Mem. Natl Inst. Polar Res., Spec. Issue, **40**, 56–68, 1986

NANNOPLANKTON FLORA IN THE SOUTHERN OCEAN, WITH SPECIAL REFERENCE TO SILICEOUS VARIETIES

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Abstract: Distributions of calcareous nannoplankton and related siliceous microorganism, and their population size along longitudinal 150 and 115°E lines in the Southern Ocean, are reported according to the results of scanning electron microscopy.

In the Southern Ocean four nannoplankton assemblages were defined, namely, subtropical, subantarctic, antarctic and circum-antarctic pack ice assemblages. The former three assemblages are composed mainly of calcareous nannoplankton, dominated by varieties of Coccolithophyceae. The last assemblage is dominated by a great number of siliceous microorganisms.

The present siliceous microorganisms are yet unnamed and their taxonomical position is not well known. But their restricted distribution and large number of individuals in the off pack ice zone must be evaluated in polar sea ecosystems.

1. Introduction

Nannoplankton are a large group of minute unicellular photosynthetic organisms in the world oceans and contribute as an important pelagic primary producer. They appeared in the Jurassic period. Their floral and phylogenic vicisitudes in the geologic past vigorously affected heterotrophs at that time as the primary producer in the marine food web, and their huge products also contributed to the formation of the present organic fuel resources.

Some paleontologists hypothesize that the rapid decrease of calcareous nannoplankton productivity caused the mass extinction of subordinate animal groups in the geologic past, especially at the end of the Cretaceous period, and they have proposed a specific overturn in the biological world (TAPPAN, 1968).

The majority of the modern nannoplankton community is composed of unicellular flagella-bearing algal organisms which have calcareous or siliceous skeletal elements. Modern calcareous nannoplankton are distributed widely in the photic zone of the world ocean except the Arctic Ocean which is covered by a permanent ice sheet. Siliceous ones are also spread in the world oceans and are especially dominant in the cold waters.

Modern and fossil nannoplankton have been studied in the biological and paleontological fields. Their biostratigraphical significance is well understood by paleontologists, stratigraphers, marine geologists, geophysicists and nowadays by mining geologists. But the status of modern nannoplankton in marine biology is very limited, and large numbers of individuals in an unit volume of water are measured only as the chlorophyll-

a content on some occasions. For their mass productivity the nannoplankton stocks and systems in the entire marine ecosystem must be further evaluated.

Previous nannoplankton records from the Southern Ocean are very meager and only HASLE (1969) was concerned with calcareous nannoplankton. SILVER *et al.* (1980) dealt with siliceous cyst forms, which the present author reports as siliceous microorganisms in this article. In the present article the author concentrates his attention on calcareous nannoplankton distributions in the Southern Ocean (Australasian sector), especially along 150 and 115°E lines.

Previously this author has reported abundant siliceous minute nannoplankton from the North Pacific Ocean (NISHIDA, 1979) and at the present time he also reports similar groups of microorganisms from the Southern Ocean. SILVER *et al.* (1980) reported similar nannoplankton assemblages from the Weddell Sea, Antarctica. The present report deals with both surface and subsurface distributions of calcareous nannoplankton and siliceous microorganism assemblages along 150 and 115°E longitudinal lines in the Southern Ocean and from the northern edge transverse in the Antarctic pack ice zone.

2. Materials and Methods

The present water samples were collected during the BIOMASS-SIBEX cruise of the HAKUHO MARU. Her serial cruise number was given as the HAKUHO MARU KH-83-4 cruise. During the cruise leaving Tokyo on 24 November 1983 and returning to Tokyo on 22 February 1984, the surface sea waters were sampled at intervals of one to five hours. Her course in the Southern Ocean is shown in Fig. 1.

In the Southern Ocean sixteen stations were set for precise multi-purpose ocea-

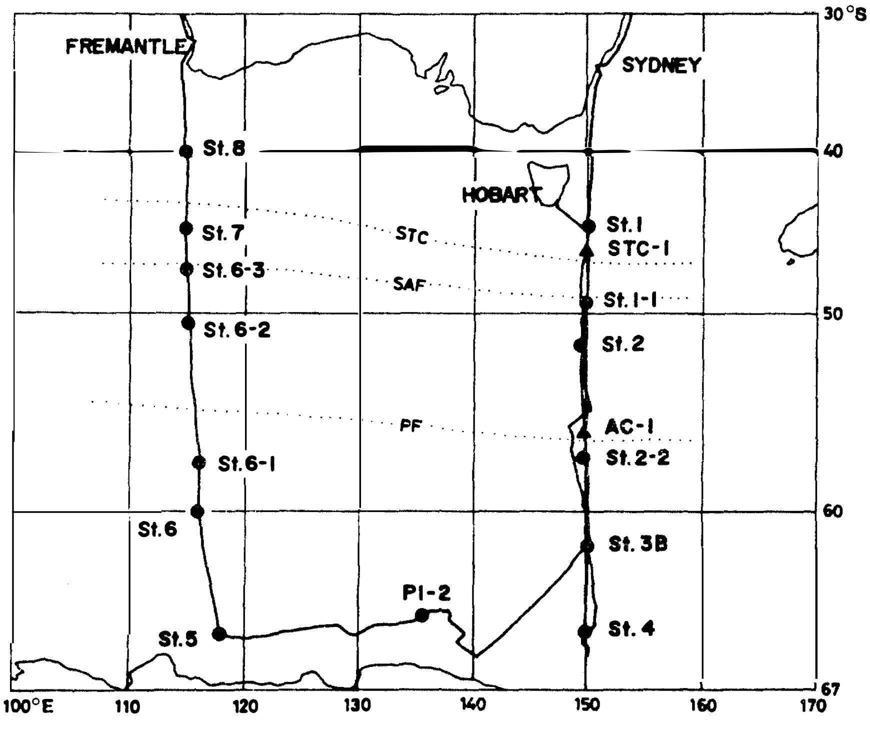

Fig. 1. Sampling location.

