Chemical Studies on the Nutrient Matter in Sea Water between Cape Town and Lützow-Holm Bay, Antarctica.

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ケープタウン・南極リュッツォウホルム湾間の 海水中の栄養塩類に関する化学的調査

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要　旨

南極観測船「宗谷」により 1957 年 10 月より 1958 年 4 月に至る期間，東京・リュッツォウホルム湾間の航行中，毎日 G.M.T. 12 時に表面海水を採集し，温度，pH，塩素量，溶在酸素，炭酸物質，栄養塩（リン酸態リン，珪酸態珪素，アンモニア態窒素，亜硝酸態窒素）等を測定した．尚パックアイス地域では，3 ケ所において 800〜2000 m まで，これら成分の亜直分布を調べた．ケープタウン・南極大陸間は，亜熱帯圏，亜南極圏，南極圏へと移行する海域であり，そこで従来行なわれている如く温度，塩素量による南極集連線，亜熱帯集連線に対する考察を行ない，更にこれら以外の上記化学成分に基づきその考察を行なってみた．その結果，水温傾度の大きい南極 44 度附近が西風漂流帯の北縁部に当る亜熱帯集連線とみられ，南緯 51 度附近に南極集連線があって，南極周辺の寒冷水が潜入して行く部域にあたると考えられる．この間を境として，南極海域では水温の変化にと

もない，pH，塩素量，アンモニア等は減少し，珪酸，リン酸，亜硝酸等の成分は逆に増加の傾向を示し，一般に南極海域ではこれらの栄養塩が豊富であることが判明した．これらの傾向は復路においても，又第 3 次観測(1958 年 12 月〜1959 年 4 月)の際に行なった結果についても同様にみられた．又炭酸物質については，全炭酸を測定した結果から遊離炭酸の分圧（Pco₂）を計算した処，南極集連線以南では Pco₂ は 6×10^{-4} atm. press. 以上の値を示し，南極集連線以北より大きい．これは往路，復路ともほぼ同様な値を示し，夏季における Pco₂ は大気中の値よりも大きく炭酸ガスが大気中に放出される状態にあるものと推定される．尚氷海域において亜直分布を調べた処，表層水は大陸に近づくにつれて厚くなっているが，その下層にある南極周極水は塩素量，密度ともほぼ一定で，珪酸，リン酸に富んだ厚い水塊で存在する．しかし全炭酸から Pco₂ を計算した処では，南極海域はよく混合されているものと推定される．

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1.　Introduction

The second Japanese Antarctic Research Expedition ship, the "Soya", left Tokyo on the 21 st of October, 1957, and returned there on the 28 th of April, 1958, after finishing the landing operation near Lützow-Holm Bay, Antarctica.

After passing through Balintang Channel, north of the Phillippine Islands, the ship went straight south toward Cape Town along the great circle via Singapore, and then followed a course from Cape Town toward Ongul Island on which the Japanese observation base was located (69°0′22″S, 39°35′24″E). The distribution of dissolved gases and nutrient matter in sea water, along the course to and from Antarctica, was observed.

It is regretted that, as the "Soya" was not equipped with sufficient instruments for oceanographic work, it was difficult to perform satisfactory observations. Sampling of surface sea water was made daily at 12.00 G. M. T. during the cruise between Tokyo and Lützow-Holm Bay, Antarctica and return, and the determination of temperature, chlorinity, dissolved oxygen, carbonate, phosphate–P, silicate–Si, ammonia–N, nitrite–N was made on board. Samples of sea water were stored in pyrex bottles of 200 ml with polyethylene stoppers. Polyethylene bottles of 1 liter and 20 liters, were used for the purpose of studying ^{14}C, ^{3}H and some of biophilelements such as Fe, Cu, B, Mn, As, I, Cr, V, Mo, etc.

In this report the consideration of Antarctic and subtropical convergences, which had been done by the measurements of temperature and chlorinity, was compared with those of the above mentioned chemical constituents in the sea region extending from the Indian Ocean to the Antarctic Sea. In addition, the results of the oceanographic observations at different depths at three stations in the pack ice region will be mentioned later. Locations of observation stations are given in Fig. 1.

2.　The methods of analyses

(1)　pH: pH meter (EHM–1 Type, Hitachi Manufacturing Co.) was used.

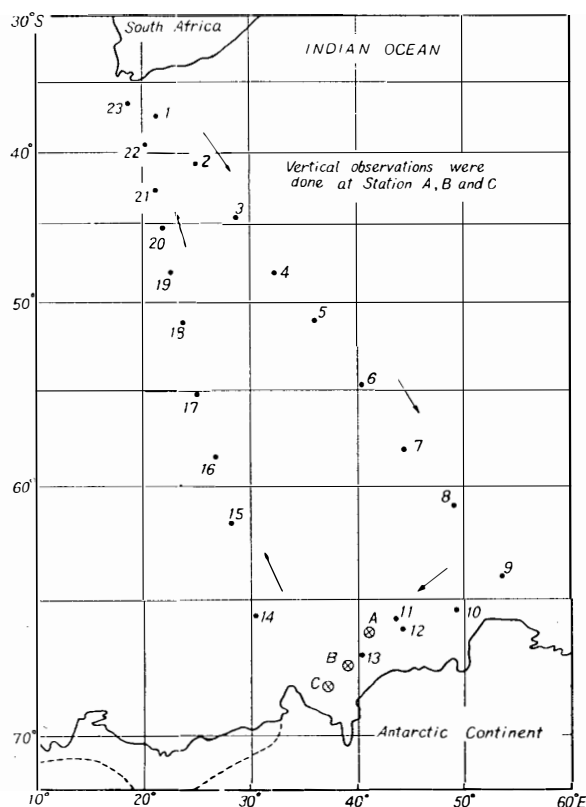(2)　Chlorinity: MIYAKE's method with uranin indicator.

