Centric Diatom Communities Found in the Antarctic Sea Ice

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南極海氷中に見出された中心目珪藻群

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要旨: これまで南北両極域において，羽状目珪藻の優占する ice algae 群集が報告されてきた．しかし南極大陸沿岸で採集された ice algae の試料から，中心目珪藻の優占した群集が見出された．1970 年 10 月 12 日，Langhovde 地先 (69°12′S, 39°37′E) の定着氷下部より採集された試料中には *Porosira pseudodenticulata* (HUST.) JOUSÉ が 96% の割合で出現した．また 1971 年 12 月 21 日，Cape Bird 沖合 (77°13′S, 166°28′E) の海氷下部より採集された試料からは，63% の出現率で *Coscinodiscus furcatus* KARSTEN が見られた．これら 2 種の中心目珪藻はコロニーを形成し，付着しやすい性質を持つようである．中心目珪藻が ice alga の優占種として出現したことは，未だ不明な部分の多い ice algae 群集の起源，形成の過程の解明に，新たな情報を与えるものとして注目される．

Abstract: It has been generally accepted that the ice algal communities are dominated by pennate diatoms in the Arctic and Antarctic seas. However, two ice algal communities found near the Antarctic Continent were dominated by centric diatoms. One sample from the bottom layer of fast ice near Langhovde (69°12′S, 39°37′E) on 12 October, 1970, was dominated by *Porosira pseudodenticulata* (HUST.) JOUSÉ. In another sample, *Coscinodiscus furcatus* KARSTEN was dominant, which was collected from the bottom layer of sea ice near Cape Bird (77°13′S, 166°28′E) on 21 December, 1971. The two centric diatom species were found to form a colony in water mount and seemed to have a nature of sedentary species as well as planktonic characters.

1. Introduction

In the fast ice and pack ice regions of Antarctica, one can observe a colored layer of sea ice. This layer consists of many species of microalgae. These generally called ice algae are widely distributed in the Antarctic region and play an important role in the ecosystem (ANDRIASHEV, 1968). Several workers have studied ice algal communities in the Antarctic region as reviewed by BUNT (1968), EL-SAYED (1971) and HORNER (1976). The similar phenomenon occurs also in the Arctic region. HORNER

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(1976) described the ice algal communities at Barrow and HSIAO (1980) reported the species composition of the ice flora from the Canadian Arctic. It is well known that most of the ice algal communities consisted of diatoms and moreover pennate diatoms almost always dominated the communities in the polar regions. However, the information on the species composition of the Antarctic ice algae is scarce. The species composition can be a key to clarify the origin and formation of the ice algal community. In this paper, the author reports two ice algal communities from the Antarctic Sea which were dominated by centric diatom species.

2. Materials and Methods

The sea ice samples were collected from three locations near the Antarctic Continent (Fig. 1). Sample A was taken from the brown colored fragment of drifting sea ice, 26 km off the Prince Olav Coast (68°20′S, 40°55′E, 18 January 1961), about 90 km NE of Syowa Station. Sample B was taken from the bottom 5 cm layer of the fast ice, 150 cm in thickness, at 80 m off the coast of Langhovde (69°12′S, 39°37′E, 12 October 1970). The bottom layer was faintly colored. Sample C was taken from the bottom 17 cm layer of the drifting ice floe, 70 cm in thickness, near the coast of Cape Bird (77°13′S, 166°28′E, 21 December 1971), Ross Island. The bottom layer of the sea ice was colorless.

