A Preliminary Report on Geochemistry of the Antarctic Ocean and Adjacent Seas

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南極海およびその関連海域における海洋化学的研究

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要 旨

第7次南極観測においては，海洋化学的研究として，南極海およびその関連海域において大気および表面海水中の炭酸ガス分圧の測定，海水中に溶存する炭酸物質および溶存鉄の定量を船上で行なった．なお全鉄，全リン，全ホー素等の研究用として試水を採取した．

第一報として船上分析の結果について報告する．

1. Introduction

Before the 7th Japanese Antarctic Research Expedition (JARE-7) was commerced the geochemical investigation committee discussed the investigation projects to be conducted during the Expedition. In compliance with the resolution made by the committee, the following studies were carried out.

Partial pressures of carbon dioxide in the air and in the surface water were measured along the cruise to investigate the carbon dioxide exchange through the boundary between the atmosphere and the hydrosphere. The phosphorus, iron and boron contents in sea water were also studied.

Analyses of the carbonic acid substances and the biologically reactive iron in sea water were carried out on board the R. V. Fuji. This paper is preliminary report of the results of these works with respect to carbon dioxide and iron. The results of the observations are summarized at the end of the paper.

Water samples were collected for analyses of the total phosphorus, the total iron and the total boron which were brought to the laboratory on land. The results of the analyses of these elements will be reported later in a separate paper.

2. Analytical methods

1) Partial pressure of carbon dioxide in the air

Infrared Gas Analyser, Model I. R.-315, mannufactured by Beckman-Toshiba Company was used. For the purpose of obtainning higher precision of measurement, the analyser was partly reconstructed by modifying the standard type,

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using a long cell of 30 cm length and having a precision of 1% over a whole span of 150 ppm ranging from 250 to 400 ppm of the carbon dioxide content.

The factors influencing the analyser readings are water vapour in air sample, temperature and the total pressure of the air sample in the cell. To remove dusts and water vapour, a special filter, which does not absorb any gas, and a phosphorus pentoxide drying column are installed on the way of the gas stream. The temperature of the sample in the cell is regulated constant at 60°C by an automatic heating device. Before each measurement, calibration of the analyser must be performed by flowing the nitrogen gases which contain lower concentration of carbon dioxide (300 ppm) and higher concentration (390 ppm) for reference standards. Pressure effect of measurement can be eliminated by adjusting the flow rate of the sample gas to the same flow rate as employed in the calibration.

For an infrared analysis of the partial pressure of carbon dioxide in sea water, an attached instrument was designed in order to equilibrate the water with the circulating air, and then the air which reached the equilibrium with sea water was analyzed. But unfortunately the equilibrator did not work well due to the trouble in the part of its glass works.

2) pH and alkalinity

The pH was measured by a pH meter with a glass electrode and a temperature compensation electrode (Model HM-5A, Tōa-Denpa Company). The instrument has a precision of ± 0.03 in pH unit when the meter is standardized by using two standard buffer solutions of different pH.

Temperature of samples was quickly equilibrated with the laboratory temperature by immersing a sampling bottle in a water tank, and measurements were carried out within 3 hours after sampling. The measured pH (pHm) values were converted to the values of pH *in situ* (pHd) by the equation given by STRICKLAND.

$$pHd = pHm - a(t - t_m) - \beta d$$

Total alkalinity determinations were done by the method of STRICKLAND. Results of the total alkalinity are expressed per litre (20°C) on the volume basis.

Carbonic acid substances in sea water such as specific alkalinity, carbonate alkalinity, the total carbon dioxide and partial pressure of carbon dioxide in sea water are calculated using the observed values of temperature, salinity, pHd and the total alkalinity of sea water by referring to the equations and related coefficients given by STRICKLAND. Coefficients for the second decimal of pH values are read with a graphical interpolations.

3) Soluble and particulate iron

For the determination of soluble and particulate iron in sea water, the meth-

ods of STRICKLAND were employed, and 500 m*l* of sea water sample was filtered through a Millipore HA filter. For the determination of soluble iron, 200 m*l* of filtrate was treated with dilute hydrochloric acid in an acetate buffer in the presence of hydroxylamine and then bathophenanthroline was added. For the determination of particulate a Millipore HA filter was treated with hot dilute hydrochloric acid (95–100°C, 10%HCl) for 15 min. The iron thus brought into solution was added with α, α'-dipyridyl in an acetate buffer in the presence of hydroxylamine. After the maximum colour developed, the extinction of the solution in 10 cm cell was measured using a wave length of 533 mμ and 522 mμ respectively against a reference of distilled water by a Hitachi Model 139 Spectrophotometer. True extinction can be obtained by subtracting a blank.

3. Results of observations

Partial pressures of carbon dioxide in the air above the ocean are shown in Table 1 and Fig. 2. In Table 1, values of partial pressure of carbon dioxide are summarized at intervals of 10 degrees of latitude. It is to be noted that the carbon dioxide content decreases regularly from the north toward the south. The mean value of 144 measurements in the area of 30°N–70°S and 10°E–140°E was 319.3 ppm, 324.3 ppm in the northern hemisphere, and 317.4 ppm in the southern hemisphere, respectively. In the latitudinal area higher than 50°S the partial pressure of car-

Table 1. Partial pressure of CO_2 in the air over the ocean

Latitude	Cruise A and B		Cruise C, D and E		Whole cruises	
					*	** ***
		ppm				
30 ~ 40° N	4	328.2	8	324 4	12	325 7±6 1
20 ~ 30	2	325 3	5	325 1	7	325 1±1 4
10 ~ 20	2	325 7	6	324 2	8	324 6±1 7
0 ~ 10° N	3	317.8	16	323 2	19	322 1±2 7
0 ~ 10° S	2	319 5	3	321 0	5	320 4±2 0
10 ~ 20	2	317.7	6	320 2	8	319 6±2 5
20 ~ 30	2	318 0	9	317 7	11	317 7±2 1
30 ~ 40	4	318 3	9	316 8	13	317 2±2 0
40 ~ 50	6	217 2	3	316 7	9	317 0±1 3
50 ~ 60					10	316 1±2 7
60 ~ 70					39	317 1±2 6
70 ~					3	315.7±1 7
	27	320 6	65	320 8	144	319 3

