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Biogeographic distribution of freshwater algae in Antarctica, and special reference to the occurrence of an endemic species of *Oedogonium*

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Introduction

Due to its inaccessibility, the data net on the distribution of freshwater algae covering Antarctica and its adjacent areas has naturally been relatively sparse as compared to many other temperate and tropical regions in both hemispheres.

From the begening of the nineteenth century onward many Europian nations organized research expedition to Antarctica. Our knowledge of the freshwater algae in Antarctica has gradually accumulated, especially during and since the International Geophysical Year (IGY, 1957-1958), and interests in many features of this region have been accelerated and expanded. The freshwater algal research in Antarctica was reviewed by Hirano (1965), and recently, Prescott (1979) made a comprehensive compilation of freshwater algae and related bibriography to the Antarctic and Subantarctic regions issued so far. Hirano (1965) reviewd the historical sketch of the studies of Antarctic freshwater algae and disccused the general features of the algal flora of Antarctica in comparison with other regions in the world. And he pointed out to study the critical appraisal on the previously known species based on the preserved specimens are required for the prospective accumulation of Antarctic data, while he emphasized the requirement of the future stidies of algal flora based on not only by fresh natural materials but also by culturing of these materials.

There has been marked progress in expanded interests of phycological researches in Antarctica during the past ten years. Taxonomic and detailed floristic studies of freshwater algae were reported by Parker, Samsel, Jr., and Prescott (1972), Therezien and Couté (1977), Seaburg, Parker, Prescott and Whiteford (1979), and Hirano (1979). Limnological ecology of freshwater and inland brackish and saline water algae were studied by Baker (1967). McNamara (1970), Goldman, Mason and Wood (1972), Koob and Leister (1972), Samsel, Jr., and Parker (1972), Campbell (1978), Akiyama (1975) and Tominaga (1977). On the taxonomy and ecology of terrestrial algae, Broady (1976, 1977-a, -b) described several new taxa belonging to Chlorophyceae and Xanthophyceae. Ecology of terrestrial algae were studied by Broady (1977-a, -b, 1979-a, -b, -c) and Akiyama (1980), and Friedmann and Ocampo (1976) demonstrated the presence of a peculiar endolithic Cyanophycean alga from an extremely inhospitable habitat in the Dry valley region, South Victoria Land, Antarctica.

Basic to an understanding of the role of algae in Antarctic aquatic and terrestrial biology is taxonomy and also the distribution of these species in this region. Though we have not sufficient data for discussing the details of the distribution of algae throughout the whole extent of Antarctica as yet, a general interpritation of geographic distribution of algae in Antarctica, if it could be made, would be of considerable interest and value for future studies.

Algal habitats in Antarctica

As mentioned by Seaburg et al. (1979) and Akiyama (1982), the freshwater and terrestrial algal habitats in Antarctica can be classfied into several characteristic microhabitats (Fig. 1). The most peculiar algal communities are recognized in chasmolithic and endo-

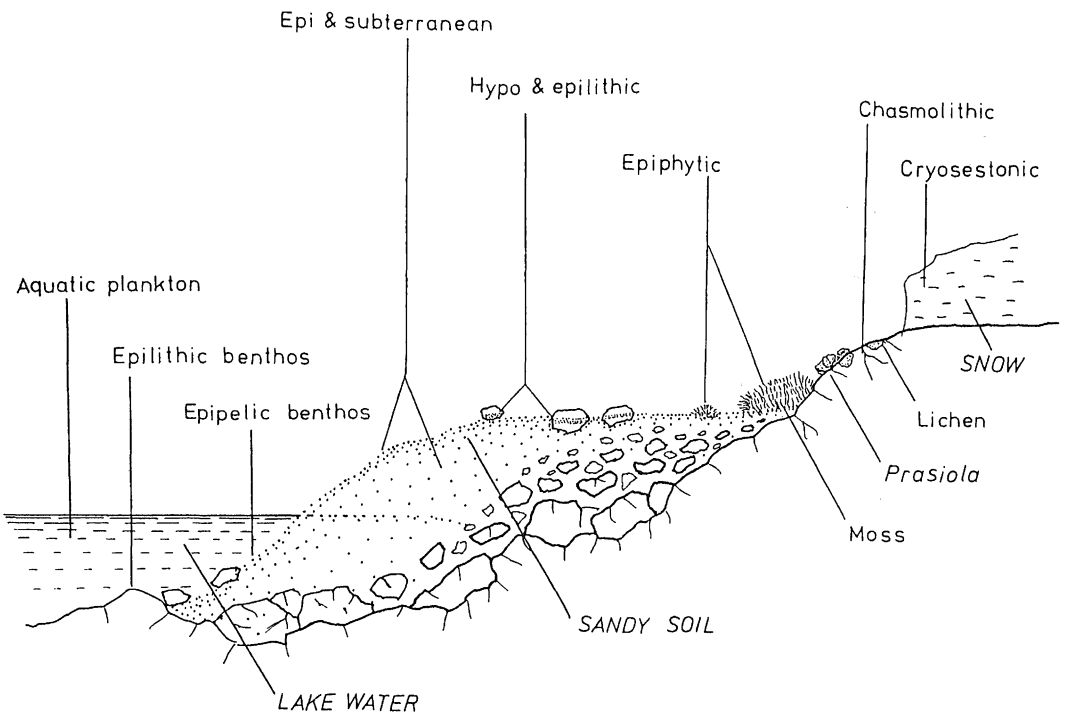

Fig. 1. Schema showing varied microhabitats of algae in the ice-free region of Antarctica.

lithic habitats. Friedmann and Ocampo (1976) reported the endolithic species of *Gloeocapsa* from the dry valley regions in South Victoria Land. A similar chasmolithic algal growths developed in narrow fissures of rock (quartz) was reported by Akiyama (1974). The presence of hypo-and epilithic algal communities in subaerial condition which developed under or lateral surfaces of stones lying or partially burried in sandy soils has been reported by many authors (Fukushima, 1959; Cameron et al., 1970; Cameron, 1972; Akiyama, 1974, 1981).