Table 1. List of stations.

Station	Lat. (S)	Long. (E)	Date	Local time	S. W. T. (°C)
1	44°59.7′	150°01.5′	1983 12 13	2021–2335	13.45
STC-1	46 45.9	150 00.6	1983 12 31	1930–2130	11.45
1-1	49 24.0	149 45.6	1983 12 30	1935–2130	7.65
2	52 04.5	149 43.5	1983 12 16	1630–1848	7.78
AC-1	56 11.8	150 02.0	1983 12 28	1100–1255	6.20
2-2	57 31.6	150 02.9	1983 12 18	1036–1218	3.04
3B	61 24.8	150 05.7	1983 12 25	2154–2345	0.19
4	64 56.1	150 12.6	1983 12 22	1800–2000	−0.47
PI-2	64 16.8	136 06.4	1984 01 16	1427–1626	−0.86
5	65 00.3	117 59.6	1984 01 18	2219–0012	0.05
6	60 00.6	116 02.1	1984 01 21	1512–1656	2.04
6-1	57 29.1	115 59.1	1984 01 23	0742–0938	2.82
6-2	50 29.5	114 59.4	1984 01 24	1837–2029	5.77
6-3	47 29.7	115 00.0	1984 01 25	1028–1231	9.19
7	44 49.2	114 54.2	1984 01 26	1810–2024	11.24
8	39 54.8	114 54.5	1984 01 28	1943–2145	15.18

nographic observation, especially for biological investigation of systems and stocks there. The water samplings were carried out by a rosette-multisampler attached to a CTD apparatus with a DO senser at each station, and the author examined materials from the photic layer extending from the surface to 150 m depth.

The locations of samplings, date, local times and surface temperature are listed in Table 1. Except Stn. 2 water samples were taken from 0, 10, 20, 30, 50, 75, 100, 125 and 150 m in depth. At Stn. 2, water sampling reached 175 m in depth, lacking the 125 m level. All columnar water samplings are linked with ordinary oceanographic data (salinity, temperature, depth and dissolved oxygen) including those on nutritive salts (PO_4, Si, NO_2, NO_3 and NH_3) contents (NEMOTO and TERASAKI, 1985).

One to five liter aliquots were prefiltered through 74 μm stainless steel meshfilters to eliminate macroplankton and through Millipore© filters which had a 0.8 μm pore size, then rinsed with nannoplankton-eliminated tap water repeatedly, and finally dried at room temperature and stored in plastic containers. Nannoplankton elimination for rinsing was made by filtration with a 0.8 μm pore size Millipore© filter. In the present study the author attempted to collect the nannoplankton with hard skeletal element, so any buffer effects were not considered.

In the onshore laboratory, a definite area of the filter sample, usually a 3 mm diameter circle, was selected, cut out, mounted on a SEM-stub with the non-paste technique, then gold-coated in an ion-spattering apparatus and studied on a Hitachi S-310 field emission scanning electron microscope (FE-SEM).

Counts were made on the whole field of a cut out filter on a stub at an appropriate magnification, normally observed 2000 times and converted to numbers of individuals in an unit volume of water. At the same time, the floral composition was examined. When nannoplankton counts were less than 300 specimens, another unit field count of a newly cut out sample was added until more than 300 specimens were attained.

The chemical composition of the siliceous microorganism group was confirmed with a Kevex 7000Q X-ray energy dispersive spectrometer (EDX) coupled to a Hitachi X-650 scanning electron microscope.

3. Results and Discussion

On the KH-83-4 cruise, three oceanographic fronts were detected on the basis of the water temperature and salinity structures as suggested by NAKAI *et al.* (1985). Along the 150°E line, the subtropical convergence (STC) was supposed at 47°S, the sub-antarctic front (SAF) at 49°S and the antarctic polar front (PF) at 56.5°S, and along the 115°E line the STC was also supposed at 43.5°S, the SAF at 47°S and the PF at 55°S.

Calcareous nannoplankton detected from the above-mentioned water column are listed below. The full forms of the taxonomical abbreviations in Table 2 can also be found in this list.

Acanthoica quatrospina LOHMANN
Anoplosolenia brasiliensis (LOHMANN) DEFLANDRE
Anthosphaera oryza (SCHILLER) GAARDER
Arisphaera unicornus OKADA and MCINTYRE
Calcidiscus leptoporus (MARRAY and BLACKMAN) LOEBLICH and TAPPAN
Calciopappus caudatus GAARDER and RAMSFJELL
Calciopappus sp.
Calyptrosphaera catillifera (KAMPTNER) GAARDER
Caneosphaera molischii (SCHILLER) GAARDER
Ceratolithus telesmus NORRIS
Coccolithus pelagicus (WALLICH) SCHILLER . . . . motile stage form
Coronosphaera mediterranea (LOHMANN) GAARDER
Discosphaera tubifera (MURRAY and BLACKMAN) OSTENFELD
Emiliania huxleyi (LOHMANN) HAY and MOHLER
Gephyrocapsa caribbeanica BOUDREAUX and HAY
Gephyrocapsa ericsoni MCINTYRE and BÉ
Gephyrocapsa oceanica KAMPTNER
Helicosphaera carteri (WALLICH) KAMPTNER
Helladosphaera fastigiata OKADA and MCINTYRE
Neosphaera coccolithomorpha LECAL-SCHLAUDER
Oolithotus fragilis (LOHMANN) OKADA and MCINTYRE
Pontosphaera sp.
Rhabdosphaera clavigera MURRAY and BLACKMAN
Sphaerocaryptra pappilifera (HALLDAL and MARKARI) HALLDAL
Syracosphaera corolla LOHMANN
Syracosphaera hystrica KAMPTNER
Syracosphaera lamina LECAL-SCHLAUDER
Syracosphaera nana (KAMPTNER) OKADA and MCINTYRE
Syracosphaera nodosa KAMPTNER
Syracosphara pulchra LOHMANN
Thorosphaera flabellata HALLDAL and MARKARI
Umbellosphaera irregularis PAASCHE