* *numbers of measurements*
** *mean value.*
*** *standard deviation*

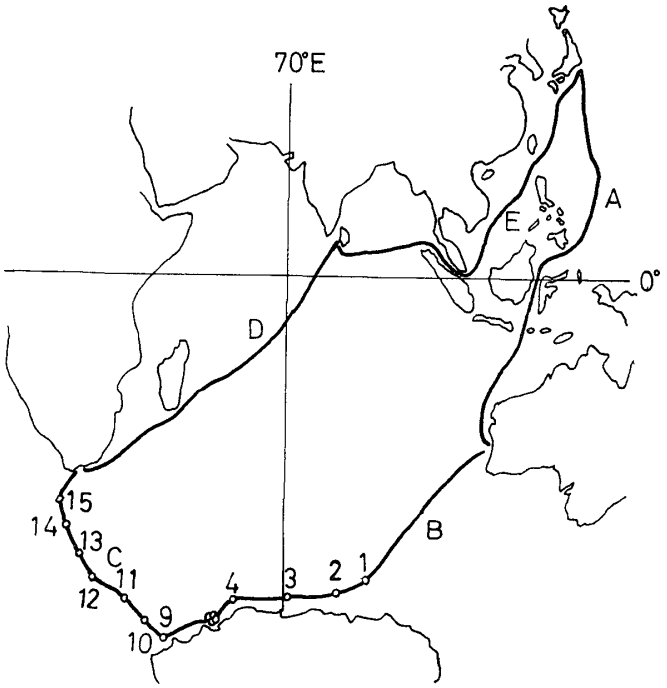

Fig. 1. Cruise chart and hydrographic stations

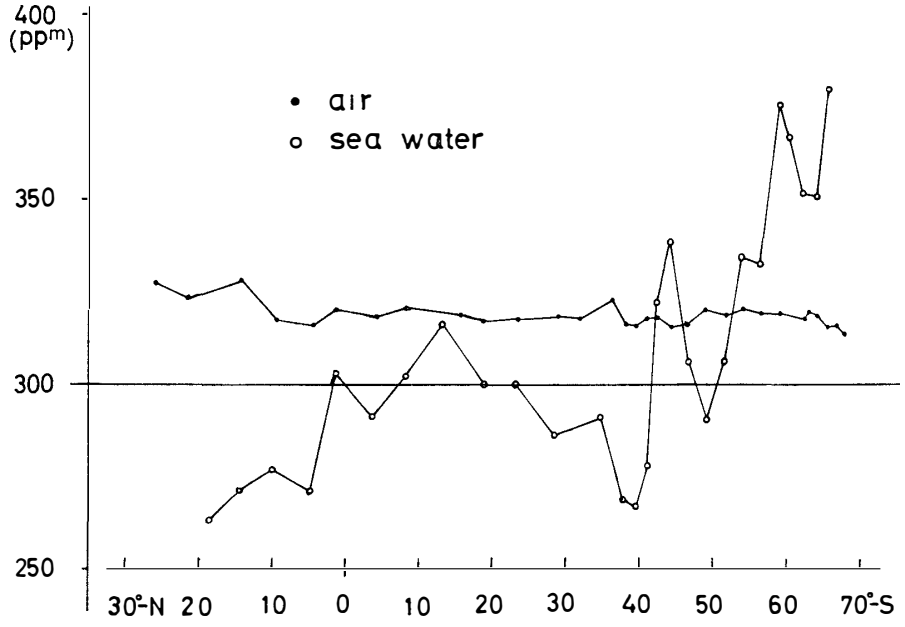

Fig 2. Partial pressure of CO_2 in the air and in surface water along the cruise A and B.

bon dioxide showed the lowest value, 316.8 ppm on an average. In the higher latitudinal area than 30°N, the values are the highest and fluctuate remarkably (standard deviation, 6.1 ppm). This result seems to reflect the effect of carbon dioxide

which is mostly released in the air in the northern hemisphere.

The variation in the meridional direction appears to be much smaller than that in the latitudinal direction.

Diurnal variation of the partial pressure of carbon dioxide does not exceed 6 ppm over the ocean. The maximum occurs at the time from midnight to early morning, and the minimum in the afternoon. To eliminate the effect of diurnal variation the time for daily measurement was fixed at 9 and 21 o'clock.

The partial pressure of carbon dioxide in surface water varies in wider range as compared with those in the air In the equatorial region, the partial pressure of carbon dioxide in surface water is slightly lower than that in the air, and in the middle latitude between 20°–40° both north and south it is much lower than that in the air. On the contrary, in the latitudinal area in the Antarctic Ocean higher than 50°S, the partial pressure of carbon dioxide in sea water is much higher than that in the air. So, it may be said that there is a tendency that carbon dioxide in the Antarctic region moves from the sea surface toward the air, whereas an opposite tendency is noticed in the northern region

The pH values of the surface water are comparatively constant, ranging from 8.24 to 8.29 in the northern area than 40°S, and begin to fall suddenly at 40°S and gradually to 8.06 toward the south. There seems to be a slight correlation between the variations of pH and the water temperature but not always parallel.