Since the pioneering work of Flint and Stout (1960), the presence of epiterranean and subterranean, so-cald soil algae were recognized by many authors (Watanabe et al., 1961; Holm-Hansen, 1964; Akiyama, 1967, 1968, 1964; Cameron, 1969, Cameron et al., 1970-b, 1971; Belcher, 1969; Bardin, 1969; Broady, 1976, 1977-a, 1979-c; Seaburg et al., 1979).

Lichen and moss communities are one of the most important macrophytic vegetation in Antarctic cold desert, especially the moss turf has an important ecological meaning particularly of a maintenance of capillary water for epiphytic algal growths. Hickman and Vitt (1973) and Broady (1977-b, 1979-a, b) demonstrated the floristic composition and population dynamics of algal communities developed on the moss plants.

Cryosestonic community known as so-called colored snow has been attracted special notice from early expedition by many authors (Fritsch, 1912; Gain, 1911*, 1912*; Wildemann, 1935*; Fogg, 1967; Kol and Flint, 1968; Akiyama, 1977, 1979). In connection to the critical appraisal on the taxonomy of some cryoalgae such as *Scotiella* and *Cryocystis* (known as *Chodatella*), recently Hoham (1974, 1975, 1979) reported the details of life cycle of these algae. Ecological studies on the snow algae of Antarctica were reported by Fogg (1967) and Akiyama (1979).

The greatest accumulation of algal biomass occur naturally in aquatic habitats such as shallow ponds and lakes receiving meltwater from glaciers, however, the relative paucity of plankton algae compared to epilithic and epipelic algae is the one of feature of Antarctic aquatic ecosystem as pointed out by Akiyama (1974) and Seaburg et al. (1979). The algal flora of brackish and saline water lake was reported by Fukushima (1962, 1964, 1968) and Akiyama (1974, 1975), and Watanuki and Ohno (1975, 1976) isolated some halophilic diatoms such as *Achnanthes brevipes* var. *intermedia* and *Tropidoneis laevissima* from inland saline lake. Campbell (1978) researched the primary production of a hyper saline lake in Vestfold Hills, Antarctica.

The above mentioned algal habitats are mainly occupied along the coastal region of ice-free area, while, Cameron (1972) demonstrated the occurrence of macrophytic algal growths composed of *Schizothrix calcicola* and *Porphyrosiphon notarsii*, and he also detected a coccoidal green alga *Neochloris aquatica* in cultures of the fragments of algal growths collected from the crevis in the morainic terrian nearby the La Gorce Mts. (86°45'S).

Occurrence and distribution of freshwater algae

The algal flora of Antarctic region differs from that of Arctic region, particularly a rapid decrease in number of taxa of green algae such as chlorococcalean and desmidean members in Antarctic region is a distinct feature of Antarctic flora in comparison to geographically corresponded latitude of Arctic region (Hirano, 1965) (Fig. 2). There is an exception, however, an abundantly developed algal flora resembling to those of temperate region has been recognized in the Kerguelen Islands. According to the recent data by Therezien and Couté (1977), 86 taxa including such cosmopolitan genera as *Coelastrum*,

* Cited from Kol (1968).

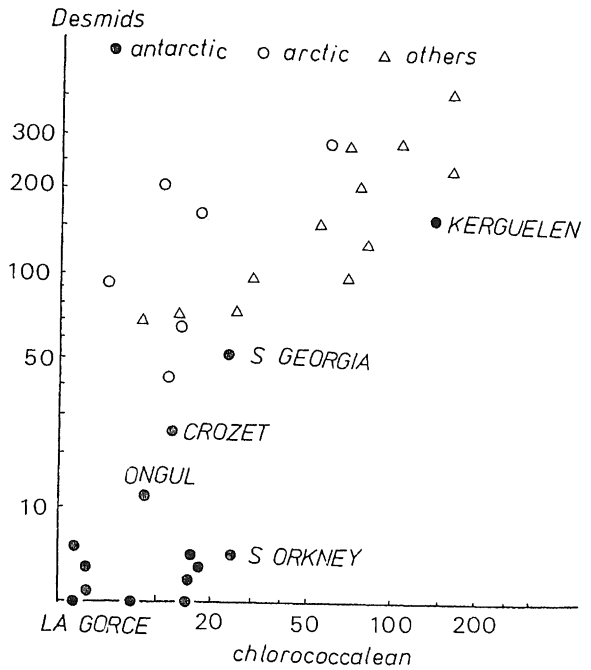

Fig. 2. Comparison of freshwater algal flora between Antarctic, Arctic and other regions.