Fig. 1.　Routes of the expedition ship, the "Soya" (Dec. 1957–Mar. 1958).

(3) Dissolved Oxygen: WINKLER's method.

(4) Carbonate: CONWAY's micro-diffusion method improved by K. SARUHASHI.

(5) Phosphate-Phosphorus: DENIGÈS's colorimetric method.

(6) Silicate-Silicon: Dienért-WANDENBULCKE's method.

(7) Nitrite-Nitrogen: GRIESS-ROMIJIN method.

(8) Ammonia-Nitrogen: Colorimetric method with NESSLER's reagent.

3. The results of observations

3. 1 Surface observation between Cape Town and Antarctica

3. 1. 1. VARIATION OF TEMPERATURE, pH AND CHLORINITY IN THE SURFACE LAYER

Fig. 2 shows the distribution of surface temperature, pH and chlorinity of sea water between the Cape of Good Hope and Ant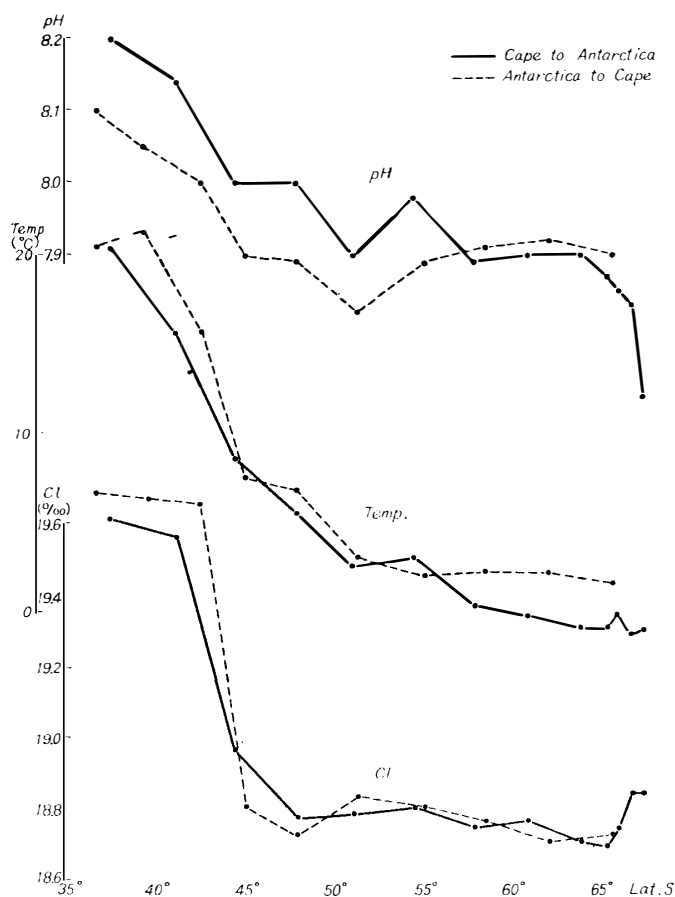arctica. Between a south offing of Africa and near 41°S the surface water temperature was higher than 15°C, while it decreased to 8. 5°C at 44°36′S and to 5. 5°C at 48°05′S. As we progressed further southward, the temperature became lower, and from 51°S to 55°S a temperature of about 2°C was observed. And the coldest water layer, with the temperature ranging from 0°C to −1. 4°C, was extended to the south of 58°S.

As shown in Fig. 2, a sharp change of water temperature at the surface occurs suddenly between 41°S and 44°S, where the water temperature goes down from 15. 6°C to 8. 5°C. Thus, it may be considered that the sub-tropical convergence is situated at about 44°S while the Antarctic convergence is located near 51°S.

Fig. 2. Variations of temperature, pH and chlorinity (Dec. 1957–Mar. 1958).

On the return cruise a similar tendency in the water temperature was observed when the Antarctic and sub-tropical convergences were found at around 51°S and 44°S respectively. The values of pH indicate 8. 0 at 44°S, and 7. 9 from 51°16′S to the edge of the ice sea. On the return cruise the same condition was recognized.

The distribution of chlorinity showed the same variation as the temperature and pH. At 44°S, the remarkable reduction in the chlorinity from 19. 56‰ to 18. 96 ‰ was observed. And in areas south of 44°S there was less saline water, about

18. 80‰, a condition which extended as far as the coast of the Continent. From these observations, the south of 51°S is considered to be the melting ice region. The variation of chlorinity at about 51°S has not been identified clearly. On the return cruise, higher saline water extended northward from 44°S.

3. 1. 2. VARIATION OF DISSOLVED OXYGEN, PHOSPHATE-P, SILICATE-SI, AMMONIA-N AND NITRITE-N

The distribution of the dissolved oxygen and the nutrient matter also showed definite changes at the Antarctic and subtropical convergences (Fig. 3).

Although the content of oxygen is 5.74 ml/L near 41°S, it increased to 6.68ml/L rapidly at the subtropical convergence and to 7.70ml/L at the Antarctic convergence and to more than 8 ml/L at the northern edge of the pack ice region near the Continent.

The saturation percentage of dissolved oxygen is given in Table 1.

On the return cruise a reduction of the oxygen amounts to 6.79 ml/L from 7.59 ml/L near the Antarctic convergence was observed and it decreased to 5.48ml/L from 6.59 ml/L at the subtropical convergence.

Concerning the content of silicate-Si in the surface layer, 4 μg-atoms/L was

Fig. 3. Variations of dissolved oxygen, phosphate-P, silicate-Si, ammonia-N and nitrite-N (Dec. 1957-Mar. 1958).

observed down to the sub-Antarctic zone near 50°S, but it increased to 15 μg-atoms/L at the Antarctic convergence. The silicate content increased as the observation stations approached the Continent and finally 40 μg-atoms/L was found on the north of the pack ice region.