The content of the total carbon dioxide is low and nearly constant in the northern hemisphere with the value of 2.0 m mole/*l*, but gradually increases toward

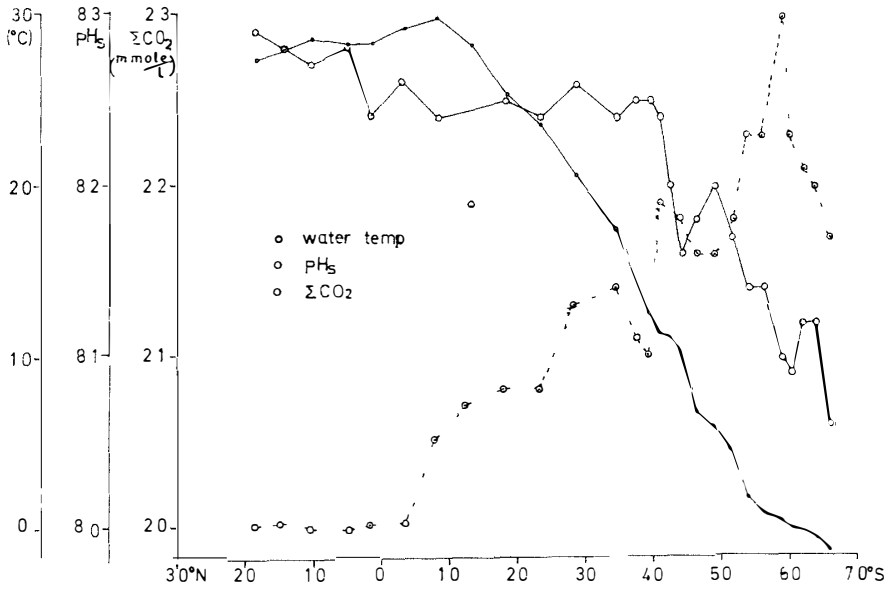

Fig 3 pH in situ and total CO_2 in surface water

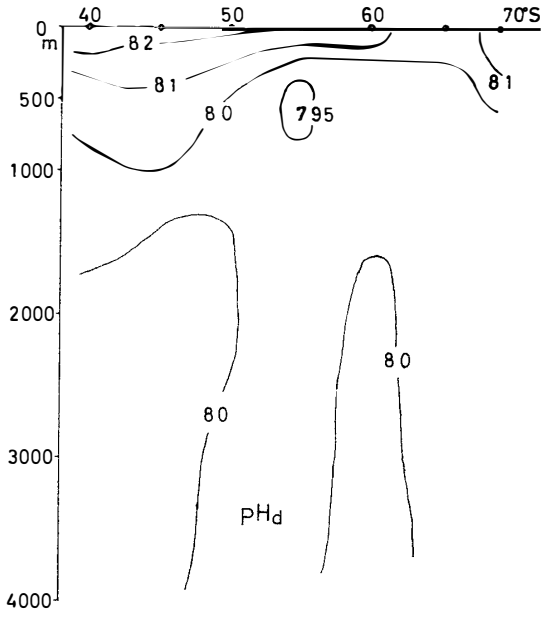

Fig 4 pH in situ in the profile C.

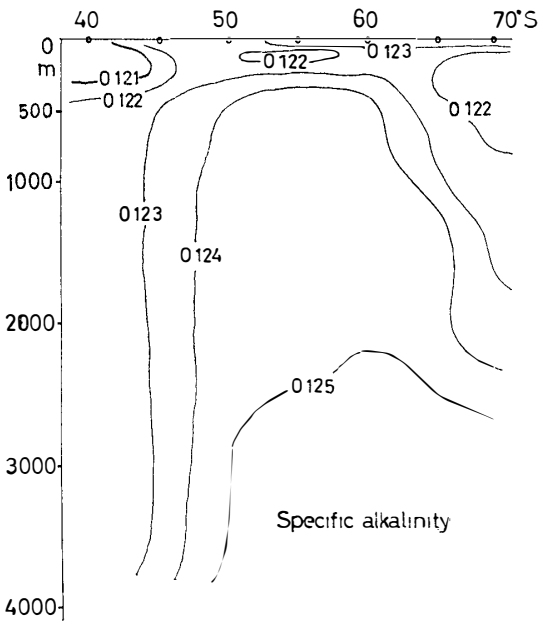

Fig. 5. Specific alkalinity in the profile C

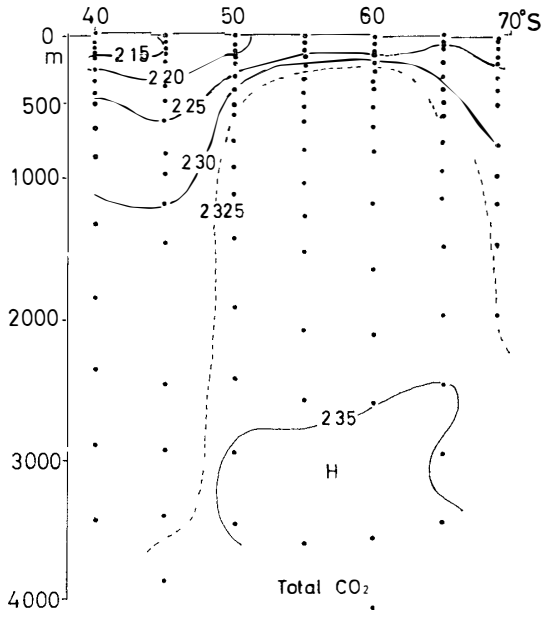

Fig 6 Total CO_2 (m mole/l) in the profile C

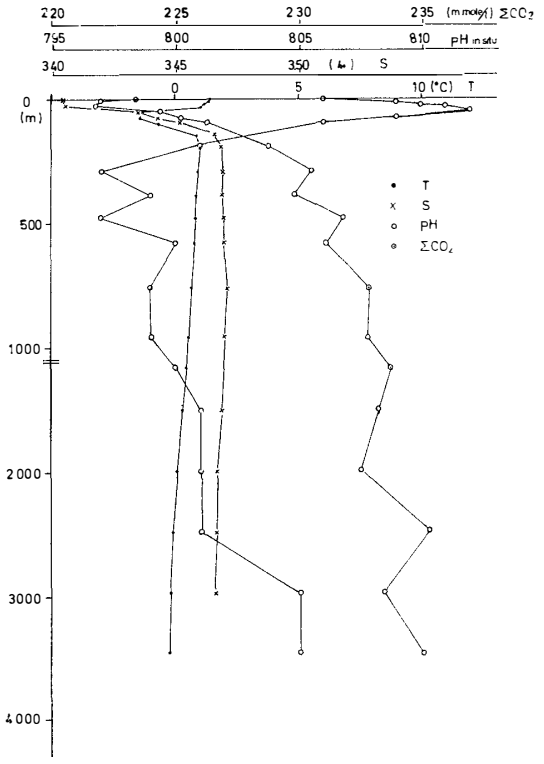

Fig. 7 Vertical distribution of pH in situ and total CO_2 at station 10 (Lat 64° 58 3′S, Long 13° 56.7′E).