The samples were preserved with formalin after melting. The original volumes

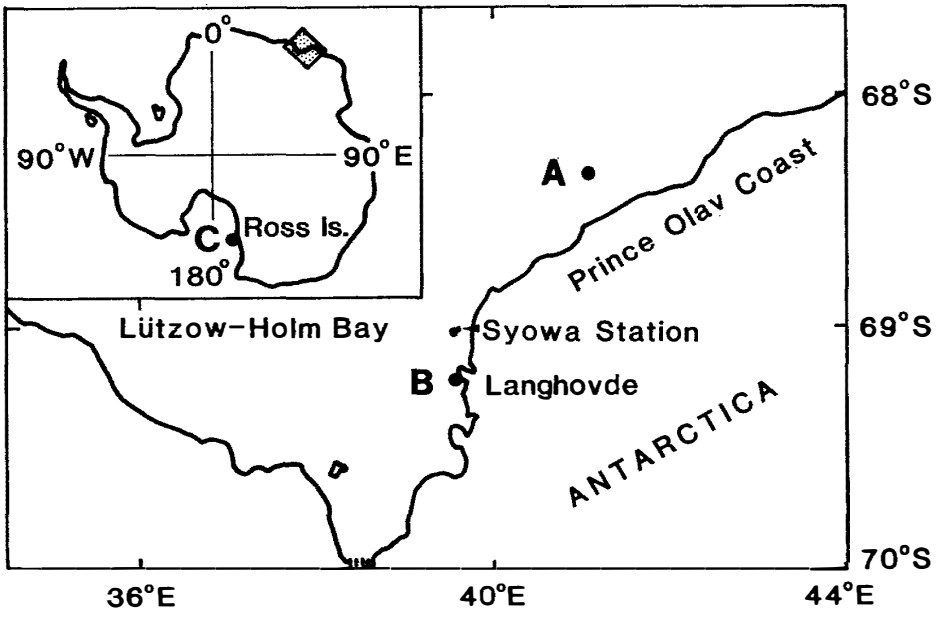

Fig. 1. Location of sampling sites (A: 68°20′S, 40°55′E, B: 69°12′S, 39°37′E, C: 77°13′S, 166°28′E).

of water samples of B and C after melting the ice samples were about 200 m*l* and 700 m*l* respectively. Water samples were concentrated by an ordinary sedimentation method and water mounts were examined by a light microscope (LM) for counting cells. In this paper, proportions of the occurrence of species in the microalgal communities are discussed. A JEOL-35 scanning electron microscope (SEM) was used for detailed morphological study of diatoms after cleaning of organic matter following the method described by SIMONSEN (1974).

3. Results and Discussion

Species composition on the basis of cell numbers for three samples is shown in Table 1. In sample A, pennate diatoms of *Pleurosigma* sp. and *Nitzschia* spp. dominated the community (more than 93 per cent) and a trace amount of centric diatoms was found by one per cent. In sample B, the community was composed mostly of one species of centric diatoms, *Porosira pseudodenticulata* (HUSTEDT) JOUSÉ. It occupied 96 per cent of the community. The cells were united in straight or curved chains (Plate 1.1). The valve surface was areolate, 11–13 areolae in 10 μm (Plate 1.2). SEM microscopy revealed scattered strutted processes without external tube on the valve

Table 1. Species composition of three ice algal communities taken in the Antarctic region.

Ice algal species	Percentage
Sample A (pack ice zone)	
Pleurosigma sp.	73
Nitzschia spp.	20
Nitzschia (section *Fragilariopsis*) spp.	4
Charcotia actinochilus (EHR.) HUSTEDT	1
others	2
Sample B (Langhovde)	
Porosira pseudodenticulata (HUST.) JOUSÉ	96
Nitzschia (sect. *Fragilariopsis*) spp.	2
Pleurosigma sp.	1
others	1
Sample C (Cape Bird)	
Coscinodiscus furcatus KARSTEN	63
Nitzschia (sect. *Fragilariopsis*) spp.	19
Navicula spp.	13
Eucampia antarctica (CASTR.) MANGIN	2
Nitzschia spp.	2
others	1

