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DISTRIBUTION OF PARTICULATE ORGANIC MATERIALS IN THE PACIFIC AND INDIAN SECTORS OF THE ANTARCTIC OCEAN IN THE AUSTRAL SUMMER

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Abstract: Particulate matter was collected from the surface through deep water layers at 31 hydrographic stations along the four transects in the Pacific sector and one transect in the Indian sector of the Antarctic Ocean. The particulate matter was analyzed for organic carbon (POC), amino acid, carbohydrate and lipid contents.

The Pacific sector was divided into three water masses, each of which was subdivided into three water layers. The average POC concentrations among the three water masses ranged from 55.6 to 82.0 μgC/l in the surface water layer (0–100 m), the value tending to decrease with depth to 24.5–47.1 and 19.2–40.4 μgC/l in the intermediate (125–200 m) and deep (300–1500 m) water layers, respectively. The values are lower than those reported in the most productive oceanic areas, but higher than those reported in low latitude areas and comparable to those reported in middle latitude areas in the Pacific and Atlantic Oceans. Along the transect in the Indian sector, the average POC concentration was 237 μgC/l in the surface water layer. This high concentration of POC was assumed to give rise to the spring phytoplankton blooming in this region.

The percentages of amino acid-, carbohydrate- and lipid-carbons in POC were determined. The percentages of amino acid- and lipid-carbons in POC increased southward to the areas where the dichothermal water was observed. Significantly high percentages of amino acid-carbon in POC were found for the particulate matter suspended in the water layer above the cold water mass. On the other hand, high values for the particulate lipid were obtained in and below the cold water mass. It was concluded that the protein-rich particulate matter was distributed in the water layer above the cold water mass, while lipid-rich particulate matter was localized in the cold water mass. The high concentration of the glycolipid and relatively low concentrations of both the simple lipid and the phospholipid were characteristics of the particulate matter suspended in the dichothermal water. Mechanisms of these characteristic distributions of the particulate amino acid and lipid were discussed.

1. Introduction

The Antarctic Ocean is often thought of as the world's most fertile area (NIENHUIS, 1981). However, the primary production rate is moderate (EL-SAYED, 1970; HOLM-HANSEN *et al.*, 1977) and the surface chlorophyll stock is not so high as previously believed (FUKUCHI, 1980). Except chlorophyll pigments, very limited data for the distribution of particulate organic constituents have been available.

Compared with the other oceanic areas, the Antarctic Ocean is characterized by low surface temperature even in the austral summer and dichothermal water (below 0°C) is always observed near the Antarctic Continent. However, there is little information on the effect of this characteristic water temperature condition upon the chemical composition of the particulate organic constituents.

In 1980–81 and 1983–84, particulate matter samples and associated hydrographic data were collected in the expeditions to the Antarctic Ocean sponsored by the Tokyo University of Fisheries on board the T. S. UMITAKA MARU (BIOMASS FIBEX and SIBEX cruises) and by the Far Seas Fisheries Research Laboratory on board the R. V. KAIYO MARU (BIOMASS SIBEX I cruise). During the cruises, particulate matter was collected at 31 hydrographic stations along a transect of 75°E in the Indian sector and

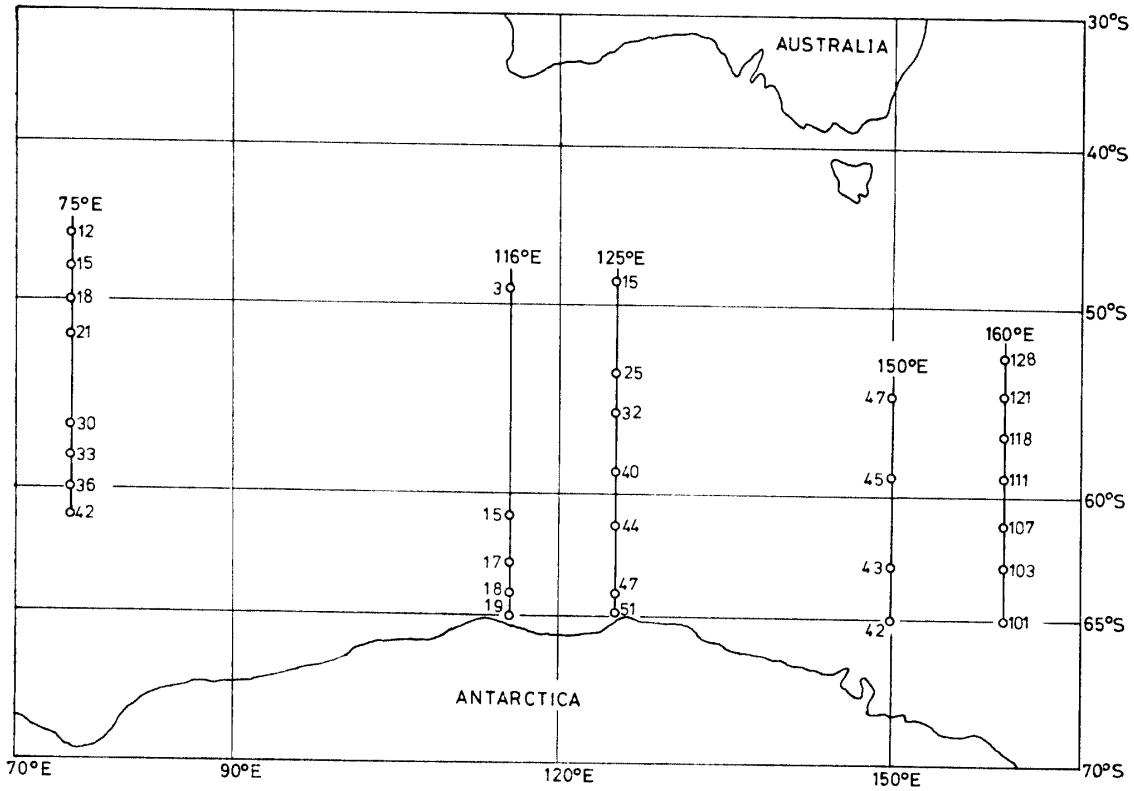

Fig. 1. Positions of hydrographic stations along the transect of 75°E (December 4–11, 1983) during the BIOMASS SIBEX I cruise (R. V. KAIYO MARU) and along the transects of 116°E (January 8–14, 1984), 125°E (December 26, 1980 – January 2, 1981), 150°E (February 2–8, 1984) and 160°E (February 2–8, 1981) during the BIOMASS FIBEX and SIBEX cruises (T. S. UMITAKA MARU).

transects of 116°, 125°, 150° and 160°E in the Pacific sector of the Antarctic Ocean (Fig. 1). Particulate matter was analyzed for organic carbon (POC), amino acid, carbohydrate and lipid contents. A detailed analysis of lipid class composition was conducted on the particulate matter collected from a southernmost hydrographic station where the dichothermal water was found.

