latter and only *Nostoc commune* is in common with my study.

Broady *et al.* (1987) studied the biologic community of warm, geothermal zones on Mt. Melbourne, detecting 10 taxa (6 Cyanobacteria and 4 Chlorophyta) of which only the following 3 Chlorophyta were also found in the present study, though not in geothermal soils: *Coccomyxa gloeobotrydiformis, Coenocystis oleifera* (=*Sphaerocystis oleifera*), and *Pseudococcomyxa simplex.*

Two samples of "vegetated soil" from the fumaroles of Mt. Rittmann were observed by Bargagli *et al.* (1996). Of the algal taxa observed overall, only *Mastigocladus laminosus* Cohn was identified at species level and it was not in common

Table 2. Floristic composition of soils of northern Victoria Land. Numbers refer to the sites shown in Table 1. * = taxa found only in culture. # = prevously recorded in Antarctic soils. ° = prevously recorded in environments different from soil. § = new record for Continental Antarctica. §§ = new record for the whole of Antarctica.

Location n°:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
CYANOBACTERIA																				
**Aphanocapsa parasitica* (Kuetzing) Krammer et Anagnostidis 1995 °										X	X									
Aphanothece saxicola Naegeli 1849 °									X											
**Calothrix braunii* Bornet et Flahault 1886 #											X									
Calothrix parietina Thuret 1875 #			X								X									
Chondrocystis dermochroa (Naegeli) Komarek et Anagnostidis 1995 °															X					
Chroococcus minutus (Kuetzing) Naegeli 1849 °								X			X									
**Cyanobacterium cedrorum* (Sauvageau) Komarek et al. 1999 °	X																			
**Cyanosarcina* cf. *spectabilis* (Geitler) Kovacik 1988			X																	
**Eucapsis minor* (Skuja) Elenkin 1933 § §			X								X									
**Eucapsis minuta* Fritsch 1912 °											X									
**Leptolyngbya foveolarum* (Gomont) Anagnostidis et Komarek 1988 #			X				X		X						X	X				X
Leptolyngbya frigida (Fritsch) Anagnostidis et Komarek 1988 #	X	X	X		X	X		X			X	X				X	X		X	X
**Lyngbya scotti* Fritsch var. *minor* Fritsch 1912 °											X									
Nodularia harveyana Thuret 1875 #			X																	
Nostoc commune Vaucher 1803 #		X						X			X					X	X		X	
Nostoc punctiforme (Kuetzing) Hariot 1891 #	X		X			X											X			
Phormidium attenuatum (Fritsch) Anagnostidis et Komarek 1988 °	X	X			X			X	X	X	X	X			X		X			
**Phormidium corium* Gomont 1890 #										X										
Phormidium priestleyi Fritsch 1917 #		X	X						X		X				X					X
**Phormidium pseudopriestleyi* (W. et G.S. West) Anagnostidis et Komarek 1988 #	X																X			
**Phormidium uncinatum* Gomont 1890 °												X								
**Scytonema schmidtii* Gomont 1901 § §						X														
Total: 22	**5**	**4**	**8**	**0**	**2**	**3**	**1**	**4**	**4**	**3**	**11**	**3**	**0**	**0**	**4**	**3**	**5**	**0**	**2**	**3**
XANTHOPHYTA																				
**Botrydiopsis arhiza* Borzi 1825 #			X								X						X			
**Botrydiopsis constricta* Broady 1976 # §		X															X			
**Chlorocloster simplex* Pascher 1939 § §																X				
**Gloeobotrys arborum* Geitler 1942 § §											X									
**Gloeobotrys gelatinosus* Reisigl 1964 § §	X		X																	
**Gloeobotrys ovalis* Reisigl 1964 § §			X					X												
**Heterotrichella gracilis* Reisigl 1964 #		X															X			
**Monodus chodatii* Pascher 1925 § §	X															X				
**Xanthonema exile* (Klebs) Silva 1979 #	X	X						X			X						X			
Total: 9	**3**	**3**	**3**	**0**	**0**	**0**	**0**	**2**	**0**	**0**	**3**	**0**	**0**	**0**	**0**	**2**	**4**	**0**	**0**	**0**