On the return cruise it was observed that the silicate content was rich between the ice edge of the Continent and a point near 51°S, but it decreased to 6 μg-atoms/L at the northern part of the Antarctic convergence. At the subtropical convergence the change was not so clear as that at the Antarctic convergence.

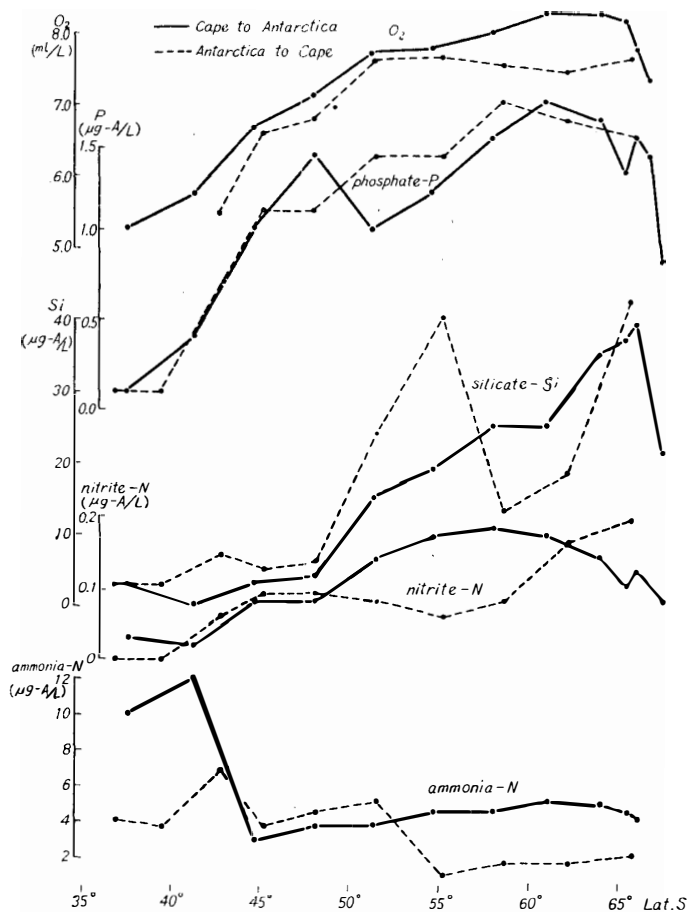Higher value of ammonia-N of 10 μg-atoms/L was shown between 37°S and

41°S, but it rapidly decreased to 4 μg–atoms/L near the subtropical convergence and the value of about 4–5 μg–atoms/L continued to the edge of the ice sea. On the contrary, little change was found at the Antarctic convergence. On the return cruise a remarkable change was also found at the subtropical convergence.

Concerning nitrite–N, rapid increase from 0. 02 μg–atoms/L to 0. 08 μg–atoms/L was observed at the subtropical convergence and it was 0.14 μg–atoms/L at the Antarctic convergence, 0. 18 μg–atoms/L between 58°S and 61°S. Nitrite–N was generally rich at the edge of the Continent. On the return cruise no difference was observed at all and only a trace amount was present in the northern region of the subtropical convergence.

As to the surface phosphate–P, in the northern part of the subtropical convergence it showed the content of about 0. 1 – 0. 4 μg–atoms/L, but near the subtropical convergence higher values, more than 1. 0 μg–atoms/L, were found. The result showed that the phosphate–P was comparatively rich in the pack ice region near the Continent. The same tendency was confirmed also on the return cruise.

The facts as stated above belong to the results of observations during the period from December 1957 to March 1958. The observation results made during the period from December 1958 to February 1959 are shown in Fig. 4.
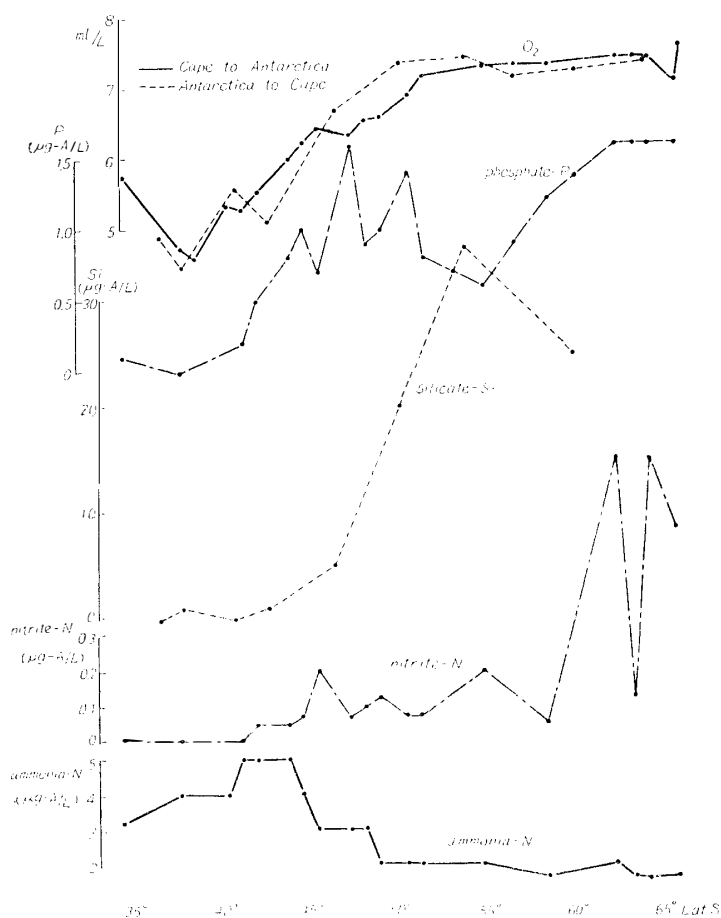

Fig. 4. Variations of dissolved oxygen, phosphate–P, nitrite–N and ammonia–N (Dec. 1958–Feb. 1959).