In this paper, we intend firstly to report the compiled data (TANOUE *et al.*, 1982; TANOUE, 1985a) on the vertical and horizontal distribution profiles of particulate organic carbon to clarify a general distribution pattern in the Pacific and Indian sectors of the Antarctic Ocean in the austral summer. Secondly, regional change in organic constituents of particulate matter will be described in relation to the water temperature condition. Finally, a characteristic vertical change in lipid class composition found in the particulate matter suspended in the dichothermal water will be reported and discussed.

2. Materials and Methods

Seawater samples were collected with a Van Dorn sampler from various depths at 31 hydrographic stations in the Antarctic Ocean (Fig. 1). Each seawater sample was filtered through a glass fiber filter (Whatman, GF/C, 47 mm in diameter) which was preignited (450°C, 6 h). Particulate matter collected onto the glass fiber filter was kept frozen at −50°C on board and also at −18°C on land until chemical analyses were completed.

A glass fiber filter with particulate matter was divided quantitatively into four radial sections for organic carbon and nitrogen, amino acid, carbohydrate and lipid analyses.

Prior to the analyses of organic carbon and nitrogen, the filter was allowed to stand in a desicator filled with hydrochloric acid vapor for 6 h. Particulate organic carbon and nitrogen were determined with CHN-Corder (Yanaco, Model MT-2).

The fluorometric method (UDENFRIEND *et al.*, 1972) was used for quantitative determination of amino acids after the hydrolysis of combined amino acids with hydrochloric acid (6N) at 105°C for 24 h. The fluorometric method was standardized on the composite sample of amino acids consisting of bulk of *Chlorella vulgaris* (FOWDEN, 1954). The amino acid-carbon content was calculated by multiplying the amino acid value by 0.475.

The filter sample soaked with sulfuric acid (72%, v/v) was allowed to stand at room temperature for 3 h. The sulfuric acid solution was first diluted to 1N by the addition of distilled water, and then hydrolysed at 105°C for 24 h. An aliquot of the hydrolysate was used for determining the total carbohydrate content by the phenol sulfuric acid method (HANDA, 1966). The carbohydrate-carbon content was calculated on the basis of total carbohydrate content multiplied by a factor of 0.40.

Lipid materials were extracted from the particulate matter with chloroform-methanol (2:1, v/v) by vigorous stirring at room temperature overnight. After removal of solid residue by filtering it through a preignited glass fiber filter (Whatman, GF/C), the filtrate was added to preignited glass ampules and dried thoroughly to remove the organic solvents. After the drying, distilled water (5 m*l*) wad added to the ampule and the

lipid-carbon content was determined by the method described by MENZEL and VACCARO (1964).

For lipid class separation, lipids were extracted from the particulate matter (65–110 *l*) and separated into individual lipid classes by silica gel column chromatography using Unisil gel (Clarkson, 100–200 mesh). Three fractions, *i.e.*, simple lipid, glycolipid and phospholipid, were collected by elution with a series of solvents increasing their polarity stepwise (TANOUE, 1985b). Each of the lipid classes was analyzed for fatty acid composition and quantified as fatty acid content by gas chromatography (TANOUE, 1985b).

3. Results and Discussion

3.1. *Horizontal and vertical distribution of the particulate organic carbon (POC) in the Antarctic Ocean*

POC concentrations were low in the surface water layers along the transects of 125 and 160°E (Fig. 2). POC concentration was maximum (higher than 80 μgC/*l*) in the water layers between the depths of 10 and 75 m along the transect of 125°E. The values tended to decrease rapidly with depth below 75 m throughout the stations. Along the transect of 160°E, maximum values of more than 50 μgC/*l* were found in the water layers between the depths of 25 and 100 m at northern stations and the maximum values of more than 70 μgC/*l* were found in the water layers above the depth of 75 m at southern stations. The concentration of POC in the surface water layer (0–100 m) along this transect was low as compared with the values found along the transect of 125°E. POC along thet ransect of 160°E decreased rapidly with depth to less than 30 μgC/*l* below the depth of 150 m. POC less than 20 μgC/*l* was found in the water layer below the depth of 500 m.