BACILLARIOPHYTA																				
Luticola muticopsis (Van Heurck) D.G. Mann 1990 #										X										
Navicula atomus (Kuetz.) Grunow 1860 #											X									
Pinnularia borealis Ehrenberg 1843 #										X										
Total: 3	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
CHLOROPHYTA																				
**Apatoccoccus* cf. *lobatus* (Chodat) Boye-Petersen 1928				X										X						
**Chlamidopodium starrii* (Fott) Ettl & Gartner 1987 °		X											X				X			
**Chlamidopodium* sp.																			X	
**Chlorella homosphaera* Skuja 1948 °	X				X	X	X	X			X									
**Chlorella saccharophila* (Krueger) Migula 1907 #								X								X				
**Chlorella vulgaris* Beijerinck 1890 #		X		X		X		X								X	X			
**Chlorococcum* sp.				X			X					X								
**Choricystis chodatii (* Jaag) Fott 1976 § §	X							X								X				
**Choricystis guttula* Hindak 1980 § §								X								X				
**Coccomyxa gloeobotrydiformis* Reisigl 1969 #	X																			X
Desmococcus olivaceus (Pers. Ex Ach.) Teiling 1954 #										X										
**Diplosphaera mucosa* Broady 1982 °			X								X									
**Gloeocystis vesiculosa* Naegeli 1849 #	X							X												X
**Heterotetracystis akinetos* Cox et Deason 1968 § §						X														
Kentrosphaera facciolae Borzi 1883 °		X	X					X					X			X				
**Klebsormidium montanum* (Skuja) S. Watanabe 1983 § §							X													
Planktosphaerella terrestris Reisigl 1964 # §								X												
**Pleurastrum insigne* Chodat 1894 § §	X							X			X									X
Pleurococcus antarcticus W. et G.S. West 1911 °		X						X			X									
Prasiola crispa (Lightfoot) Meneghini 1838 #	X																			
**Pseudococcomyxa simplex* (Mainx) Fott 1981 #								X												
**Raphidonema pyrenoidifera* Korschikoff var. *elongata* Broady 1982 °					X															
**Raphidonema sempervirens* Chodat 1913 #																		X		
**Scotiellopsis oocystiformis* (Lund) Puncocharova et Kalina 1981 #		X							X											
**Scotiellopsis terrestris* (Reisigl) Puncocharova et Kalina 1981 #																X				
**Sphaerocystis oleifera* Broady 1976 #			X																	X
**Stichococcus bacillaris* Naegeli 1849 #	X	X	X		X	X		X		X	X		X			X	X			X
**Stichococcus* cf. *chlorelloides* Grintzesco et Peterfi 1932											X									
**Stichococcus mirabilis* Lagerheim 1893 § §		X	X		X						X						X			X
Total: 29	**7**	**7**	**5**	**3**	**4**	**4**	**3**	**12**	**1**	**2**	**7**	**1**	**3**	**1**	**0**	**7**	**4**	**1**	**1**	**6**
Total species: 63	**15**	**14**	**16**	**3**	**6**	**7**	**4**	**18**	**5**	**7**	**22**	**4**	**3**	**1**	**4**	**12**	**13**	**1**	**3**	**9**

with the samples analysed in the present study.

Analysis of the samples revealed that the Chlorophyta represent the richest component of the microalgal flora of the soils. This result is consistent with those of various studies conducted in various locations in Antarctica (Table 3).

Again, it is difficult to compare the data from the present study with those reported in the literature with respect to the algal microflora of Antarctic soil. In fact, it is sometimes difficult to understand if the type of sampling carried out took into account the algal patina of the soil or whether the soil apparently lacked in algal growth.

The analysis of mineral soil without macroscopic algal growth has never been the focus of a single work; thus it is difficult to compare the data presented herein with those from other works, in which the type of sampling is sometimes not well specified.

Results of the principal studies on Antarctic soil Algae are summarized in Table 3. The number of species represented in mineral soils ranges from 13 to 98.

After comparing the results with the literature, a partial similarity can be observed in Vestfold Hills soils (Broady, 1986), where 11 species are in common with northern Victoria Land microflora and also in Signy Island (Broady, 1979a, 14 species) and Windmill Island (Ling and Seppelt, 1998, 10 species).

Some species are widespread in the whole of Antarctica, and differences among northern Victoria Land microflora and other zones of the Continent are possibly due only to the low number of studies carried out to date.

Overall, collation with the available literature shows that 30 of the 63 taxa detected have previously been recorded in soil samples from other locations in Antarctica. Of these, 9 are Cyanobacteria, 4 Xanthophyta, 3 Bacillariophyta, and 13 Chlorophyta. The most widespread species include: *Nostoc commune, Leptolyngbya frigida* (= *Phormidium frigidum*), and *Phormidium priestleyi* (Cyanobacteria), *Xanthonema exile* (=*Heterothrix exilis*) (Xanthophyta), *Pinnularia borealis* and *Luticola muticopsis* (= *Navicula muticopsis*) (Bacillariophyta), and *Stichococcus bacillaris* and *Prasiola crispa* (Chlorophyta). The high number of species not detected by previous studies is certainly related to the scarce attention paid to this type of environment to date; this is also confirmed by that fact that many of the algae reported in the present study are more or less often found in other environments (algal mats, epiphytes on mosses, in snow patches, etc.) and locations of Antarctica.

However -to the author's knowledge- 15 species have not been previously reported for Continental Antarctica and 13 are new records for the whole of Antarctica. These species are marked with § or §§ in Table 2 and a description of each is reported at the end of this part.