3. 1. 3. THE DISTRIBUTION OF THE TOTAL CARBONIC ACID SUBSTANCE

By using CONWAY's micro-diffusion method, the total carbonate in sea water was determined and from these observations the content of the free carbonic acid was calculated using the observed values of pH, water temperature and chlorinity by SARUHASHI's table. The values of CO_2, CO_2/Cl and the partial pressure of dissolved free H_2CO_3, Pco_2 will be given in Table 2-1 and 2-2.

The amount of the total carbonate increased as the observation stations approached the Continent. And the value of CO_2/Cl also increased from 0.097 to 0.116 near the subtropical convergence. Nearly the same value was observed at the edge of pack ice region.

The partial pressure, Pco_2 of free carbonic acid in surface sea water was calculated to be 5.3 $\times 10^{-4}$ atm. press. at the subtropical convergence, 6.1 $\times 10^{-4}$ atm. press. at the Antarctic convergence and approaching the ice sea

Fig. 5. Variation of the partial pressure of free carbon dioxide in sea waters between Cape Town and Lützow-Holm Bay.

higher values of Pco_2 were generally observed.

On the homeward cruise, in the floating ice zone, a higher value of Pco_2 of 6×10^{-4} atm. press. was observed and Pco_2 reduced gradually as we progressed northward.

This fact suggests that in summer Pco_2 in the surface water is greater than that of the atmosphere and it is evident that there is a condition to release CO_2 into the atmosphere from the ocean. The relation between pH and Pco_2 is given in Fig. 4, which shows the fact that observed Pco_2 in sea water is higher than averaged values of Pco_2 calculated by MCCLENDON.

3. 2 Observations in the pack ice region

After the " Soya " arrived at the outer boundary of the pack ice region of the Enderby

Fig. 6. The relation between pH and the partial pressure of carbon dioxide in sea waters.

Land (64°11′S, 53°48′E) on the 20 th of December, 1957, she was stuck in the ice. She could hardly escape from the pack ice region on the 6 th of February, 1958. During this period vertical observations of the sea were done at following three stations.

    (A) Lat. 66°46′S, Long. 41°18′E   (B) Lat. 67°46′S, Long. 38°53.5′E
    (C) Lat. 68°32′S, Long. 36°30′E

Vertical distribution of water temperature at three stations in and near Lützow-Holm Bay is illustrated in Fig. 7. Station (A) is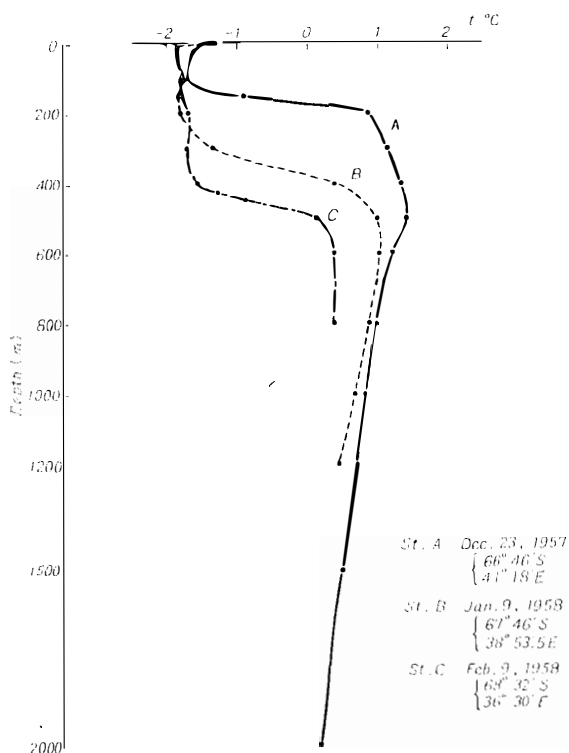 located near the outer boundary of the pack ice region, and Station (C) is in the middle of the Bay surrounded by thick ice floes, while Station (B) is situated between (A) and (C). As shown in the figure the surface layer, with a temperature of about −1.8°C, became thicker as observation stations approached the inside of the pack ice region, the thickness being approximately 100 m, 300 m, and 400 m respectively at Stations (A), (B) and (C). From vertical distribution curves, it is to be observed that the depth of the minimum temperature layer was found between 10 and 100 meters deep. On the other hand, the maximum temperature layer in Antarctic circumpolar water was observed between 500 and 600 meters deep, and the higher the latitude, the deeper the layer of maximum temperature. This suggests that the higher the latitude, a more violent mixing occurs between the surface and the Antarctic circumpolar waters. If the layer with the water temperature of 0°C is regarded as the lowest limit of Antarctic surface water, the thickness of surface water increased regularly in the order of (A), (B) and (C) (respectively 200, 400 and 500 meters).

Fig. 7. Vertical distribution of water temperature near Antarctica.