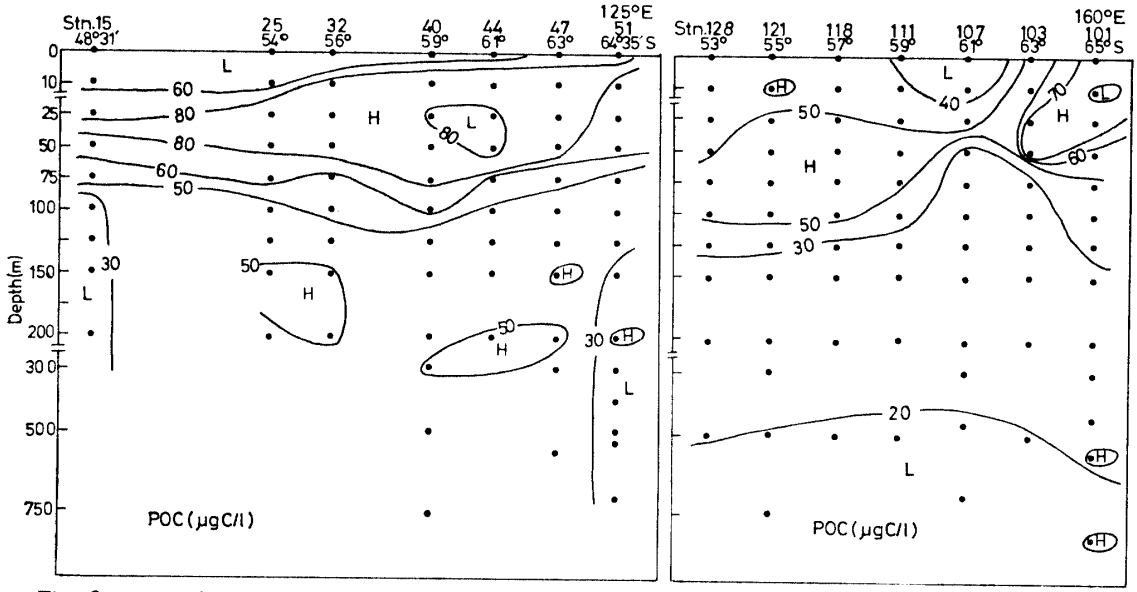

Fig. 2. Distribution profiles of particulate organic carbon (POC) along the transects of 125°E (December 26, 1980 – January 2, 1981) and the 160°E (February 2–8, 1981) during the BIOMASS FIBEX cruise (T. S. UMITAKA MARU).

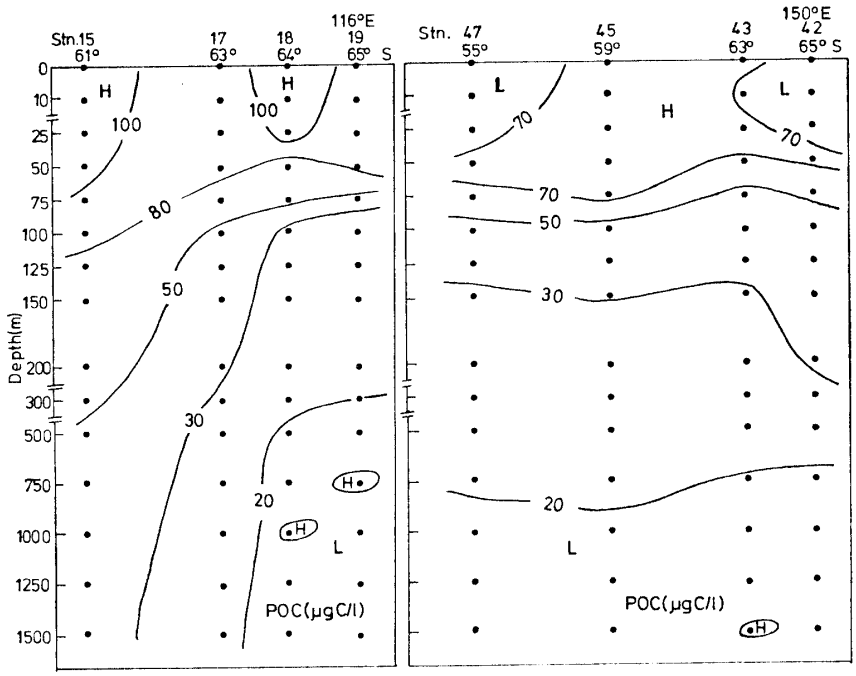

Fig. 3. Distribution profiles of POC along the transects of 116° E (January 8–14, 1984) and 150° E (February 8–12, 1984) during the BIOMASS SIBEX cruise (T. S. UMITAKA MARU).

The POC concentration was high in the surface water layers and maximum values of more than 100 μgC/l were found at Stns. 15 and 18 along the transect of 116°E (Fig. 3). The values decreased with increasing depth. However, differences in the concentrations of POC were found among the stations in the intermediate and deep water layers. Higher values of POC were found at northern stations, while lower values were found at southern stations. Along the transect of 150°E, maximum values of more than 70 μgC/l were found in the surface water layers, decreased to the values of less than 30 μgC/l below the depth of 150 m, and then became less than 20 μgC/l below the depth of 750 m. The concentration of POC in the surface water layer along the transect of 150°E was low as compared with the values found along the transect of 116°E (Fig. 3).

Along the four transects in the Pacific sector, POC concentrations in the surface water layer were determined to be less than 100 μgC/l at most of stations except two stations (Figs. 2 and 3). However, extremely high concentrations of POC were obtained during the BIOMASS SIBEX I cruise along the transect of 75°E in the Indian sector (Fig. 4). The values of more than 600 μgC/l were determined in the surface water layer at Stn. 18. The POC concentration of more than 200 μgC/l is distributed widely from Stn. 18 (49°59.5'S) to Stn. 30 (56°00.3'S) along this transect. The distribution profile of chlorophyll *a* along this transect did not exactly coincide with that of POC. Concentration maximum of chlorophyll *a* was found in the 50 m depth layer at Stn. 21 (KOMAKI, 1985). To estimate the contribution of phytoplankton to POC, the relationship between the concentrations of chlorophyll *a* and POC at each station was examined (Fig. 5). POC/Chl. *a* was less than 100 in the 20–75 m depth layers at Stn.

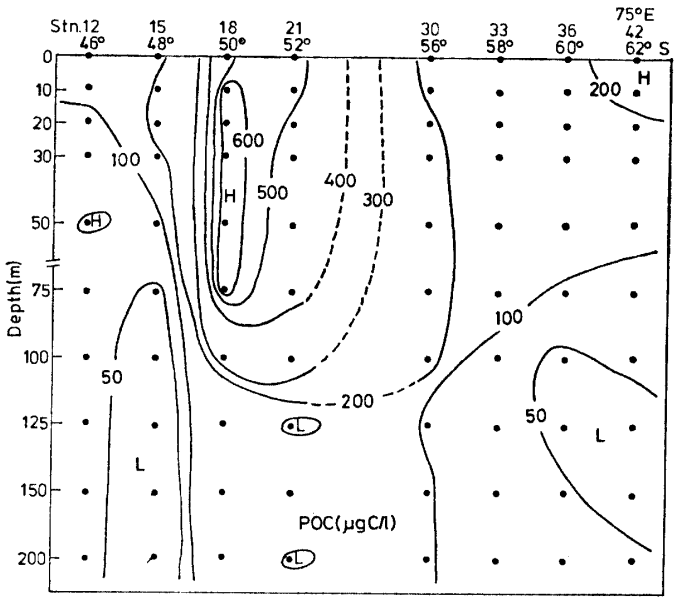

Fig. 4. Distribution profile of POC along the transect of 75° E (December 4–11, 1983) during the BIOMASS SIBEX I cruise (R. V. KAIYO MARU).