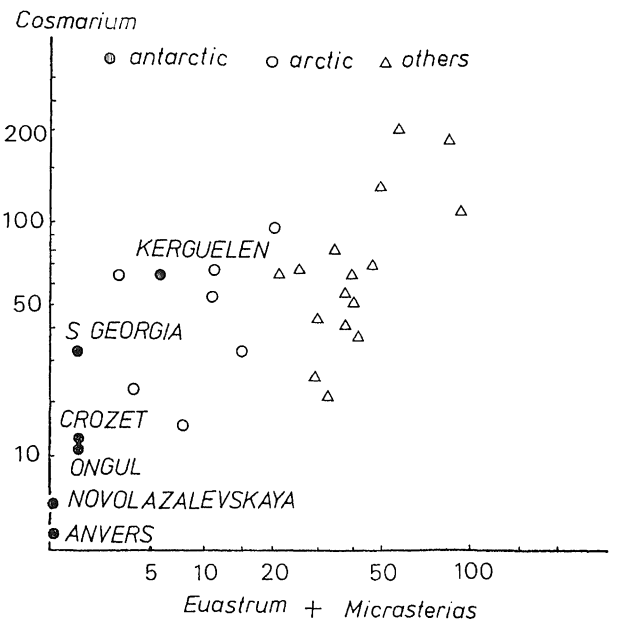

Fig. 3. Comparison of desmidean flora between Antarctic, Arctic and other regions.

Scenedesmus and *Pediastrum* belonging to the chlorococcalean algae and 113 taxa of desmids are recorded in this region. On the floristic feature of Arctic desmidean flora, high percentage of the members of *Cosmarium* has been pointed out already by Croasdale and Grönblad (1964), and Hirano (1968). And they also alluded to the trend of decreasing of the member representative of *Micrasterias* toward the north. According to this view point, the both polar desmidean flora are more clearly characterized respectively. Namely, the floristic structure of desmids in the Kerguelen Islands is more similar to Arctic region than that of temperate region, though, the majority of Antarctic desmidean flora is extremely scarce in the members representative of *Micrasterias* (Fig. 3).

The geographical distribution of desmids in Antarctic region is strictly restricted especially in Subantarctic islands. Among them, the Kerguelen Islands is the most abundant in the floristic composition both in genera and species. Amount to 142 species including varieties and formae have been recorded so far. In contrast, the Crozet Islands and South Georgia which are situated in the similar latitude to Kerguelen, nevertheless, both floras are poor in comparison to that of Kerguelen. In the Antarctic continent, distribu-

tion of desmids is strictly limited in several localities only in coastal ice-free region. As noted previousely, the species of *Cosmarium* is one of the most important dominant element in Arctic desmid-flora. In the case of Antarctic desmid-flora, the same trend also can be recognized. Eighteen taxa belonging to *Cosmarium* have been reported from the Antarctic continent and the adjacent islands so far, and these taxa are account for 69% of all desmidean members found in the Antarctic contient. Especially in the area of Syowa Station in the Prince Olav Coast, Enderby Land, Hirano (1979) reported 12 taxa of *Cosmarium* including one new species and 4 of new varieties. And he noted that among these species, *Cosmarium cucurubita*, a species already known in Fritsch's record (1912) from South Orkney under the name of *Penium* sp. is comonly distributed in this region. This species and three other species of *Cosmarium* are also recognized in Novolazarevskaya by Lavrenko (1967), and Komárek and Růžička (1966). On the global distribution of these *Cosmarian* taxa, most of them are widely distributed in both hemispheres with the exception of *Cosmarium antarcticum* and some of new varieties and new species from Syowa Station (Fig. 4).

Staurastrum, well known as one of the most common desmid found in many temperate region is also distributed in Antarctic and Subantarctic regions, however they are strictly