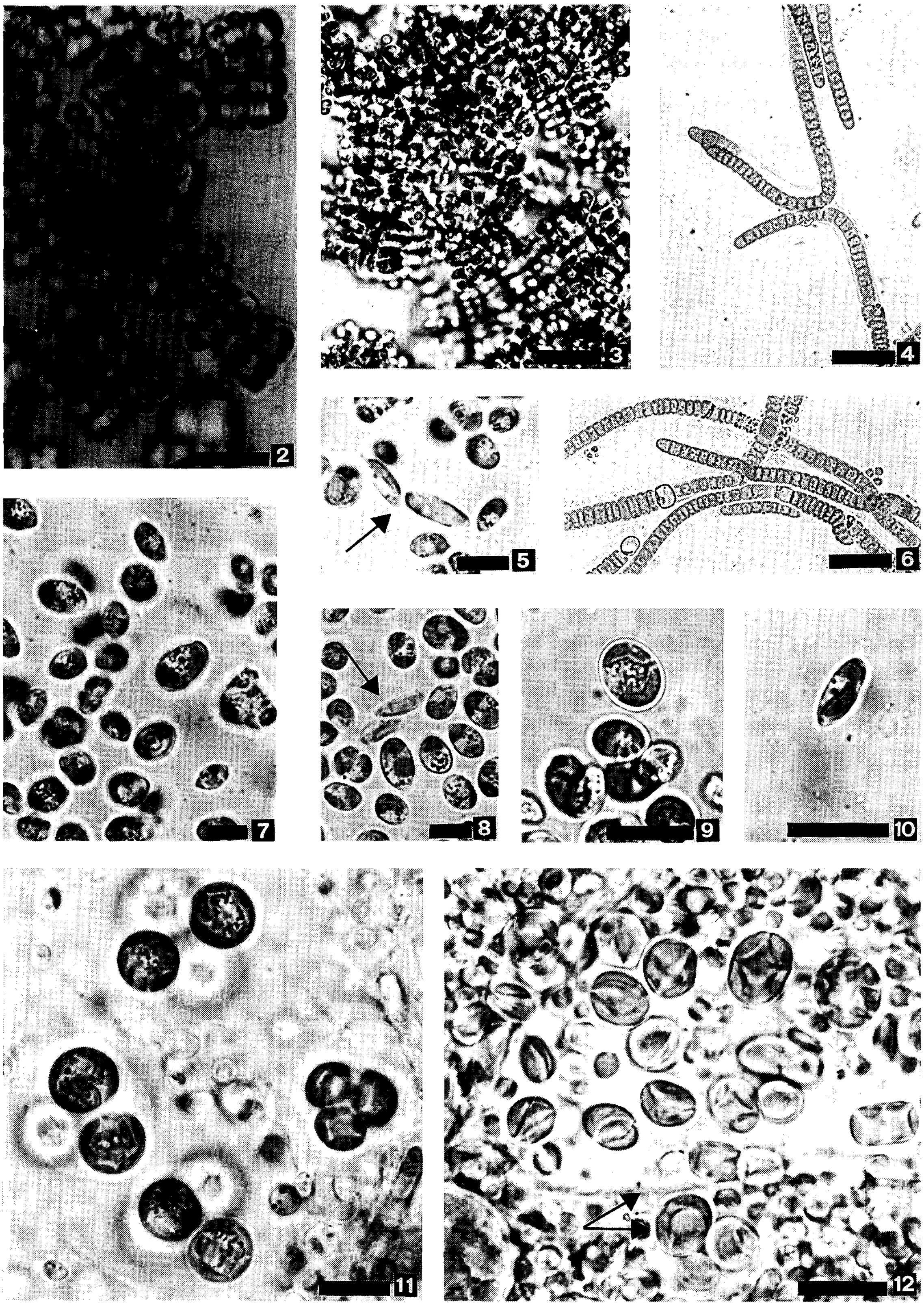
In particular Chlorophyta present in soil correspond poorly with those present in aquatic environments and other subaerial environments at the same locations. Thus, in general, many species of Chlorophyta and Xanthophyta which are shown to be absent when observing living material with light microscope are probably present in the soil as propagules carried by the wind or by birds or introduced by man near the Bases during the last century.

These taxa do not develop, playing the role of potential colonizers capable of developing when external conditions become suitable for their growth.