the south to the value of 2.3 m mole/l in the southern hemisphere. Correlation of the carbon dioxide variation to the water temperature seems to be more distinct than that of pH.

Fig. 4 shows the vertical distribution of pH in the profile along the line from the Antarctic to South Africa. In the Antarctic region further south than 50°S, pH values in deep water below 200 m are nearly 8.0 and almost constant. In the latitudinal area lower than 50°S, values vary in a wider range from 7.96 to 8.26. The minimum layer of pH lies at the depth of 1000–1400 m.

Specific alkalinity in the profile C (from the Antarctic to South Africa) is shown in Fig. 5. The minimum value (0.121–0.122) lies at the depth of 50–200 m. Below this depth it increases with depth and reaches 0.125 in the south of 50°S and 0.123 in the north of 50°S in bottom water. Antarctic surface water has a specific alkalinity of 0.123 which spreads further toward the north to 55°–50°S.

The total carbon dioxide along profile C is shown in Fig. 6. The valus lie in the range of 2.10–2.37 m mole/l. The content increases from the surface to the depth of 200 m in the south of 50°S and to the depth of 1200 m in the north of 50°S Below these depths values of the total carbon dioxide are almost constant, being 2.35 in the south of 50°S and 2.30 in the north of 50°S in bottom water.

A sum of the soluble and the particulate iron represented by the amounts of the biologically reactive iron, as shown in Fig. 8. The analytical results of 108 samples collected at 15 serial observation stations show that the mean value of soluble iron is 0.10 μg-atoms/l and that of particulate iron is 0.05μg-atoms/l. The amounts of soluble iron vary in a very wide range, both horizontally and vertically, and the minimum value seems to occur at the depth of 50–300 m. The amounts of the particulate iron are generally low at the depth of 0–300 m, and become higher in waters deeper than 500 m.

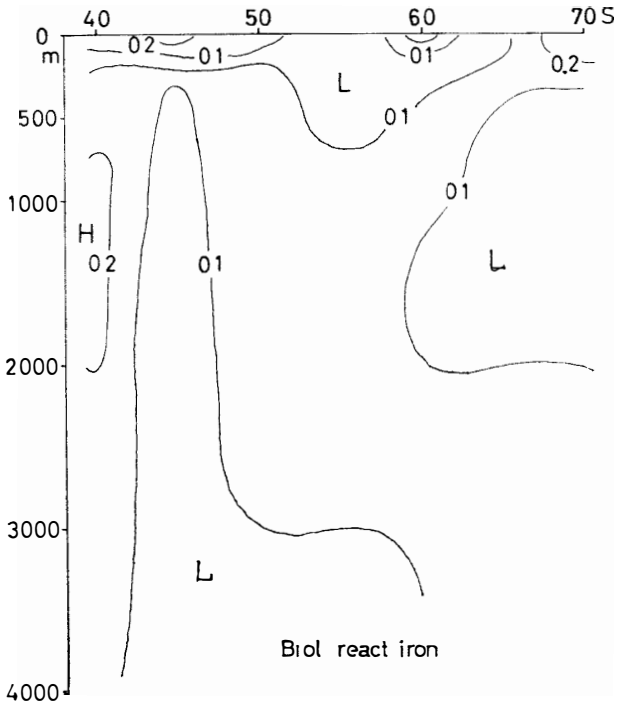

Fig. 8. Biological reactive iron in the profile C (μg-atoms/l).

The general trend of distribution of the biologically reac-

tive iron both horizontally and vertically is not clear in the present investigation.

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Appendices

St. No 1	Date Dec 18, 1965	Lat 59°16.′0 S	Depth	Weather
	Time 0300～0730	Long 97°19 ′0 E	4450m	cloudy

Depth m	T (°C)	S (‰)	pHd	Total A (mequi/l)	Specific A	ΣCO_2 (m mole/l)	Biol react iron (μg-atm/l)		
							sol	part	sol+part
0	0 2	34 03	8 09	2 47	0 128	2 32	0. 36	0 02	0 38
10	−0 05	03	04	—	—	—	—	—	—
20	−0 06	.03	16*	45	127	29	—	—	—
30	−0 03	03	08	—	—	—	—	—	—
50	−0 11	04	08	39	124	.25	0 02	0 08	0 10
75	−0 45	05	14*	42	125	26	—	—	—
100	−0 77	13	08	46	127	32	0 08	0 07	0 15
150	0 49	36	01	43	125	31	—	—	—
200	1 47	51	7 98	.46	126	35	—	—	—
293	1 84	62	98	46	125	35	0 09	0 17	0 26
391	1 87	67	96	48	126	38	—	—	—
486	1 85	70	94	48	126	39	0 01	0 28	0 29
580	1 81	72	97	46	125	36	—	—	—
770	1 65	74	99	48	126	37	—	—	—
965	1 49	74	8 00	49	126	38	0 13	0 02	0 15
1, 165	1 32	74	7 95	50	127	41	—	—	—
1, 380	—	72	95	48	126	39	—	—	—
1, 880	0 62	70	98	48	126	38	0 12	0 04	0 16
2, 380	0 36	69	98	48	126	38	—	—	—
2, 880	—	67	8 01	49	126	39	0 21	0 23	0 44
3, 380	0 00	67	01	48	126	38	—	—	—
3, 880	−0 09	67	01	48	126	38	0 23	0 10	0 33