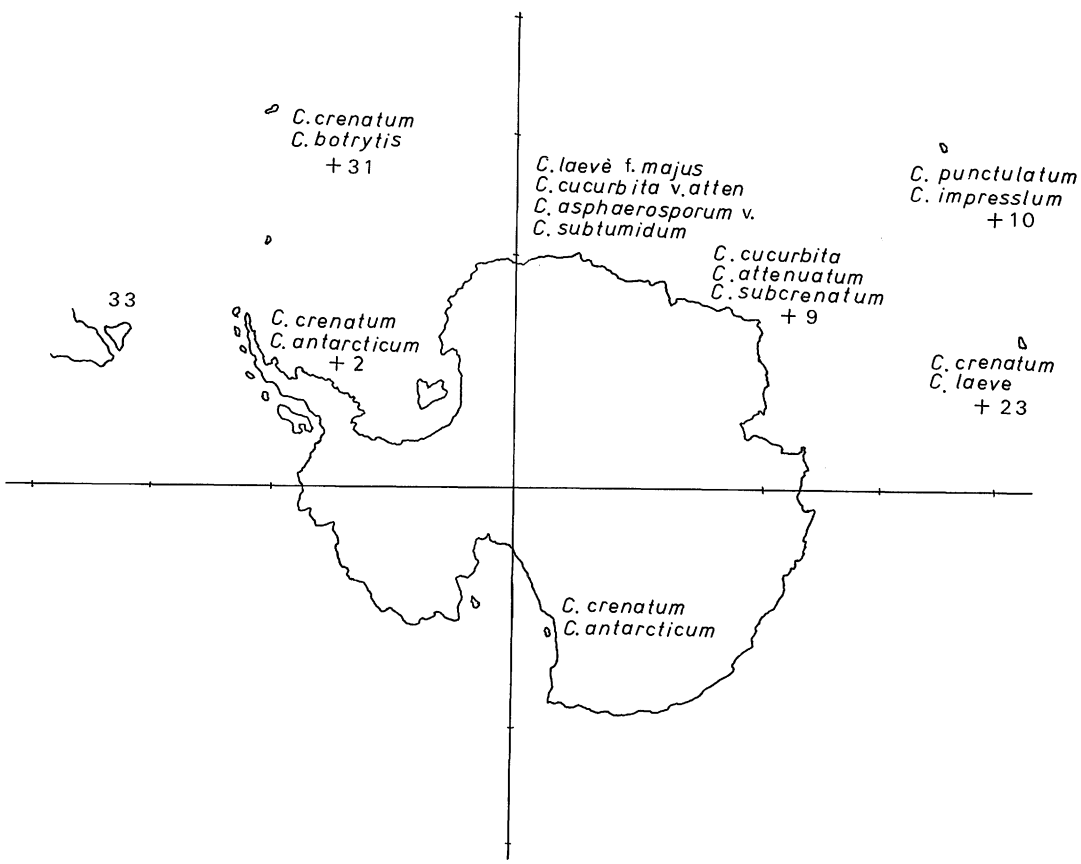

Fig. 4. Distribution of *Cosmarium* in Antarctica and adjacent region.

limited compared with the distribution of Cosmarian members. Eleven taxa including such common species as *S. mutica* and *S. margaritaceum* have been recorded from Kerguelen and six taxa of *Staurastrum* also recognized in South Georgia. Hirano (1965) suggested that the absence of such genera as *Staurastrum* and *Closterium* is one of the most noticiable feature of the Antarctic algal flora. But, according to the subsequent researches, Parker, Samsel, Jr., and Prescott (1972) recognized *S. dilatatum* var. *insignis* from Anvers Island located in the middle part of Palmer Peninsula, and later Akiyama (1974) reported the occurrence of *Staurastrum* sp. in the coastal ice-free area along the Lützow Holm Bay nearby the Syowa Station. Two formae of *Staurastrum dilatatum* have been known from South Georgia (Carlson, 1913). This species also has been known as widely distributed species in both hemispheres (Skuja, 1928, 1956; Scott and Grönblad, 1957), besides it has been also commonly recorded from Arctic Alaska (Hirano, 1968), Labrador (Croasdale and Grönblad, 1964) and Devon Island (Croasdale, 1965) (Fig. 5).

The occurrence of four other desmids known from Antarctic continent and adjacent islands are restricted only in the Palmer Peninsula and Novolazarevskaya, Princess Astrid Coast. These are *Cylindrocystis brebissonii*, *C. cohaerens*, *Penium curtum* and *Pleurotaeniopsis* in Palmer Peninsula, and *Netrium oblongum* and *Cylindrocystis crassa* in Novolazarevskaya. All of these species are well known as cosmopolitan algae in temperate region. On the

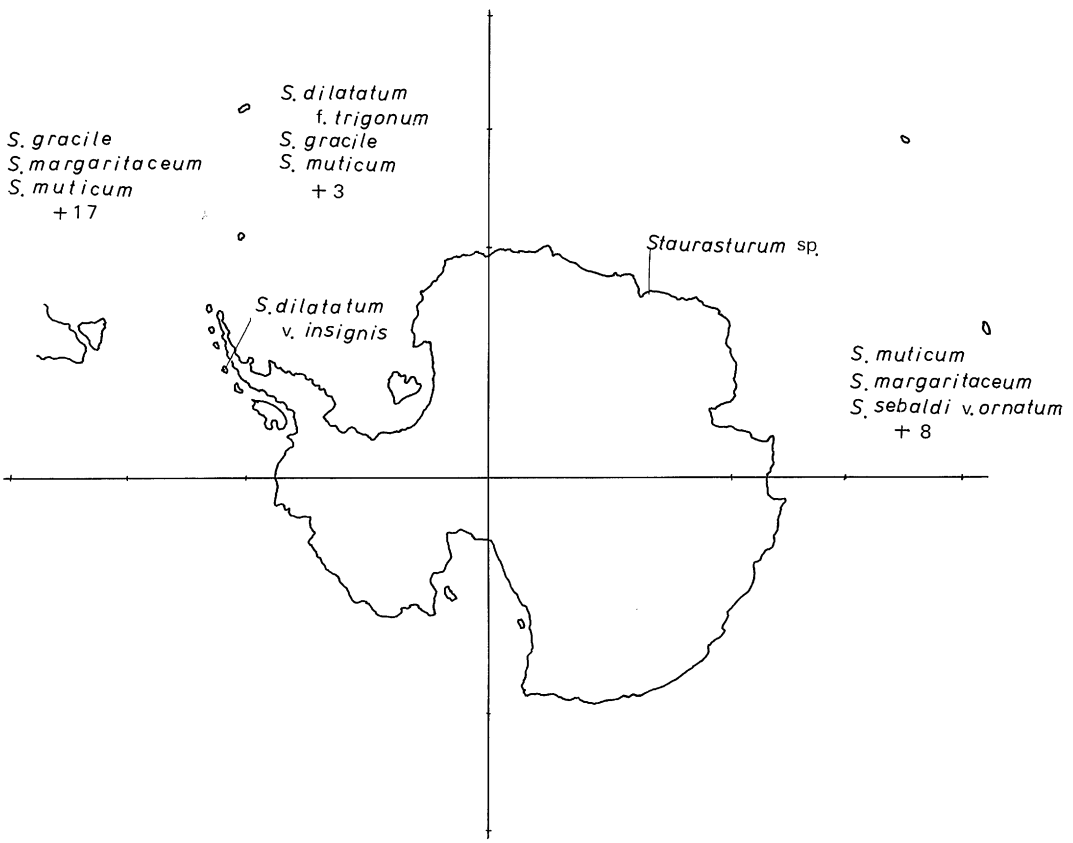

Fig. 5. Distribution of *Staurastrm* in Antarctica and adjacent region.