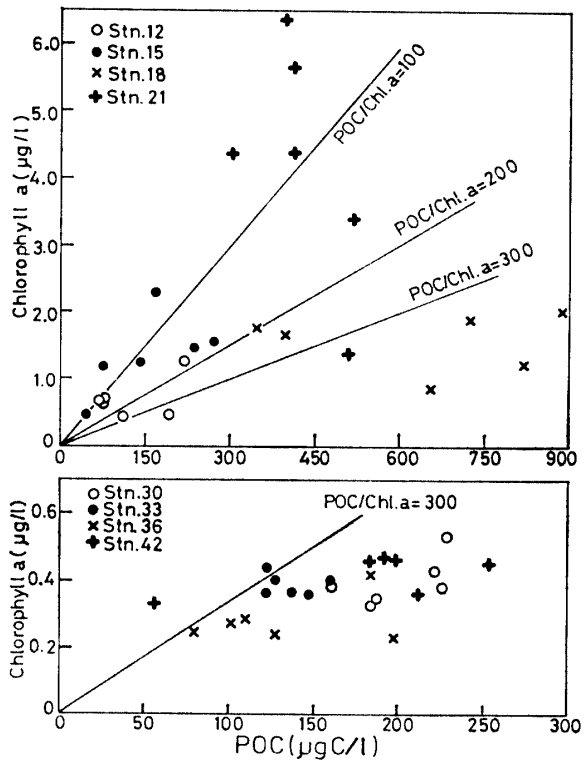

Fig. 5. Relationship between the concentrations of chlorophyll a and POC at each station along the transect of 75° E.

21, indicating that most of the POC was phytoplankton. POC/Chl. *a* was more than 200 at Stn. 18 where the highest concentration of POC was found (Fig. 4). These observations suggested that blooming of phytoplankton, which had occurred and finished at Stn. 18, migrated southward and occurred at Stn. 21.

PLANCKE (1977) reported that surface chlorophyll *a* in the Antarctic Ocean appeared to be maximum in spring (November) and then tended to decrease with time from summer (January) to autumn (March–April). FUKASE (1962) also reported that phytoplankton cell number in waters south of Cape Town was found to be higher in middle to late December than in late February to early March. Seasonal variabilities of chlorophyll *a* and phytoplankton standing stock are largely due to the seasonal change in phytoplankton production as reported by FUKUCHI (1980). The particulate matter samples along the transect of 75°E in the Indian sector were collected on December 4–11, 1983. On the other hand, the particulate matter samples along the four transects in the Pacific sector were collected during the periods of December 26, 1980 to January 2, 1981 and January 8 to February 12, 1984. It was considered that the extremely high concentration of POC obtained along the transect of 75°E was due to the spring blooming of phytoplankton in this region. In comparing the distribution profiles of POC along the four transects in the Pacific sector, a little higher values of POC were also observed along the transects of 116 and 125°E on January 8–14, 1984 and December 26, 1980 to January 2, 1981 relative to those obtained along the transects of 150 and 160°E on February 8–12, 1984 and February 2–8, 1981, respectively. Such a regional variability of POC concentration might be also due to the seasonal change in the primary productivity in these regions as mentioned above, although the spring blooming of phytoplankton had already finished in the Pacific sector.

The Pacific sector of the Antarctic Ocean can be divided into three water masses and the water is also divided into surface (0–100 m), intermediate (125–200 m) and deep (300–1500 m) water layers at each station along the four transects. The average concentration of POC is summarized in Table 1.

The average concentration of POC was almost the same order of magnitude in each

Table 1. Summary of the average concentration (±1 SD) of particulate organic carbon (μgC/l) in the Pacific and the Indian sectors in the Antarctic Ocean.

Sampling period	Water layers		
	0–100 m	125–200 m	300–1500 m
Pacific sector			
Subtropical Convergence–Antarctic Convergence			
Dec. 25, 1980–Feb. 7, 1981	58.1±17.1 (28)*	36.6±13.9 (14)	28.5± 9.30 (6)
Jan. 8–Feb. 13, 1984	75.5±28.3 (12)	47.1±19.3 (6)	40.4±23.1 (12)
Antarctic Convergence–Antarctic Divergence			
Dec. 25, 1980–Feb. 7, 1981	55.6±20.9 (29)	33.5± 9.10 (13)	26.4±13.4 (11)
Jan. 8–Feb. 13, 1984	82.0±28.2 (24)	37.3±16.1 (12)	31.7±16.2 (24)
Southern area of Antarctic Divergence			
Dec. 25, 1980–Feb. 7, 1981	61.6±22.7 (24)	35.5±15.4 (12)	33.1±22.3 (18)
Jan. 8–Feb. 13, 1984	68.8±28.9 (24)	24.5±5.07 (9)	19.2± 5.02 (18)
Range	55.6–82.0	24.5–47.1	19.2–40.4
Indian sector (area between Stn. 12 (45°59.5′S) and Stn. 42 (61°00.2′S))**			
Dec. 4–Dec. 11, 1983	237±190 (56)	84.1±41.5 (24)	

* Number in parentheses indicates the number of sample.

** Average values of the whole area examined are presented, because the position of the front is not clear.

of the water layers throughout the water masses in the Pacific sector. The average concentration of POC ranged from 55.6 to 82.0 μgC/l in the surface water layer and decreased with depth to 19.2–40.4 μgC/l in the deep water layer. The average concentration of POC along the transect of 75°E in the Indian sector was 237 μgC/l in the surface water layer. This value was several times higher than those obtained in the Pacific sector, because the value represented the concentration level of POC in the spring blooming season (early December) in the Antarctic Ocean. Since a specific high value of POC was not found throughout the stations along the four transects in the Pacific sector (Figs. 2 and 3), it is considered that the values obtained in the Pacific sector might represent the background concentration level of POC during the austral summer in the Pacific sector of the Antarctic Ocean. The concentration level of POC in the Pacific sector was higher than those reported in low latitude areas of the Indian Ocean (NEWELL and KERR, 1968; CHESTER and STONER, 1974), of the Pacific Ocean (HOLM-HANSEN, 1969; GORDON, 1971) and of the Atlantic Ocean (CHESTER and STONER, 1974; GORDON, 1977), lower than those reported in the northern North Pacific and the Bering Sea (TANOUE and HANDA, 1979). The value obtained in the present study was comparable to those reported in middle latitude areas of the Pacific Ocean (HANDA *et al.*, 1972) and of the Atlantic Ocean (BANOUB and WILLIAMS, 1972; GORDON, 1977). This fact is in agreement with the statement that the primary production rate is moderate in the Antarctic region (EL-SAYED, 1970; HOLM-HANSEN *et al.*, 1977). However, it should be noticed that the concentration level of POC in the Antarctic Ocean might increase in the spring blooming season (Fig. 4 and Table 1) as high as those found in the most productive oceanic area such as the Oyashio area of the Northwest Pacific (TANOUE and HANDA, 1979).