* *value doubtful*

St No 2	Date Dec 19, 1965	Lat 63°00 ′4 S	Depth	Weather
	Time 1000～1330	Long. 89°12 ′0 E	3820m	snow

Depth m	T (°C)	S (‰)	pHd	Total A (mequi/l)	Specific A	ΣCO_2 (m mole/l)	Biol react iron (μg-atm/l)		
							sol	part	sol+part
0	−0 7	33 94	8 08	2 39	0 124	2 25	0 09	0 08	0 17
11	−1 36	93	08	38	124	24	—	—	—
20	−1 38	93	08	37	123	23	—	—	—
30	−1 42	93	08	37	123	23	—	—	—
47	−1 54	99	09	37	123	23	0 02	0 03	0 05
70	−1 54	34 23	08	38	122	24	—	—	—
93	−0 91	34	05	38	122	26	0 01	0 06	0 07
143	0 19	49	01	39	122	28	—	—	—
220	0 34	55	7 98	39	122	29	—	—	—
315	0 98	65	96	39	122	29	0 09	0 08	0 17
405	1 17	69	96	40	122	31	—	—	—
495	1 15	71	96	40	122	31	0 12	0 25	0 37
590	1 08	71	96	43	122	33	—	—	—
770	0 99	—	95	40	122	31	—	—	—
950	0 73	69	92	40	122	32	0 17	0 02	0 19
1. 150	0 62	69	94	42	123	34	—	—	—
1, 610	0 31	67	95	45	124	36	—	—	—
2, 070	0 09	67	93	43	123	35	0 07	0 04	0 11
2, 550	−0 06	67	92	42	123	34	—	—	—
3, 035	−0 19	66	93	42	123	34	0 24	0 10	0 34
3, 525	−0 24	66	92	40	122	33	0 25	0 12	0 37

St. No. 3	Date Dec. 21, 1965 Time 0930～1210	Lat. 64°17.′5 S Long. 71°15.′5 E	Depth 3440m	Weather cloudy

Depth m	T (°C)	S (‰)	pHd	Total A (mequi/l)	Specific A	ΣCO$_2$ (m mole/l)	Biol. react. iron (μg-atm/l)		
							sol	part	sol+part
0	−1 1	33.47	8 07	2 37	0 125	2 23	0 01	0.04	0.05
10	−1 29	.47	08	34	.124	21	—	—	—
20	−1 15	.58	08	.31	.122	.18	—	—	—
30	−1.31	34.00	.07	.33	.121	.19	—	—	—
50	−1 60	.18	.07	.35	.121	.22	0.00	0 03	0 03
75	−1 70	.26	.07	.37	.122	.23	—	—	—
100	−1 53	29	.07	.37	.122	.23	0 18	0 16	0 34
149	−0 65	.41	.03	.37	121	25	—	—	—
199	−0 46	.47	.01	37	.121	.26	—	—	—
296	1 32	.67	7 94	.38	.121	.30	0 13	0 02	0 15
394	1 25	.69	.94	.39	.122	.31	—	—	—
491	1 22	.70	96	38	121	28	0.19	0 06	0 25
605	1.19	.72	97	38	.121	28	—	—	—
800	1.01	.71	96	39	122	30	—	—	—
990	0 84	.71	.96	.39	122	30	0 23	0 19	0 42
1,190	0 73	.70	95	40	.122	31	—	—	—
1,480	0 52	.69	.95	.40	.122	31	—	—	—
1,970	0 24	.67	.93	.40	122	.32	0.09	0 16	0 25
2,460	−0 01	.66	.93	39	121	.31	—	—	—
2,950	−0.18	.66	.90	.40	.122	.33	0 16	0 02	0.18

St No 4	Date Dec. 24, 1965 Time 0840～1100	Lat. 64°36 ′0 S Long. 53°14 ′5 E	Depth 3500m	Weather snow

Depth m	T (°C)	S (‰)	pHd	Total A (mequi/l)	Specific A	ΣCO$_2$ (m mole/l)	Biol react iron (μg-atm/l)		
							sol	part	sol+part
0	−1 3	33 58	8 11	2 37	0 124	2 22	0 16	0 07	0 23
9	−1 48	.58	15	34	.123	19	—	—	—
18	−1 51	.69	15	.34	.123	.19	—	—	—
27	−1 55	34 06	.14	37	.123	21	—	—	—
46	−1 67	.09	.13	.37	.122	22	0.03	0 03	0 06
69	−1 72	.11	.13	.37	122	22	—	—	—
92	−1 55	.20	08	.37	122	23	0 01	0 01	0 02
135	0 88	.55	00	.39	.122	.28	—	—	—
185	1 65	67	7 99	.40	122	.29	—	—	—
285	1 57	69	.97	42	.123	31	0 11	0 03	0 14
380	1 50	71	97	.40	.122	.30	—	—	—
477	1.41	72	8.00	.42	123	.30	0 53	0 06	0 59
574	1 36	.72	.02	43	123	.31	—	—	—
764	1 08	.71	01	42	.123	.30	—	—	—
953	0 81	70	7 98	43	123	32	0 42	0 17	0 59
1,148	0 62	69	.98	.43	.123	.32	—	—	—
1,430	0 41	.68	99	45	124	.34	—	—	—
1,910	0 03	66	8 01	.45	.124	34	0 24	0 18	0 42
2,400	−0 20	.66	00	.43	123	32	—	—	—
2,890	−0 41	65	7.99	44	.124	.33	0 20	0.07	0 27
3,380	−0 51	.64	.99	43	.123	32	0 07	0 09	0 16