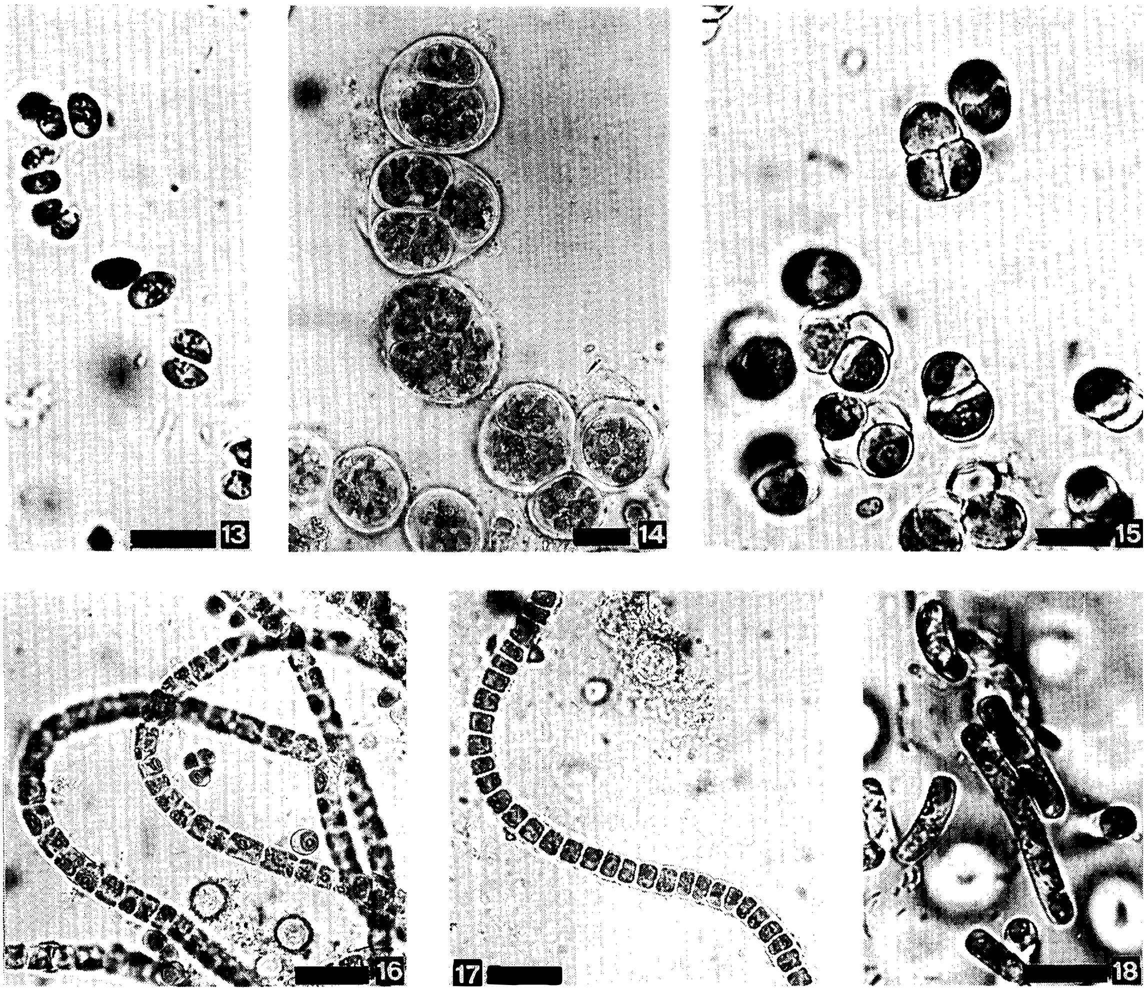
In contrast, Cyanobacteria are more often observed in other Antarctic habitats and

Table 3. Some previous studies on Antarctic soil algae. CY = Cyanobacteria; XA = Xanthophyta; BA = Bacillariophyta; CH = Chlorophyta. * = n° of species in common with this study (Table 2).

Author(s)	N° soil species	N° species in common*	Sampling locality	Land/Island
Holm-Hansen (1964)	14	3 CY 1 CH 2		southern Victoria Land
Akiyama (1967)	32	6 CY 1 XA 2 BA 2 CH 1	Syowa Station	Dronning Maud Land
Kol (1968)	15	4 CY 3 CH 1	Haswell Island	Queen Mary Land
Broady (1979a)	98	14 CY 5 XA 3 BA 2 CH 4	Signy Island	South Orkney Islands
Broady (1979b)	16	5 CY 2 XA 1 BA 1 CH 1	Horseshoe Island, Alexander Island	Antarctic Peninsula
Seaburg *et al.* (1979)	33	7 CY 4 BA 1 CH 2	Dry-Valleys	southern Victoria Land
Broady (1984)	17	5 CH 5	Mt. Erebus	Ross Island
Broady (1986)	33	11 CY 5 BA 3 CH 3	Vestfold Hills	Princess Elizabeth Land
Broady (1989)	13	2 CH 2	Edward VII Peninsula	Marie Byrd Land
Pankow *et al.* (1991)	44	6 CY 2 BA 2 CH 2	SchirmacherOase	Dronning Maud Land
Ling & Seppelt (1998)	48	10 CY 1 BA 2 CH 7	Windmill Islands	Wilkes Land
Ohtani *et al.* (2000)	21	3 BA 1 CH 2	Syowa Station	Dronning Maud Land



Figs. 2–12.



Figs. 13–18.