3.2. Percentages of particulate amino acid-, carbohydrate- and lipid-carbons in POC

Amino acids, carbohydrates and lipids in the particulate matter were determined as major biochemical components. Average percentages of amino acid-, carbohydrate- and lipid-carbons in POC are summarized for each water mass and each water layer (Table 2). Sums of these three components constituted 68.4–80.3% of POC as a carbon base in the surface water layers (0–100 m) and the values decreased with depth to 62.6–71.5% and 50.7–61.8% in the intermediate (125–200 m) and deep (300–1500 m) water layers, respectively. Horizontally, sums of the values throughout the water layers increased from a range of 50.7–68.4% in the water mass between the subtropical Convergence and the Antarctic Convergence to a range of 61.8–80.3% in the southern area of the Antarctic Divergence.

The amino acids were the largest component in the particulate organic matter in the surface water layers throughout the water masses (Table 2). The average percentage of amino acid-carbon in POC in the surface water layer (0–100 m) was in a range of 32.9–38.6% in the Pacific sector and 27.8% in the Indian sector. The value decreased with increasing depth to ranges of 24.7–25.9 and 16.1–20.1% in the intermediate (125–200 m) and deep (300–1500 m) water layers in the Pacific sector, respectively. The percentage of amino acid-carbon in POC was not identical among the water masses from the surface to the deep water layers. The average value in the surface water layer tended to increase toward the south from 32.9% in the water mass between the Subtropical Convergence and the Antarctic Convergence to 38.6% in the southern area of the

Table 2. Summary of the average percentages (±1 SD) of amino acid-, carbohydrate- and lipid-carbons in the particulate organic carbon (POC) in the Pacific and the Indian sectors in the Antarctic Ocean.

Water layer (m)	Amino acid-C[a)] / POC	Carbohydrate-C[b)] / POC	Lipid-C[c)] / POC	a)+b)+c) / POC
		(%)		
Pacific sector				
Subtropical Convergence–Antarctic Convergence				
0–100	32.9± 7.06(40)*	11.6±3.13(40)	23.9±3.63(39)	68.4
125–200	25.3±11.5 (18)	11.6±4.04(20)	25.7±5.21(21)	62.6
300–1500	16.1± 8.04(17)	10.8±6.12(17)	23.8±2.80 (7)	50.7
Antarctic Convergence–Antarctic Divergence				
0–100	35.9± 8.00(55)	11.3±2.45(57)	24.0±5.23(53)	71.2
125–200	24.7± 9.18(28)	11.6±4.23(29)	28.5±6.96(30)	64.8
300–1500	17.0± 7.66(30)	10.0±2.92(34)	24.9±5.87(21)	51.9
Southern area of Antarctic Divergence				
0–100	38.6± 8.50(36)	11.1±2.98(36)	30.6±5.35(34)	80.3
125–200	25.9± 3.67(18)	11.1±3.42(16)	34.5±8.33(18)	71.5
300–1500	20.1± 3.64(29)	11.0±4.03(30)	30.7±5.74(20)	61.8
Indian sector (area between Stn. 12 (45°59.5′S) and Stn. 42 (61°00.2′S))**				
0–100	27.8± 8.48(42)	—	—	—
125–200	19.6± 5.24(18)	—	—	—

* Number in parentheses indicates the number of sample.

** Average values of the whole area examined are presented, because the position of the front is not clear.

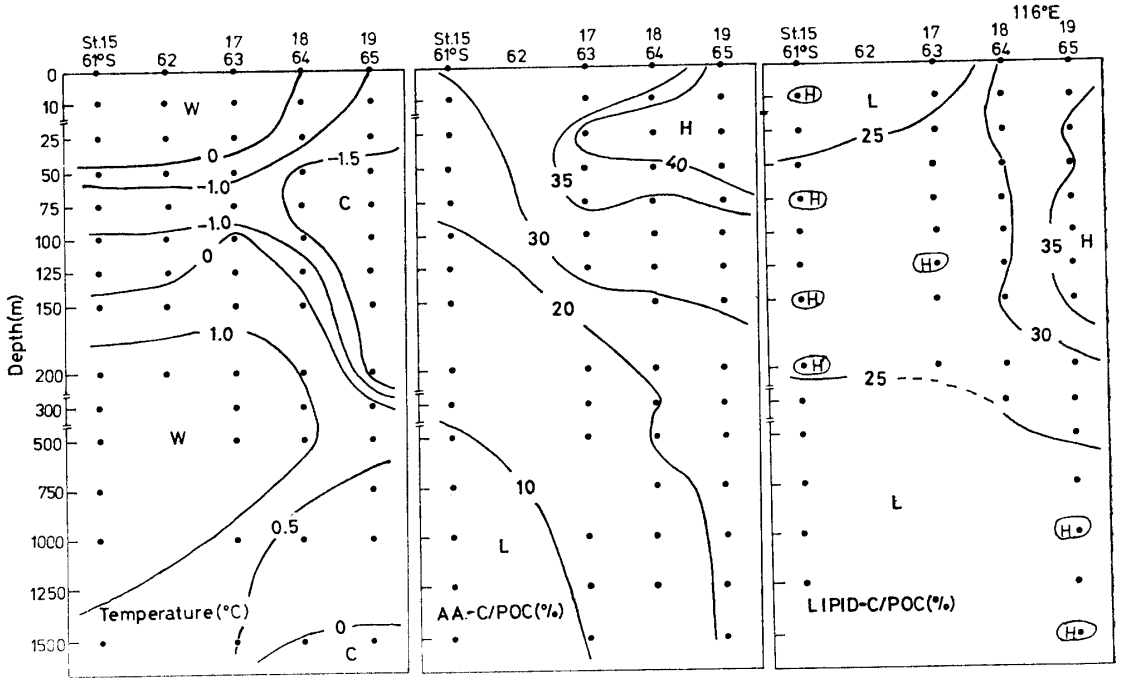

Fig. 6. Distribution profiles of water temperature and percentages of particulate amino acid- and particulate lipid-carbons in POC along the transect of 116° E.