Umbellosphaera tenuis KAMPTNER
Umbilicosphaera hulburtiana GAARDER

Some nannoplankton species were found only in the surface water samples and their floral list is given below. Almost all of the following taxa were found in the subtropical water mass and each population size was small.

Braarudosphaera sp.
Calyptrosphaera oblonga LECAL
Ceratolithus cristatus KAMPTNER
Coccolithus pelagicus (WALLICH) SCHILLER
Hayaster perplexus (BRAMLETTE and RIEDEL) BUKRY
Helicosphaera hyalina GAARDER
Helicosphaera pavimentum OKADA and MCINTYRE
Helladosphaera aurisinae KAMPTNER
Helladosphaera cornifera (SCHILLER) KAMPTNER
Helladosphaera sp.
Michaelsalsia sp.
Oolithotus fragilis cavum OKADA and MCINTYRE
Periphyropora mirabilis (SCHILLER) KAMPTNER
Pontosphaera syracusana LOHMANN
Sphaerocaryptra marsielli BORCETTI and CATI
Sphaerocaryptra sp.
Thoracosphaera heimi (LOHMANN) KAMPTENR
Umbilicosphaera sibogae (WEBER van-BOSSE) GAARDER
Umbilicosphaera sibogae foliosa (KAMPTNER) OKADA and MCINTYRE

Nannoplankton composition and numbers of individuals in an unit volume of water are presented in Table 2. The floral composition and numbers of individuals of the four nannoplankton assemblages defined in the Australasian sector of the Southern Ocean are as follows.

The subtropical assemblage is characterized by a few dominant taxa with many minor associated species and large numbers of individuals. The superior position in the subtropical assemblage is occupied by *Emiliania huxleyi* on the 150°E line, and *E. huxleyi* and *Umbellosphaera tenuis* on the 115°E line. *E. huxleyi* has a typical warm water characteristic, that is, typical intersegmental slits are observable on its proximal shield (Plate 1, Fig. 10). In this assemblage the population of the superior taxon sometimes exceeds 110×10^3 individ./*l* and commonly has more than 20×10^3 individ./*l*. Typical subtropical assemblages are seen down to 50 m depth in the column at Stn. 1, down to 75 m depth in the column at Stns. STC-1 and 8.

The subantarctic assemblage is composed of one predominant species and some minor associated species. The total number of individuals is commonly about 10×10^3 individ./*l* to 20×10^3 individ./*l* and *E. huxleyi* occupies the superior position in the assemblage. The following are assigned to the present assemblage: down to 75 m depth in the column at Stn. 1-1, the entire column at Stn. 2, down to 50 m depth in the column at Stn. AC-1, the entire column at Stn. 2-2 and down to 75 m depth in the column at Stn. 6-3.

Table 2. Nannoplankton composition in the water column of Stns. 1, STC-1, 1-1, 2, AC-1, 2-2, 3B, 4, PI-2, 5, 6, 6-1–6-3 and 7. Abundances are represented in numbers of individuals in a milliliter of water.