St No	Date	Lat	Depth	Weather
5	Time 0730～0800	Long 40°52.′2 E	280m	cloudy

Depth m	T (°C)	S (‰)	pHd	Total A (mequi/l)	Specific A	ΣCO₂ (m mole/l)	Biol react iron (μg-atm/l)		
							sol	part	sol+part
0	−0 8	33 66	—	—	—	—	0 16	0.03	0 19
6	−1 00	.66	—	—	—	—	—	—	—
12	−1 03	73	—	—	—	—	—	—	—
20	−1 19	97	—	—	—	—	—	—	—
34	−1 29	.99	—	—	—	—	—	—	—
55	−1 32	34 01	—	—	—	—	0 07	0 03	0 10
77	−1 48	06	—	—	—	—	—	—	—
127	−1.74	19	—	—	—	—	0 09	0 01	0 10
175	−1 82	21	—	—	—	—	—	—	—
221	−1 83	23	—	—	—	—	—	—	—
265	−1 82	25	—	—	—	—	0 01	0 03	0 04

St No	Date	Lat	Depth	Weather
6	Time 1330～1400	Long 39°32 ′7 E	272m	fair

Depth m	T (°C)	S (‰)	pHd	Total A (mequi/l)	Specific A	ΣCO₂ (m mole/l)	Biol react iron (μg-atm/l)		
							sol	part	sol+part
0	3 0	(27 37)	—	—	—	—	0 17	0 02	0 19
10	−0 66	33 78	—	—	—	—	—	—	—
20	−1 55	34 02	8 23	2 37	0 123	2 19	—	—	—
30	−1 57	05	13	39	124	24	—	—	—
50	−1 61	10	12	39	124	25	0 07	0 08	0 15
75	−1 61	14	11	38	123	24	—	—	—
100	−1 53	18	11	38	123	24	0 04	0 02	0 16
150	−1 46	23	09	39	123	25	—	—	—
200	−1 46	23	09	39	123	25	—	—	—
250	−1 54	26	10	39	123	25	0 02	0 03	0 05

St No	Date	Lat	Depth	Weather
7	Time 1130～1245	Long 38°50 ′5 E	m	fair

Depth m	T (°C)	S (‰)	pHd	Total A (mequi/l)	Specific A	ΣCO₂ (m mole/l)	Biol react iron (μg-atm/l)		
							sol	part	sol+part
0	−0 6	32 78	8.10	2 24	0 121	2 10	0 01	0 03	0.04
10	−0 94	70	12	24	121	.10	—	—	—
20	−1 14	33 10	12	26	.120	.12	—	—	—
30	−1 19	51	12	27	120	13	—	—	—
50	−1 47	34 08	13	34	121	21	0 06	0 05	0 11
75	−1 72	17	11	35	122	.21	—	—	—
100	−1 75	20	.10	35	122	22	0 03	0 04	0 07
149	−1 76	23	.09	35	122	22	—	—	—
198	−1 77	24	09	37	122	23	—	—	—
297	−1 58	32	06	37	.122	24	0 04	0 01	0 05
395	0.63	61	01	39	122	27	—	—	—
495	0 93	67	00	40	122	29	0 02	0 05	0 07
594	0 83	68	7 99	42	123	.31	—	—	—
794	0 57	67	98	40	122	30	—	—	—
994	0 36	67	98	.42	123	32	0 03	0 04	0 07
1,190	0 21	66	97	40	.122	31	—	—	—
1,480	0 04	66	97	.44	.124	.34	—	—	—
1,972	−0 20	65	8 00	.45	125	34	0 10	0 06	0 16

St. No. 8	Date Feb 6, 1966 Time 1410~1540	Lat 67°11 '3 S Long 43°50. '0 E	Depth m	Weather cloudy

Depth m	T (°C)	S (‰)	pHd	Total A (mequi/l)	Specific A	ΣCO$_2$ (m mole/l)	Biol react iron (μg-atm/l)		
							sol	part	sol+part
0	−0 8	33 61	8 12	2 37	0 124	2 22	—	—	—
10	−0 92	62	13	35	124	21	—	—	—
17	−0 86	62	14	34	123	19	—	—	—
26	−0 84	61	14	34	.123	19	—	—	—
42	−0 93	65	16	35	123	19	—	—	—
62	−1 70	34 12	14	37	122	21	—	—	—
84	−1 75	.17	12	37	122	22	—	—	—
130	−1 75	19	.12	.37	122	22	—	—	—
174	−1 75	21	12	38	122	24	—	—	—
272	−1 53	27	10	38	122	24	—	—	—
362	0 15	54	07	40	.123	27	—	—	—
451	1 23	.69	03	.40	122	28	—	—	—
545	1 20	71	02	42	123	30	—	—	—
720	0 93	70	02	42	123	30	—	—	—
909	0 72	70	02	43	123	31	—	—	—
1,092	0 59	69	02	44	124	32	—	—	—
1,346	0 29	67	01	44	124	33	—	—	—

St No 9	Date Feb 13, 1966 Time 0800~0920	Lat 69°08 '6 S Long 16•37 '0 E	Depth m	Weather fair

Depth m	T (°C)	S (‰)	pHd	Total A (mequi/l)	Specific A	ΣCO$_2$ (m mole/l)	Biol react iron (μg-atm/l)		
							sol	part	sol+part
0	−0 8	33 35	8 18	2.34	0 124	2 17	0.25	0 04	0.29
10	−0 81	35	20	34	124	17	—	—	—
20	−0 78	55	20	34	123	17	—	—	—
30	−0 13	85	.19	37	123	19	—	—	—
50	−0 05	92	18	37	123	19	0 24	0 05	0 29
75	−1 60	34 22	15	38	122	22	—	—	—
100	−1 70	29	11	.39	123	25	0 01	0 02	0 03
150	−1 64	34	10	38	.122	.24	—	—	—
200	−1 47	38	10	37	.121	.23	—	—	—
300	−0 53	54	06	39	122	26	0 15	0.02	0 17
400	0 71	65	01	40	.122	29	—	—	—
500	0 89	—	01	40	—	29	0 05	0 01	0 06
600	0 78	69	01	40	122	29	—	—	—
790	0 61	68	7 99	40	122	30	—	—	—
990	0 44	68	8 00	43	123	32	0 11	0 01	0 12
1,190	0 31	—	7 99	43	—	32	—	—	—
1,480	0 14	67	99	43	123	32	—	—	—
1,980	−0 08	66	8 00	43	123	32	0 07	0 03	0 10