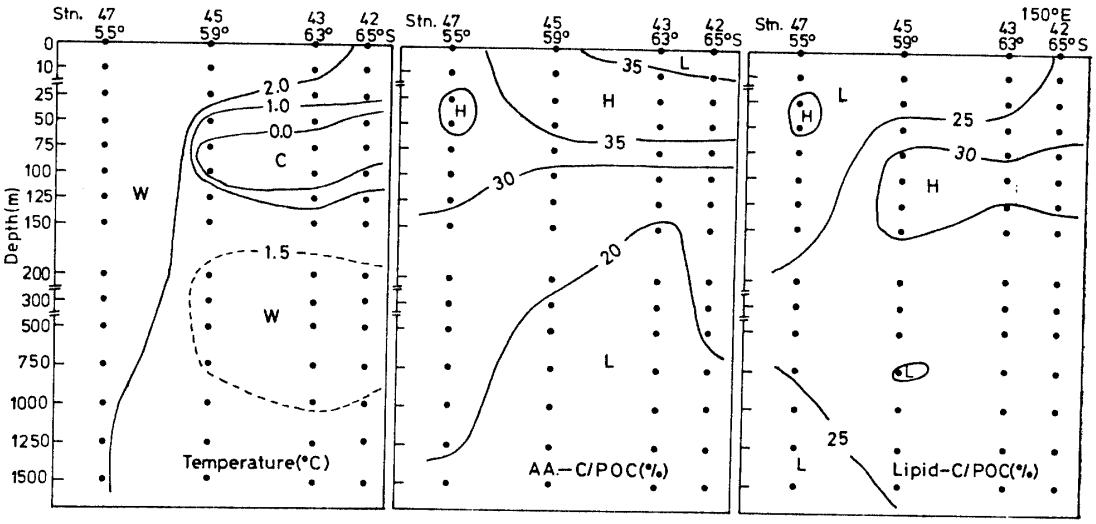

Fig. 7. Distribution profiles of water temperature and percentages of particulate amino acid- and particulate lipid-carbons in POC along the transect of 150° E.

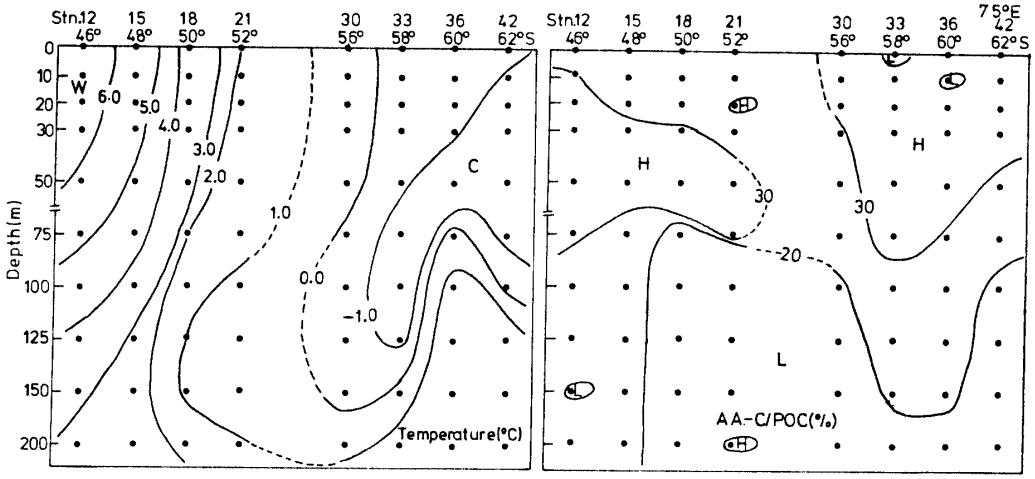

Fig. 8. Distribution profiles of water temperature and percentage of particulate amino acid-carbon in POC along the transect of 75° E.

Antarctic Divergence. More detailed distribution profiles of the percentage of amino acid-carbon in POC are shown in relation to the water temperature profiles (Figs. 6–8). Significantly high values of more than 40% were observed in the water layer above the cold water mass (lower than −1.5°C) along the transect of 116°E (Fig. 6). Relatively low values (lower than 20%) were found in the intermediate and deep water layers in the northern area where a warm water mass (higher than 1.0°C) was found. High values of more than 35% were also observed in the water layer above the cold water mass (lower than 0°C) along the transect of 150°E (Fig. 7). Low values (lower than 20%) of amino acid-carbon/POC in the intermediate and deep water layers were also found in relation to the distribution of the warm water mass (higher than 1.5°C). Along the transect of 75°E, high values of more than 30% were again found in the water layer above the cold water mass (lower than −1.0°C) (Fig. 8). Along

this transect in the Indian sector, the value of more than 30% was also determined in the subsurface water layer in the northern area, although relatively high values could not be found in the northern areas along the transects of 116 and 150°E (Figs. 6 and 7). As mentioned previously, the high concentration of POC was observed in the northern areas along the transect of 75°E (Fig. 4), therefore, the relatively high values observed in this northern region might be due to the spring blooming of the phytoplankton. On the other hand, significantly high values were observed always in the water layers above the cold water mass regardless of either sampling areas or sampling periods along the transects in both the Pacific and the Indian sectors. It can be concluded that the protein-rich particulate matter is commonly localized in the water layer above the cold water masses. JØRGENSEN (1968) studied the mechanism of temperature adaptation of a diatom, *Skeletonema costatum*, and found that the concentration of protein per cell increased with decreasing temperature. It is also known that the enzymatic protein concentration in higher plants increases from autumn to winter to achieve low temperature resistance (SIMINOVITCH *et al.*, 1968). Even in the water layer above the cold water mass, the protein-rich particulate matter is distributed in the southern area along each transect where the water temperature was low as compared with that of the northern area. It is assumed that phytoplankton cells living in the water layer above the cold water masses adapt themselves to low water temperature by increasing their enzymatic concentration. This, in turn, results in protein-rich particulate matter in the surface water layer as observed in the present study.