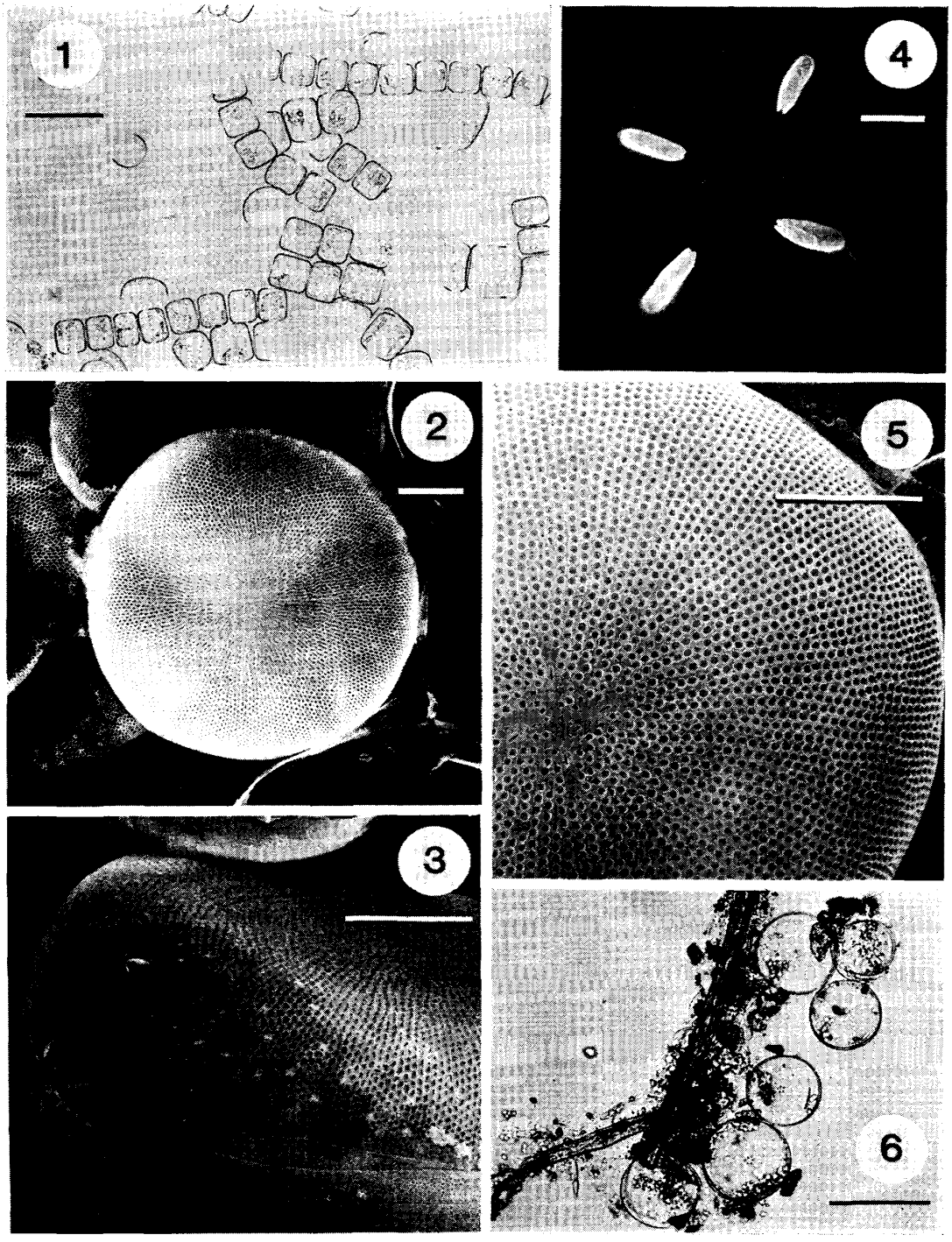

Plate 1. 1–3. *Porosira pseudodenticulata*, Langhovde. 4–6. *Coscinodiscus furcatus*, Cape Bird. 1. Cells united in chains. LM, water mount. Bar=100 μm. 2. Valve surface with areolation. SEM. Bar=10 μm. 3. A pair of labiate processes and scattered processes with girdle. SEM. Bar=10 μm. 4. Central labiate processes, arranged in a star-like pattern. SEM. Bar=2 μm. 5. Valve surface with areolation. SEM. Bar=10 μm. 6. Cells forming aggregation on a fibrous body. LM, water mount. Bar=100 μm.

surface and a labiate process with short external tube near the margin (Plate 1.3). Diameter of the valve ranged 40–85 μm and the mean was 61 μm (n=70). Sample C included 63 per cent of *Coscinodiscus furcatus* KARSTEN, 19 per cent of *Nitzschia* (section *Fragilariopsis*) spp., 13 per cent of *Navicula* spp. and 1–2 per cent of *Eucampia antarctica* (CASTRACANE) MANGIN and others. This community was composed almost of the centric diatoms in standing stock, as the *Nitzschia* and *Navicula* species are small in volume compared with the *Coscinodiscus* species. The diameter of the valve of *C. furcatus* ranged 44–102 μm and the mean was 69 μm (n=59). Two to ten central thickenings, usually 4–6, arranged in a star-like pattern, were labiate processes observed by SEM (Plate 1.4). Valve surface was covered with coarse (12–15 areolae/10 μm) areolation (Plate 1.5). Areolae were arranged from the center to the margin dividing dichotomously. Cells were sometimes found attaching to a fibrous body (Plate 1.6).

In Antarctica, dominant diatoms found in the sea ice can be summarized in Table 2, from the works describing ice algal species (BUNT and WOOD, 1963; BURKHOLDER and MANDELLI, 1965; FUKUSHIMA and MEGURO, 1966; RICHARDSON and WHITAKER, 1979). All of these diatoms except for five species reported by BUNT and WOOD (1963) are pennate species. BURKHOLDER and MANDELLI (1965) reported large numbers of *Fragilariopsis* (=*Nitzschia*) *curta* and *Nitzschia seriata*. FUKUSHIMA and MEGURO (1966) found 13 species of diatoms from the bottom of the ice and among them, four species *i.e. Amphipleura rutilance* var. *antarctica*, *Amphiprora kufferathii*, *Nitzschia stellata* and one unidentified species of *Pleurosigma* were reported as abundant. RICHARDSON and WHITAKER (1979) found 44 species of microalgae in the 12 samples from the ice foot during winter at Signy Island, and 35 species of these were diatoms.