Station	Species	Depth (m)								
		0	10	20	30	50	75	100	125	150
	Acant. quatrospina	.3	—	—	—	—	—	—	—	—
	Anopl. brasiliensis	—	—	—	.4	.1	—	—	—	—
	Anthosphaera oryza	.3	.1	—	—	—	—	—	—	—
	Arisph. unicornus	—	.1	.3	.4	.1	—	—	—	—
	Calcid. leptoporus	.3	.4	1.6	1.7	.2	.4	.3	—	—
	Calciop. caudatus	—	—	—	.9	.2	—	—	—	—
	Calciopappus sp.	1.4	—	.5	—	—	—	—	—	—
	Calypt. catillifera	.3	—	.5	—	—	—	—	—	—
	Caneosph. molischii	.3	.6	1.6	.6	—	—	—	—	—
	Ceratolit. telesmus	—	—	—	—	—	.1	—	—	—
	Coron. mediterranea	—	—	—	.2	.1	—	—	—	—
	Discosph. tubifera	—	—	—	—	.1	—	—	—	—
1	*Emiliania huxleyi*	95.0	74.5	99.3	82.3	32.4	7.8	4.8	.9	.2
	Gephyroc. ericsoni	1.7	1.1	1.9	.6	.5	.1	.1	—	—
	Gephyroc. oceanica	.3	.2	—	.2	.3	.6	.6	—	—
	Helicosph. carteri	.3	—	.3	.2	.1	.1	.1	—	—
	N. coccolithomorpha	—	—	—	.2	—	—	—	—	—
	Oolithot. fragilis	—	—	—	.2	—	—	—	—	—
	Sphaer. pappilifera	—	.1	—	.2	—	—	—	—	—
	Syracosph. corolla	.6	.1	.3	.4	.1	.1	—	—	—
	Syracosphaera nana	—	.4	.8	—	.1	—	—	—	—
	Syracosph. pulchra	.3	.4	1.1	.4	.1	.1	.1	—	—
	Umbel. irregularis	—	.2	.3	.2	.2	.1	.1	—	—
	Umbellosph. tenuis	—	—	—	.2	.1	—	—	—	—
	Others	.9	.6	.3	1.3	—	—	—	—	—
	Acant. quatrospina	—	—	—	.6	—	—	—	—	—
	Arisph. unicornus	—	—	—	.6	—	—	—	—	—
	Calcid. leptoporus	.4	1.7	1.7	.6	2.2	.3	.4	.1	.2
	Caneosph. molischii	—	—	.4	2.3	2.2	.3	—	—	—
	Coron. mediterranea	—	—	—	—	.4	—	.1	—	—
	Emiliania huxleyi	141.3	158.1	152.5	186.6	146.9	97.6	7.9	1.9	2.6
	Gephy. caribbeanica	—	—	—	—	—	—	—	.1	—
STC-1	*Gephyroc. ericsoni*	1.3	.9	3.5	2.3	2.6	1.7	.4	—	—
	Gephyroc. oceanica	—	—	—	.6	.4	.3	—	—	—
	Helicosph. carteri	.4	—	—	—	.4	—	.1	—	.1
	N. coccolithomorpha	.4	—	—	—	—	—	—	—	—
	Syracosph. corolla	.9	1.3	.9	.6	.9	.3	—	—	—
	Syracosph. pirus	1.3	.9	.4	3.5	1.3	.3	—	—	—
	Syracosph. pulchra	.4	—	.4	2.9	.9	.9	.1	—	—
	Others	—	.4	—	—	—	.6	—	—	.1
	Acant. quatrospina	.3	.4	—	—	—	.4	—	—	—
	Calcid. leptoporus	.1	.3	.1	.4	.4	—	.2	.1	.1
1-1	*Caneosph. molischii*	.1	.3	.3	—	.6	—	—	—	—
	Coron. mediterranea	—	—	.1	—	—	—	—	—	—
	Emiliania huxleyi	92.6	86.4	55.2	62.0	59.5	22.7	6.9	1.2	1.3

Table 2. Continued.

Station	Species	Depth (m)								
		0	10	20	30	50	75	100	125	150
1-1	*N. coccolithomorpha*	—	.1	—	—	—	—	—	—	—
	Si-microorganisms	.1	—	—	—	—	—	.1	—	—
2	*Acant. quatrospina*	—	.2	—	—	—	—	.2	—	—
	Calcid. leptoporus	.2	.1	.1	.3	.3	1.3	.8	.3	.1
	Calciopappus sp.	.6	—	—	—	—	—	1.0	—	—
	Caneosph. molischii	.6	.2	.1	.2	—	—	.5	—	—
	Coron. mediterranea	—	—	.1	—	—	—	—	—	—
	Emiliania huxleyi	74.8	25.0	34.6	42.5	81.0	96.0	52.2	32.4	14.1
	Gephyroc. ericsoni	.8	—	.2	.5	—	—	—	—	—
	Gephyroc. oceanica	.2	.1	—	.1	.1	—	—	.1	.1
	Helicosph. carteri	.2	.1	—	.1	—	—	—	.1	—
	Syracosph. corolla	.2	.1	—	.1	—	—	—	—	—
	Syracosphaera nana	.2	.1	—	—	—	—	—	—	—
	Syracosph. pirus	—	—	.1	.1	—	—	—	—	—
	Syracosph. pulchra	.2	—	—	—	—	—	—	—	—
	Umbel. irregularis	—	.1	—	.1	—	.3	.2	.1	—
	Umbellosph. tenuis	—	—	—	.1	—	—	—	.1	—
AC-1	*Calcid. leptoporus*	—	.2	.4	.4	.5	.1	.1	.1	.1
	Caneosph. molischii	—	.2	.2	.2	—	—	—	—	—
	Emiliania huxleyi	116.2	64.8	64.3	62.4	68.3	2.7	1.8	.3	.3
	Gephyroc. ericsoni	—	—	—	—	—	.1	—	—	—
	Syracosph. pirus	—	.2	—	—	—	—	—	—	—
	Syracosph. pulchra	—	—	—	—	.1	—	—	—	—
2-2	*Calcid. leptoporus*	—	—	—	—	—	.1	—	—	.1
	Calciopappus sp.	—	—	—	—	—	.1	—	—	—
	Emiliania huxleyi	139.1	137.8	81.8	64.8	64.8	43.2	43.2	28.8	6.4
	Helicosph. carteri	—	—	—	—	.2	—	—	.1	—
	Umbel. irregularis	—	—	—	—	.2	—	.1	—	—
3B	*Emiliania huxleyi*	.1	.1	—	.6	.7	—	—	.1	.3
4	*Emiliania huxleyi*	1.1	.1	2.3	1.0	.1	.1	.1	—	—
	Gephyroc. oceanica	.1	—	—	—	—	—	—	—	—
	Umbel. irregularis	—	.1	+	.1	.1	—	—	—	—
	Si-nannoplanktons	12.7	4.9	6.9	15.3	3.8	72.0	226.1	216.0	6.5
PI-2	*Calcid. leptoporus*	.1	.3	—	.1	—	—	—	—	—
	Emiliania huxeleyi	1.7	.3	.3	.5	+	—	3.5	—	—
	Gephy. caribbeanica	—	—	—	.1	—	—	—	—	—
	Gephyroc. ericsoni	.1	.1	.1	.3	—	—	—	—	—
	Helicosph. carteri	—	—	—	—	—	—	—	—	+
	Syracosph. pulchra	+	—	—	—	—	—	—	—	—
	Si-nannoplanktons	2.3	11.1	12.1	20.9	33.1	146.3	69.7	25.6	11.5
5	*Calcid. leptoporus*	—	—	—	—	—	—	—	+	+
	Emiliania huxleyi	+	+	.1	.1	+	—	—	+	—
	Gephyroc. ericsoni	—	—	—	—	—	—	.6	—	—
	Gephyroc. oceanica	—	—	—	—	—	—	—	+	—
	Si-nannoplanktons	3.2	6.2	8.6	7.2	77.8	100.8	72.0	57.6	16.6

Table 2. Continued.