The carbohydrates were the smallest among the three components analyzed in the particulate organic matter. The percentage of this fraction was determined to be in a range of 10.0–11.6% throughout the water layers and water masses. Values did not show a significant change either horizontally or vertically (Table 2).

The percentage of particulate lipid-carbon in POC showed a significant change either horizontally and vertically (Table 2). The lipids were the second largest component in the particulate organic matter in the surface water layers. The average percentage of lipid-carbon in POC did not decrease with depth and lipids were the largest component in the intermediate and deep water layers. The average percentage of particulate lipid-carbon in POC was in a range of 23.9–30.6% in the surface water layer. The values tended to increase to a range of 25.7–34.5% in the intermediate water layers and then to decrease to a range of 23.8–30.7% in the deep water layers. Horizontally, the values found from the surface to the deep water layers tended to increase toward the south from a range of 23.8–25.7% in the water mass between the Subtropical Convergence and the Antarctic Convergence to a range of 30.6–34.5% in the southern area of the Antarctic Divergence. The highest value of 34.5% was found in the particulate matter collected from the intermediate water layer in the southern area of the Antarctic Divergence. To make this characteristic trend more clear, distribution profiles of the percentage of particulate lipid-carbon in POC were compared with those of the water temperature along the four transects of the Pacific sector (Figs. 6, 7 and 9). Along the transect of 116°E, the high value of more than 35% was distributed in the cold water mass (lower than −1.5°C) (Fig. 6). High values of more than 30% were observed in and below the cold water mass (lower than 0°C) along the transect of 150°E (Fig. 7). The high values of more than 40% were also determined in the particulate matter col-

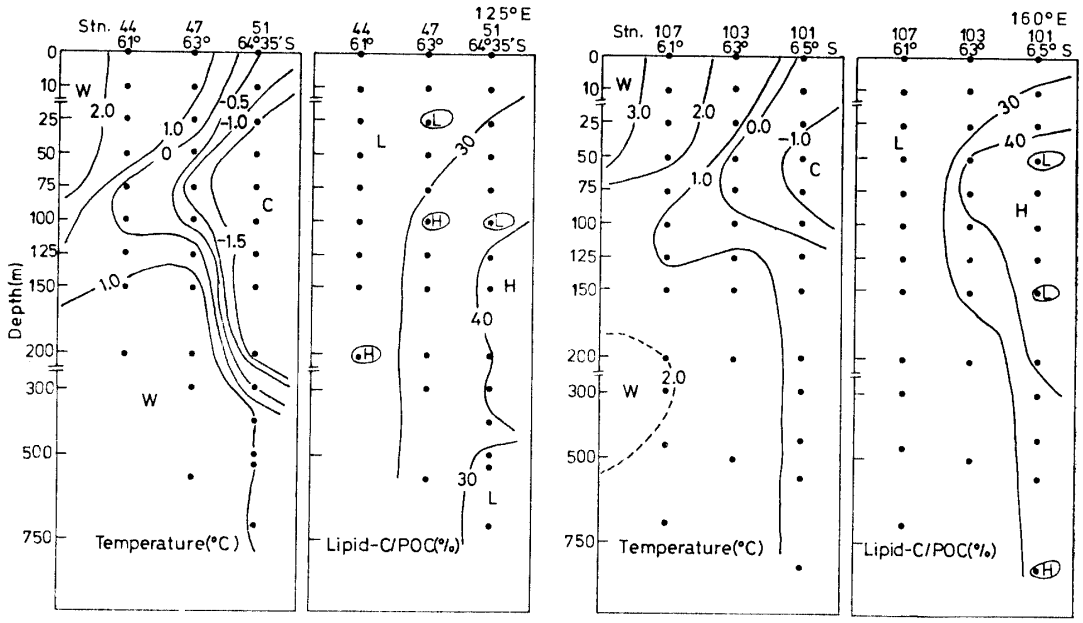

Fig. 9. Distribution profiles of water temperature and percentage of particulate lipid-carbon in POC along the transects of 125° and 160° E.

lected from the cold water mass and just below the cold water mass along the transects of 125° and 160°E (Fig. 9). Since the high percentage of particulate lipid-carbon in POC is always found in the particulate matter collected from the cold water mass and just below the cold water mass along the transects examined, it is concluded that the distribution of lipid-rich particulate matter in these water layers is a common phenomenon during the austral summer throughout the whole area of the Antarctic Ocean where the dichothermal water is widely found.

3.3. Lipid class composition of particulate organic matter suspended in the dichothermal water of the Antarctic Ocean

A significantly high percentage of particulate lipid-carbon in POC was commonly observed in the dichothermal water (Figs. 6, 7 and 9). To understand a mechanism by which lipid-rich particulate matter was localized in the dichothermal waters, more detailed lipid composition analyses were conducted in the particulate matter collected from the various depths at the southernmost station (Stn. 19) along the transect of 116°E (Fig. 1).

The concentrations and the compositions of simple lipid, glycolipid and phospholipid in the particulate matter at the various depths together with chlorophyll *a* and POC at Stn. 19 are summarized in Fig. 10. The simple lipid was the major lipid class in the particulate matter at the depths of 0, 10, 200 and 750 m. The concentration of the simple lipid was 16.2 and 5.59 $\mu g/l$ at the depths of 0 and 10 m which accounted for 81.3 and 77.5% of the total lipid, respectively. However, the concentration of simple lipid decreased remarkably to 1.32 $\mu g/l$ accounting for 30.3% of the total lipid at the depth of 80 m. At the depths of 200 and 750 m, the concentration of simple lipid increased to 4.89 and 2.75 $\mu g/l$ which accounted for 71.2 and 70.9% of the total lipid, respectively.