Table 2. List of dominant diatom species found in the Antarctic sea ice, reported by (1) BUNT and WOOD (1963), (2) BURKHOLDER and MANDELLI (1965), (3) FUKUSHIMA and MEGURO (1966) and (4) RICHARDSON and WHITAKER (1979).

Amphipleura rutilance var. *antarctica*[3]
Amphiprora kufferathii[3], *A. kjellmanii*[1], *A. oestrupii*[1]
Biddulphia weissflogii[1]
Coscinodiscus subtilis[1]
Eucampia balaustium[1]
Navicula glaciei[4]
Nitzschia curta[2],[4], *Nit. linearis*[1]
Nit. seriata[1],[2], *Nit. martiana*[1], *Nit. stellata*[3]
Pleurosigma antarctica[1]
Rhizosolenia alata[1], *R. rostrata*[1]

Two species, *Navicula glaciei* and *Nitzschia curta* formed more than 90 per cent of the microalgal material. BUNT and WOOD (1963) examined seven samples from the lower layer of the ice and reported 32 species of microalgae, all diatoms. Eleven species were numerically dominant, that is, they were present in at least six out of seven samples. Among them, five species (*Biddulphia weissflogii*, *Coscinodiscus subtilis*, *Eucampia balaustium*, *Rhizosolenia alata* and *R. rostrata*) were centric diatoms. This is the only paper that described centric diatoms as dominant species.

The dominance of pennate diatoms in the ice algal communities is also seen in the Arctic region. HORNER (1976) reported on the ice algal community at Barrow, that many pennate diatoms were dominant whereas some centric diatoms such as *Chaetoceros septentrionalis* ØSTRUP were found in small numbers. HSIAO (1980) also described that, in most sea ice samples from the Canadian Arctic centric diatoms formed a small portion of the total population and that exceptional two (out of 105) samples from the top of the ice had centric forms of 14.2 per cent and 21.1 per cent. In the northern hemisphere, DUNBAR and ACREMAN (1980) reported the ice algal communities dominated by centric diatoms not from high latitudes but from such low latitudes as the Gulf of St. Lawrence. They ascribed the presence of the centric diatom community to the short life of the ice for the settlement of sedentary pennate diatoms or to the strong light intensity which inhibits the growth of shade-adapted sedentary diatoms, compared with the high latitudes where pennate diatoms dominated.

An example of ice algal communities often found in the Antarctic pack ice region is represented in sample A. This pennates-dominant community falls in with the epontic community described by BUNT and WOOD (1963), which "consists . . . of attached species of *Pleurosigma*, *Nitzschia*, *Amphiprora*, *Fragilaria*, etc. as well as non-attached species living with them as part of that community . . . .". But, in the present observation, two ice algal communities (samples B and C) dominated by centric diatoms were found near the Antarctic Continent. HASLE (1969) observed a high cell density of *Porosira pseudodenticulata* in a water sample collected close to Deception Island. It was also recorded in the net samples from the Weddell Sea and in melted ice samples (HASLE, 1973) and she concluded that "its distribution can evidently be characterized as antarctic, circumpolar". Sample C was dominated also by a centric diatom, *Coscinodiscus furcatus*. This species is restricted to the Antarctic region and particularly abundant close to the Antarctic Continent (HARGRAVES, 1968). In the southern hemisphere, the present study showed that the centric diatom communities appeared in some restricted areas in high latitudes beyond 69°S, where pennate diatom communities were distributed widely. The two reasons pointed out by DUNBAR and ACREMAN (1980) do not seem to account for the appearance of the Antarctic ice algal community, dominated by centric diatoms.

As mentioned above, two centric diatoms, *P. pseudodenticulata* and *C. furcatus* were reported as the plankton of neritic Antarctic waters. In this study, however, they were found to form a chain shaped colony or an aggregation on a fibrous body. Possibly they were suspended in the interstitial sea water among ice crystals or attached to them. The latter characteristic is similar to that of sedentary species. It is assumed that the two centric diatoms which dominated the ice algal communities have the nature of both planktonic and, in view of colony formation, sedentary species. It is presumed that some centric diatoms which, to some extent, have nature of sedentary species, can settle on the surface of ice crystals and grow to form the colored layer of the ice in Antarctica, though the origin of the ice algal community is not yet clear. Further investigation on the species composition of ice algal communities will give useful information to clarify the origin and formation of the ice algal community.

Acknowledgments

I gratefully express my thanks to Prof. T. HOSHIAI, National Institute of Polar Research, for the samples and for his critical reading of the manuscript. Thanks are also extended to Dr. H. TAKANO, Tokai Regional Fisheries Research Laboratory for offering the precious literature on diatoms in his laboratory.

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(Received August 7, 1981; Revised manuscript received September 11, 1981)