Station	Species	Depth (m)								
		0	10	20	30	50	75	100	125	150
	Calcid. leptoporus	.3	+	+	+	—	—	+	—	.1
	Emiliania huxleyi	13.2	14.0	14.8	13.4	26.8	18.0	4.2	1.3	1.4
6	*Helicosph. carteri*	—	—	—	—	—	+	—	—	—
	Syracosph. pulchra	—	—	.1	—	.1	—	—	—	—
	Si-nannoplanktons	—	.1	—	—	.8	—	.5	2.7	.1
	Calcid. leptoporus	—	—	—	—	.1	—	—	—	—
6-1	*Emiliania huxleyi*	16.4	21.7	20.4	18.9	24.5	29.8	3.2	3.7	2.3
	Si-nannoplanktons	—	—	—	—	—	—	.6	2.2	.7
6-2	*Emiliania huxleyi*	32.4	.1	6.0	6.9	—	25.2	7.5	.1	.7
	Acant. quatrospina	—	—	.1	—	—	—	—	—	—
	Calcid. leptoporus	6.9	2.7	3.5	3.5	3.6	3.6	2.2	.5	+
	Emiliania huxleyi	10.5	15.6	16.8	9.1	16.1	14.9	4.2	1.7	.5
	Gephy. caribbeanica	—	—	—	—	—	—	—	.1	—
6-3	*Gephyroc. ericsoni*	.4	.1	—	—	.2	.2	.1	—	—
	Helicosph. carteri	.1	+	—	—	.1	+	.1	+	+
	Syracosph. lamina	—	—	.1	—	—	—	—	—	—
	Syracosph. pulchra	—	.1	—	—	—	.1	—	—	—
	Umbel. irregularis	—	+	—	+	+	+	—	—	—
	Acant. quatrospina	—	—	.1	.2	.2	.1	—	—	—
	Anopl. brasiliensis	—	.1	—	.1	—	—	—	—	—
	Calcid. leptoporus	3.1	1.2	1.1	2.4	2.3	2.4	2.4	1.2	.3
	Caneosph. molischii	1.5	1.9	2.1	2.3	2.2	1.1	.1	—	—
	Calypt. catillifera	—	.3	—	.4	.4	.1	—	—	—
	Emiliania huxleyi	6.8	5.7	6.1	13.4	10.8	12.0	4.3	.6	.1
	Gephy. caribbeanica	.2	.1	—	.3	.1	.1	.1	—	—
	Helicosph. carteri	+	+	.1	.1	—	+	—	.1	.1
7	*Hellad. fastigiata*	.2	—	.1	—	—	—	—	—	—
	Rhabdosph. clavigera	—	—	.1	.1	—	—	—	—	—
	Sphaer. pappilifera	—	—	—	—	—	.1	—	—	—
	Syracosph. corolla	—	.1	.1	.1	—	.1	—	—	—
	Syracosph. hystrica	2.2	1.9	2.8	—	—	—	—	—	—
	Syracosph. lamina	.3	—	.1	—	—	—	—	—	—
	Syracosph. nodosa	—	—	.3	1.5	.6	1.4	—	.1	—
	Syracosph. pulchra	.9	.3	.1	2.0	1.5	.7	—	.1	—
	Umbellosph. tenuis	.1	.4	+	.1	.1	.1	—	—	—
	Others	—	—	.4	1.0	.3	.1	—	—	—

The antarctic assemblage is monospecific and meager in number of nannoplankton. A typical antarctic assemblage is seen at Stn. 3B. Commonly, this assemblage is composed only of *E. huxleyi*. This species in the assemblage posesses a characteristic feature of cold water form, that is, the proximal shield shows a connected non-slit structure (Plate 1, Fig. 11).

The circum-antarctic pack ice assemblage is characterized by the abundant occurrence of unnamed siliceous microorganisms with minor calcareous nannoplankton.

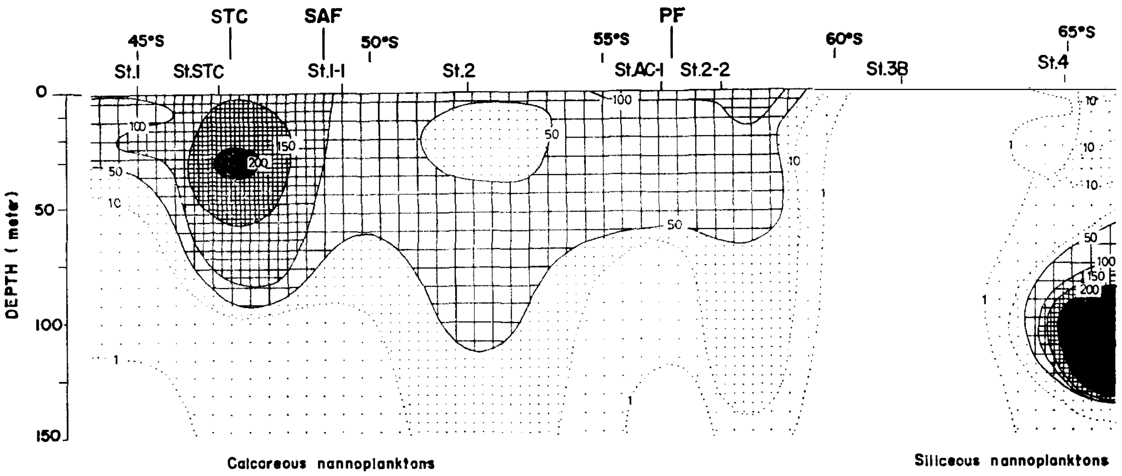

Fig. 2. Nannoplankton distribution in a vertical plane along the 150°E line in the Southern Ocean. Numbers of individuals are presented in No/ml.