As to pH and the chlorinity, in the surface water pH was below 8.0 and the chlorinity was as low as 18.85‰, while in Antarctic circumpolar water pH exceeds 8 and the chlorinity attains the constant value of about 19.21‰, down to 2000 m at Station A (Figs. 8–1, 9–1, 10). From this observed fact it may be considered that the water mass with the chlorinity of 19.21‰ was present in a very large amount in subsurface waters around Antarctica. The lower chlorinity found near the surface might result from the melting of older pack ice, run-off of glacial water, and the excess of precipitation over evaporation.
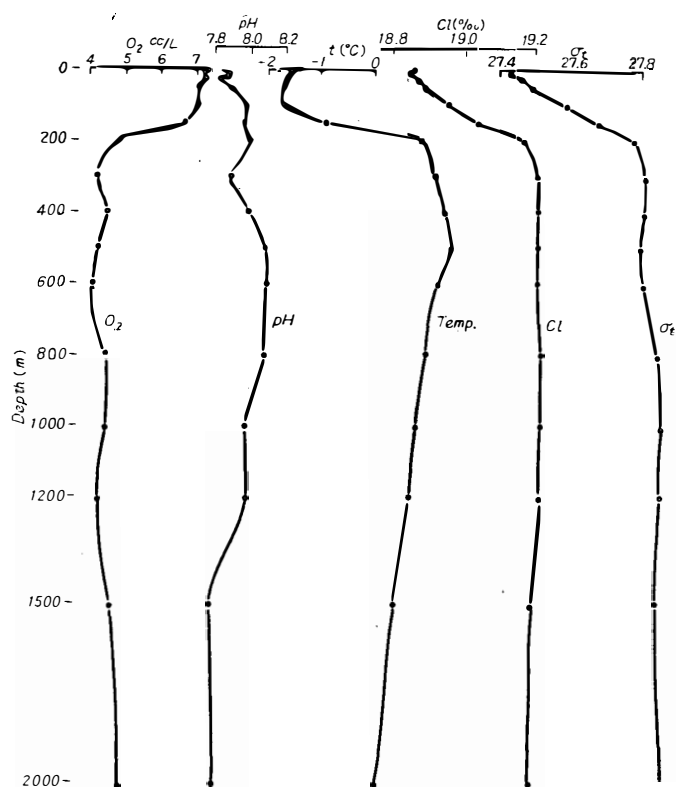
Fig. 8-1. Vertical distribution of dissolved oxygen, pH, temperature, chlorinity and σ_t at Station A.
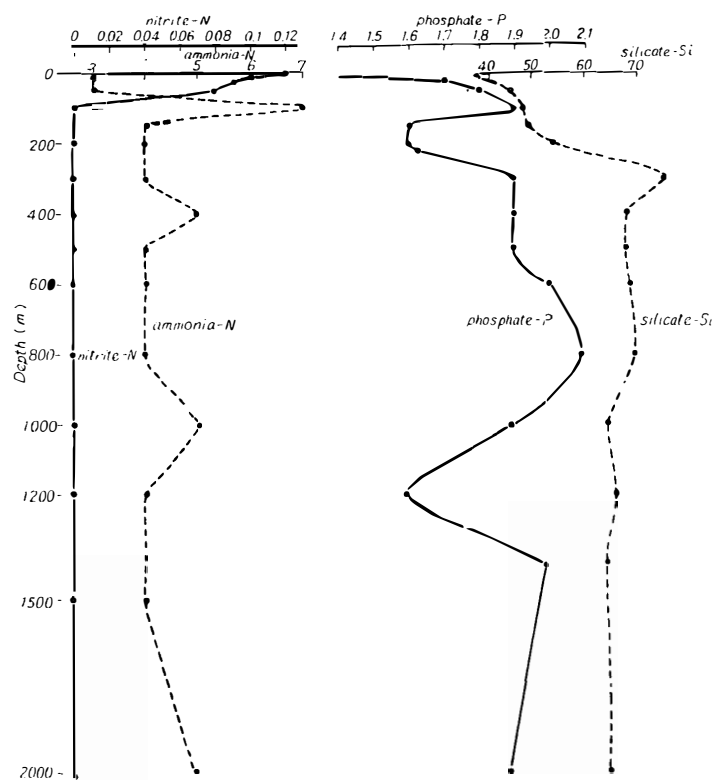
Fig. 8-2. Vertical distribution of nutrient matter at Station A. (unit, μg-atoms/L)
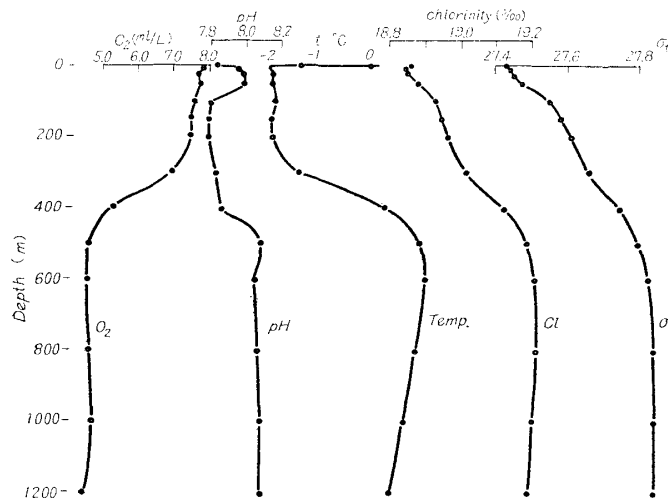
Fig. 9-1. Vertical distribution of dissolved oxygen, pH, temperature,
          chlorinity and σ_t at Station B.
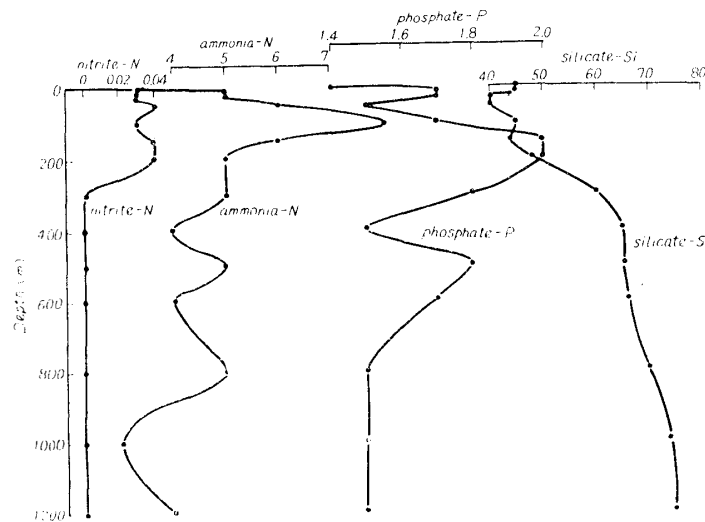
Fig. 9-2. Vertical distribution of nutrient matter at Station B.
          (unit, μg-atoms/L)

The mass and thickness of Antarctic circumpolar water with the chlorinity of

Fig. 10. Vertical distribution of pH, temperature,
         chlorinity and σ_t at Station C.