St No 10	Date Feb 14, 1966	Lat 64°58 ′3 S	Depth	Weather
	Time 1520～1800	Long 13°56 ′7 E	m	cloudy

Depth m	T (°C)	S (‰)	pHd	Total A (mequi/l)	Specific A	ΣCO$_2$ (m mole/l)	Biol react iron (μg-atm/l)		
							sol	part	sol+part
0	1 4	34 05	8 06	2 37	0 123	2 23	0 06	0 04	0 10
9	1 36	05	09	37	123	22	—	—	—
20	1 17	05	10	37	123	22	—	—	—
30	1 02	06	11	37	123	.22	—	—	—
48	−1 35	36	12	39	123	24	0. 01	0 03	0 04
71	−1 41	43	09	39	123	25	—	—	—
94	−0 67	52	06	29	122	26	0 03	0 02	0 05
140	0 89	67	—	—	—	—	—	—	—
189	0 99	69	01	40	122	29	—	—	—
289	0 90	69	7 96	40	122	31	0 09	0 04	0 13
383	0 83	69	98	40	122	30	—	—	—
476	0 80	70	96	42	123	32	0 04	0 04	0 08
575	0 76	70	99	42	123	31	—	—	—
755	0 63	71	97	43	123	33	—	—	—
952	0 50	70	97	43	123	33	0 03	0 02	0 05
1, 152	0 39	—	98	44	—	34	—	—	—
1, 495	0 24	68	99	44	124	33	—	—	—
1, 980	0 00	67	98	43	123	33	0 03	0 07	0 10
2, 470	−0 16	66	97	45	125	35	—	—	—
2, 960	−0 25	66	99	44	124	33	0 07	0 04	0 11
3, 450	−0 29	—	98	45	—	35	—	—	—

St No 11	Date Feb 16, 1966	Lat 59°56 ′0 S	Depth	Weather
	Time 0550～0940	Long 12°15 ′6 E	m	cloudy

Depth m	T (°C)	S (‰)	pHd	Total A (mequi/l)	Specific A	ΣCO$_2$ (m mole/l)	Biol react iron (μg-atm/l)		
							sol	part	sol+part
0	0 8	33 88	8 17	2 38	0 124	2 20	0 21	0 04	0 25
7	0 69	—	18	38	124	20	—	—	—
15	0 68	87	18	38	124	20	—	—	—
22	0 75	88	20	38	124	20	—	—	—
40	0 52	90	20	38	124	20	—	—	—
50	0 18	91	20	38	124	20	0 16	0 02	0 18
67	−1 63	34 15	18	38	123	21	—	—	—
100	−1 71	19	14	39	123	24	0 01	0 02	0 03
133	−0 85	39	09	40	123	26	—	—	—
198	0 43	66	7 98	43	123	32	—	—	—
259	0 44	67	96	44	124	34	0 15	0 01	0 16
320	0 42	68	97	44	124	34	—	—	—
388	0 37	67	97	44	124	34	0 12	0 03	0 15
515	0 31	67	98	44	124	33	—	—	—
646	0 25	66	97	44	124	34	—	—	—
815	0 16	—	98	44	—	34	0 08	0 02	0 10
1, 192	0 00	65	99	44	124	33	—	—	—
1, 645	−0 16	64	8 00	44	124	33	—	—	—
2, 110	−0 27	64	00	45	125	34	0 05	0 03	0 08
2, 590	−0 34	—	00	46	—	35	—	—	—
3, 080	−0 40	63	00	—	—	—	0 26	0 06	0 32
3, 560	−0 46	63	01	45	125	34	—	—	—
4, 080	−0 50	63	02	45	125	34	—	—	—

St. No 12	Date Feb 17, 1966 Time 1800～2245	Lat 55°12 '5 S Long. 9°32. '5 E	Depth m	Weather cloudy

Depth m	T (°C)	S (‰)	PHd	Total A (mequi/l)	Specific A	ΣCO$_2$ (m mole/l)	Biol react iron (μg-atm/l)		
							sol	part	sol+part
0	1 0	34. 04	8 11	2 40	0 124	2. 25	0. 01	0. 02	0. 03
10	0. 87	. 03	. 12	38	. 124	. 23	—	—	—
20	0. 87	. 04	. 12	38	124	. 23	—	—	—
30	0 88	. 04	. 12	. 38	. 124	. 23	—	—	—
50	0 91	. 05	12	. 38	. 124	23	0. 03	0 05	0 08
75	−0. 69	19	13	. 38	. 123	. 23	—	—	—
105	−1 26	. 36	. 06	. 38	. 122	. 26	0 05	0 03	0 08
151	−0. 42	51	. 03	. 40	. 122	. 28	—	—	—
207	0 18	. 60	7. 99	. 41	. 123	31	—	—	—
302	0 43	66	97	43	124	33	0 07	0 02	0 09
405	0 49	67	. 94	. 43	124	34	—	—	—
510	0 48	68	. 94	43	. 124	34	0 01	0 05	0 06
603	0 46	. 68	. 94	41	123	33	—	—	—
823	0 36	. 68	95	43	. 124	. 34	—	—	—
1, 048	0 22	67	96	41	. 123	33	0 12	0 04	0. 16
1, 262	0. 12	. 67	96	. 43	124	. 34	—	—	—
1, 525	0 04	68	96	43	124	34	—	—	—
2, 075	−0 19	. 67	98	43	124	. 33	0. 07	0 06	0 13
2, 575	−0 29	65	97	43	. 124	33	—	—	—
3, 090	−0 35	65	. 95	—	—	—	0 01	0 07	0 07
3, 600	−0 42	. 65	. 96	. 44	125	36	—	—	—
4, 130	−0 49	64	95	43	. 124	34	0 08	0 05	0 13