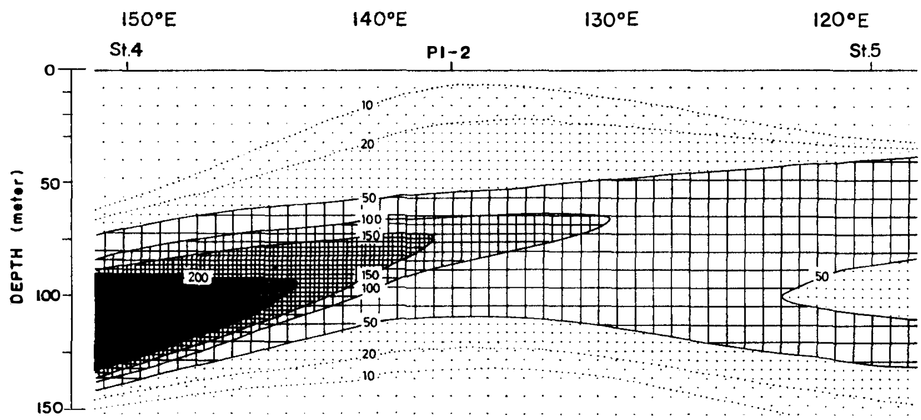

Fig. 3. Siliceous microorganism distribution in a vertical plane along the outer edge of the pack ice zone in the Antarctic Sea. Numbers of individuals are represented in No/ml.

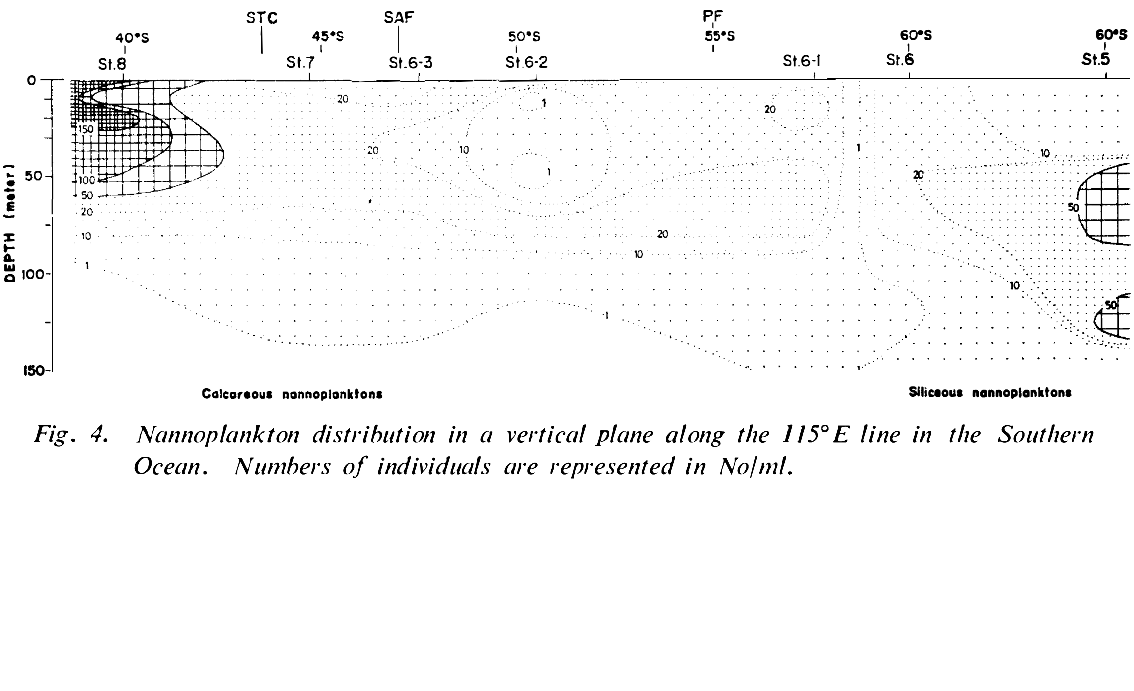

Fig. 4. Nannoplankton distribution in a vertical plane along the 115°E line in the Southern Ocean. Numbers of individuals are represented in No/ml.

Typical groups of this assemblage are seen at Stns. 4, PI-2 and 5.

Chemical composition of organisms was confirmed with an energy dispersive spectrometer (EDX). Almost all of the hard parts of the organisms were constructed of silicon with other minor minerals. However, the skeletal part of *E. huxleyi*, a predominant Coccolithophyceae in the Southern Ocean, is wholly composed of calcium carbonate.

Nannoplankton population in the subsurface layer along the 150 and 115°E lines and occurrences of siliceous organisms in the off pack ice zone between 150 and 115°E are presented in Table 2. Along the 150 and 115°E sections the number of calcareous nannoplankton individuals is maximal in the subsurface layer shallower than 50 m in depth. On the other hand, siliceous microorganisms have their optimum habitat in the lower part of the photic layer. In the present cruise the highest number of individuals was *ca.* 226×10^3 individ./*l* at 100 m depth at Stn. 4.