19.21‰, are large. The density of this water is also practically constant. But it was observed that the rate of mixing between the surface and the Antarctic circumpolar water was so great near the Continent that the interface could not be clearly observed (Fig. 10).

The amount of dissolved oxygen was about 7 ml/L in the surface

water, but it decreases to 4 ml/L in Antarctic circumpolar water. At the depth

where the water temperature was observed to be maximum, the minimum content of oxygen was observed, and at a deeper layer an increasing amount of oxygen was observed again.

The results of determination of the distribution of nutrient matter are as follows (Figs. 8-2, 9-2).

The higher and the uniform distribution of phosphate, silicate and ammonia contents around the Antarctic Continent would suggest the uniformity of the circumpolar water.

Concerning phosphate and ammonia, the contents in surface water were respectively about 1.4 μg–atoms/L and 3 μg–atoms/L and a few changes were observed in the vertical direction.

Silicate in surface water was more than 40 μg–atoms/L and increased with the depth. The vertical gradient is greater and a content of silicate in circumpolar water of more than 70 μg–atoms/L was found.

As regards nitrite, from 0.03 to 0.12 μg–atoms/L was found in the surface layer. It decreased with the depth and finally, only a trace amount was observed in circumpolar water.

From surface water down to 2000 meters (Table 8) the content of the total carbonic acid showed the value of about 1.98 m. mol/L. Judging from vertical distribution of density *in situ* of sea water, it was clearly observed that the uniformity of the total carbonic acid content was due to the vertical mixing of sea water. From the determination of total carbonate, the partial pressure P_{CO_2} *in situ* of CO_2 or H_2CO_3 in sea water was calculated. It was noticed that P_{CO_2} in sea water exceeds that in the atmosphere (0.03%). In the Antarctic Ocean, and especially near Antarctica, it was as high as 6.0×10^{-4} atm. press.

Table 1-1 Oceanographical data observed by the observation ship,

Station No.	Date	Location Lat.	Location Long.	Temp. (°C)	Chlorinity (‰)	Salinity (‰)	σt
1	Dec. 12	37-37.0 S	21-26.0 E	20.4	19.61	35.43	25.00
2	13	41-17.0 S	25-02.0 E	15.6	19.56	35.34	26.12
3	14	44-36.0 S	28-42.0 E	8.5	18.96	34.25	26.62
4	15	48-05.0 S	32-15.0 E	5.5	18.77	33.91	26.78
5	16	51-16.0 S	35-57.0 E	2.5	18.78	33.93	27.09
6	17	54-40.0 S	40-13.0 E	3.0	18.80	33.96	27.08
7	18	58-02.0 S	44-42.0 E	0.3	18.74	33.86	27.19
8	19	61-01.0 S	49-07.0 E	−0.3	18.76	33.89	27.25
9	20	63-58.0 S	53-29.0 E	−1.0	18.70	33.78	27.19
10*	21	65-31.0 S	49-14.0 E	−1.0	18.69	33.77	27.18
11*	22	66-00.0 S	43-17.0 E	−0.3	18.74	33.86	27.22
12*	23	66-52.0 S	44-17.0 E	−1.4	18.84	34.04	27.41
13*	30	67-28.2 S	60-13.4 E	−1.1	18.84	34.04	27.40

* Observation in pack ice region.

Table 1-2 Oceanographical data observed by the observation ship,

Station No.	Date	Location Lat.	Location Long.	pH	Temp. (°C)	Chlorinity (‰)	Salinity (‰)
14	Feb. 25	65-43.4 S	30-23.4 E	7.90	1.5	18.72	33.80
15	26	62-09.2 S	28-23.0 E	7.92	2.1	18.70	33.78
16	27	58-47.4 S	26-41.0 E	7.91	2.2	18.76	33.89
17	28	55-12.0 S	25-11.0 E	7.89	2.0	18.80	33.96
18	Mar. 1	51-24.0 S	23-39.0 E	7.82	3.0	18.83	34.02
19	2	48-02.0 S	22-34.0 E	7.89	6.8	18.72	33.82
20	3	45-12.0 S	21-42.0 E	7.90	7.5	18.80	33.96
21	4	42-43.5 S	21-00.0 E	8.00	15.8	19.65	33.50
22	5	39-29.5 S	20-14.1 E	8.05	21.3	19.67	35.53
23	6	36-51.5 S	18-41.0 E	8.10	20.5	19.68	35.55

the Soya, between Cape Town and Lützow-Holm Bay.

O_2 (cc/L)	O_2/O'_2 (%)	pH	Silicate-H (μg-atoms/L)	Ammonia-N (μg-atoms/L)	Nitrite-N (μg-atoms/L)	Phosphate-P (μg-atoms/L)
5.25	99	8.20	3	10	0.03	0.1
5.74	100	8.14	tr.	12	0.02	0.4
6.68	100	8.00	3	2.8	0.08	1.0
7.11	100	8.00	4	3.6	0.08	1.4
7.70	101	7.90	15	3.6	0.14	1.0
7.75	103	7.98	19	4.4	0.17	1.2
7.97	99	7.89	25	4.4	0.18	1.5
8.24	101	7.90	25	5.0	0.17	1.7
8.23	99	7.90	35	4.8	0.14	1.6
8.13	98	7.87	37	4.4	0.10	1.3
7.72	94	7.85	39	4.0	0.12	1.5
7.30	87	7.83	—	—	—	1.4
—	—	7.70	21	—	0.08	0.8

the Soya, between Lützow-Holm Bay and Cape Town.