contrary, in Subantarctic islands, especially in the Kerguelen Islands, the desmidean flora of this region is abundantly developed. Thirteen genera including 57 species and varieties with some formae are recognized from The Kerguelen Islands so far. Among them, the following taxa are specially interested since they are commonly found in Arctic and alpine region ; *Gonatozygon brebissonii* var. *alpestre*, *Closterium tumidum* var. *nylandicum*, *Staurodesmus acarides* and *Staurastrum punctulatum* var. *kjellmani* (Fig. 6).

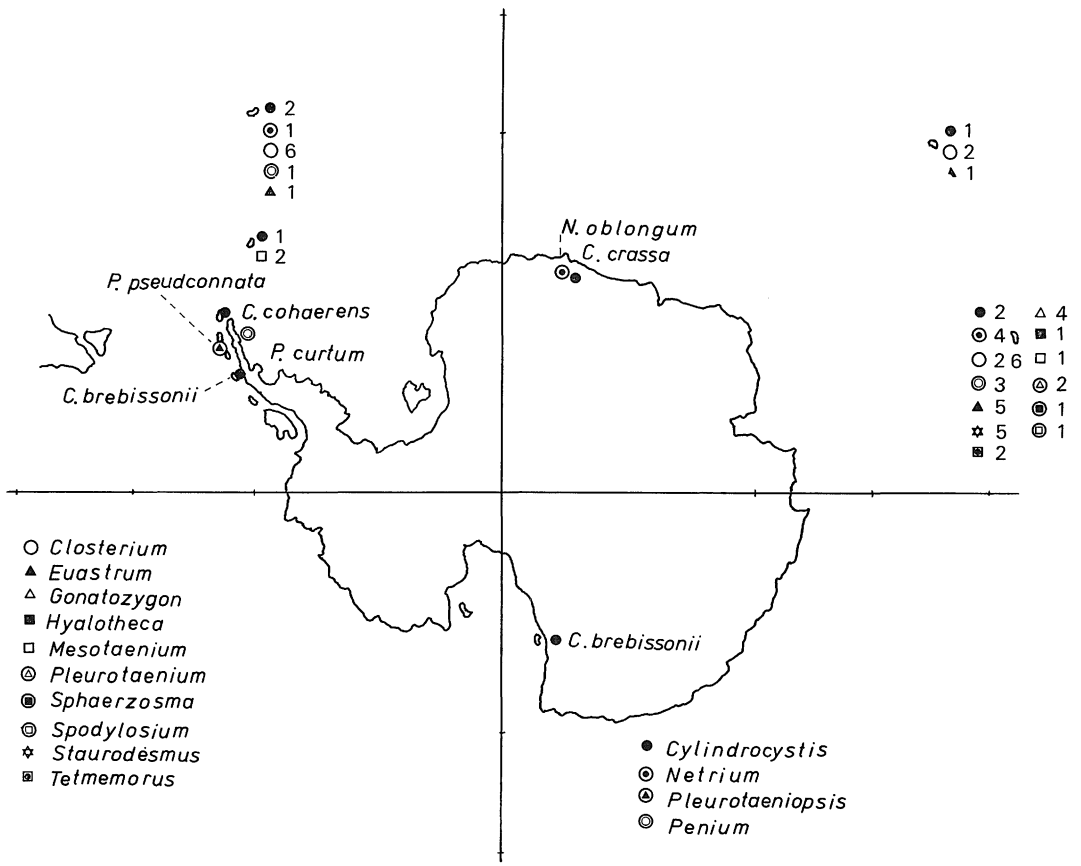

Fig. 6. Distribution of desmidean genera (showing number of species) in Antarctica and adjacent region.

In summerizing the data previousely mentioned, 6 genera including 26 species and some varieties can be recongnized in Antarctic continent and its adjacent islands so far, and 17 genera including 195 species containing some varieties and formae can be recognized throughout the whole extent of Antarctic and Subantarctic regions. And the amount of desmidean taxa found in Subantarctic region is about 13 times as much as that of Antarctic continent, and number of genera in Antarctic continent decrease into approximately one third of that of Subantarctic region.