Concerning the distribution of these organism, the author obtained them from the off pack ice zone in the Southern Ocean and did not encounter them in the northern sea of the polar front. Their surface distribution is restricted in the polar current area. Similar forms of siliceous microorganisms could not be observed during the cruise from Tokyo to the Antarctic Polar Front via Sydney, and from the Antarctic Polar Front to Tokyo via Fremantle and Cebu, Philippines. Precise surface nannoplankton distribution will be reported in a separate paper.

In the water columns siliceous microorganisms were optimally dominant at 100 m depth at Stn. 4, where water temperature was 0.80°C, and their population size attained to 226×10^3 individ./*l*. At Stn. PI-2, siliceous microorganisms had their optimum habitat at 75 m depth where the water temperature was −1.59°C. At Stn. 5, the maximum number of individuals was counted at 75 m where the water temperature was −1.72°C and their population size was 100×10^3 individ./*l*.

In a previous paper (NISHIDA, 1979), the author called the microorganisms "siliceous nannoplankton" because of their occurrence with pelagic calcareous nannoplankton in open sea areas. But in this paper, the name "siliceous microorganism" is preferred because of the scarcity of planktonic confirmation of the microorganisms and their rather cystose morphological impression.

During the present cruise, six forms of siliceous organic bodies were obtained from Stns. 4, PI-2 and 5. The morphology of the organisms was commonly hexahedral spheroid, but some tetrahedral bodies occurred. The spheroids are composed of a single wall plate which has a circular, disc-like structure with some kind of surface ornamentation.

Based on surface ornamentation, the author distinguished six different forms. These surfaces are characterized by: 1) short knobs and slits (Plate 1, Fig. 4), 2) short knobs and perforated striae (Plate 1, Figs. 1 and 2), 3) arranged knobs (Plate 1, Fig. 5), 4) smooth surface (Plate 1, Fig. 3), 5) long processes occurring on the surface (Plate 1, Figs. 6 and 7), and 6) limbs and furcated spines (Plate 1, Figs. 8 and 9).

From the northern hemisphere, NISHIDA (1979) reported two froms: one with rather linearly arranged knobs and another with perforated striae. BOOTH *et al.* (1980) found some types of similar microorganisms, especially having wide and large flared limbs on the smooth, knobed and striated surface.

The present unnamed siliceous organisms in the Southern Ocean are worthy of note with regard to the biological system there. Previously, some similar, related forms were reported by NISHIDA (1979) from the surface water of the Aleutian area in the northern hemisphere. He showed the specimens as *gen. et sp. indet.* with two SEM photographs. Later BOOTH *et al.* (1980) reported comparable specimens from the Gulf of Alaska as similar to the well-known planktonic taxa. In the southern hemisphere SILVER *et al.* (1980) reported first from the Weddell Sea the siliceous cysts which are presumably the product of pelagic microorganisms, possibly Acanthoecacean choanoflagellates.

Concerning their population size, NISHIDA (1979) reported 140×10^3 individ./*l* from the surface water off the Aleutian Islands in the summer of 1974, where the cold Subarctic Current prevails throughout the year. BOOTH *et al.* (1980) obtained 700×10^3 individ./*l* from the water of the Gulf of Alaska. In the southern hemisphere SILVER *et al.* (1980) first reported related forms from the Weddell Sea of Antarctica and obtained 586×10^3 individ./*l*. The present population sizes may be somewhat smaller than that reported by BOOTH *et al.* (1980) and SILVER *et al.* (1980), but discrepancies in population size are common in ecological fluctuation.

SILVER *et al.* (1980) reported the forms related to the present organisms from deep water (2800 m) in the equatorial Pacific (0°22′S, 35°33′W) and suggested their wide distribution spreading from the Gulf of Alaska of the North Pacific to the Weddell Sea of Antarctica. On the other hand, many modern planktologists (HONJO and OKADA, 1974; OKADA and HONJO, 1973; OKADA and MCINTYRE, 1977; NISHIDA, 1979 and others mentioned above) have investigated the surface distributions of nannoplankton from all over the Pacific Ocean with electron microscopy, but microorganisms were not found, except those by NISHIDA (1979) and BOOTH *et al.* (1980). Their distribution is limited to the subsurface layer of the polar seas. Their horizontal distribution in the Southern Ocean is given in Table 2 and their vertical distribution in Fig. 3. On their occurrence in the equatorial Pacific deep water (SILVER *et al.*, 1980), the presnet author holds a hypothesis that the original habitats of the siliceous microorganisms were restricted to the subsurface layers of the polar seas and were transported, probably in a cyst state,

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Plate 1. *Siliceous microorganisms and calcareous nannoplankton from the Southern Ocean. Scale bar represents 1 μm. Number with prefix NUESEM shows SEM photograph negative film number deposited in Nara University of Education.*

Fig. 1. Siliceous microorganism having short knobs and central process. Stn. PI-2 —100 m level, NUESEM12-890.

Fig. 2. Same as Fig. 1 but for Stn. 4 —100 m level, NUESEM12-914.

Fig. 3. Siliceous microorganism. Smooth surface with central process. Stn. PI-2 —100 m level, NUESEM 12-901.

Fig. 4. Siliceous microorganism. Radially arranged short knobs and slits of the surface. Stn. PI-2 —100 m level, NUESEM12-908.

Fig. 5. Siliceous organism. Short and sporadically spattered knobs on the smooth surface. Stn. PI-2 —100 m level, NUESEM12-897.

Fig. 6. Siliceous microorganism having smooth surface and central bifurcated long process. Stn. PI-2 —100 m level, NUESEM12-893.

Fig. 7. Same as Fig. 6 but for Stn. PI-2 —100 m level, NUESEM12-895.