σt	O_2 (cc/L)	O_2/O'_2 (%)	Silicate-Si (μg-atoms/L)	Ammonia-N (μg-atoms/L)	Nitrite-N (μg-atoms/L)	Phosphate-P (μg-atoms/L)
27.08	7.60	97	42	2.0	0.19	1.5
27.02	7.42	96	18	1.6	0.16	1.6
27.09	7.51	98	13	1.6	0.08	1.7
27.17	7.62	98	40	0.9	0.06	1.4
27.13	7.59	101	24	5.0	0.08	1.4
26.54	6.79	98	6	4.4	0.09	1.1
26.56	6.59	97	5	3.6	0.09	1.1
26.20	5.48	96	7	6.8	0.06	0.7
24.84	—	—	3	3.6	0.00	0.1
25.07	—	—	3	4.0	0.00	0.1

Table 2-1. The distribution of total carbonic acid substance and partial pressure
of CO_2 in sea water between Cape Town and Lützow-Holm Bay.

Station No.	Location Lat.	Location Long.	pH	Temp. (°C)	Cl (‰)	ΣCO_2 (m. mol/L)	ΣCO_2/Cl	$P_{CO_2} \times 10^4$ (atm. press.)
1	37°37′0 S	21°26′0 E	8.20	20.4	19.61	1.99	0.102	4.0
2	41°17′0 S	25°02′0 E	8.14	15.6	19.56	1.98	0.097	5.0
3	44°36′0 S	28°42′0 E	8.00	8.5	18.96	2.20	0.116	5.3
4	48°05′0 S	32°15′0 E	8.00	5.5	18.77	2.19	0.116	5.2
5	51°16′0 S	35°57′0 E	7.90	2.5	18.78	2.03	0.118	6.1
6	54°40′0 S	40°13′0 E	7.98	3.0	18.80	2.06	0.110	4.5
7	58°02′0 S	44°42′0 E	7.89	0.3	18.74	2.24	0.119	6.2
8	61°01′0 S	49°07′0 E	7.90	−0.3	18.76	2.03	0.108	5.7
9	63°58′0 S	53°29′0 E	7.90	−1.0	18.70	2.20	0.122	7.1
10	65°31′0 S	49°14′0 E	7.87	−1.0	18.69	2.18	0.117	6.7

Table 3. Subsurface oceanographic observation

Depth (m)	Temp. (°C)	Chlorinity (‰)	Salinity (‰)	σt	O_2 (cc/L)
0	−1.4	18.86	34.07	27.43	7.30
10	−1.56	18.85	34.05	27.43	7.19
25	−1.65	18.87	34.09	27.46	7.21
50	−1.68	18.89	34.12	27.49	7.06
100	−1.70	18.96	34.25	27.59	7.07
150	−0.91	19.04	34.39	27.68	6.62
200	−0.88	19.17	34.63	27.78	4.84
300	1.13	19.21	34.70	27.81	4.21
400	1.33	19.21	〃	27.81	4.51
500	1.43	19.21	〃	27.80	4.24
600	1.22	19.21	〃	27.81	4.12
800	0.98	19.22	34.72	27.85	4.53
1000	0.83	19.22	〃	27.86	4.52
1200	0.69	19.22	〃	27.86	4.34
1500	0.44	19.20	34.69	27.85	4.72
2000	0.13	19.20	〃	27.87	5.01

Bottom depth (m): 4100

Table 2-2.   The distribution of total carbonic acid substance and partial pressure of
CO_2 in sea water between Lützow-Holm Bay and Cape Town.

| Station | Location | | pH | Temp. | Cl | ΣCO_2 | $\Sigma CO_2/Cl$ | $Pco_2 \times 10^4$ |
No.	Lat.	Long.		(°C)	(‰)	(m. mol/ L)		(atm. press.)
14	65°43′4 S	30°23′4 E	7.90	1.5	18.72	2.17	0.116	6.2
15	62°09′2 S	28°23′0 E	7.92	2.1	18.70	—	—	—
16	58°47′4 S	26°41′0 E	7.91	2.2	18.76	2.42	0.129	6.8
17	55°12′0 S	25°11′0 E	7.89	2.0	18.80	—	—	—
18	51°24′0 S	23°39′0 E	7.82	3.0	18.83	2.45	0.131	9.0
19	48°02′0 S	22°34′0 E	7.89	6.8	18.72	1.92	0.103	5.5
20	45°12′0 S	21°42′0 E	7.90	7.5	18.80	1.78	0.095	5.5
21	42°43′5 S	21°00′0 E	8.00	15.8	19.65	1.99	0.102	5.1
22	39°29′5 S	20°14′1 E	8.05	21.3	19.67	2.11	0.108	5.3
23	36°51′5 S	18°41′0 E	8.10	20.5	19.68	1.69	0.086	3.5

(A), 23 Dec. 1957, Lat. 66°46′S, Long. 41°18′E.

O_2/O'_2 (%)	pH	Silicate-Si (μg-atoms/L)	Ammonia-N (μg-atoms/L)	Nitrite-N (μg-atoms/L)	Phosphate-P (μg-atoms/L)
87	7.83	42	3.0	0.12	1.4
86	7.88	39	3.0	0.10	1.4
86	7.83	42	3.0	0.09	1.7
84	7.89	46	3.0	0.08	1.8
84	7.98	48	7	Nil	1.9
81	7.97	49	4	//	1.6
61	8.00	54	4	//	1.6
54	7.89	75	4	//	1.9
58	8.00	68	5	//	1.9
54	8.09	68	4	//	1.9
53	8.10	69	4	//	2.0
58	8.10	70	4	//	2.1
58	7.99	65	5	//	1.9
55	8.00	67	4	//	1.6
59	7.80	65	4	//	2.0
62	7.83	66	5	//	1.9