Figs. 2–3. *Eucapsis minor* (scale bars: Fig. 2 = 10 μm; Fig. 3 = 20 μm).
Figs. 4, 6. *Scytonema schmidtii* (scale bars = 50 μm).
Figs. 5, 8. *Chlorocloster simplex* (arrowed, scale bars = 10 μm).
Fig. 7. *Monodus chodatii* (scale bar = 10 μm).
Fig. 9. *Gloeobotrys gelatinosus* (scale bar = 10 μm).
Fig. 10. *Choricystis chodatii* (scale bar = 10 μm).
Fig. 11. *Gloeobotrys arborum* (scale bar = 10 μm).
Fig. 12. *Gloeobotrys ovalis* (colonies are arrowed, scale bar = 10 μm).
Fig. 13. *Choricystis guttula* (scale bar = 10 μm).
Fig. 14. *Heterotetracystis akinetos* (scale bar = 10 μm).
Fig. 15. *Pleurastrum insigne* (scale bar = 10 μm).
Figs. 16–17. *Klebsormidium montanum* (scale bars = 20 μm).
Fig. 18. *Stichococcus mirabilis* (scale bar = 10 μm).
Photographs of cultured specimens.

often as the dominant group, since they are capable of surviving repeated freeze-drying and rehydration (Vincent, 1988). Also in this case, fragments or forms of resistance coming above all from dry algal mats may have reached the soil, finding, during the favourable season, conditions suitable for development, resulting also in macroscopic growths (*e.g., Nostoc commune*). This type of microalgal distribution seems to be controlled by the availability of water, while it does not seem to be influenced by the content of nitrogen or of organic matter, and the pH simply tends to limit the number of species present.

Floristic notes on new records of Continental Antarctica and the whole of Antarctica: (further more detailed descriptive studies to confirm the identity of some of the following algae will be carried out):

CYANOBACTERIA

Eucapsis minor (Skuja) Elenkin 1933 (Fig. 2–3)

(Syn.: *Eucapsis alpina* Clements et Shantz var. *minor* Skuja 1926)

Komárek and Anagnostidis (1999), Fig. 350.

Cells spherical or hemispherical, blue-green, 2 μm in diameter, forming cubic colonies of 32–64 or more cells. In solid BBM medium cells in small colonies are often densely arranged in larger ones embedded in a colourless, hyaline mucilage.

New record for Antarctica.

Scytonema schmidtii Gomont 1901 (Fig. 4, 6)

Geitler (1932), Fig. 483b.

Trichomes single or in small aggregations, torulose and undulate, 6–11 μm broad, with intercalary heterocysts of 10 μm in diameter. Cells broader than longer, slightly constricted and granulated at the cross walls. Sheath thick, yellowish. Specimens in culture forming hormogones and false branches.

New record for Antarctica.

XANTHOPHYTA

Botrydiopsis constricta Broady 1976

Broady (1976), Fig. 325; Ettl and Gärtner (1995), Fig. 34: a.

Adult cells single, spherical, 25–35 μm in diameter, with many lenticular, parietal chromatophores lacking pyrenoids. Young cells up to 10 μm with few parietal chromatophores. Cell wall thin, smooth. Reproduction by aplanospores, zoospores and vegetative division. Aplanospores spherical, 4–4.5 μm in diameter with 2–3 chromatophores contained in large numbers inside aplanosporangium. Zoospores $5\text{–}6.5 \times 2\text{–}2.5$ μm, with two flagella of unequal length, with one chromatophore and stigma, released in large numbers by rupture of sporangium wall. Vegetative division occurs in old cultures: cells spherical became ellipsoidal then constricting, forming two daughter cells of different sizes. The characteristic "budding" process described by Broady (1979a) was also observed in solid BBM medium cultures with pyriform mother cell forming daughter bud separated by deepening constriction.

Previously recorded by Broady (1976, 1979a) at Signy Island (Maritime Antarctica).

New record for Continental Antarctica.

Chlorocloster simplex Pascher 1939 (Fig. 5, 8)

Pascher (1939), Fig. 325; Ettl and Gärtner (1995), Fig. 29: b.

Cells irregular, fusiform, with unequal sides, straight or half moon shape. Cells heteropolar with one apex conical and one broadly rounded, 14–18 μm long and 3–4 μm broad.

Chromatophore single, cup-shaped or sometimes ribbon-like, parietal. Cell wall colourless. Reproduction by 2 autospores formed by oblique division of mother cell (Fig. 8).

New record for Antarctica.

Gloeobotrys arborum Geitler 1942 (Fig. 11)

Geitler (1942), Fig. 5; Ettl and Gärtner (1995), Fig. 37: b.

Cells spherical in clusters of 2 or 4, inside irregular and homogeneous mucilage. Cells 8–8,5 μm in diameter with 4–6 plate- or ribbon-like chromatophores lacking pyrenoids. Reproduction by 4 spherical autospores released by rupture of mother cell wall.

New species for Antarctica.

Gloeobotrys gelatinosus Reisigl 1964 (Fig. 9)

Reisigl (1964), Fig. 10; Ettl and Gärtner (1995), Fig. 37: e.