As previousely noted, the algal flora of Antarctic region differs from that of the Arctci region, namely, a rapid decrease in number of floristic components especially in Antarctic continent and its adjacent islands in comparison to the same corresponding latitude

of Arctic region is the particular feature of this flora. The occurrence of majority of aquatic algae in Antarctica, strictly limited to the coastal ice-free areas which are situated mostly along the 70°S circle in Antarctica, since the farsouthern parts of Antarctic inland from 70°S are generally covered with the continental glacier permanently. Thus the majority of aquatic algae may not be able to thrive under such inhospitable condition. On the contrary, in Arctic region, more hospitable habitats for aquatic algae such as tundra and so-called polygon districts are widely developed in this region. These extremely differentiated circumstances between both polar regions are considered to be ascribable to possess the different temperature condition in each other. Namely, there is no influence of warm ocean current in Antarcatic region, however in Arctic region, a warm current, the North Atlantic Drift, penetrates to north beyond the Arctic circle and then separates into two branches. One of these current flows along the western side of Greenland, and the other reaches up to the western sea coast of Spitzbergen. It seems that these different meteorological background relating to each oceanographic difference, particularly on the distribution pattern of oceanic current exert a deep influence on the distribution of algae both in qualitatively and quantitatively.

On the distribution of chlorococcalean algae in Antarctica, quite similar trend as regarded in desmidean algae can be recognized (Fig. 7). Especially, the occurrence of free

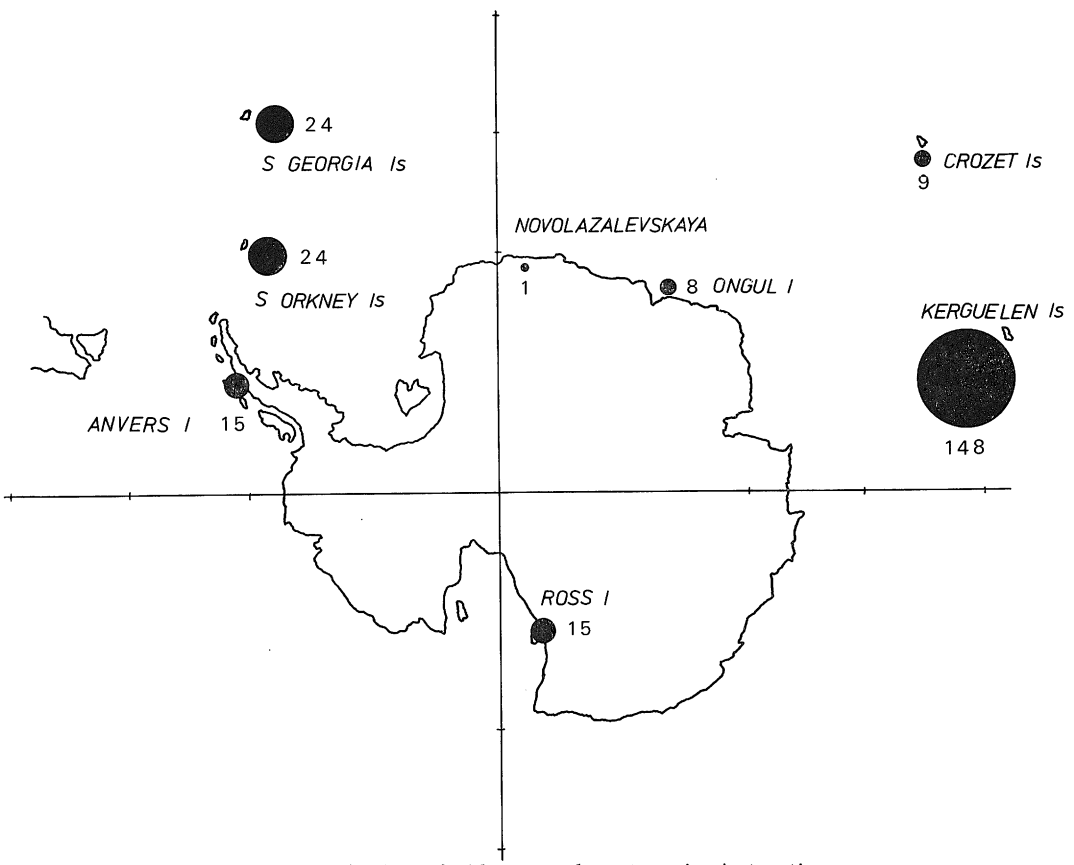

Fig. 7. Distribution of chlorococcalean taxa in Antarctica.