Table 4. Subsurface oceanographic observation

Depth (m)	Temp. (°C)	Chlorinity (‰)	Salinity (‰)	σt	O_2 (cc/L)
0	−1.3	18.86	34.07	27.43	7.89
10	−1.88	18.85	34.05	27.44	7.79
25	−1.82	18.86	34.07	27.45	7.70
50	−1.83	18.88	34.11	27.47	7.72
100	−1.77	18.93	34.17	27.55	7.56
150	−1.82	18.95	34.24	27.58	7.49
200	−1.81	18.97	34.27	27.61	7.45
300	−1.34	19.02	34.36	27.66	6.97
400	0.34	19.13	34.56	27.75	5.29
500	0.98	19.19	34.67	27.80	4.68
600	1.04	19.21	34.70	27.83	4.66
800	0.87	19.22	34.72	27.85	4.72
1000	0.66	19.21	34.70	27.85	4.83
1200	0.43	19.20	34.69	27.85	4.65

Bottom depth (m) : 3620

Table 5. Subsurface oceanographic observation
(C), 9 Feb. 1958, Lat. 68°32′S, Long. 36°30′E.

Depth (m)	Temp. (°C)	Chlorinity (‰)	Salinity (‰)	σt	pH
0		18.81	33.98		8.00
10	−1.83	18.81	33.98	27.38	8.00
25	−1.83	18.82	34.00	27.39	8.11
50	−1.82	18.82	34.00	27.39	8.13
100	−1.77	18.86	34.07	27.44	8.10
150	−1.75	18.88	34.10	27.48	8.15
200	−1.70	18.92	34.18	27.53	8.20
300	−1.72	18.97	34.27	27.61	8.20
400	−1.59	19.01	34.34	27.66	8.07
500	+0.11	19.15	34.60	27.80	8.10
600	+0.37	19.19	34.67	27.84	8.13
800	+0.37	19.24	34.76	27.92	8.15

Bottom Depth (m) : 880

(B), 9 Jan. 1958, Lat. 67°46.0'S, Long. 38°53.5'E.

O_2/O'_2 (%)	pH	Silicate-Si (μg-atoms/L)	Ammonia-N (μg-atoms/L)	Nitrite-N (μg-atoms/L)	Phosphate-P (μg-atoms/L)
94	7.84	45	3	0.03	1.4
92	7.96	45	5	0.03	1.7
91	8.00	40	5	0.03	1.7
91	8.00	40	6	0.04	1.5
89	7.80	45	8	0.03	1.7
89	7.80	44	6	0.04	2.0
88	7.80	48	5	0.04	2.0
85	7.84	60	5	trace	1.8
66	7.87	65	4	//	1.5
60	8.10	65	5	nil	1.8
59	8.06	66	4	trace	1.7
60	8.08	70	5	//	1.5
61	8.10	74	3	//	1.5
58	8.10	75	4	//	1.5

Table 6.   Vertical distribution of total CO_2 in sea water at Station A.

Depth (m)	Chlorinity (‰)	Temp. (°C)	pH	Total CO_2 (m. mol/L)	$\Sigma CO_2/Cl$
0	18.68	−1.4	7.83	1.98	0.105
10	18.85	−1.56	7.88	2.39	0.126
25	18.87	−1.65	7.83	1.94	0.103
50	18.89	−1.68	7.89	1.96	0.103
100	18.96	−1.70	7.98	1.86	0.096
150	19.04	−0.90	7.97	1.86	0.098
200	19.17	0.88	8.00	1.92	0.100
300	19.21	1.13	7.89	1.81	0.094
400	19.21	1.33	8.00	1.90	0.099
500	19.21	1.43	8.09	1.84	0.096
600	19.21	1.22	8.10	1.94	0.101
800	19.22	0.98	8.10	1.90	0.099
1000	19.22	0.83	7.99	1.88	0.098
1200	19.22	0.69	8.00	1.94	0.101
1500	19.20	0.44	7.80	1.98	0.103
2000	19.20	0.13	7.83	2.00	0.104

Table 7. Vertical distribution of total CO_2 in sea water at Station B.

Depth (m)	Chlorinity (‰)	Temp. (°C)	pH	Total CO_2 (m. mol./L)	$\Sigma CO_2/Cl$
0	18.86	−1.3	7.84	1.83	0.0970
10	18.85	−1.88	7.96	1.82	0.0966
25	18.86	−1.82	8.00	1.85	0.0981
50	18.88	−1.83	8.00	1.75	0.0927
100	18.93	−1.77	7.80	1.80	0.0951
150	18.95	−1.82	7.80	1.82	0.0960
200	18.97	−1.81	7.80	1.94	0.1023
300	19.02	−1.34	7.84	1.87	0.0983
400	19.13	0.34	7.87	1.80	0.0941
500	19.19	0.98	8.10	1.95	0.1017
600	19.21	1.04	8.06	1.83	0.0953
800	19.22	0.87	8.08	1.88	0.0979
1000	19.21	0.66	8.10	1.93	0.1005
1200	19.20	0.43	8.10	1.89	0.0985

Table 8. Vertical distribution of total CO_2 in sea water at Station C.

Depth (m)	Chlorinity (‰)	Temp. (°C)	pH	Total CO_2 (m. mol./L)	$\Sigma CO_2/Cl$
0	18.81		8.00	2.31	0.1228
10	18.81	−1.83	8.00	—	—
25	18.82	−1.83	8.11	—	—
50	18.82	−1.82	—	—	—
100	18.86	−1.77	8.10	2.09	0.1108
150	18.88	−1.75	8.15	2.05	0.1087
200	18.92	−1.70	8.20	1.98	0.1047
300	18.97	−1.72	8.20	2.10	0.1107
400	19.01	−1.59	8.07	2.22	0.1168
500	19.15	0.11	8.10	—	—
600	19.19	0.37	8.13	2.21	0.1152
800	19.24	0.37	8.15	1.99	0.1035