Cells single or in clusters of 4, ellipsoidal-ovate in shape, inside a thick, irregular mucilage. Cells 7–10 μm long and 6–7 μm broad, with 2–3 discoidal or cup-shaped chromatophores, lacking pyrenoids. Nucleus not clearly visible. Cell wall thick. Reproduction by 2–8 oval autospores. In old cultures, cells often containing granules in chromatophores.

New record for Antarctica.

Gloeobotrys ovalis Reisigl 1964 (Fig. 12)

Reisigl (1964), Fig. 12; Ettl and Gärtner (1995), Fig. 37: d.

Cells single ellipsoidal-ovate, 5–6 μm in diameter, irregularly arranged in a fluid and irregular mucilage. Cells with 1–2 cup-shaped or ribbon-like, pale green chromatophores. Cell wall thin, becoming thicker during reproduction. Reproduction by 2–4 subspherical autospores released by rupture of sporangium wall.

New record for Antarctica.

Monodus chodatii Pascher 1925 (Fig. 7)

Pascher (1925), Fig. 30c; Ettl and Gärtner (1995), Fig. 28: i.

Cells asymmetrical, ellipsoidal or ellipsoidal-ovate, with slightly different apices, one broadly rounded, one slightly narrowed, 10–11 μm long and 7–8 μm broad, with 2–4 discoidal chromatophores. Cell wall thin. Reproduction by 2 flat autospores released by rupture of the sporangium wall.

New record for Antarctica.

CHLOROPHYTA

Choricystis chodatii (Jaag) Fott 1976 (Fig. 10)

Komárek and Fott (1983), Tab. 181, Fig. 3.

Cells ellipsoidal, slightly heteropolar, 5–7 μm long and 2–3 μm broad with a parietal chromatophore without pyrenoid. Reproduction by 2 ellipsoidal autospores released by rupture of the sporangium wall.

New record for Antarctica.

Choricystis guttula Hindak 1980 (Fig. 13)

Komárek and Fott (1983), Tab. 181, Fig. 6.

Cells single or in row of 2–4, drop-like, with one apex slightly cuneate and one broadly rounded, 5–6 μm long and 3 μm broad without mucilage envelope. Chromatophore

parietal, ring-like, without pyrenoid. Cell wall smooth, hyaline. Reproduction by 2 autospores released by rupture of the sporangium wall.
New record for Antarctica.

Heterotetracystis akinetos Cox et Deason 1968 (Fig. 14)

Cox and Deason (1968), Figs 8–12; Ettl and Gärtner (1995), Fig. 87: b.

Young cells ellipsoidal, adult spherical, 12–15 μm in diameter with thick cell wall. Chromatophore parietal, cup-shaped with a basal pyrenoid surrounded by 3–5 starch grains. Reproduction by ellipsoidal zoospores (7–15 μm × 5–11 μm) with flagella of different length. Cells in old cultures in liquid BBM with cell wall up to 3 μm thick.
New record for Antarctica.

Klebsormidium montanum (Skuja) S. Watanabe 1983 (Fig. 16–17)

Watanabe (1983), Figs 19, 55; Ettl and Gärtner (1995), Figs. 203: c, d.

Filaments uniseriate; cells cylindrical, with parallel sides in younger filaments becoming barrel-shaped in older ones, so the filaments are constricted at the cross walls. Cells 5–8 μm long and 6–8 μm broad. Single, ring-like parietal chromatophore with one pyrenoid with many starch grains. Reproduction by ellipsoidal zoospores of 10 × 5 μm with flagella of the same length and a chloroplast in the basal part containing one pyrenoid. The stigma is absent. Reproduction by fragmentation of filaments often occurs.
New record for Antarctica.

Planktosphaerella terrestris Reisigl 1964

Reisigl (1964), Fig. 26; Ettl and Gärtner (1995), Fig. 124: a.

Young cells ovate, adult cells spherical, 10–15 μm in diameter, with thin cell-wall. Numerous parietal plate-like chromatophores each with one pyrenoid. Reproduction by 2–16 autospores released by rupture of sporangium wall. Each ovoidal autospore (3–5 μm broad) with more than one chromatophore each with one pyrenoid. Previously reported in Signy Island soils (Maritime Antarctica) by Broady (1979a), Davey (1991 a, b) and Davey and Clarke (1991).
New record for Continental Antarctica.

Pleurastrum insigne Chodat 1894 (Fig. 15)

Chodat (1894), Fig. 29: 14–27; Ettl and Gärtner (1995), Figs 188: b, c.

Cells spherical single or in groups of 2–4 enclosed in a irregular sarcinoid matrix, 5–9 μm long and 6–10 μm broad. One or 2 chromatophores with one pyrenoid. Reproduction by drop-like zoospores, 6 μm long and 3 μm broad, with 2 flagella of the same length.
New record for Antarctica.