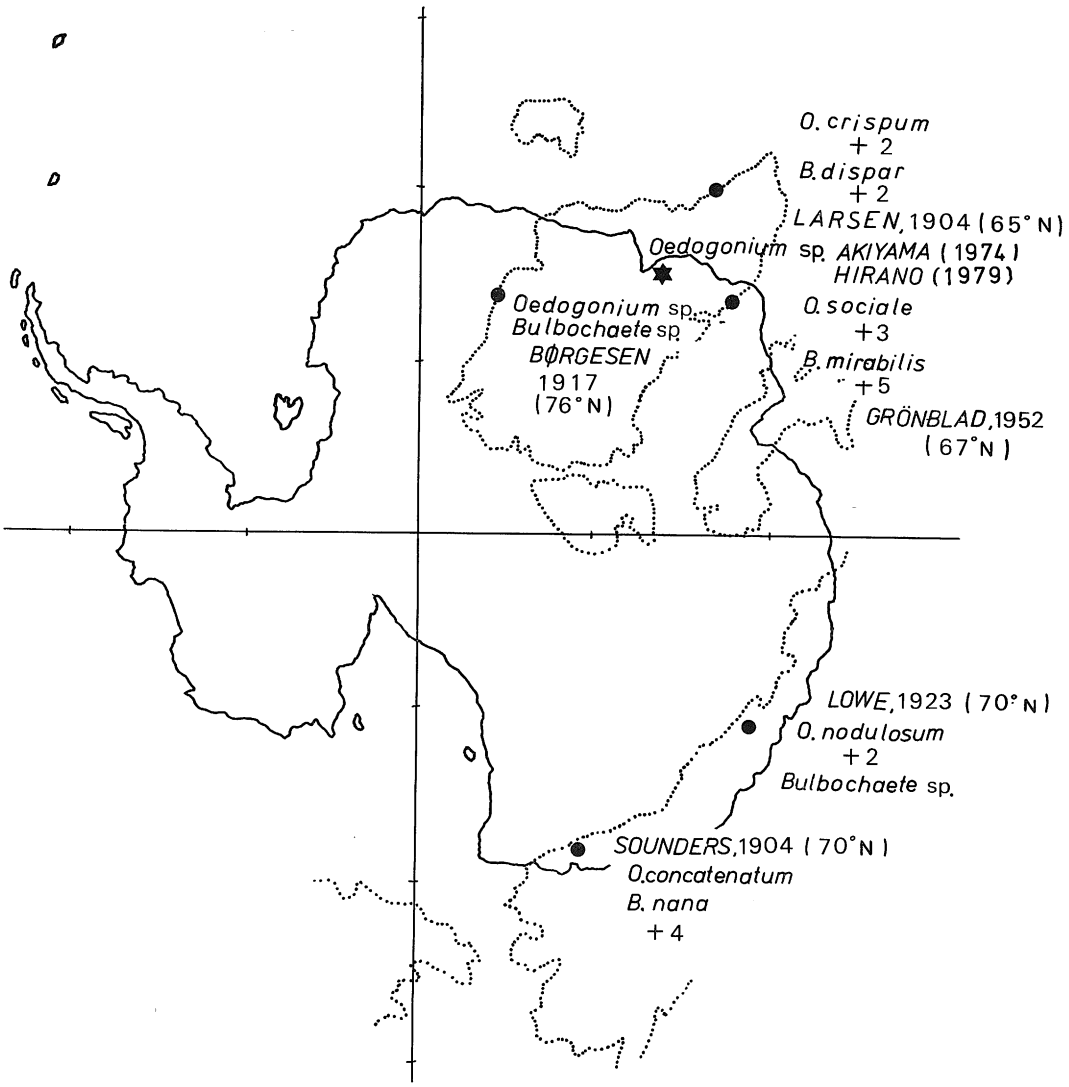

Fig. 8. Distribution of *Oedogonium* in both polar regions.

living planktonic forms is strictly limited only in Palmer Peninsula and Novolazarevskaya. *Oocystis* known as a cosmopolitan genus, occurs only in Palmer Peninsula. Two taxa of this genus. *O. lacustris* and *O. borgei* are regarded from Anvers Island by Parker et al. (1972). Among the presented species, *O. lacustris* is also recorded from Signy Island and the Kerguelen Islands. Recently, Therezien and Couté (1977) recorded the following taxa from the Kerguelen Islands ; *O. borgei, O. lacustris, O. marssonii, O. parva, O. solitaria* forma *major* and *O. submarina.* Among them, *O. submarina* is also in common with Crozet Island. In comparison to the Arctic flora, Prescott (1965) reported the occurrence of 14 taxa of *Oocystis* including 3 taxa mentioned in the above, namely *O. borgei, O. lacustris* and *O. submarina* from Malikpuk Lake nearby Point Barrow (71°12'N), Alaska.

It is well known trend especially in eutrophic lakes and ponds in both temperate and

tropical regions, a number of coenobial genera notably *Pediastrum* and *Scenedesmus*, *Actinastrum*, *Crucigenia*, *Dictyosphaerium* etc. may be abundant as a dominant species of varied water bodies, and often dense blooms of these algae occur in small lakes and ponds. The occurrence of these algae notably *Scenedesmus* and *Pediastrum* is limited only in the Subantarctic islands with an exception of *Scenedesmus armatus* found in Schirmacher Oasis (70° 45'S), Novolazarevskaya. Komárek and Růžička (1966) recorded this alga from an epipelic community composed of mainly blue-green algae such as *Phormidium frigidum*, *Nostoc punctiformae* and *Oscillatoria simplicissima* var. *antarctica* and associated with some desmidean algae. The majority of species of *Scenedesmus* recorded in Antarctic and Subantarctic regions are mostly found in the Kerguelen Islands. Therezien and Couté (1977) reported 37 taxa including two new taxa as follows; *Scenedesmus courbetensis* nov. sp. and *S. subspicatus* var. *kerguelensis* nov. var. Among these 38 taxa, such species as *S. brevispina* and *S. ecornis* are common both in the Kergulen and Crozet Islands. From South Georgia, 3 taxa as *S. bijugatus*, *S. quadricauda* and *S. aculeolatus* f. *octocellularis* are recorded (Prescott, 1979), among them, *S. bijugatus* and *S. quadricauda* are widely distributed particularly in the Kerguelen Islands. In comparison to Arctic region, Prescott and Vinyard (1965) recorded 14 taxa of *Scenedesmus* from Malikpuk Lake in Arctic Alaska, among them only 3 taxa such as *S. armatus*, *S. denticulatus* and *S. quadricauda* are common to the Antarctic flora.