St. No. 13	Date Feb. 19, 1966 Time 0050～0315	Lat. 50°02 '5 S Long. 10°29. '4 E	Depth m	Weather cloudy

Depth m	T (°C)	S (‰)	pHd	Total A (mequi/l)	Specific A	ΣCO$_2$ (m mole/l)	Biol react. iron (μg-atm/l)		
							sol	part	sol+part
0	3 8	33 89	8 17	2. 37	0 123	2 18	0 06	0 06	0 12
10	3 72	89	20	—	—	—	—	—	—
20	3 72	89	20	37	. 123	. 18	—	—	—
30	3 69	89	21	37	123	. 17	—	—	—
60	3 71	88	20	. 37	123	. 18	0 08	0 04	0. 12
75	3 63	87	20	37	123	. 18	—	—	—
102	2 61	92	18	37	123	19	0 02	0. 05	0. 07
145	1 37	. 98	. 15	. 38	. 124	22	—	—	—
194	1. 57	34 09	10	38	123	. 24	—	—	—
284	1. 84	22	06	40	. 124	27	0 09	0. 04	0 13
378	2 01	31	01	41	124	. 30	—	—	—
488	2 16	41	7 97	41	124	31	0 18	0 02	0. 20
555	2 22	46	96	. 43	. 124	33	—	—	—
741	2 27	58	95	43	124	. 34	—	—	—
925	2 30	66	. 97	44	124	34	0 08	0 05	0 13
1, 123	2. 25	71	98	. 44	124	34	—	—	—
1, 415	2 16	76	8 00	44	124	33	—	—	—
1, 905	1 78	76	00	44	124	33	0 11	0. 02	0 13
2, 420	1 28	73	00	44	. 124	33	—	—	—
2, 940	0 94	71	7 99	. 47	125	37	0 05	0 02	0 07
3, 450	0 75	69	98	47	125	37	—	—	—

St No 14	Date Feb 20, 1966 Time 0250～0540	Lat 45°12 ′5 S Long 11°44 ′5 E	Depth m	Weather cloudy

Depth m	T (°C)	S (‰)	pHd	Total A (mequi/l)	Specific A	ΣCO_2 (m mole/l)	Biol react ıon (μg-atm/l)		
							sol	part	sol+part
0	7 6	34 07	8 19	2 38	0 124	2 17	0 19	0 08	0 27
10	7 66	05	20	38	124	17	—	—	—
18	7 63	06	21	.37	123	16	—		—
28	7 65	05	21	37	123	16	—	—	—
42	7 62	.06	21	37	123	16	0 04	0 02	0 06
64	7 61	06	21	37	123	16	—	—	—
86	7 61	05	21	37	123	16	0 02	0 07	0 09
134	5 80	17	19	35	121	15	—	—	—
183	5 00	16	15	35	121	17	—	—	—
263	4 79	20	13	35	121	18	0 10	0 07	0 17
360	4 10	.20	11	37	122	21	—	—	—
463	3 61	19	09	38	123	23	0 00	0 04	0 04
606	3 12	21	06	38	123	25	—	—	—
814	2 67	29	04	40	123	27	—	—	—
974	2 60	39	00	40	123	28	0 02	0 06	0 08
1,197	2 60	51	7 96	40	123	30	—	—	—
1,453	2 63	63	96	41	123	32	—	—	—
1,953	2 48	75	99	—	—	—	0 00	0 03	0 03
2,455	2 15	78	8 01	43	123	31	—	—	—
2,920	1 70	76	01	43	123	31	0 04	0 04	0 08
3,390	1 27	74	00	43	123	31	—	—	—
3,860	0 90	71	7 99	44	124	34	0 11	0 07	0 18

St No 15	Date Feb 21, 1966 Time 1710～1950	Lat 39°57 ′0 S Long 14°54 ′0 E	Depth m	Weather cloudy

Depth m	T (°C)	S (‰)	pHd	Total A (mequi/l)	Specific A	ΣCO_2 (m mole/l)	Biol react ıon (μg-atm/l)		
							sol	part	sol+part
0	15 ●	35 22	8 24	2 43	0 122	2 14	0 13	0 04	0 17
8	14 96	17	24	—	—	—	—	—	—
17	15 00	19	25	—	—	—	—	—	—
24	14 99	16	25	40	120	11	—	—	—
40	14 68	.10	26	40	120	11	0 09	0 08	0 17
60	14 07	01	26	—	—	—	—	—	—
80	12 56	34 87	24	40	121	13	0 01	0 04	0 05
118	12 21	86	21	38	121	13	—	—	—
160	10 95	93	17	38	121	16	—	—	—
237	9 20	75	12	38	121	20	0 10	0 11	0 21
325	7 66	59	08	38	121	22	—	—	—
415	6 21	50	05	38	122	24	0 10	0 02	0 12
485	5 40	45	04	40	123	26	—	—	—
658	3 68	36	01	40	123	28	—	—	—
850	3 55	48	7 98	40	123	29	0 15	0 08	0 23
1,040	2 91	56	97	—	—	—	—	—	—
1,325	2 79	68	97	41	123	31	—	—	—
1,840	2 62	77	8 01	43	123	31	0 21	0 08	0 29
2,350	2 43	83	03	43	123	31	—	—	—
2,885	2 23	84	02	43	123	31	—	—	—
3,420	1 76	80	02	43	123	31	0 05	0 09	0 14