Stichococcus mirabilis Lagerheim 1893 (Fig. 18)

Ettl and Gärtner (1995), Fig. 204: j.

Cells cylindrical single or in short chains, often curved, with rounded poles, 2–3 μm broad and up to 20 μm long. Chromatophore parietal, encircling less than half of cell wall. Reproduction by transverse vegetative cell division.
New record for Antarctica.

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References

Akiyama, M. (1967): On some Antarctic terrestrial and subterranean algae. Mem. Fac. Educ. Shimane Univ., **1**, 36–56.

Anagnostidis, K. and Komárek J. (1988): Modern approach to the classification system of cyanophytes 3—Oscillatoriales. Algol. Stud., **50–53**, 327–472.

Bargagli, R., Broady, P.A. and Walton D.W.H. (1996): Preliminary investigation of the thermal biosystem of Mount Rittmann fumaroles (northern Victoria Land, Antarctica). Antarct. Sci., **8**, 121–126.

Broady, P.A. (1976): Six new species of terrestrial algae from Signy Island, South Orkney Islands, Antarctica. Br. Phycol. J., **11**, 387–405.

Broady, P.A. (1979a): The terrestrial algae of Signy Island, South Orkney Islands. Br. Antarct. Surv., Sci. Rep., **98**, 117 p.

Broady, P.A. (1979b): A preliminary survey of the terrestrial algae of the Antarctic Peninsula and South Georgia. Br. Antarct. Surv. Bull., **48**, 47–70.

Broady, P.A. (1982): New records of Chlorophycean micro-algae cultured from Antarctic terrestrial habitats. Nova Hedwigia, **36**, 445–484.

Broady, P.A. (1984): Taxonomic and ecological investigation of algae on steam-warmed soil on Mt. Erebus, Ross Island, Antarctica. Phycologia, **23**, 257–271.

Broady, P.A. (1985): A preliminary report of phycological studies in northern Victoria Land and on Ross Island during 1984–85. Melbourne Univ. Progr. in Antarctic Studies. Rep., **66**, 132 p.

Broady, P.A. (1986): Ecology and taxonomy of the terrestrial algae of the Vestfold Hills. Antarctic Oasis, ed. by J. Pickard. Sydney, Academic Press, 165–202.

Broady, P.A. (1987a): A floristic survey of algae at four locations in northern Victoria Land. N.Z. Antarct. Rec., **7**, 8–19.

Broady, P.A. (1987b): The morphology, distribution, and ecology of *Pseudococcomyxa simplex* (Mainx) Fott (Chlorophyta, Chlorellaceae), a widespread terrestrial Antarctic alga. Polar Biol., **7**, 25–30.

Broady, P.A. (1989): Survey of algae and other terrestrial biota at Edward VII Peninsula, Marie Byrd Land. Antarct. Sci., **1**, 215–224.

Broady, P.A. (1992): Identification of propagules—algae. BIOTAS Manual of Methods, ed. by D.D. Wynn-Williams. Cambridge, SCAR, 23 p.

Broady, P.A. (1996): Diversity, distribution and dispersal of Antarctic terrestrial algae. Biodiversity Conserv., **5**, 1307–1335.

Broady, P.A., Given, D., Greenfield, L. and Thompson, K. (1987): The biota and environment of fumaroles on Mt. Melbourne, northern Victoria Land. Polar Biol., **7**, 97–113.

Chodat, R. (1894): Matériaux pour servir a l'histoire des Protococcoidées. Bull. de l'Herbier Boisser, **2**, 585–616.

Cox, E.R. and Deason, T.R. (1968): *Axilosphaera* and *Heterotetracystis*, new Chlorosphaeracean genera from Tennessee soil. J. Phycol., **4**, 240–249.

Chantanachat, S. and Bold, H.C. (1962): Phycological Studies. II. Some algae from arid soils. Austin, Texas, Univ. Texas Publ., **6218**, 75 p.

Davey, M.C. (1989): The effects of freezing and desiccation on photosynthesis and survival of terrestrial Antarctic algae and Cyanobacteria. Polar Biol., **10**, 29–36.

Davey, M.C. (1991a): Effects of physical factors on the survival and growth of Antarctic terrestrial algae. Br. phycol. J., **26**, 315–325.

Davey, M.C. (1991b): The seasonal periodicity of algae in Antarctic fellfield soils. Holarctic Ecology, **14**, 112–120.

Davey, M.C. and Clarke, K.J. (1991): The spatial distribution of microalgae on Antarctic fellfield soils. Antarct. Sci., **3**, 257–263.

Davey, M.C., Davidson, P.B., Richard, K.J. and Wynn-Williams, D.D. (1991): Attachment and growth of

Antarctic soil Cyanobacteria and algae on natural and artificial substrata. Soil Biol. Biochem., **23**, 185–191.

Ettl, H. and Gärtner, G. (1995): Syllabus der Boden-, Luft- und Flechtenalgen. G. Fischer Verlag, Stuttgart, Jena, New York, 721 p.