The occurrence of *Pediastrum* is strictly limited only in Subantarctic region. Nineteen taxa of *Pediastrum* have been recorded from Subantarctic region so far. Account for 84% of all recorded taxa of *Pediastrum* from Subantarctic region distributed in the Kerguelen Islands. Four taxa of *Pediastrum* found in South Georgia are *P. boryanum*, *P. duplex*, *P. muticum* and *P. muticum* var. *crenulatum*, and two species (*P. boryanum* and *P. muticum*) are common to the Kerguelen Islands. In comparison with Arctic regions, among 19 taxa of *Pediastrum* found in Subantarctic region, the following taxa are also commonly distributed in the Arctic region; *P. boryanum* (Canada, Lowe, 1923; Alaska, Prescott and Vinyard, 1965; East Greenland, Larsen, 1904), *P. duplex* (Canada, Lowe, 1923; Alaska, Prescott and Vinyard, 1965), *P. kawraiskyi* (Alaska, Prescott and Vinyard) and *P. tetras* ((Canada, Lowe 1923). These taxa are also widely distributed in temperate and tropic regions (Philipose, 1967).

On the distribution of filamentous green algae belonging to Ulotrichales and Chaetophorales in Antarctica, approximately 15 genera including 57 taxa have been recorded with the exception of some short filamentous terrestrial and cryosestonic algae such as *Stichococcus* and *Koliella* (=*Rhaphidonema*). Among them, highly branched members such as *Draparnaldia*, *Stigeoclonium* and *Coleochaete* have been known only from the Kerguelen Island (Therezien and Couté, 1977). On the contrary, uniseriate, unbranched filamentous algae such as *Ulothorix*, *Klebsormidium*, *Binuclearia* and *Micorspora* are commonly distributed in coastal ice-free regions of Antarctic continent and its adjacent island. These algae generally grow on submerged stones and are often intermingled with other epipelic algal growths in lakes, ponds and running waters.

Algae belonging to the Oedogoniales are one of the most peculiar and highly developed in their organization and life cycle with oogamous reproductive organ among other freshwater green alage. Ecologically, most of the species of *Oedogonium* and *Bulbochaete* are epilithic and epiphytic in aquatic environment, however the another genus *Oedocladium* is stricly terrestrial on damp soil surface. The algae belonging to these genera are mostly known from temperate and tropical regions and widely distributed in both hemispheres (Hirn, 1900; Tiffany, 1955). The occurrence of these algae in Antarctic region particularly on the species of *Bulbochaete* are limited only in the Kerguelen Islands. Wille (1924) recorded *B. mirabilis* which was epiphytic on *Tolypella* and sterile specimens of *B. nana* from several localities in the Kerguelen Islands. Additionally, he recognized also some sterile filaments of *Bulbochaete* and *Oedogonium*. Recently, Therezien and Couté (1979) recorded two taxa of *Oedogonium* viz. *O. gunni* and *O. rufescens* var. *exiguum*. Fritsch (1910, 1912) recorded some fragments of sterile filaments of *Oedogonium* in yellow and red snow samples obtained from South Orkney. According to Prescott (1979), 8 species of *Oedogonium* and 2 species of *Bulbochaete* have been known so far, and all these species are distributed only in Subantarctic islands.

Recently, Akiyama (1974) and Hirano (1979) recognized many fertile filaments of *Oedogonium* from several localities nearby the Syowa Station. The habitats of our plant are mostly freshwater and often slightly brackish water lakes and ponds distributed in West Ongul Island, Skarvus Nes and Skallen. Two of the later localities are located in the coastal region of Antarctic continent along the Lützow Holm Bay. Some limnological data of these habitats are shown in table 1. This alga grows as an epipelic benthos forming a soft cussion-like mats in the litoral zone of shallow lakes and ponds, and often torn-off fragments of algal mats are carried away near the shore by wind. Plant mass is yellowish orange in color. The vegetative cell of this alga is very narrow, mostly 4-8 μ in diameter and 15-50 μ in length, the basal cell is lacking a holdfast or haptera, and the

Table 1. Limnological feature of habitats of Antarctic *Oedogonium* found in the area nearby the Syowa Base, Antarctica

Locality	Hyotanike (Skarvs Nes)	Oike (Skallen)	Rappaike (Skallen)	Oike (West Ongul)
Date	2, Feb. 1973	12, Feb. 1973	13, Feb. 1973	16, Feb. 1973
Atomo. Temp. C°	−0.8	−4.2	−3.2	+0.8
Water Temp. C°	+7.7	+1.5	+2.1	+3.9
Chlorinity mg/l	695.6	64.0	26.2	101.5
Dissoleved Oxygen ml/l	9.56	10.75	9.4	9.22
PO_4 μg/l	0.04	0.06	0.16	0.08
NO_2 μg/l	0.02	0.03	0.04	—
NO_3 μg/l	—	—	0.1	—
SiO_2 μg/l	45.0	95.0	38.0	17.0

plants may be dioecious and macrandrous. One of the most peculiar characteristic of this alga can be regarded of its 8-12, mammilate projections of oogonium with inframedian operculation and scorbiculate or fine verrucose structure of mature spore wall. Our species very resemble to *O. platygynum* Wittrock, but it differs clearly from *O. platygynum* by the presence of fine verrucose ornamentation of mature spore wall in our materials. We have concluded from these unique morphological details of this alga that the alga may be a new endemic Oedogonian species in Antarctica.

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