Fig. 8. Same as Fig. 6 but for Stn. PI-2 —100 m level, NUESEM12-906.

Fig. 9. Same as Fig. 6 but for Stn, PI-2 —100 m level, NUESEM12-899.

Plate 1

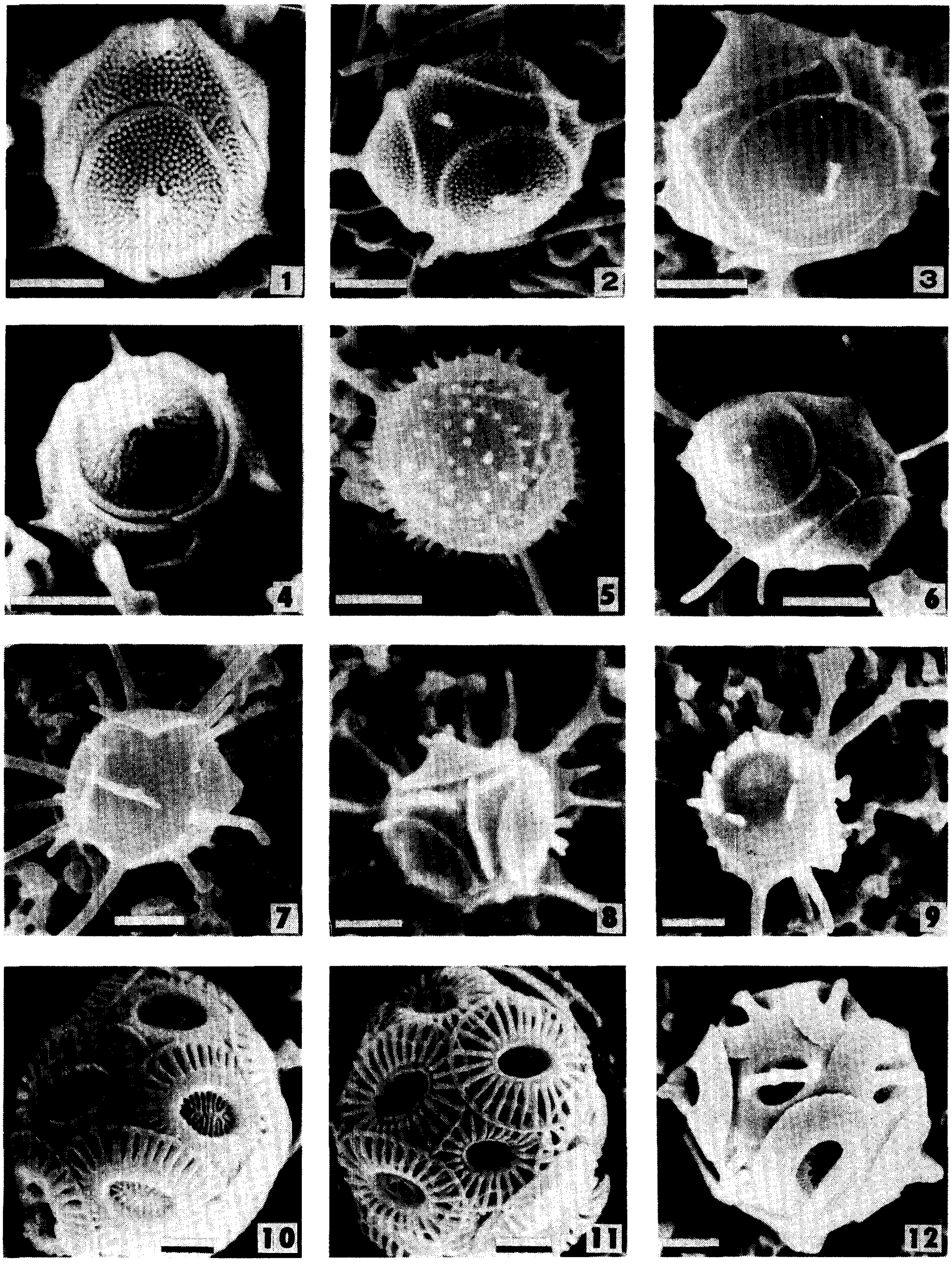

Fig. 10. Emiliania huxleyi (*LOHMANN*) *HAY and MOHLER*. *Warm water form.* *36°58.69′S, 150° 19.48′E, surface water.* *NUESEM 12-924.*

Fig. 11. Emiliania huxleyi (*LOHMANN*) *HAY and MOHLER*. *Cold water form.* *58°00.56′S, 150° 05.49′E, surface water.* *NUESEM 12-922.*

Fig. 12. Gephyrocapsa ericsoni *McINTYRE and BÉ*. *36°58.69′S, 150°19.48′E, surface water* *NUESEM 12-928.*

to the equatorial deep water by the Antarctic Deep Current. It is most likely that their solid cystose form has facilitated the long distance transport under non-photic conditions.

MARCHANT and NASH (1985) illustrated the gut contents of a krill *Euphausia superba* by electron microscope photographs, which show that the microorganisms were found in a good state of perservation. From these observations, the present microorganisms are assessed to be an important food contributor to the krill subsistence economy.

Acknowledgments

The author express his sincere thanks to Prof. T. NEMOTO of the Ocean Research Institute, University of Tokyo, for his competent guidance during the BIOMASS-SIBEX Expedition, and to the scientific members of the R.V. HAKUHO MARU KH-83-4 cruise. His acknowledgments are extend also to Captain I. TADAMA and the crew of the vessel for their devoted support in the scientific operations and for providing the comfortable daily life during the cruise.

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(*Received April 1, 1985; Revised manuscript received July 12, 1985*)