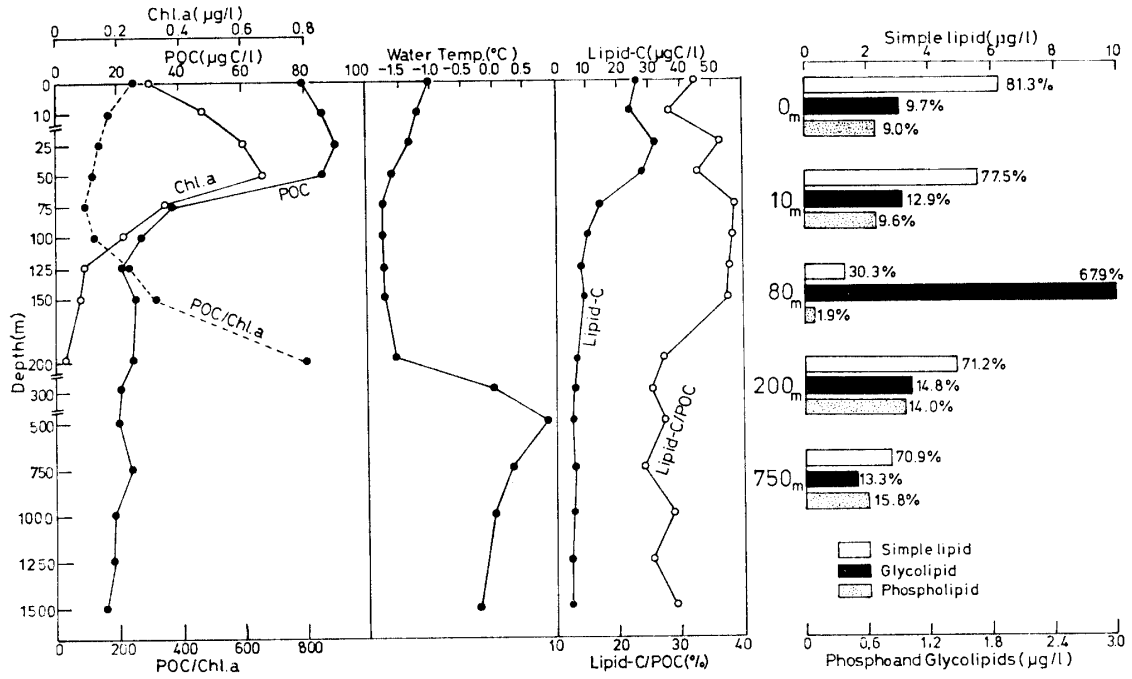

Fig. 10. Vertical distributions of POC, chlorophyll a, POC/chl. a, water temperature, particulate lipid-carbon, percentage of particulate lipid-carbon in POC and simple-, glyco- and phospholipids in the particulate matter at Stn. 19 along the transect of 116° E.

The glycolipid was the minor lipid class at the depths of 0, 10, 200 and 750 m. The concentration of the glycolipid at the depths of 0 and 10 m was 0.74 and 0.93 $\mu g/l$, accounting for 9.7 and 12.9% of the total lipid, respectively, whereas at the depth of 80 m the concentration of glycolipid increased significantly to 2.96 $\mu g/l$ which accounted for 67.9% of the total lipid in the particulate matter. The concentration of the glycolipid decreased to 1.01 and 0.52 $\mu g/l$ accounting for 14.8 and 13.3% at the depths of 200 and 750 m, respectively.

The phospholipid was the minor lipid class in the particulate matter throughout the water layers. Except the particulate matter at the depth of 80 m, the concentration of the phospholipid was in a range of 0.61–0.96 $\mu g/l$ and the percentage of the phospholipid in the total lipid tended to increase with increasing depth from 9.0% at 0 m to 15.8% at 750 m. At the depth of 80 m, concentration of the phospholipid was 0.08 $\mu g/l$, accounting for 1.9% of the total lipid. The concentration of the phospholipid at the depth of 80 m was one order of magnitude lower than those found in the other particulate matter collected from the surface through deep water layers.

The high concentration of the glycolipid and relatively low concentrations of both the simple lipid and phospholipid were characteristic in the lipid class composition of the particulate matter at the depth of 80 m where the lowest water temperature (−1.7°C) was found (Fig. 10). It is assumed that a significant high percentage of the particulate lipid-carbon in POC found in the dichothermal water is mainly due to the increase in the glycolipid concentration of the particulate matter suspended in this cold water. It is established that the glycolipids are concentrated in the lamellar membranes of chloroplast (thylakoids) as the "chloroplast" lipids of algae and higher plants

(LICHTENTHALER and PARKE, 1963; WOOD, 1974). Exclusive of the pigments and small amounts of unidentified lipids, the glycolipid constituted about 80% of the total thylakoid lipids in the higher plants. It is suggested that the increase in the glycolipid concentration in the dichothermal water may be due to the increase in the thylakoid lipids of the phytoplankton suspended in this cold water.

Diatoms and dinoflagellates were predominant organisms in the surface water but cell volumes of the diatoms and dinoflagellates decreased with increasing depth, while a minute spindle-shaped alga was dominant in the cold water mass at this station (HARA and TANOUE, unpublished data). In higher plants, the phospholipid and glycolipid contents increased under low temperature (YOSHIDA, 1974; DE YOE, 1979), but the phospholipid concentration decreased in the cold water mass in the present study (Fig. 10). On the other hand, it has been known that the phytoplankton grown under the blue-green light condition increase their thylakoid number among the various phytoplankton groups (JEFFREY and VESK, 1977; VESK and JEFFREY, 1977). Although there was no data on the light quality, secchi disk reading was 13 m at Stn. 19. The depth of the 1% light level was 60 and 75 m at the southernmost stations along the transects of 125° and 160°E, respectively (MORINAGA, personal communication). It can be considered that light penetrating to the cold water mass consists predominantly of low intensity blue-green radiation. The increase in chloroplast lipids might be due to the physiological adaptation of the phytoplankton living in the dichothermal water to the light quality. However, the remarkable decrease in the phospholipid concentration in the cold water mass cannot be explained by the physiological adaptation of the diatoms and the dinoflagellates. Although taxonomic position of the minute spindle-shaped alga found in the dichotermal water is not clear at the present time, it is suggested that the increase in the thylakoid lipids in the dichothermal water gives rise not only to the physiological adaptation of the phytoplankton to the light quality but also to a change in the phytoplankton species composition induced by the low water temperature.

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