Fumanti, B., Alfinito, S. and Cavacini, P. (1995): Floristic studies on freshwater algae of Lake Gondwana, northern Victoria Land (Antarctica). Hydrobiologia, **316**, 81–90.

Fumanti, B., Cavacini, P. and Alfinito, S. (1997): Benthic algal mats of some lakes of Inexpressible Island (northern Victoria Land, Antarctica). Polar Biol., **17**, 25–30.

Geitler, L. (1932): *Cyanophyceae*. Kryptogamen-Flora von Deutschland, Österreich und der Schweiz, Bd. **14**, ed. by L. Rabenhorst. Leipzig, Akad. Verlaggsges., 1196 p.

Geitler, L. (1942): Entwicklungsgeschichte und Systematik neuer bemerkenswerter atmophytischer Algen aus Wien. Flora, **136**, 1–29.

Holm-Hansen, O. (1964): Isolation and culture of terrestrial and freshwater algae of Antarctica. Phycologia, **4**, 43–51.

Kol, E. (1968): Algae from the Antarctica. Ann. His. Nat. Mus. Nat. Hung., **60**, 71–77.

Komárek, J. and Anagnostidis, K. (1999): *Cyanoprokaryota*. 1 Teil: *Chroococcales*. Süßwasserflora von Mitteleuropa, Bd. **19/1**, ed. by H. Ettl *et al*. Jena, G. Fischer-Verlag, 548 p.

Komárek, J. and Fott, B. (1983): *Chlorophyceae: Chlorococcales*. Das Phytoplankton des Süßwassers, **7** Teil, 1 Hälfte, ed. by A. Thienemann. Stuttgart, Schweizerbart, 1044 p.

Krammer, K. and Lange-Bertalot H. (1986): *Bacillariophyceae*. 1 Teil: *Naviculaceae*. Süßwasserflora von Mitteleuropa, Bd. **2/1**, ed. by H. Ettl J. Gerloff, *et al*. Jena, G. Fischer-Verlag, 876 p.

Ling, H.U. and Seppelt, R.D. (1998): Non-marine algae and cyanobacteria of the Windmill Island region, Antarctica with descriptions of two new species. Algol. Stud., **89**, 49–62.

Ohtani, S., Kousuke, S., Yamamoto, H., Aridomi, Y., Itoh, R. and Fukuoka, Y. (2000): Distribution of soil algae at the monitoring sites in the vicinity of Syowa Station between austral summers of 1992/93 and 1997/98. Polar Biosci., **13**, 113–132.

Pankow, H., Haendel, D. and Richter, W. (1991): Die Algenflora der Schirmacheroase (Ostantarktika). Beih. Nova Hedwigia, **103**. Berlin-Stuttgart, J. Cramer, 197 p.

Pascher, A. (1925): Heterokontae. Die Süßwasserflora Deutschlands, Österreichs und der Schweiz, H. **11**, ed. by A. Pascher. Jena, G. Fischer, 118 p.

Pascher, A. (1939): Heterokonten. Kryptogamenflora von Deutschland, Österreich und der Schweiz, Bd. **11**, ed. by L. Rabenhorst. Leipzig, Akad. Verlagsges., 1092 p.

Reisigl, H. (1964): Zur Systematik und Ökologie alpiner Bodenalgen. Österr. Bot. Z., **111**, 402–499.

Seaburg, K.G., Parker, B.C., Prescott, G.W. and Whitford, L.A. (1979): The algae of Southern Victorialand, Antarctica. Bibl. Phycol., **46**. Vaduz, J. Cramer, 169 p.

Simeoni, U., Baroni, C., Meccheri, M., Taviani, M. and Zanon, G. (1989): Coastal studies in northern Victoria Land (Antarctica): Holocene beaches of Inexpressible Island, Tethys Bay and Edmonson Point. Boll. Oceanog. Teor. Appl., **7**, 5–17.

Smith, R.I.L. (1984): Terrestrial plant biology of the sub-Antarctic and Antarctic. Antarctic Ecology, **1**, ed. by R.M. Laws. London, Academic Press, 61–162.

Società Italiana della Scienza del Suolo (1985): Metodi normalizzati d'analisi del suolo. Edagricole, 100 p.

Stanier, R.Y. and Cohen-Bazire, G. (1977): Phototrophic prokaryotes: the Cyanobacteria. Ann. Rev. Microbiol., **31**, 225–274.

Vincent, W.F. (1988): Microbial ecosystems in Antarctica. Cambridge, Cambridge University Press, 304 p.

Watanabe, S. (1983): New and interesting green algae from soils of some Asian and Oceanic regions. Arch. Protistenk., **127**, 223–270.

Wynn-Williams, D.D. (1988): Microbial colonization of Antarctic fellfield soils. Proceedings of the 4th Intern. Symp. Microbial Ecol., ed. by F. Megusar. Ljubijana, Yugoslavia, 191–200.

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